**МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ**

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# ІНЖЕНЕРНА ГРАФІКА

## КОНСПЕКТ ЛЕКЦІЙ

ПОЛТАВА 2015

Конспект лекцій складено відповідно до робочої програми з дисципліни «Нарисна геометрія, інженерна та комп'ютерна графіка».

Містить теоретичні відомості з основ комп'ютерної графіки і геометричного, проекційного та машинобудівного креслення згідно вимог Державних стандартів України.

Призначений для студентів-іноземців напряму підготовки 6.050304 - Нафтогазова справа, що навчаються англійською мовою.

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# INTRODUCTION

The educational discipline “Descriptive Geometry, Engineering and Computer Graphics” is complex and consists of two modules: M1 is Descriptive Geometry (first term); M2 is the Engineering and Computer Graphics (second term). Two modules are the organic whole, where one part develops and complements the other one.

***Engineering graphics*** is based on the method of projected depictions and studies the set of state standards of convention, simplification and features of application of this method to the exposition of graphic project-designed documentation. The subject of engineering graphic is a construction and reading of drawings, sketches, charts, which are graphic facilities of jigging, maintainance and transmission of technical ideas in the process of their development and realization. Engineering graphic foresee acquisition of the students’ abilities and skills to express technical ideas with the help drawing, and also to understand the interaction of component parts and the principle of action of the technical articles represented on drawings.

Knowledge, abilities and skills, gained in the process of learning, are necessary for the study of different disciplines, for doing term-papers and diploma projects, and also in the future engineering activity. Mastering drawing as the mean of expression of the technical idea, and the production document takes place during the process of study at the university.

As a result of learning the module:”Engineering and Computer Graphic” a student must:

- ♦ know the methods of construction of depictions (including axonometry projections) of objects, and also conventions in ESKD, concerning these objects;
- ♦ be able to define the geometrical forms of the parts, according to their depictions to draw these depictions from life and from the drawing of general view of mechanism;
- ♦ be able to do the drawing of timber atticles, sectional and unsectional connections;
- ♦ be able to read and to make drawings of the general view and frame-clamping units, and also to do these drawings, taking into account the requirements of standards of ESKD.

Engineering and computer graphic arts contains three content modules, in particular:

M1 is the Geometrical and projected drawing;
M2 is Depiction of connected parts;
M3 is the Design documentation.

Computer graphics is a modern instrument of automation, upgrading and acceleration of planning. The principles of computer graphics are taught out on the basis of the system “KOMPAS”.

Drawing — Drawing may be defined as the representation of an object by systematic lines. Ordinarily, the idea conveyed by the word ‘drawing’ is a pictorial view in which an object is represented as the eyes see it. A pictorial view shows only the outside appearance of an object.

Engineering Drawing — Engineering drawing is a graphic language which has its own rules. It gives complete description of an object or a machine part as regards shape, size and all other internal details from which it can be constructed or manufactured.

Machine Drawing — Machine drawing may be defined as the representation of a machine component or machine by lines according to certain set rules. A machine drawing generally gives all the external and internal details of the machine component from which it can be manufactured.

# 1 GEOMETRICAL AND PROJECTING DRAWING
## 1.1 COMMON RULES OF DRAFT SHAPING AND FINISHING

When shaping and finishing drafts it is obligatory keep strictly to demands of State Standards.

**Formats State Standard 2.301-68***

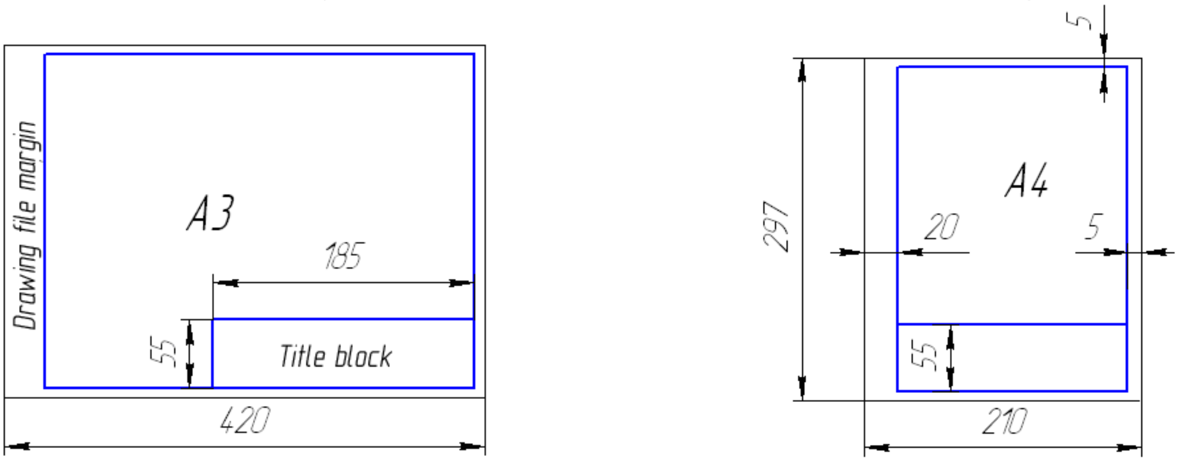
The standard sizes of a drawing sheets are given in Table 1.1.

Table 1.1– Standard sizes of a drawing sheets

| Denotation | A0 | A1 | A2 | A3 | A4 |
|---|---|---|---|---|---|
| Sizes of sides, mm x mm | 841x1189 | 594x841 | 420x594 | 297x420 | 210x297 |

The layout of drawing sheet is shown in Fig. 1.1.

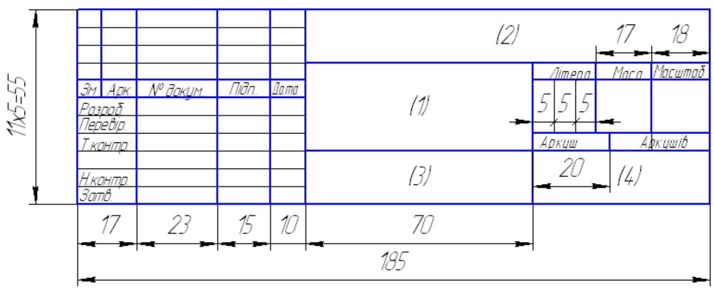
The title block takes place along longer or shorter side of format on all of formats (except for A4). ***Title block is stirred only along shorter side on the sheets of format of A4*** (fig.1.1, b)**.**



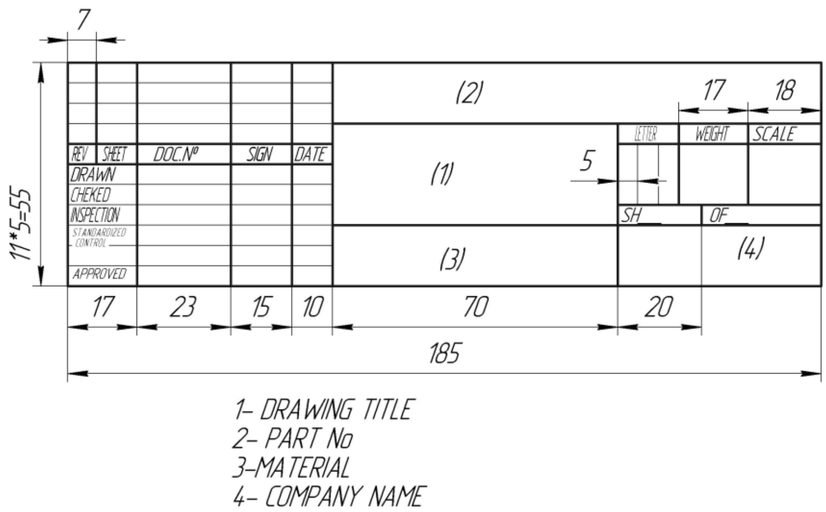

a b

Figure 1.1 - Title block

There are three forms of title block. Title block (form 1) is intended for all of cases of drawings and charts is shown in figure 1.2




a




b

Figure 1.2 – Form 1 of title block (a– in Ukraine, b – in English)

The title blocks (form 2 and form 2a) are used for the text document (specification) are shown in figure 1.3 (on the first sheets) and in figure 1.4 (on the next sheets).

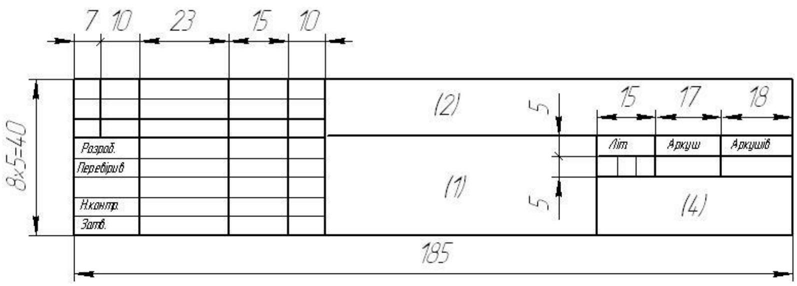



Figure 1.3 – Form 2 of title block

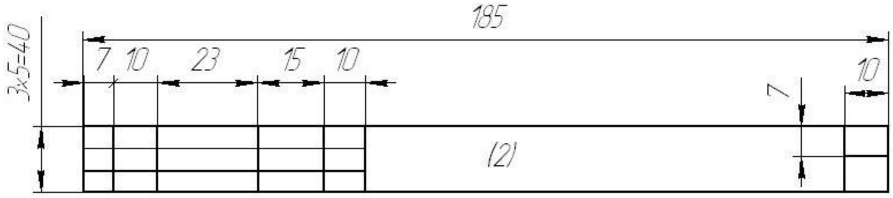



Figure 1.4 – Form 2a of title block

Title blocks indicate: in column 1 is the name of the article; in column 2 is the denotation of a document; in column 3 is the denotation of part material ; in a column 4 is the index of production.

Nonstandard title block can be used in doing home works in geometrical and projecting drawings (figure 1.5).

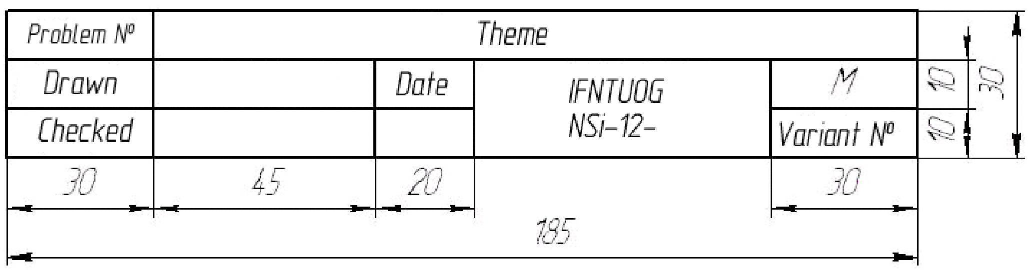



Figure 1.5 – Non-standard title block

**Scales State Standard 2.302-68***

A scale is the correlation of linear sizes of the depiction to the actual sizes of the object.

The various types of scales used in machine drawing are:

1. Full scale
2. Reduced scales (scales of dimensions).
3. Enlarged scales (scales of augmentation).

The standard scales are given in Table 1.2.

Table 1.2 – Scales

| | |
|---|---|
| Reduced scale | 1:2; 1:2,5; 1:4; 1:5; 1:10, 1:15; 1:20; 1:25; 1:40; 1:50; 1:75; 1:100; 1:200; 1:400; 1:500; 1:800; 1:1000 |
| Full scale | 1:1 |
| Enlarged scale | 2:1; 2,5:1; 4:1; 5:1; 10:1; 20:1; 40:1; 50:1; 100:1 |

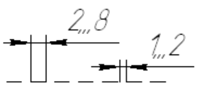
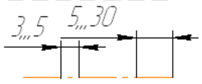
The scale is indicated in the proper column of title block on a drawing .

**Lines State Standard 2.303-68***

National Ukrainian Standards established nine types of lines according to its graphical shape and thickness. All lines of the same type must have the same thickness. For this end they sharpen pencils in shape of cone or in shape of spade and they use the proper hardness of pencils. Thus lines of s/3 thickness are recommended to draw by pencils of T, 2T, 3T (H, 2H, 3H), and lines of s, s/2 or 1,5s thickness by pencils of MT, TM (HB, BH).

The types of lines are shown in a table 1.3.

Table 1.3 – Lines

| Name | Shape | Thickness of the line | Application |
|---|---|---|---|
| Continuous thick basic | | (S) 0,5 ... 1,4 mm | Working frame of format, lines of visible contour |
| Continuous thin | | S/3 ... S/2 | Lines are an extension, dimension, leader and shadings |
| Continuous waved | | S/3 ... S/2 | Break lines |
| Dashed (hidden) |  | S/3 ... S/2 | These lines are used to show the hidden features of a part. |
| Dashed pointed (center) |  | S/3 ... S/2 | Axial and central lines |
| Cutting plane line |  | S ... 1,5 S | Line of section |

**Drawing Fonts State Standard 2.304-81***

Draft fonts are obligatory when lettering the drawings by hand. National Ukrainian Standards established such dimensions of fonts in millimetres: 1,8; 2,5; 3,5; 5; 7; 10; 14; 20, 28; 40. Font 1,8 is not recommended. Four types of font are established for Russian, Latin, Greek letters, Arabic and Roman numerals. Those types of font calls A and B, and each of them may be right (without inclination), and inclined fonts with angle of 75°. For each type of font its height h is defined by height of capital letters. Height of letters is measured in millimeters along a perpendicular to the base of an inscription. Width d of font lines is defined according to type of font. For A font type d=l/14h, and for E: d=l/10h. It is recommended to make up lettering E inclined font type. Base parameters of E font type are given in table 2.

For correct lettering an auxiliary grid should be drawn by thin lines. The vertical and horizontal grid step is equal to thickness of heavying in of the font.

The main requirements for lettering are

1. Legibility
2. Uniformity
3. Ease of writing
4. Rapidity of execution.

Single stroke letters meet these requirements and are universally used. Good lettering should conform to uniformity of thickness, style, scope, size and spacing.

Modern Roman — Refer to Fig. 1.6.

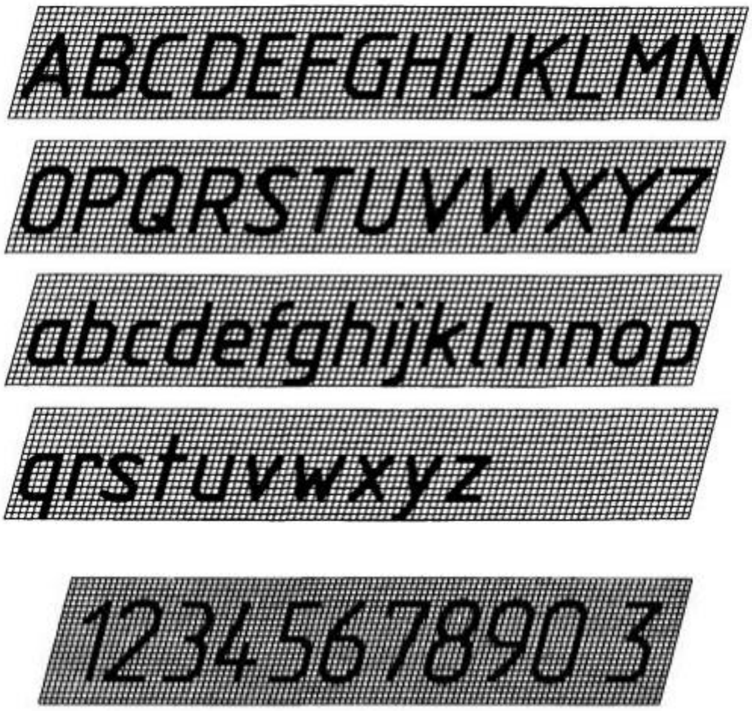
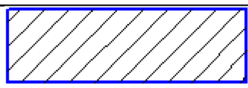
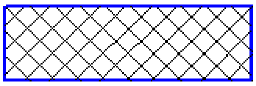
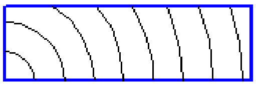
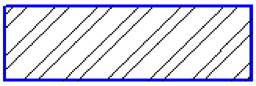
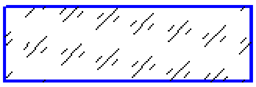
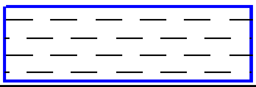



Figure 1.6 – Fonts

**Conventional Representation of Materials State Standard 2.306-68***

A variety of materials are used for making machine components. It is therefore preferable to follow different conventions of section lining for different materials as given in Table 1.4.

Table 1.4 – Conventional Representation of Materials

| Material | Denotation |
|---|---|
| Metals and hard alloys |  |
| Non-metal materials, after the exception of indicated below |  |
| Wood |  |
| Ceramics and silicate materials |  |
| Glass and transparent materials |  |
| Liquids |  |

It is nesessaty to take the corner of 30°or 60° instead of 45° if the lines of shading coincide with the direction of the lines of contour. Narrow areas of cuts with a width  less than 2 mm, allow to show blacken (figure 1.7).

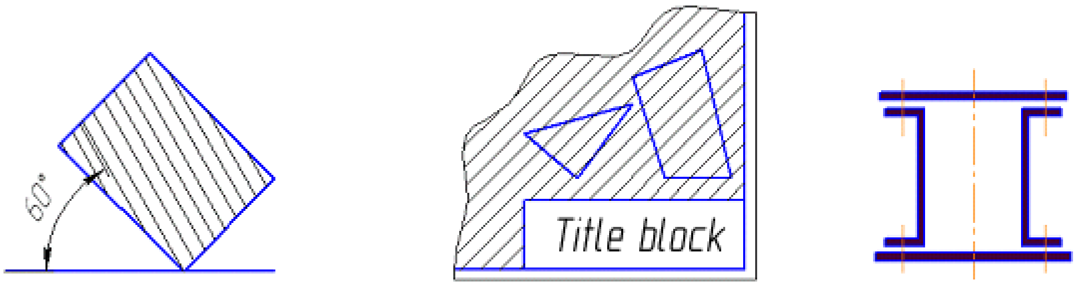



Figure 1.7 – Examples of Conventional Representation of Materials

**Dimensioning State Standard 2.307-68**

Every drawing besides showing the true shape of an object, must supply its exact length, breadth, height, sizes and position of holes, grooves, etc. The procedure of presenting this information on a drawing sheet is called dimensioning. Lines, symbols, numerals and notes are used for this purpose.

There are two types of dimensions required to be shown on a drawing:

a) Overall dimension (size or functional dimension), and

b) Location or datum dimensions, shown by letters S and L respectively.

The size dimension indicates size such as length, breadth, height, diameter, etc.

The location dimension shows locations or exact position of various constructional details within the objects.

Fig. 1.8 shows the size and location dimensions.

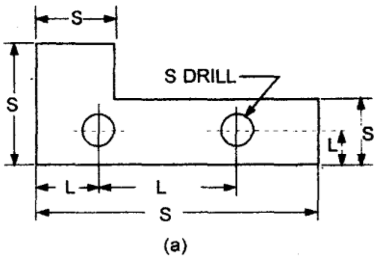



Figure 1.8 – Size and  location dimension

Extension and Dimension lines (continuous thin) are used for dimensioning (in mm)

The various types of dimension lines are:

1. Dimension line — It is a thin continuous line terminated by arrowheads touching the outlines or extension lines.
2. Extension line — It is a thin line drawn outside and along the outline.
3. Arrowhead — An arrowhead is placed at each end of a dimension line. Its pointed end touches an outline or an extension line. The length of arrowhead should be min 2.5mm. (fig.1.9).

Dimension lines are drawn parallel to a segment which is measured or on the concentric arc of measureable corner and limited  the arrowheads (fig. 1.9).

It is desirable to draw dimension lines out of the contour of the depiction. It is necessary to avoid crossing of dimension and extension lines.

The lines of contour, axial, central and extension lines are not used as dimension lines.

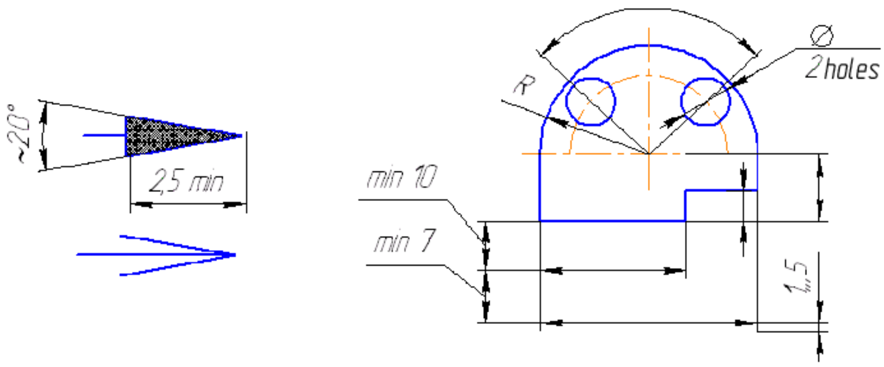
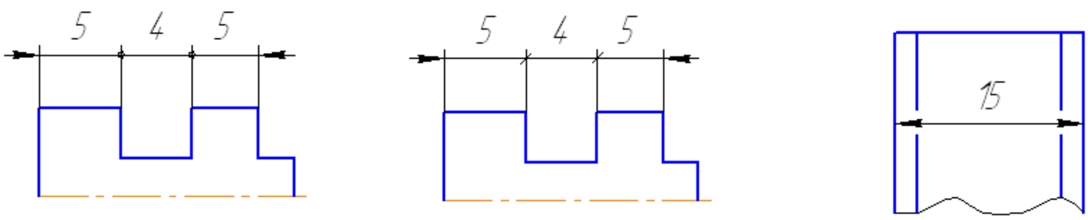



Figure 1.9 – Examples of dimensioning

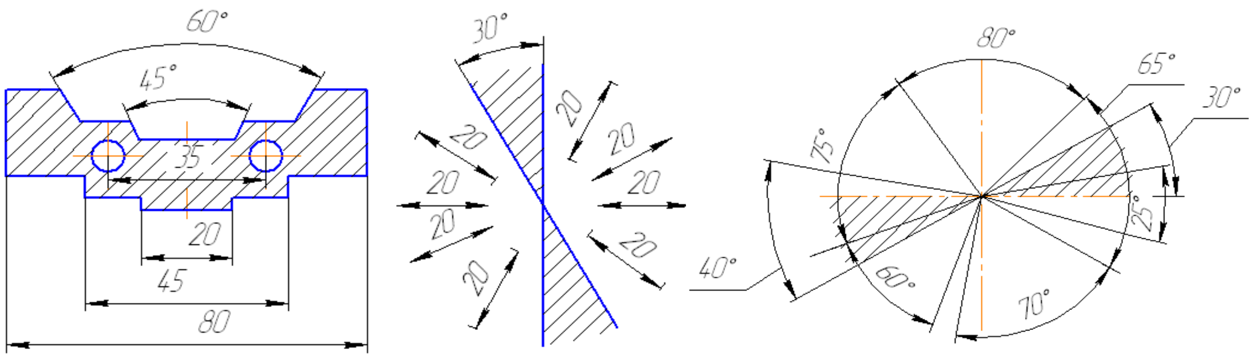
It is allowed to replace pointers notch which are drawn under the corner of 45° to the dimension lines, or clear points if a place is not enough for arrowheads on dimension lines. If a place is not enough for arrowheads through the close located contour or extension line it can be cut (fig. 1.10).

Figure 1.10  Examples of dimensioning




The dimensions are placed above the dimension lines and may be read either from the bottom or from the right side of the drawing (fig. 1.11).

Linear dimensions on drawings are indicated in mm, and angular – in degrees, minutes, seconds with denotation of metages. Dimension number 5 mm high is marked above a size line in the distance of 0,5... 1 mm as possible nearer to the middle. Above parallel lines (or by concentric arcs) dimension numbers fill in offset (fig. 1.11 – a). Dimensioning at various inclinations of dimension lines is shown in figure 1.11 –b, c.




a) b) c)

Figure 1.11 – Examples of dimensioning

Dimensions of diameters and radiuses

Dimensions of diameters should be followed by symbol ∅ before a dimension.

The circles should be dimensioned as shown in Fig. 1.12.

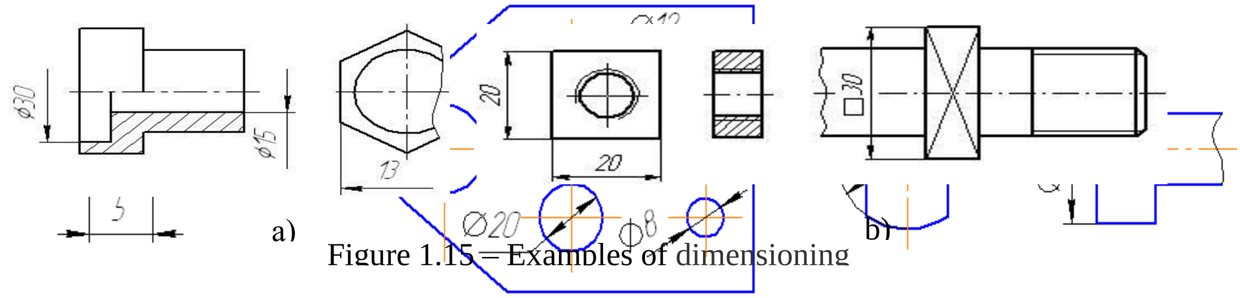



Figure 1.15 – Examples of dimensioning

Figure 1.12 – Examples of dimensioning Examples of

The Latin letter R is put before a dimension while dimensioning of radius . Some examples of dimensioning of radiuses are shown in figure 1.13.

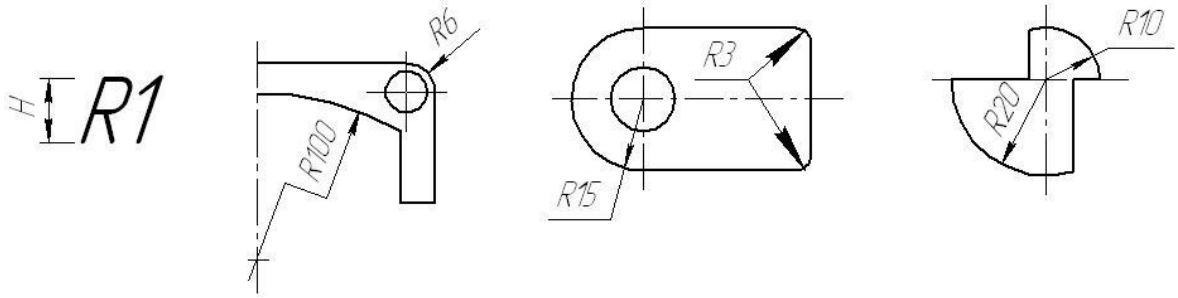



Figure 1.13– Examples of dimensioning

Location of holes should be dimensioned where possible in the plan view of holes as shown in Fig. 1.14.

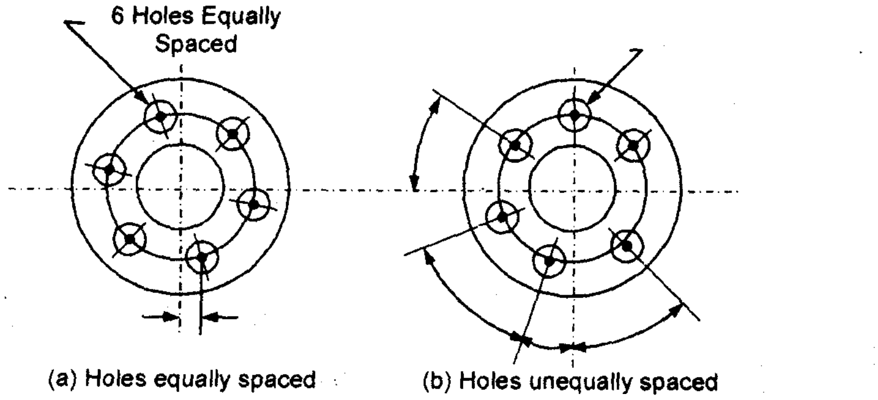



Figure 1.4 – Dimensioning holes on pitch circle

A dimension line can be broken in cases, as shown in figure 1.15 a.
The square should be dimensioned as shown in 1.15 b.

As a rule, the size of the same elements of a product is applied once and representing the number of elements on a shelf or under a shelf extension line (figure 1.16 a).

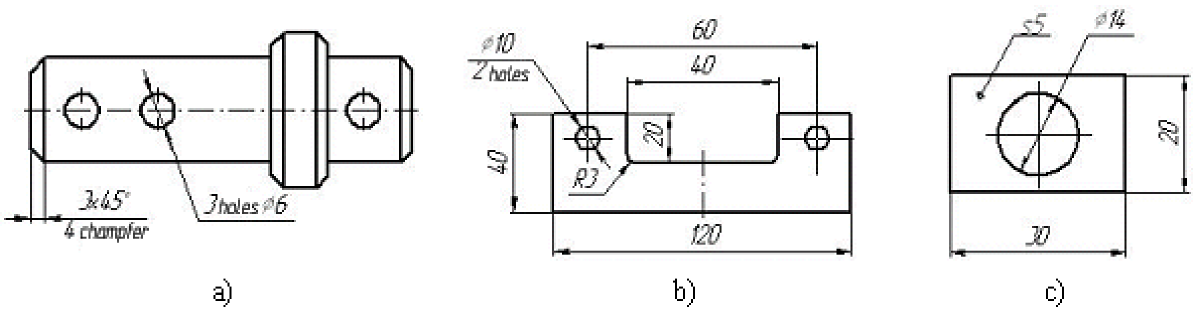



Figure 1.16 - Examples of dimensioning.

The sizes of two symmetrically placed elements (radius R3) of the product (except of holes or chamfers) are marked one time without pointing their amount (fig.1.16 b). The dimension of thickness of a part in one projection (plank) are marked on a foot-note-shelf (s5) as shown in figure 1.16 c.

The size of a spherical surface should be dimensioned as shown in Fig. 1.17. A sphere is marked by the signs ∅ or «R». If it is difficult to distinguish a sphere from other surfaces, the word «Sphere» is written or the sign ∅ is put before a dimension.

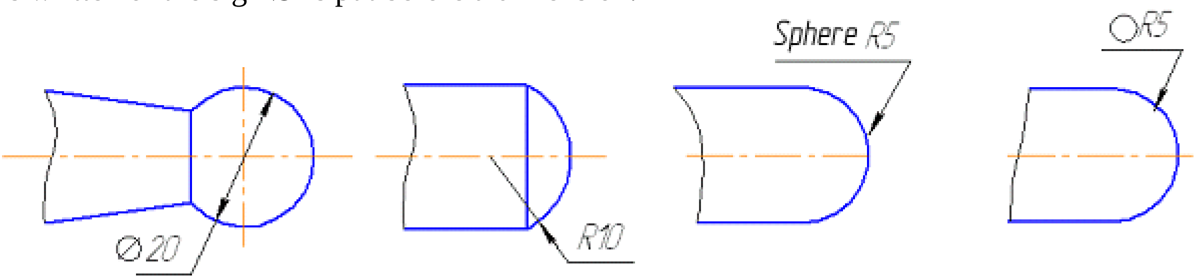



Figure 1.17 - Examples of dimensioning

A chamfer is a beveled edge connecting two surfaces. If the surfaces are at right angles, the chamfer will typically be symmetrical at 45 degrees.

The chamfers are dimensioned by two linear sizes or by linear and angular sizes. The chamfers made under the angle of 45±, are marked through a sign “X ”. Some examples of dimensioning the chamfers are shown in figure 1. 18.

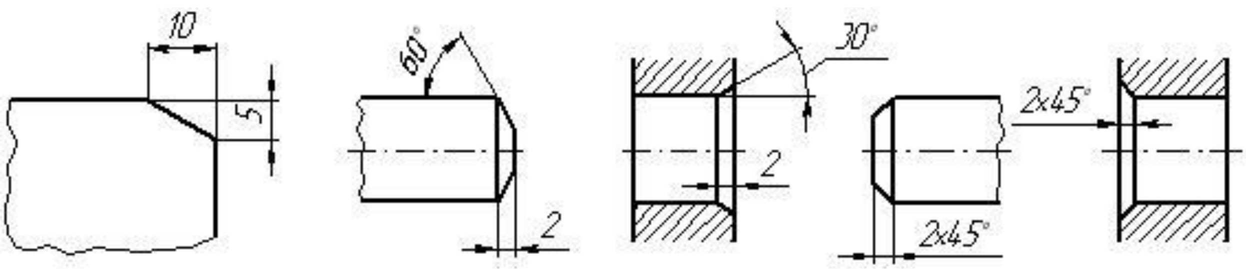



Figure 1.18 - Examples of dimensioning

There are two basic methods of dimensioning: progressive dimensioning and continuous dimensioning.

1. Progressive dimensioning — In this method of dimensioning, all dimensions on the drawing are shown from a common base line, as shown in Fig. 1.19. Cumulative error is avoided in this method.

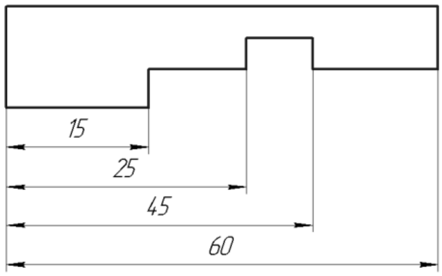



Figure 1.19 - Progressive dimensioning

2. Continuous dimensioning — In this method, dimensions are arranged in a straight line. An overall dimension is placed outside the smaller dimension. One of the smaller dimensions is generally omitted which is least important, as shown in Fig. 1.20.

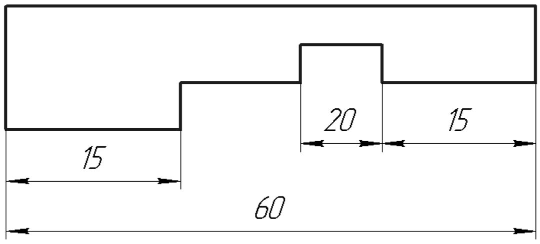



Figure 1.20 - Continuous dimensioning

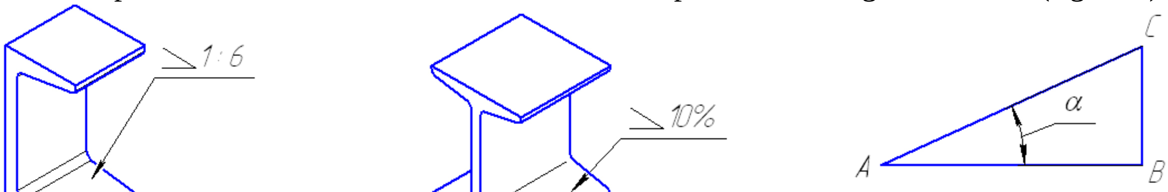
Finally, there are the general rules for dimensioning. The following rules should be observed while dimensioning:

1. Standard sizes of letters and figures should be used.
2. All dimensions should be specified in mm.
3. As far as possible dimensions should be placed outside the views.
4. Dimension lines should not run in the direction included in the hatched area.
5. Dimensions should be taken from visible outlines rather than from dashed lines.
6. Dimensions should be given from a base line, a centre line, an important hole, or a finished surface which may be readily established.
7. Dimensions should be quoted only once in one view.
8. Overall dimensions should be placed outside the intermediate dimensions.
9. Dimensions should be placed outside a sectional view.
10. Dimension line should not cross. Also dimension lines and extension lines should not cross.
11. When there are several dimension lines, the shorter dimension should be nearer the view.
12. Do not use outlines for dimensions.

## 1.2 SOME GEOMETRICAL CONSTRUCTIONS

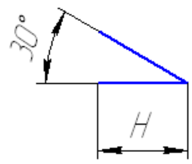
**The Slope State Standard 8908 – 81**

The slope characterizes inclination of one line or a plane according to the other (fig.1.21)




$$i = tg\,\alpha = BC/AB$$

Figure 1.21 – The examples of slope.




To mark the slope on a drawing a sign ∠ or ⊳ is put before a size number, where H is a font size. Slope examples are shown on figure 1.22.

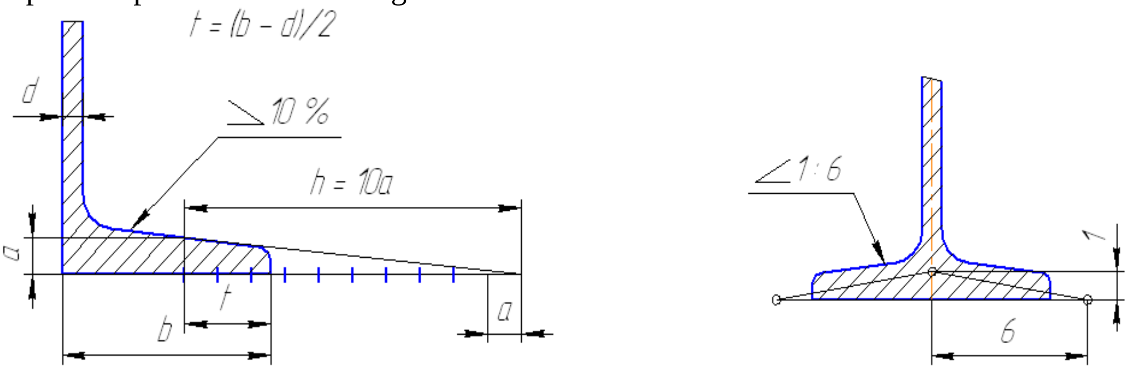
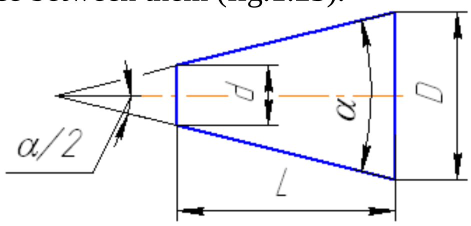



Figure 1.22 – The examples of slope

***The Taper State Standard 8593-81***

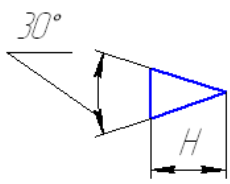
A taper is defined as unit alteration in a specified length measured along the axis in case of a shaft and a base line or a center line in case of flat pieces as shown in Fig. 1.23.

The taper is the correlation of difference of diameters of two cone cross-sections toward distance between them (fig.1.23).




$$C = (D - d)/L = 2tg\alpha/2$$

Figure 1.23 – The calculation of taper




To mark the taper on a drawing a sign ◁ or ▷ is used which is put before a dimension (fig.1.24).

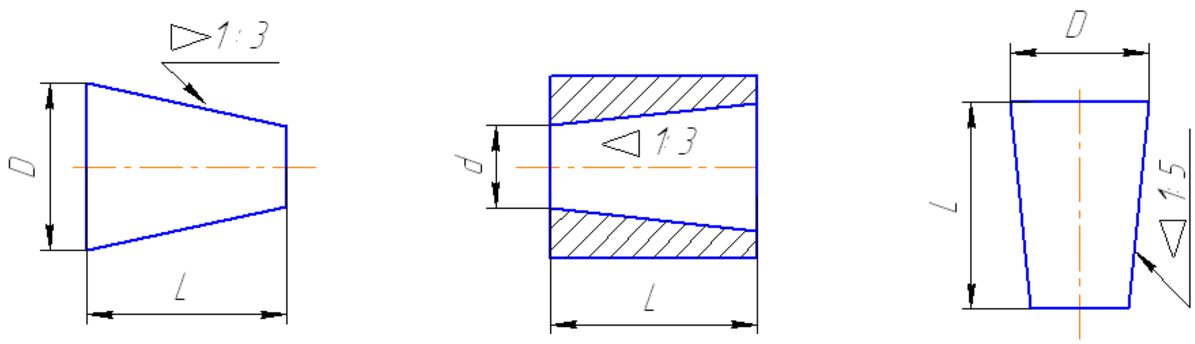



Figure 1.24 – The examples of taper

**QUESTIONS FOR SELFCHECK**

1. What are basic formats according to the State Standard?
2. What kind of scales do you know?
3. When are linear and angular sizes used?
4. What types dimensioning on a drawing do you know?
5. How are slope and taper marked?

# 2 PROJECTION DRAWING

An important part of drawing work is the representation of the exact shape and size of a solid object. The solid which has length, breadth and thickness (three dimensional) is regarded as two dimensional on the surface of a drawing sheet.

State Standard 2.305-68 sets the rules of object depictions (wares, buildings and their component parts) on the drawings of all branches of industry.

The number of depictions of an object must be minimum but sufficient for determination of its form and forms all its elements.

The method of rectangular projection is used for the depictions, when an object is placed between the eye of the observer and the plane of projections. The basic planes of projections are chosen six verges of hollow cube, in the middle of which an object is placed which is projected on the internal verges of the cube. Then the basic planes of projections are combined with a frontal plane which result in a complex picture (fig.2.1).

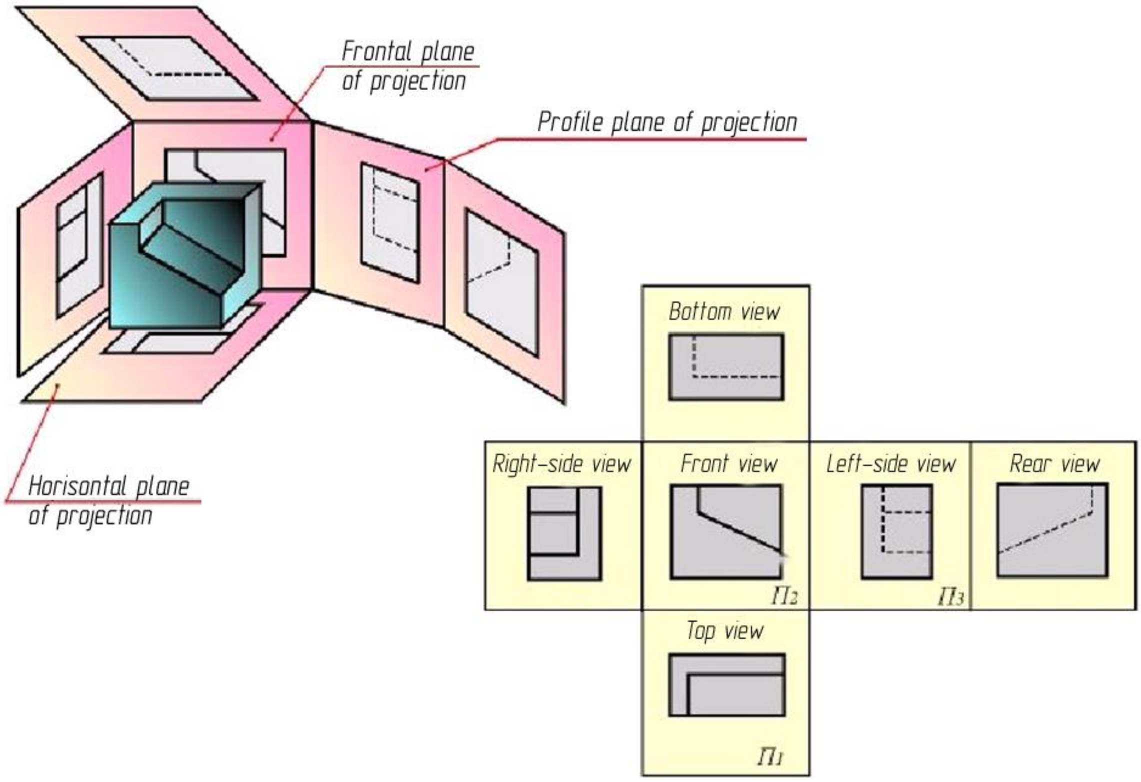



Figure 2.1– The basic planes of projections

A depiction on the frontal plane of projections is considered to be the main. An object is placed in relation to the frontal plane of projections so that a representation on it (the main depiction) gives the most complete picture of form and sizes of an object.

The depictions are divided into views, sectional views and sections according to a State Standard 2.305-68 standard .

## 2.1 VIEWS

A view is the depiction of a visible part of a surface of any object, facing the observer.

Views on the basic planes of projections are the main ones. They have the followings names (fig.2.1):

1 – front view (main view);

2 – top view;

3 – left-side view;

4 – right-side view;

5 – bottom view;

6 – rear view.

If all the views are placed on one sheet in direct projected connection, they are not inscribed.

If projected connection is broken, or views are separated by other depictions, or made on different sheets, then the view is accompanied by the capital letter of the Ukrainian alphabet, and the direction of planning is shown by a pointer with the same capital letter (fig.2.2).

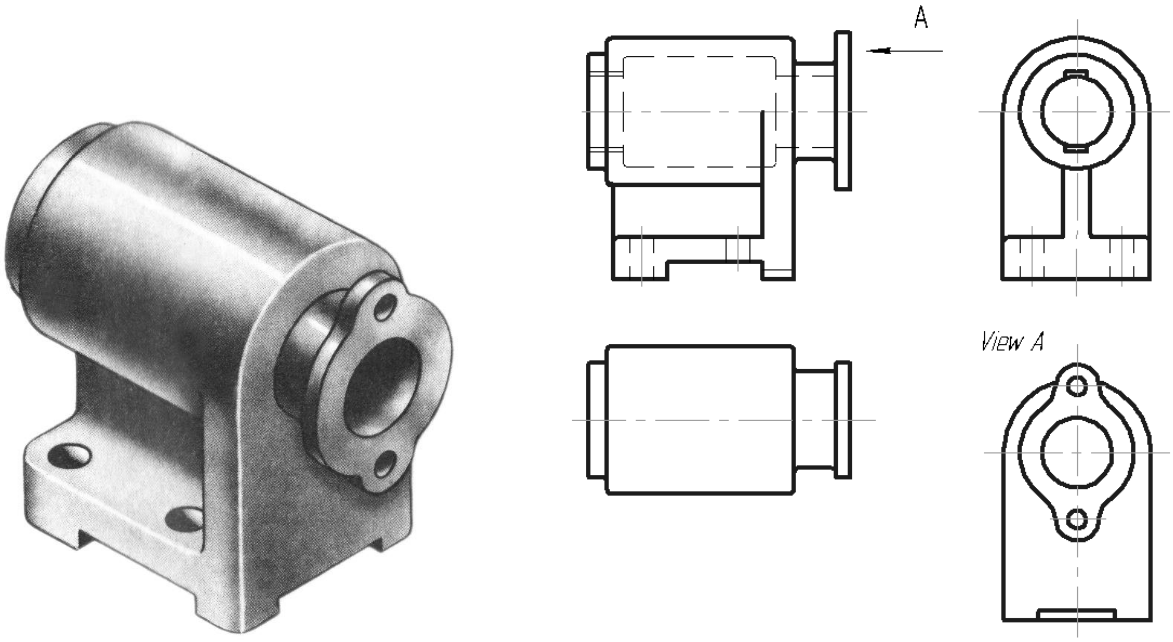



Figure 2.2 – Views of models

Besides basic, auxiliary and partial views are distinguished.

The auxiliary view is a view, which is received by projection on the plane, not parallel to any of basic planes of projections. This view is used, when a part of the object is inclined to the basic planes of projections and is represented on them in a distorted view. The auxiliary plane is placed parallell to the inclined element of the part and projected on this plane, without distortion. The auxiliary view is marked by a pointer and a letter. If the auxiliary view is placed in a direct connection with the corresponding image, the pointer and the inscription above the view are not inscribed (fig.2.3). The auxiliary view can be turned. Then a sign is added to its inscription .

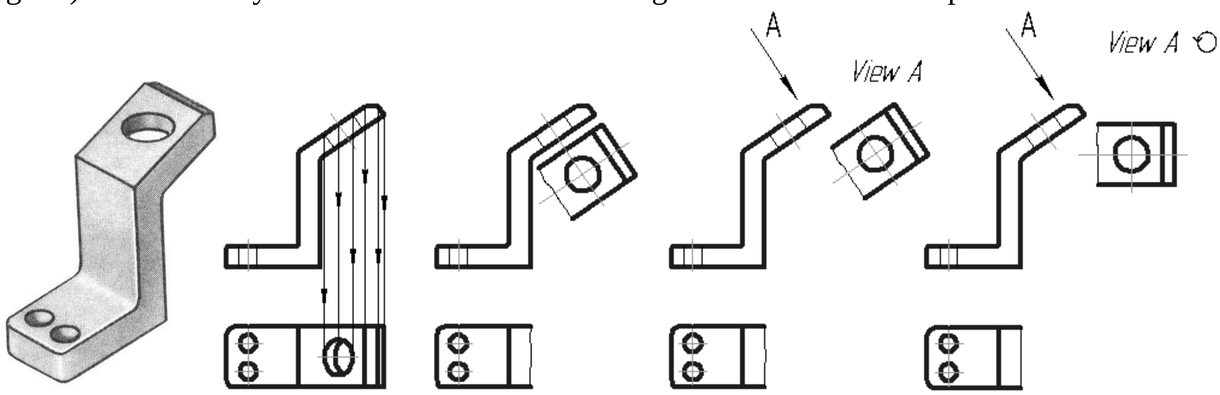



Figure 2.3 – The auxiliary views

The partial view is the view of the limited part of an object or its separate element (fig.2.4).

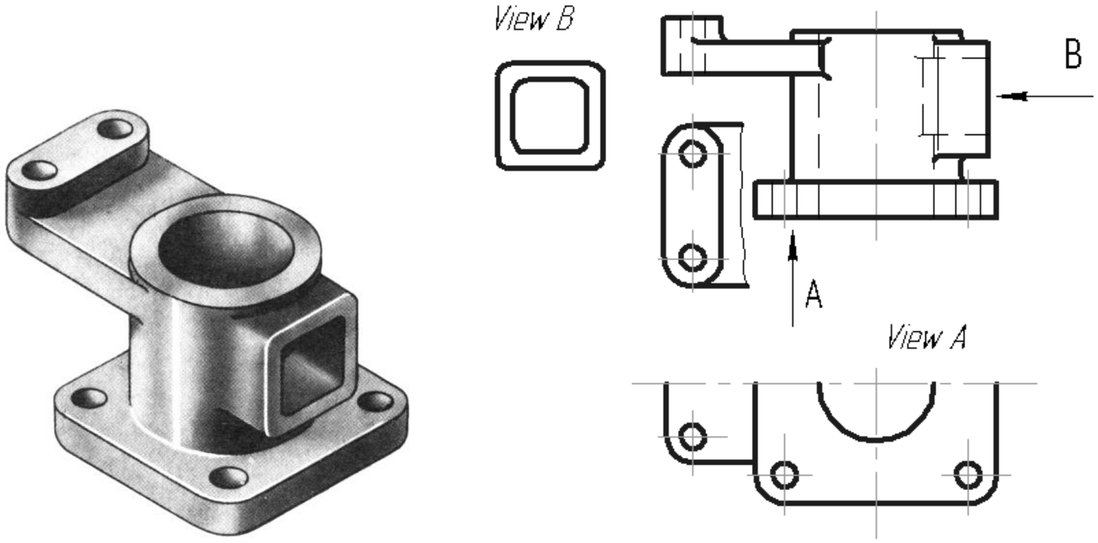



Figure 2.4 – The partial views

Partial views are made to show the form and sizes of a small element of the part, for example, a hole, a flange, ets. The partial view is made by projecting of the necessary element on one of the basic planes of projections. Partial views are placed on the field of drawing, without projectied connection with a basic image, but they are have to be nearer to the place of location and correspond to the position of element on the basic image. The partial view is limited on a drawing by a continuous wavy line or by lines of the contour of element. Partial views are marked in figure in the same way as the auxiliary ones.

## 2.2 SECTIONAL VIEWS

A drawing must give the complete picture of external and internal form of a part. As it is generally known, the internal form of an object can be shown by hatched lines. However when the form of an object is complicated, there are a lot of hatched lines, which, crossing each other, darken the drawing and make it difficult to read. Sectional views is used to expose the internal form of an object.

A sectional views is a depiction of an object, relatively cut by one or several planes (fig.2.5). The sectional views shows what is placed in a cut plane and behind it. The internal contours of a part on a sectional views are shown by continuous main lines, as well as the visible contour of an object. What gets in a cut plane, is called a sectional view and it is shaded. Places, where a cut plane passes through cavities, are not shaded.

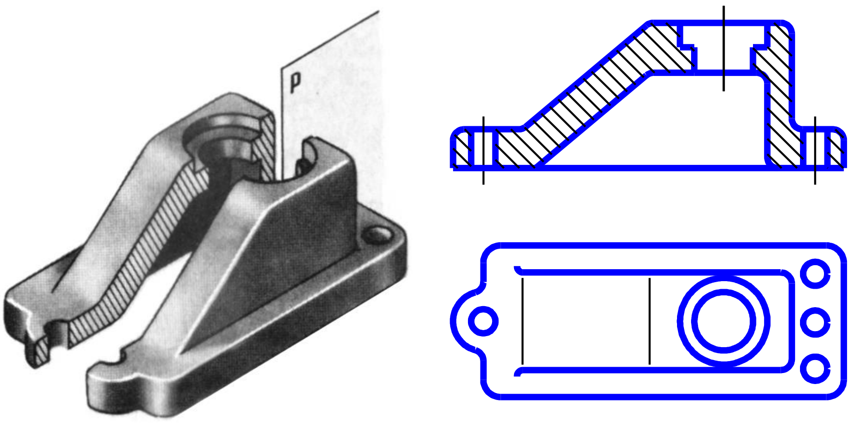



Figure 2.5 – A sectional views

Thus, to get a sectional drawing, it is necessary:

- To make a cutting plane in the right place;
- To set aside the part of an object, placed between the observer and the cutting plane;
- To project the remaining, part on the proper plane of projections and depict on the place of one of the basic views or on the free field of the drawing;
- To design a sectional drawing, if it is necessary, with inscript.

It should be remembered that a sectional viewsis a conventional representation and the part of an object, placed between an observer and a cutting plane, is set aside too. A conventional cutting touches only this depiction and does not influence all the others. So, for example, a sectional views on the frontal plane of projections does not change a top view.

Classification of sectional views.

The sectional views are divided according to the followings features:

1. Accoding to the position of a cutting plane in relation to the horizontal plane of projections sectional views are divided into horizontal, vertical and inclined.

The horizontal drawing is a sectional views which is formed by a cutting plane, parallel to the horizontal plane of projections. Most frequently this sectional views is disposed in the place of top or bottom views (fig.2.6).

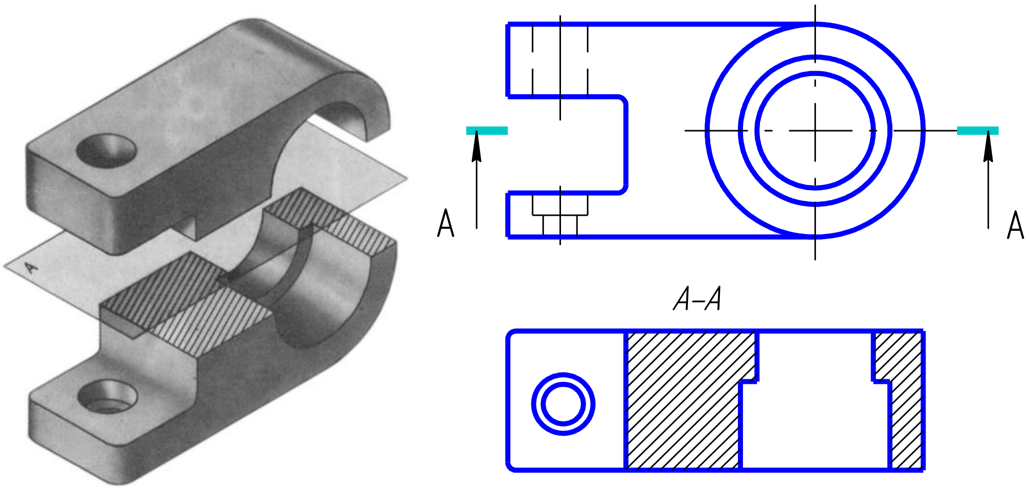
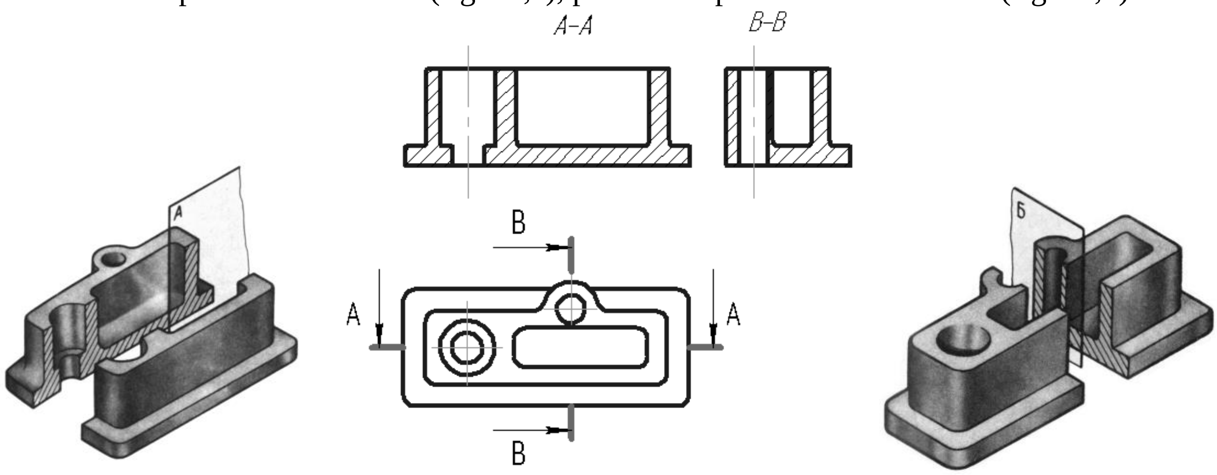



Figure 2.6 – The horizontal sectional view

The vertical drawing is a sectional drawing, which is formed by a cutting plane, perpendicular to the horizontal plane of projections. If a cutting plane is parallel to the frontal plane of projections, a vertical sectional views is named frontal; if it is parallel to the profile plane of projections, a sectional views is named a profile. As a rule, these sectional views are disposed in place of basic views: frontal in place of front view (fig.2.7,a), profile– in place of left-side view(fig.2.7,b).




a b

Figure 2.7 – The vertical sectional views

Sloping drawing is a sectional views which is formed by a cutting plane, which forms with the horizontal plane of projections a corner which differs from direct. These sectional views are used when an object has the inclined located elements (fig. 2.8). A sloping sectional views is designed on an auxiliary plane, parallel cutting, which is then combined with the plane of figure. It can be disposed at any place of the sheet both in direct projected connection and without it.

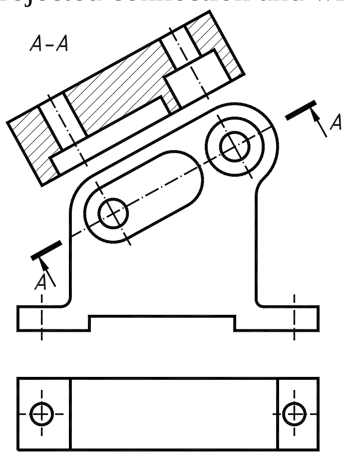



Figure 2.8 – The sloping sectional view

2. Depending on the position of cutting plane in relation to the basic measurings of object, sectional views can be divide into longitudinal and cross-sectional.

A cut is named longitudinal, if a cutting plane is directed along length or height of an object, and cross-sectional, if a cutting plane is directed perpendicularly to length or height of an object.

3. Depending on the amount of cutting planes, a sectional views can be divided into simple and complicated.

The simple drawing is a sectional views which formed by one cutting plane. All the above sectional views are considered to be simple.

The complicated drawing is a sectional views which is formed by two or more cutting planes. Such sectional views are divided into a offset section and broken.

An offset section is a complicated sectional views which is formed by parallel cutting planes (fig.2.9). A sectional views is done, as though depictions which are contained on all of parallel planes are combined in one plane (without denotation of limits of each planes).

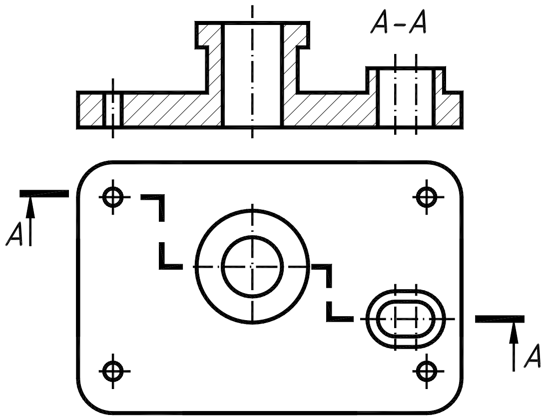



Figure 2.9 – An offset section

The broken section is a complicated sectional views which is formed by unparallel cutting planes, thus one plane or some of them usually inclined to the basic planes of projections (fig.2.10). The broken sectional views is represented, as though a ramp is turned in vertical or horizontal position to combination with direction of basic cutting plane. When the combined planes appear parallel to one of basic planes of projections, it is necessary to dispose the broken sectional views in place of the proper view.

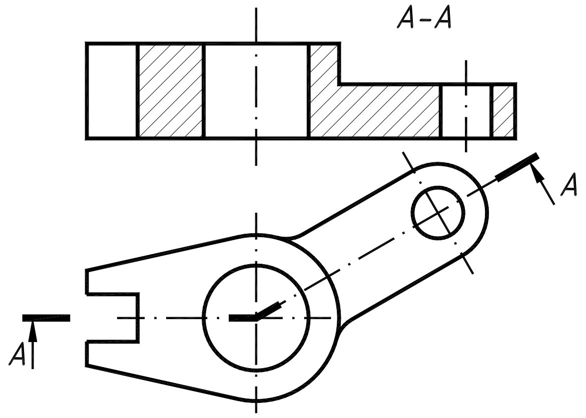



Figure 2.10 – The broken section

4. Depending on plenitude of implementation sectional views are divided into complete and partial sectional views.

A complete sectional views is a depiction which exposes the internal structure of an object on all of section, that when a cutting plane cuts an object through.

A partial sectional view is name a depiction which exposes the internal structure of a part only in the limited, separate place. Partial sectional views are separated from the whole part by a continuous wavy line which must not coincide with the lines of contour (fig.2.11).

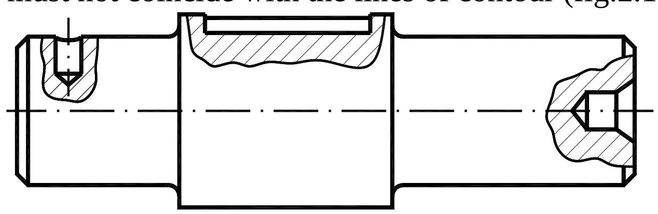


Figure 2.11 – A partial sectional view

Denotation of sectional views .

Denotation of sectional views containe three elements (fig.2.12):

1. Position of cutting plane is specified the broken a secret line of a section. The initial and eventual strokes of a line of section must not cross the contour of the proper depiction.

2. On initial and eventual strokes it is needed to put pointers, indicative direction of look. Pointers must be inflicted in the distance 2...3 мм from the external end of stroke. At a complicated cut the strokes of the broken a secret line of a section conduct also at the bends of line of section.

Near pointers, indicative direction of look from exteriority of corner, formed a pointer and stroke of line of section, on a horizontal line inflict the uppercases of the Ukrainian alphabet. The letters should be in alphabetical order without reiterations.

3. A sectional views must be over the depiction according to the type «A — A» without underlining.

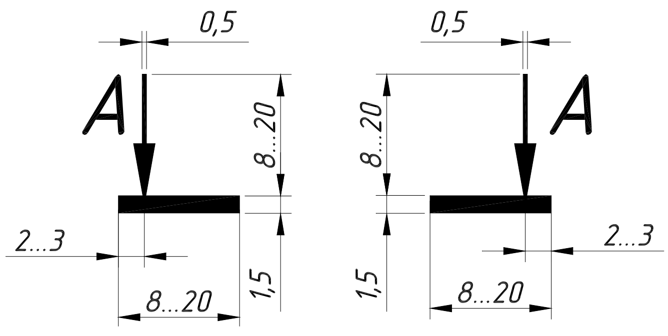



Figure 2.12 – Denotation of sectional views

If a cutting plane coincides with the symmetry plane of object, and a sectional views is executed in the place of the proper view in projected connection, for horizontal, vertical and profile sectional views , marking position of a cutting plane is not needed and a sectional views is not accompanied inscription.  A frontal sectional views is not marked (fig. 2.13).

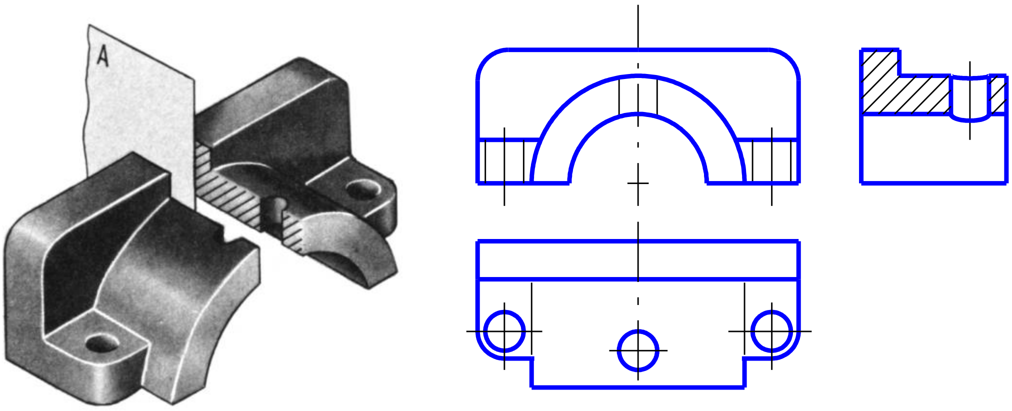



Figure 2.13 – Denotation of sectional views

However much simple sloping sectional views and complicated sectional views are always marked. Here are some examples of construction and denotation of sectional drawing. In a fig. 2.14 a horizontal sectional views is executed «A — A» in the place of view from above. A plane figure, lying in a cutting plane, is a figure of a section is shaded, and visible surfaces, located under a cutting plane, limited contour lines and are not shaded.

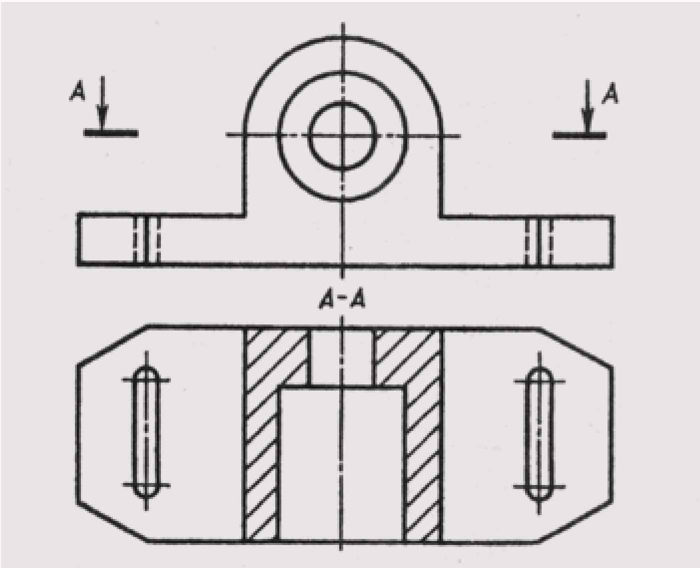



Figure 2.14 – A horizontal sectional view

A sloping sectional views is executed in fig. 2.15. It can be drawn in to projected connection in accordance with the direction, indicated pointers, or to dispose in any place of drawing. A local sectional views is executed, showing the through cylindrical openings on the basis of part  on a main view.

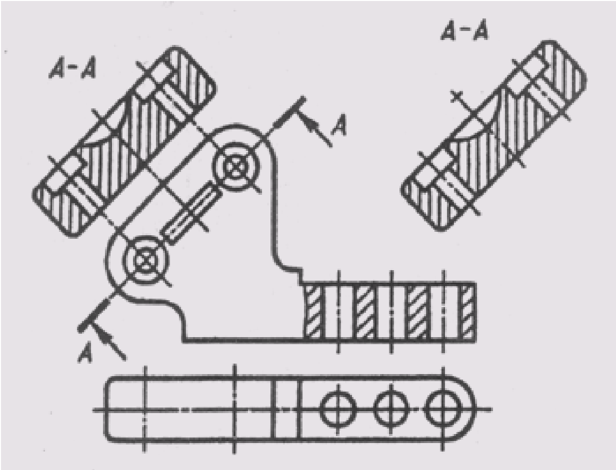



Figure 2.15 – A sloping sectional view

A complicated frontal sectional view is drawn in fig. 2.16 in a place of the main view, executed three frontal parallel planes. At the implementation of step sectional views all of parallel cutting planes are relatively combined in one, I.e. a difficult sectional views is designed as an simple. A transition from one cutting plane to other is not reflected on a difficult sectional drawing.

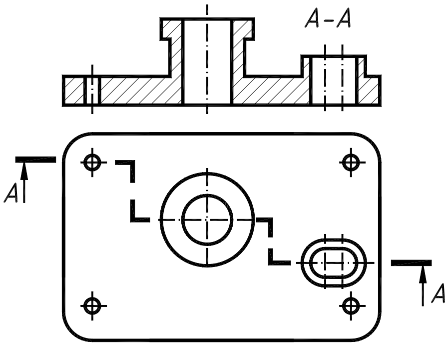



Figure 2.16 – A complicated frontal step sectional view

At the construction of the broken sectional views (fig. 2.17) one cutting plane is disposed parallell to some basic plane of projections, and the second cutting plane is turned to combination with first. The figure of section and sectional views  located in it turn together with a cutting plane and  is executed in the turned position by the figures of section.

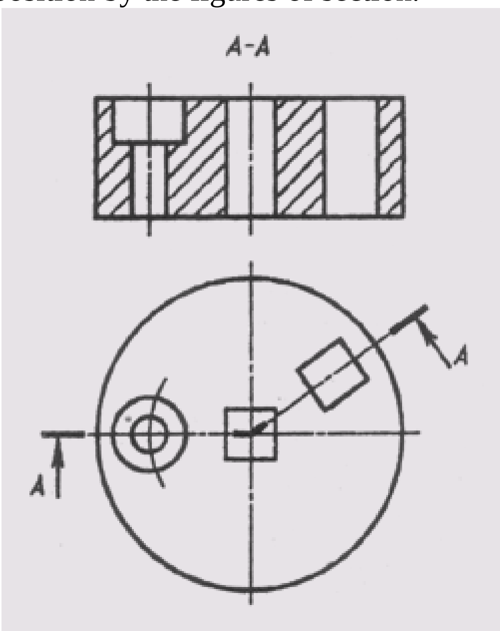



Figure 2.17 – The broken sectional view

A part of the view and a part of the sectional views can be joined in one depiction of an object, dividing them with a wavy line (fig.2.18).

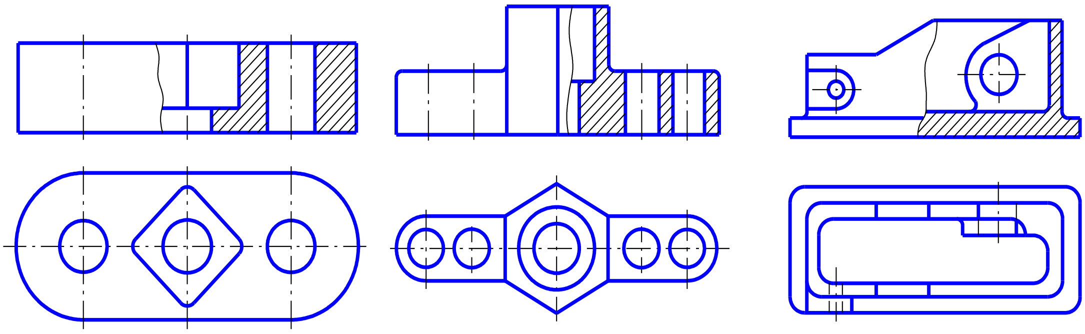


Figure 2.18 – A part of the view and a part of the sectional view

If we combine the half of view and half of sectional drawing, each of which is a figure symmetric, the ax of symmetry serves as a dividing them line. In fig. 2.19 four depictions of part are executed, thus on each of them the half of view is connected with the half of the proper sectional views . On a main view and left-side view a sectional views is disposed on the right of vertical ax by symmetries, and on top view and bottom view— on the right of vertical or from below from the horizontal ax of symmetry.

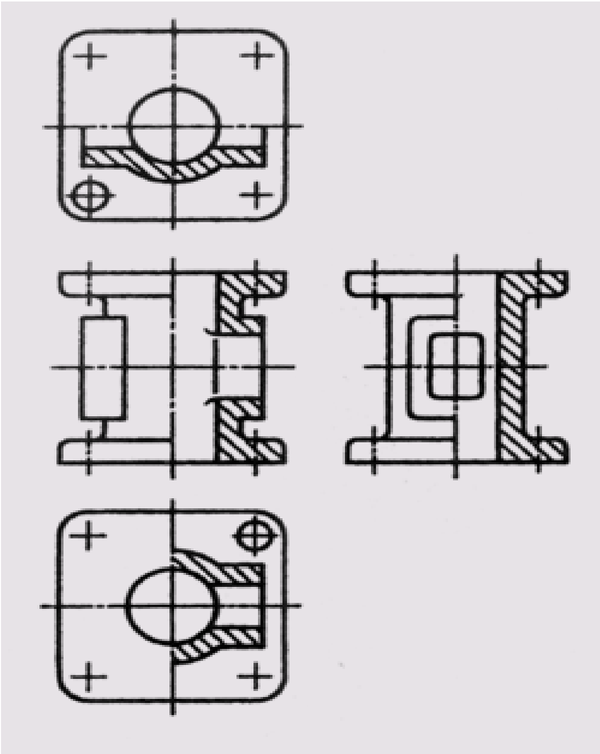


Figure 2.19 – Combining the half of view and half of sectional drawing

If the contour line of object coincides with the ax of symmetry (fig. 2.20), a border between a view and sectional views is specified a wavy line which is conducted so that to save the depiction of a rib.

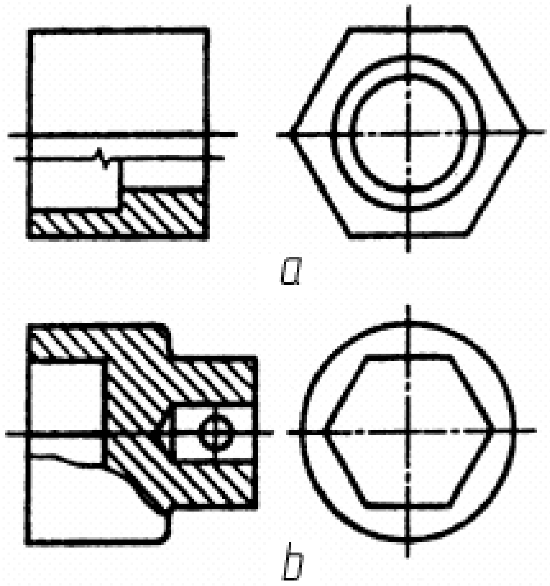



Figure 2.20 – Combining the half of view and half of sectional drawing

Shading of section figure, included in a sectional drawing, must be executed according to State Standard 2.306—68. Metals and their alloys designate in a section shading continuous striolas in thick from *S/3* to *S/2,* which conduct parallell between itself under the corner of 45° to the lines of scope of drawing (fig. 2.21). The line of shading can bring slope to the left or to the right, but in a the same side on all of depictions of the same part.

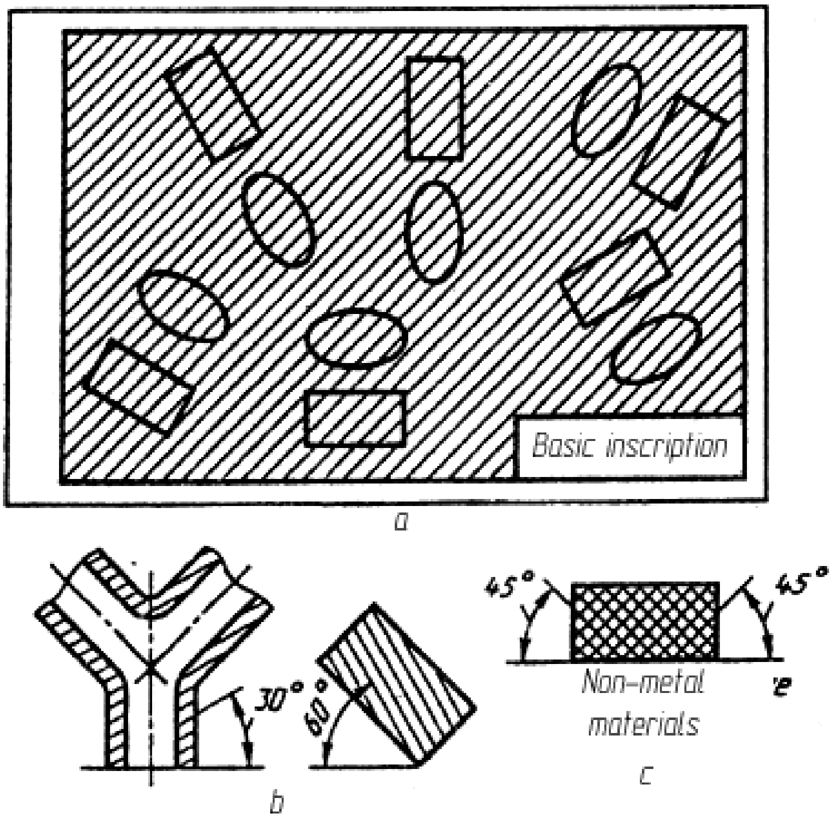
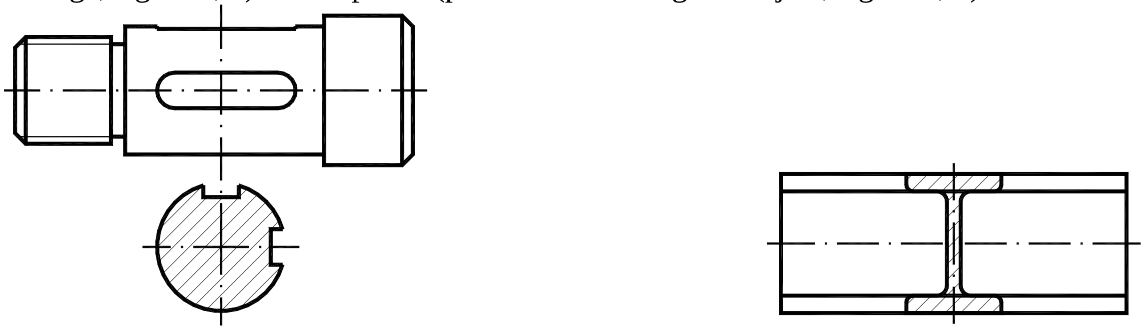



Figure 2.21 – Shading of section figure

## 2.3 SECTIONS

Except of views and sectional views, sections are often used on drawings. A section is the depiction in a figure, got at a mental section one or a few planes, on in case when on a drawing only that got in a cutting plane. A section differs from a sectional views that on its represent that directly gets in a cutting plane only. Sections enter in the complement of sectional drawing, but can exist and as independent depictions.

Sections, which are not in sectional views, divide into taken away (carried out separately from a basic image, fig.2.22, a) and imposed (placed on the image of object, fig.2.22, b).



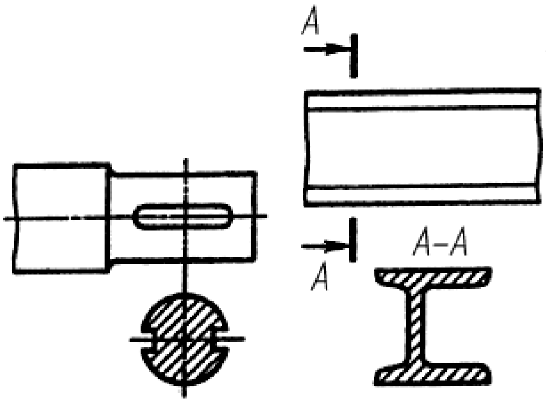
a b

Figure 2.22 – Types of sections

It is necessary to give a preference sections taken away, which can be disposed in a sectional views between parts of the same depiction.

The contour of the taken away section is drawn continuous by mainlines, and imposed — continuous thin, thus the contour of basic depiction is not interrupted in the place of location of the imposed section .

Denotation of sections in general case likes denotation of sectional drawings, I.e. the position of a cutting plane is represented by lines sections, on which inflict pointers, givings direction of look and designated the identical uppercases of the Ukrainian alphabet. Inscription on a type «A — A» (fig. 2.23) execute above a section in this case.




a b

Figure 2.23 – Denotation of sections

For the asymmetrical imposed sections or executed in the break of basic image, section with pointers a line is drawn, but it is not designated in a letter (fig. 2.24). Imposed symmetric section and symmetric section, executed in the break of basic image design without causing the line of section (fig.2.25).

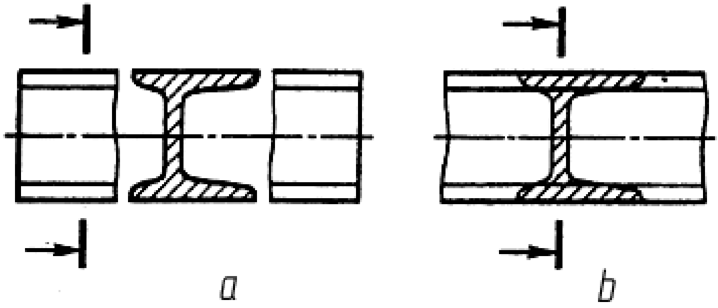


Figure 2.24 – Denotation of sections

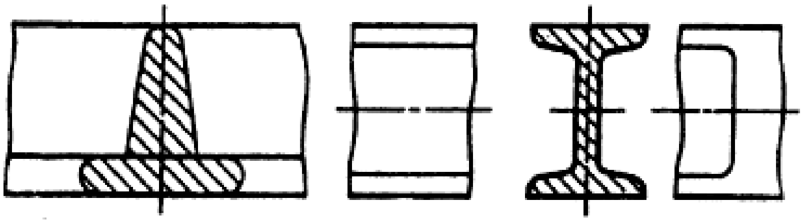


Figure 2.25 – Denotation of sections

If a cutting plane passes through the ax of surface of rotation, limiting opening or deepening, the contour of opening or deepening is drawn fully.

If a cutting plane passes through the through unround opening and section turns out consisting of separate independent parts, it is necessary to use sectional drawings, but not sections.

## 2.4 BEARING-OUT ELEMENTS

A bearing-out element is a depiction in the enlarged scale of a part of an object, which contains elements which are not on a basic depiction. Bearing-out elements are used, when auxiliary explanations are needed in regard to a form, sizes or other information (fig.2.26).

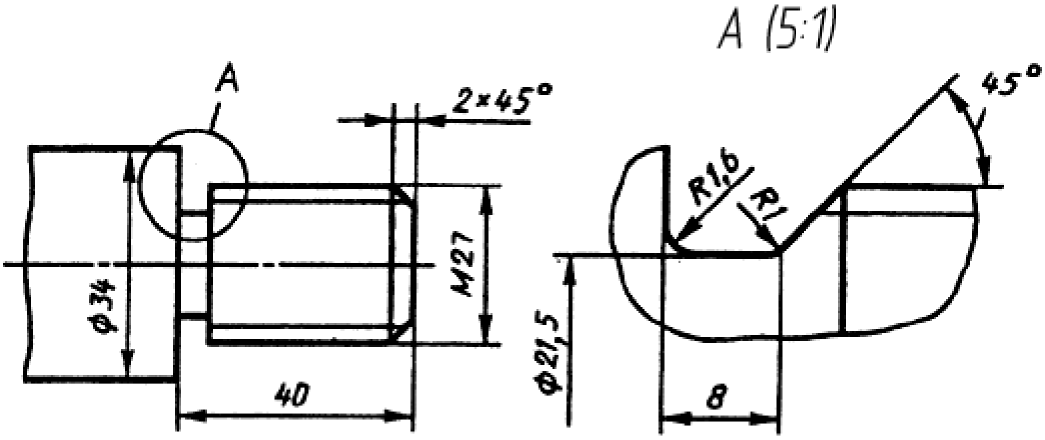



Figure 2.26 – A bearing-out element

At the construction of bearing-out element the proper place of basic depiction is marked the continuous line and designate the capital letter of the Ukrainian alphabet on the shelf of line-bearing-out. Above a bearing-out element a record is done on a type A (5 : 1). In a fig. 2.26 the example of implementation of bearing-out element is resulted.

## 2.5 CONVENTION AND SIMPLIFICATION AT THE CONSTRUCTION OF IMAGES

State Standard 2.305—68 recommends to apply some conventions and simplification at implementation of different images of object.

1- If an image is a symmetric figure, it is possible to draw the half of image or slightly more halves of depiction only, limiting to his axial or wavy line (fig. 2.27, a).

2 – If a few identical, evenly placed elements have an object, dark-and-light this object fully show one or two such the element, and other – simplified or de bene esse (fig.2.27, b);

3 – It is also possible to represent part of object, specifying the amount of elements, their location and others like that (fig.2.27, c);

4 – Rivets, bolts, nuts, keys, etc. are not sectioned. It is a convention in machine drawing that shafts, nuts, bolts, screw and all other threaded parts, keys, cotters and other simple fastening devices, spokes, ribs, webs are not sectioned. Therefore only a small portion of the sectioned object is shown with hatched lines. Thin walls do not shade the spoke of fly-wheels, pulleys, gear-wheels, rib of inflexibility, if a cutting plane is placed along the ax of such element (fig.2.27, d).

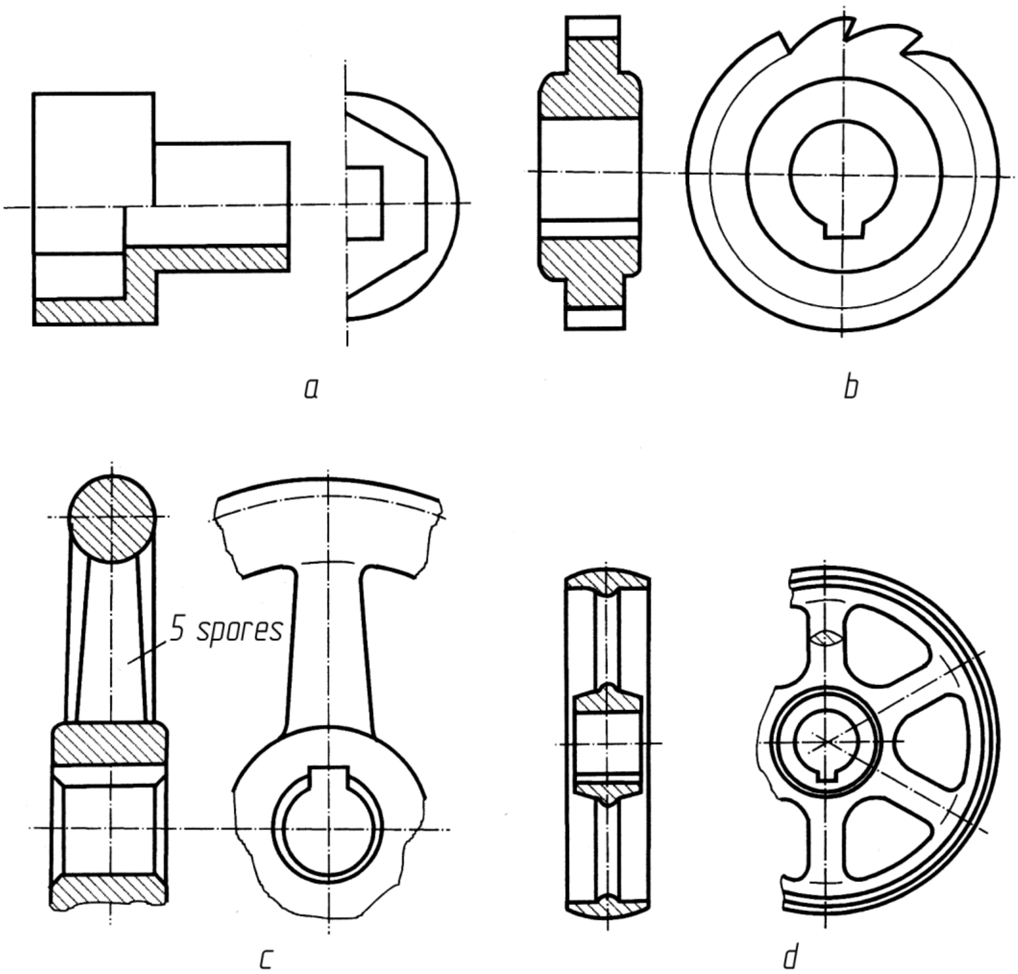



Figure 2.27 – Conventions and simplification

5 – The smooth transition from one surface to other is represented conventionally or not nearly represented (fig. 2.28, a);;

6 – It can be allowed simplifications, analogical to mentioned on a picture  (fig.2.28, b);

7 – It can be allowed  to represent insignificant taper or slope with an increase (fig.2.28, c);

8 - Details which have large length, permanent crossrunner or such, that changes appropriately, it is possible to show with a break (fig.2.28, d);

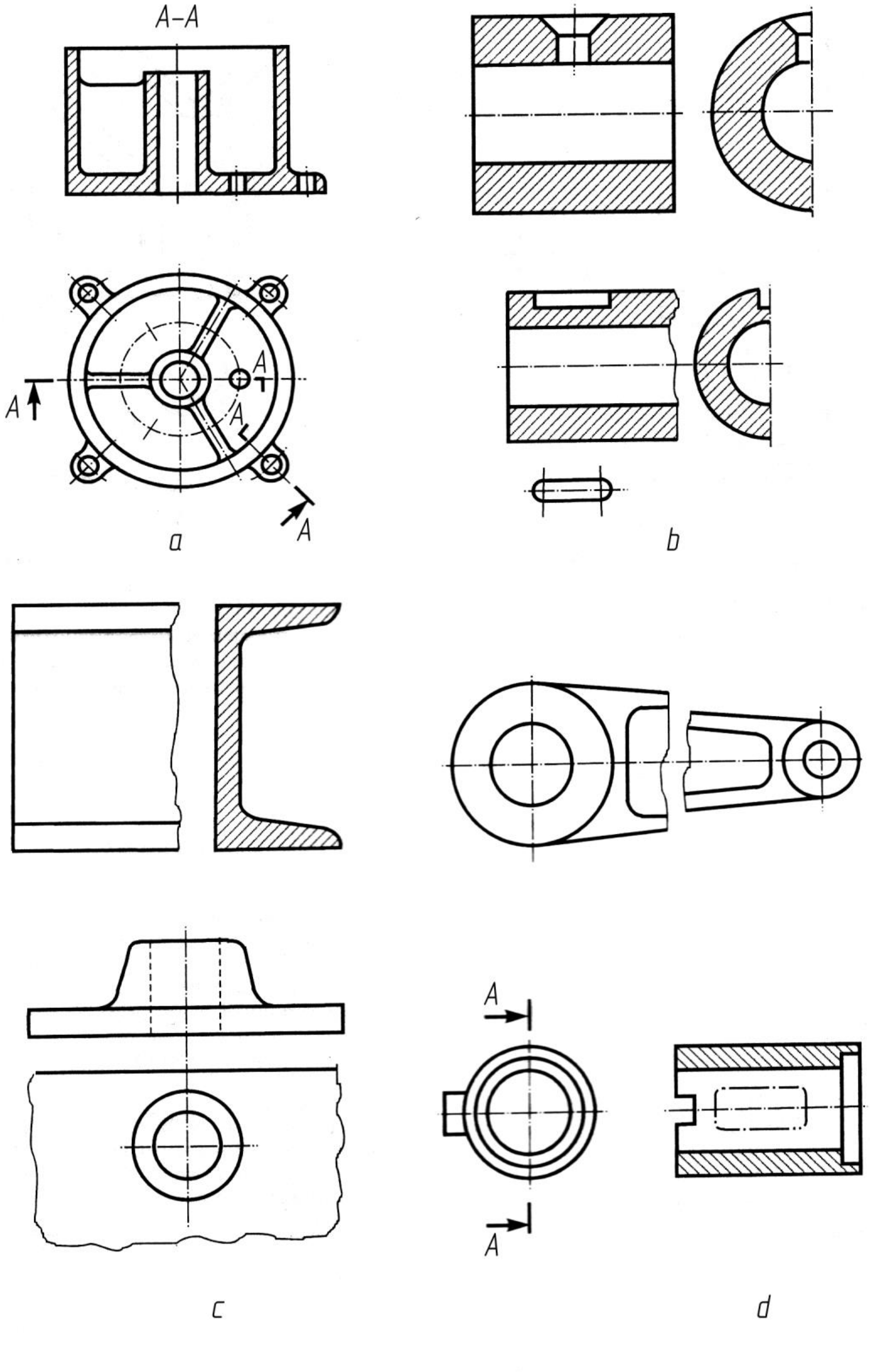



Figure 2.28 – Conventions and simplification

9 – It can be allowed  part of object, placed between an observer and cutting plane, to show directly on sectional views  by an incrassate dash-dotted line is the so-called “imposed projection” for simplification of picture and diminishing of amount of images (fig.2.28, e);

10 –It is assumed to give an opening contour only for the image of openings in gear-wheels, pulleys, and also for wedge key channels in place of complete depiction of a part (fig.2.29).

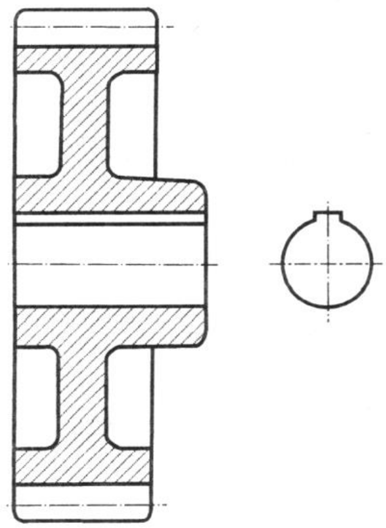


Figure 2.29 – Conventions and simplification

**QUESTIONS FOR SELFCHECK**

1. What State Standard  sets the rules of object depictions?
2. What kind of vies do you know?
3. When are views and sectional views used?
4. What is denotation of sectional views?
5. What difference between sectional views and sections?

# 3 AXONOMETRIC PROJECTIONS
## 3.1 BASIC CONCEPTS, DETERMINATIONS, CLASSIFICATION

Practical receptions of construction of visual images– axonometric projections and technical drawings are based on the theory of axonometric and perspective projections.

Visual images have a large practical value, they are widely used in different spheres of activity. A necessity in an visual image arises up at reading of drawing of an article, when it is difficult to imagine its structural form. A person who is not familiar with the methods of the ortogonal planning on three planes of projections, is hardly be able to imagine immediately what is shown in fig. 3.1.

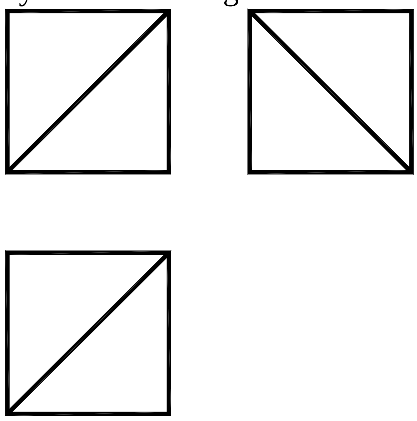


Figure 3.1 – Visual images

Axonometric projections are used to facilitate the process of spatial imagination. The example of this drawing is shown in figure 3.2. The view of a cube with a cut in a axonometric projection and its projection on three planes is shown.

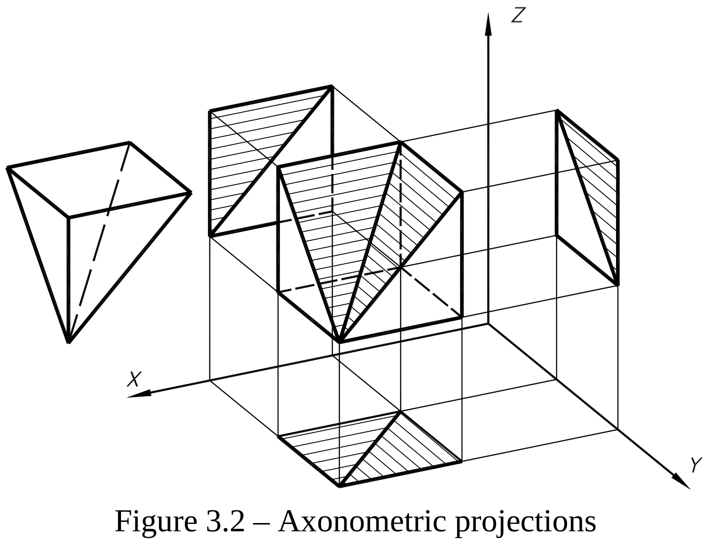



Figure 3.2 – Axonometric projections

Consequently, with the help of axonometric projections we can show the structure of the whole article and the structure of its separate parts, technological processes of treatment, assembling and installing. Axonometric projections are used for the transmission of the technical project of an author while planning and constructing new articles.

While looking at the visual depiction of an object, you get to know about it only on the basis of the unique appearance which is presented from one immobile point of view. Most of the component parts of an object, which find out its form on the whole might be seen on the visual depiction. Separate parts of an object must not fully close other its parts.

A view, got at parallel projections of an object together with the axes of rectangular co-ordinates of x, y, z to which it is taken in space, on some plane $^{0}\Pi$ is called an axonometric projection. · Thus the plane $^{0}\Pi$, which an object is designed on, is called axonometric, and projections on it axes of 0x, 0y, 0z is called axonometric axes. The size of corner between them depends on the direction of planning and the position of a plane $^0\Pi$ according to the axes of $x, y, z$ . The main positions of parallel projections are also used for axonometric projections : the axonometric projections of parallel lines are parallel between themselves; even segments which belong to the parallel lines are designed in even segments; if a point divides a segment in a certain correlation, its an axonometric projection divides the axonometric projection of cutting-off in that correlation. Segments on the axes of coordinates of x, y, z are designed generally with distortion. The sizes of projected objects are also distorted. The coefficients (indexes) of the distortion on axes equal the attitude of axonometric co-ordinates (on a drawing) toward natural (on an object). Depending on the direction of projected rays axonometric projections are divided into rectangular and oblique-angled. Axonometric projections are called rectangular, if a corner between projected rays and a plane of $^0\Pi$ is equal 90. °Axonometric projections are called oblique-angled, if a corner between projected rays and plane of $^0\Pi$ less than from a direct corner. Depending on the distortion of linear sizes of an object along axes axonometric projections are divided into isometry and dimetry. State standard 2.317-69 recommends to use two types of rectangular axonometric projections – isometry (figure 3.3) and dimetry (figure 3.4) and three types of oblique-angled axonometric projections – frontal isometry (figure 3.5), horizontal isometry (figure 3.6) and frontal dimetry (figure 3.7).

## 3.2 TYPES OF AXONOMETRY
### 3.2.1 RECTANGULAR ISOMETRIC PROJECTION

**Izometry** is a axonometric projection with the equal indexes of distortion for all three axes. Figure 3.3,a shows a sphere in a rectangular isometric projection the diameter of which equals a metage. A corner between axes is 120°. Place this sphere into a cube ribs of which, also equal to the direction of axonometric axes (see fig. 3.3,b). Project a sphere on the verge of cube. Such type of planning is called American. The projections of the sphere on the verge of a cube are smaller in size (disfigured). That segment of coordinate ax long 1 mm in rectangular izometry will be represented the segment of axonometric ax long 0,82 mm. Correlation 1 / 0,82=1,22 times determines a coefficient down-scaling on which we increase the sphere (see figure 3.3,c). Now the projections of the sphere as ellipses are inscribed in the verge of a cube (see figure 3.3,d). The major ax of ellipse makes 1,22 diameter – D of a projection circle of the sphere (equator, frontal meridian, type meridian), and minor axis – 0,71 diameter. Place a sphere in the usual (europian) first angle projection method. Figure 3.3,e shows the correlation for determination of length of cuttings-off of major [AB] and minor [CD] axes of ellipses. Sizes of cuttings-off [1, 2] and [3, 4] equal the diameter of projected circle of a sphere, and in general case the diameter of a cylinder or a hole on a figure. While making of quaternary cuts in rectangular izometry follow to the rules resulted of hatching as shown in fig.3.3,f. Stroke lines are drawn parallell to the axonometric axes.

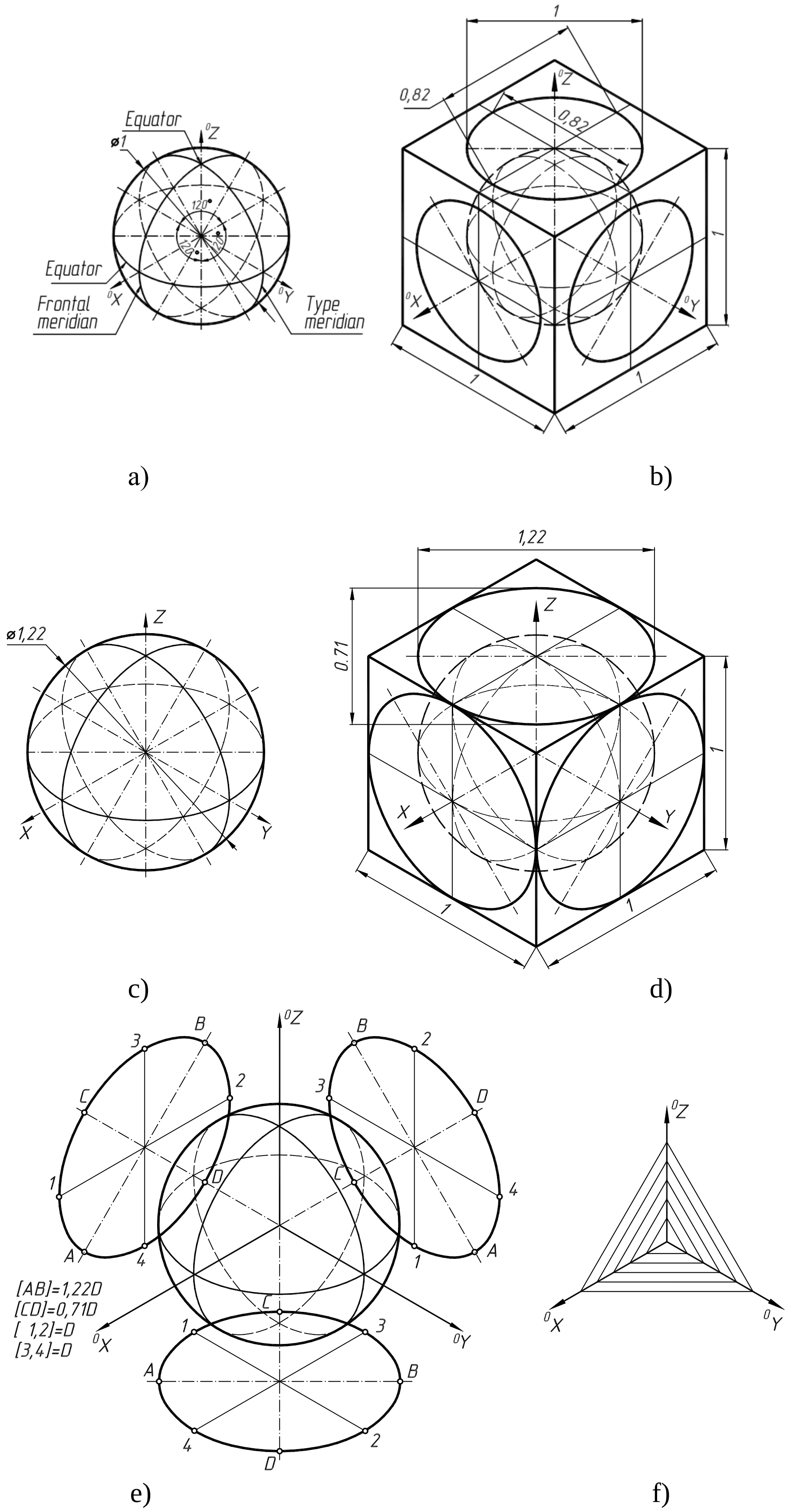
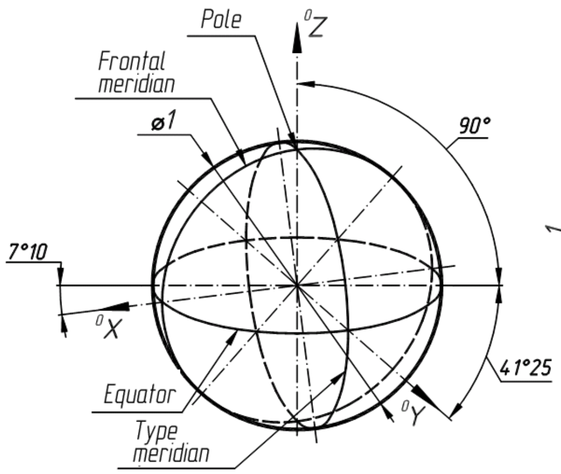


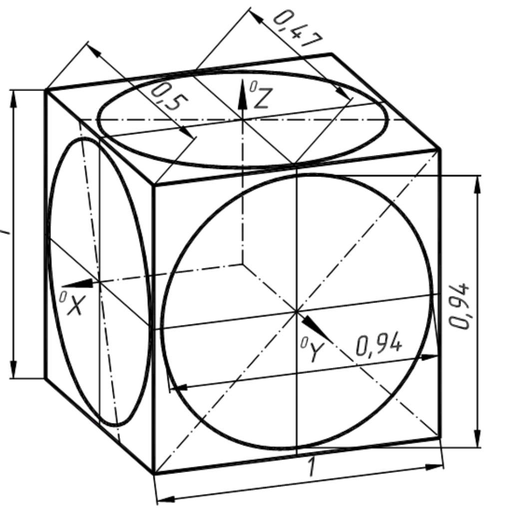

Figure 3.3 – Izometry

### 3.2.2 RECTANGULAR DIMETRY PROJECTION

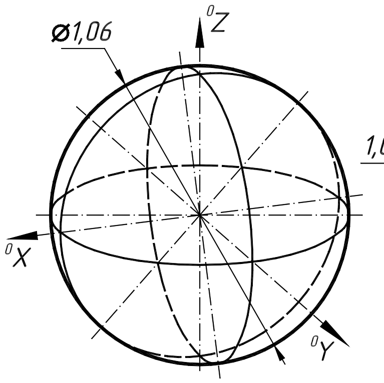
**Dimetry** is an axonometric projection with the identical indexes of the distortion on two axes. Figure 3.4,a shows a sphere in a rectangular dimetric projection the diameter of which equals a metage. A corner between a horizontal line and the axis X equals 7°10’, and the axis of Y - 41°25’. Place this sphere into a cube ribs of which, are equal the direction of axonometric axes X and Z, and to the direction to axes Y a rib in rectangular dimetry will look half less (figure 3.3,b). Project a sphere on the verge of a cube. The projections of a sphere on the verge of a cube are smaller in sizes (disfigured). That segment of coordinate ax of 1 mm long in rectangular dimetry will be represented in a segment of 0,94 mm long to direction of axes X and Z, and by a segment of 0,47 mm long to direction of axes Y. Correlation 1 / 0,94=1,06 times determines a coefficient down-scaling on which we increase a sphere (figure 3.3,c). Now the projections of a sphere as ellipses are inscribed in the verge of a cube (see figure 3.3,d). The major axis of ellipses is 1,06 diameter – D of projection circle of a sphere (equator, frontal meridian, type meridian), and minor axis is a 0,95 diameter on the frontal plane of projections and 0,35 diameter on horizontal and profile planes. Place a sphere in the usual (europian) first angle projection method. Figure 3.3,e shows the correlation for determination of the length of cuttings-off of major axis [AB] and minor axis [CD] of an ellipse on the frontal plane of projections and minor axis- [EF ] ellipses on horizontal and profile planes. The size of the sections [1, 2] and [3, 4] is equal to the diameter of the projection circle of a sphere (in general case to diameter of a cylinder or a hole on a figure), and the section [5, 6] to the half of diameter of the projection circle of a sphere. While making sectional drawings in rectangular izometry follow the rules of hatching as shown in figure 3.3,f.



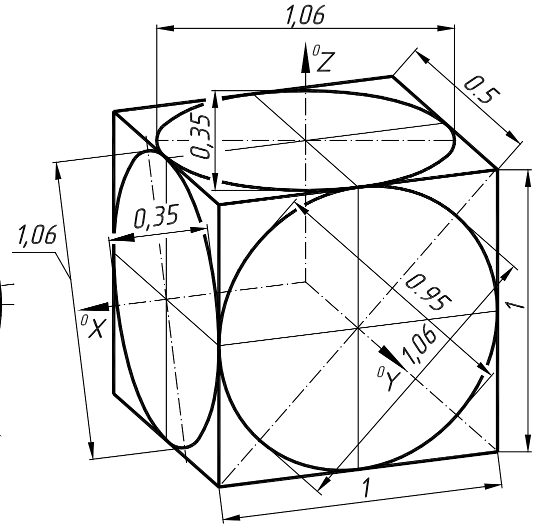

a)



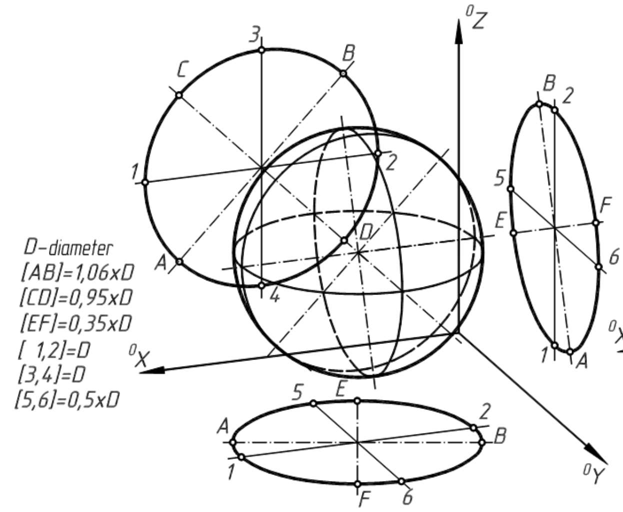

b)



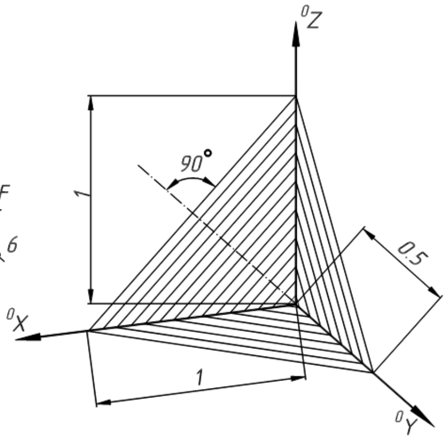

c)




d)




e)




f)

Figure 3.4 – Dimetry

## 3.2.3 AKSONOMETRICAL OBLIQUE-ANGLED PROJECTIONS STATE STANDARD 2.317-69

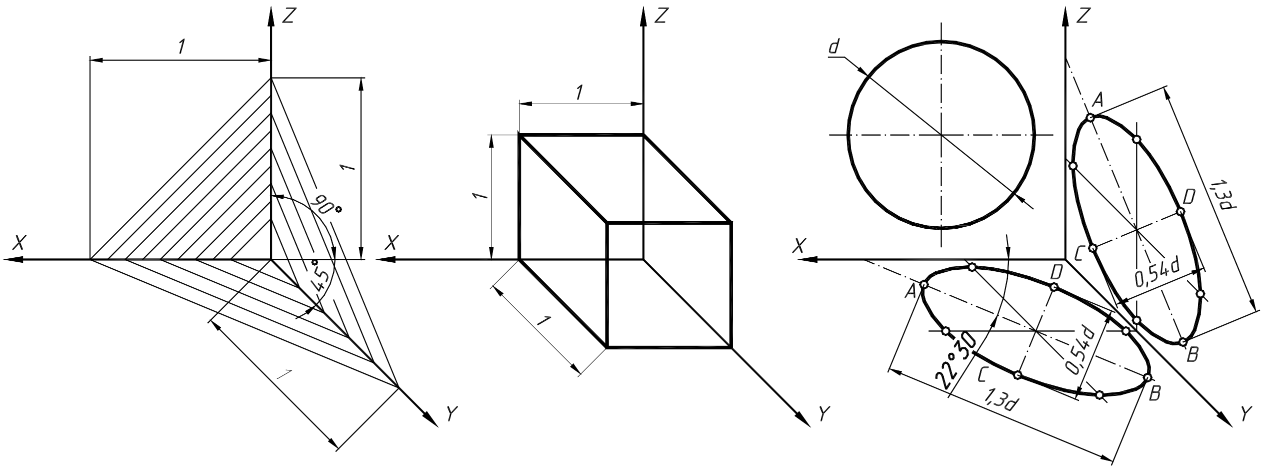



Figure 3.5 - Frontal izometry

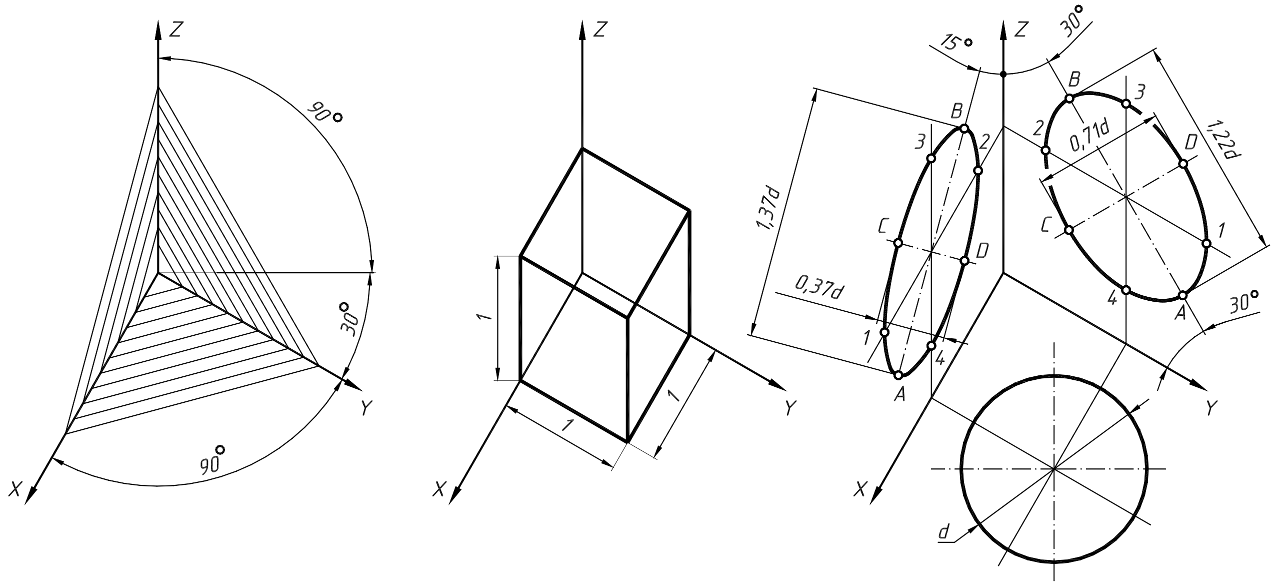



Figure 3.6 - Horizontal izometry

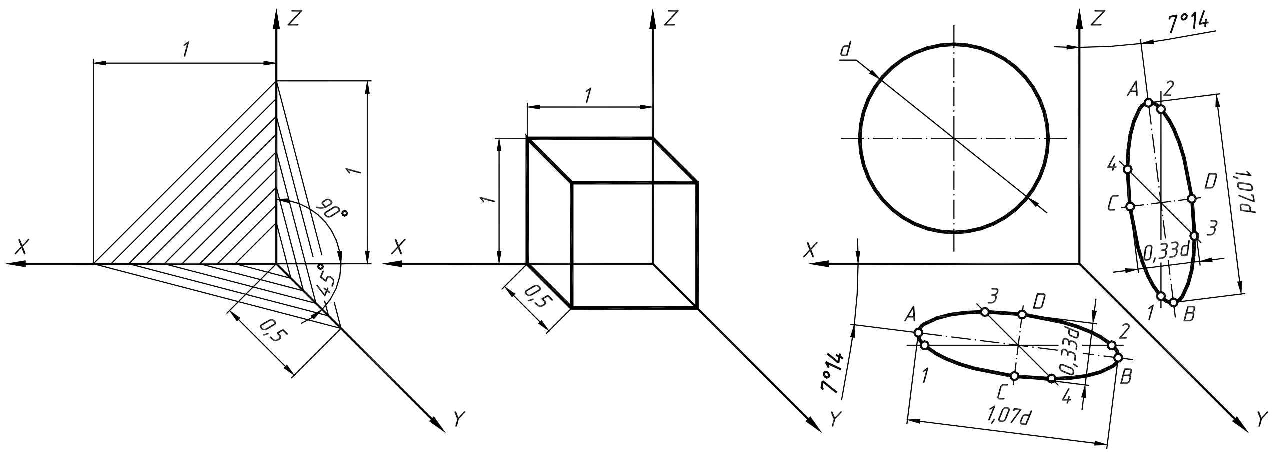



Figure 3.7 - Frontal dimetry

## 3.3 METHODS OF MODELING THE FIGURES AXONOMETRIC PROJECTIONS
## 3.3.1 AXONOMETRY OF PLANE FIGURES

For modeling of a point in axonometry a coordinate broken line is drawn taking into account the coefficients of distortion on the axes of x, y, and z depending on the type of axonometry.

**Let's consider modeling of an axonometry of point, line and plane figure in rectangular izometry.**

In izometry coefficients of distortion on the axes of x, y, and z are equal and equal 1.

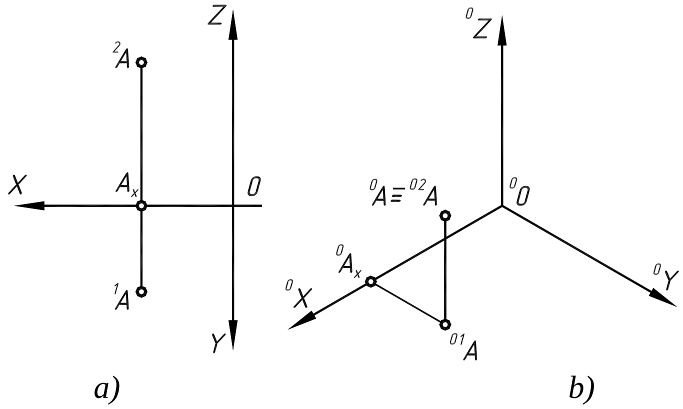



Figure 3.8 – Modeling of a point in axonometry

The segment $OA_x$ (figure 3.8, a) put from a point $^{0}0$ for the axes $^{0}x$ of the axonometrical system of coordinates (figure 3.8, b). Through the obtained point $^{0}A_x$ draw a straight line, parallel to $^{0}y$, on which a segment is drown, equal a segment $A_x\,{}^{1}A$. · Point $^{01}A$ is obtained from which draw a straight line, parallel $^{0z}$ · On this line draw the segment $^{01}A^{02}A$, equal the segment of $A_x{}^{2}A$. The obtained point $^{0}A$ is the isometric projection of point A. The axonometrical segments make an axonometrical coordinate plane.

Making the considered model for every point of axonometrical figure, we can draw the model of this figure in axonometrical projections. Figure 3.9 b shows the construction of rectangular izometry for the segment AB, and figure 3.10 b shows a construction of rectangular izometry of a plane figure ABC.

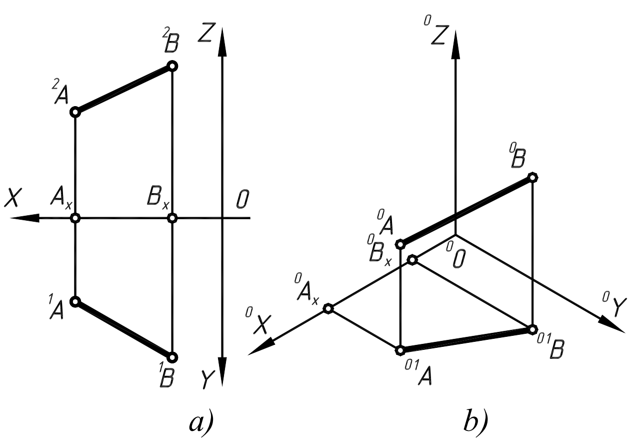



Figure 3.9 – Construction of rectangular izometry AB

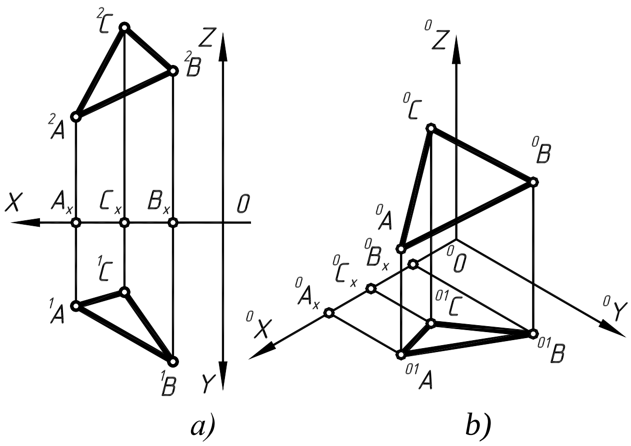



Figure 3.10 – onstruction of rectangular izometry for the segment of a plane figure ABC

**Let's consider the modeling of rectangular izometry of a plane figure** which is in a plane of projections (or in a level plane). As flat figures have two measurings that is why for their modeling in axonometry two axes are used, which are chosen depending on to which of the planes of projections the figure is parallel.

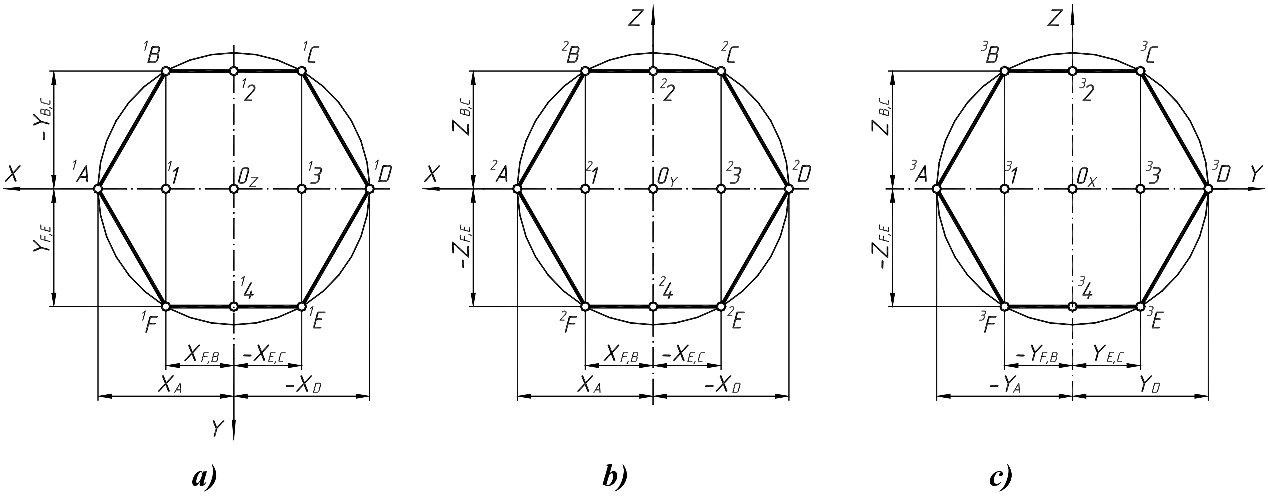
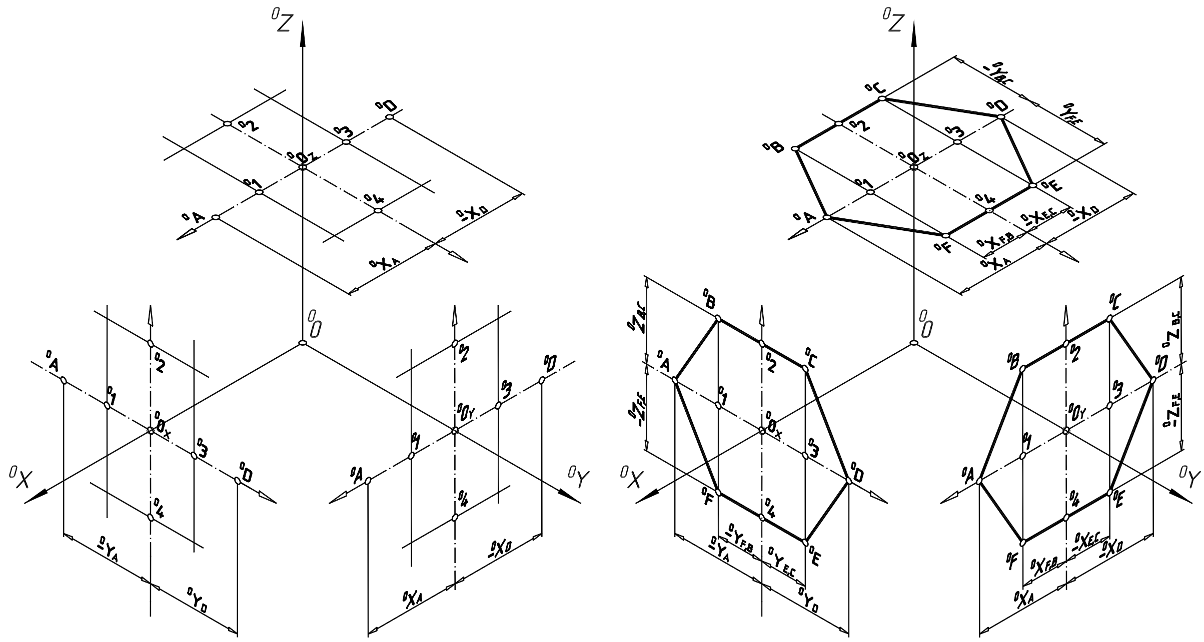



Figure 3.11 – The modeling of correct hexagon

Figure 3.11 shows a correct hexagon which is placed: a) parallel to the horizontal plane; b) – parallel to the frontal plane of projections; c) parallel to the profile plane of projections. The modeling of every point in a axonometrical projection generally is carried out after the description as shown in fig.3.8, we will use the well-known rule: the axonometrical projections of parallel lines are parallel between themselves. Through auxiliary points 1, 2, 3, 4, which are on axonometrical axes, draw lines parallel the proper axonometrical axes (see figure 3.12, a) and on their crossing mark the points of

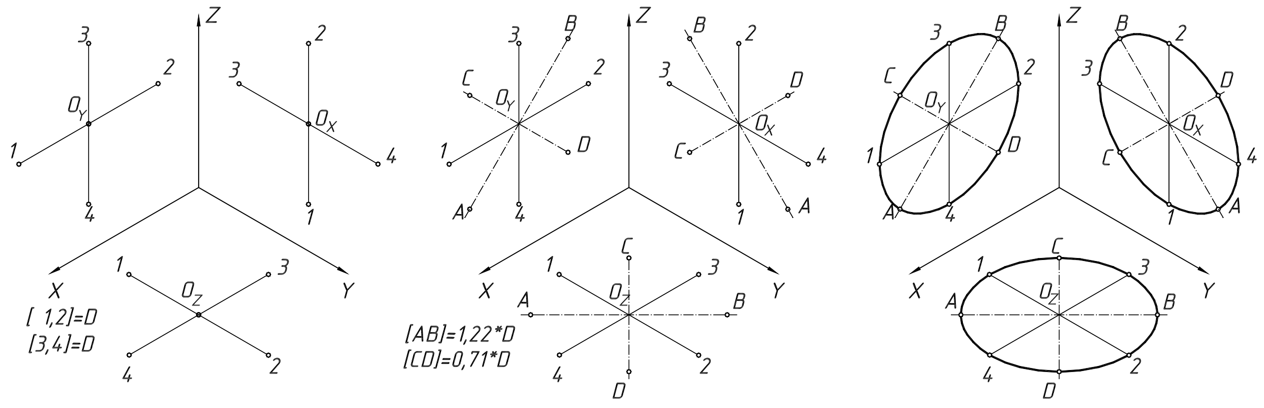
$^0B$, $^0C$, $^0E$, $^0F$. Points $^0A$, $^0D$ are also on the proper axonometrical axes while connecting all of axonometrical projections of points, we'll get an axonometrical projection of a figure (see fig. 3.12 b).




*a)* *b)*

Figure 3.12 – The modeling of correct hexagon

Axonometry of a free circle can be built as an aggregate of axonometrical projections of certain number of points of this circle. In any type of axonometry a circle will be projected in an ellipse. For the modeling of a rectangular izometry of a circle (see fig. 3.13, a) which is in a coordinate plane (or in a level plane ), at first it is necessary to build axonometry of its center (points of $0_X$, $0_Y$, $0_Z$ (figure 3.8)) to draw through the obtained point lines, parallel to the proper two axonometrical axes (segment: [1, 2] = D (there is a diameter of a circle inplane), and [3, 4] = D). Then draw the minor axis of an ellipse (segment [CD] = 0,71 × D (dash-dotted line)) parallel the axonometrical axis out of this plane, and a major axis (segment [AB] = 1,22 × D) which will be perpendicular (see figure 7.13, b). An ellipse is drawn on the obtained eight points by the curve (figure 3.13, c).




*a)* *b)* *c)*

Figure 3.13 – Axonometry of a free circle

**Let's consider the modeling of a rectangular dimetry of a plane figure** which lies in a plane of projections (or in a plane level). Let's remind, that it is a axonometrical projection with the identical indexes of distortion on two axes – X and Z.

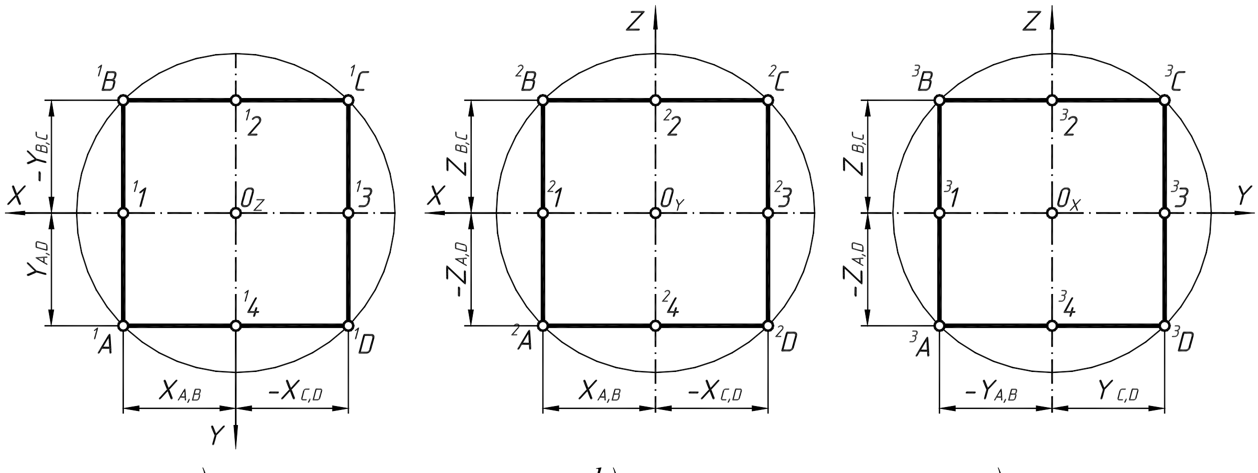



Figure 3.14 – Axonometry of a free circle

Figure 3.14 shows a square which is placed: a) parallel to the horizontal plane; b) – parallel to the frontal plane of projections; c) parallel to the profile plane of projections. Taken together these squares are the projection of a cube on the ortogonal planes of projections. In a rectangular dimetry this cube is shown in figure 3.4 d. It is evident, that the length of a verge to the direction of axis Y is twice less. The modeling of every point in an axonometrical projection is generally carried out after the description in figure 3.8, that is why we'll use the well-known rule: the axonometrical projections of parallel lines are parallel between themselves. Through auxiliary points 1, 2, 3, 4, which are on axonometrical axes, draw lines parallel the proper axonometrical axes (see fig. 3.15, a) and on their crossing mark the points of $^0$B, $^0$C, $^0$E, $^0$F. Points of $^0$A, $^0$D are also found on the proper axonometrical axes. Connecting all the axonometrical projections of points, we'll obtained an axonometrical projection of a figure (see fig. 3.15, b).

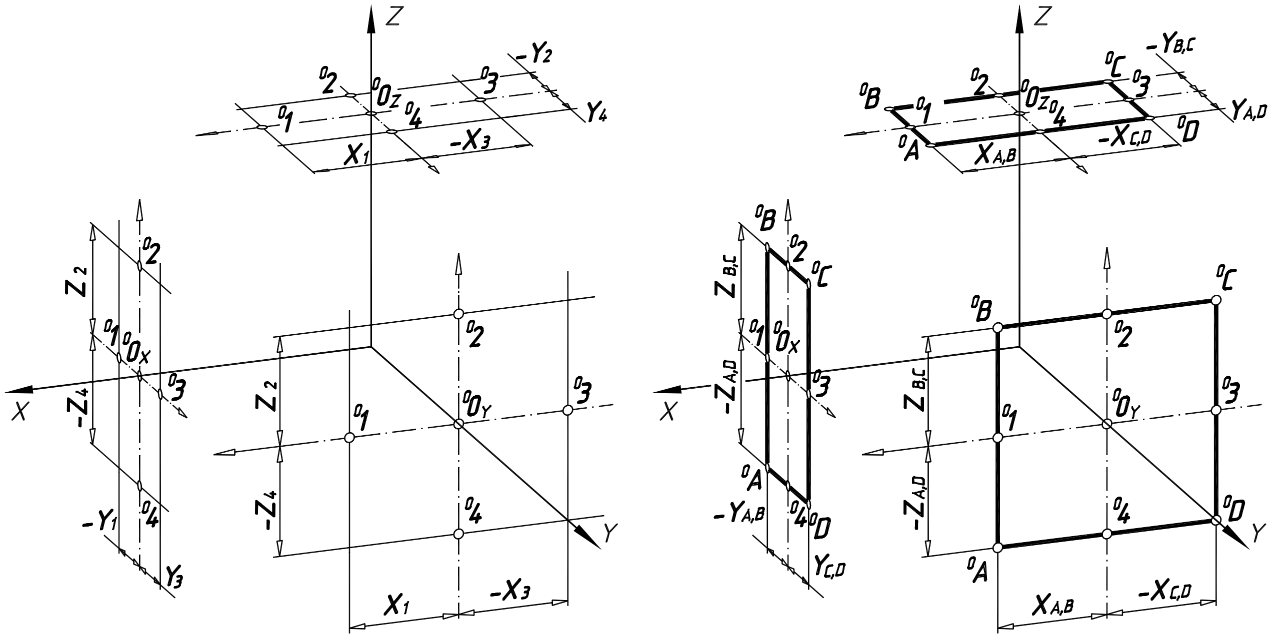
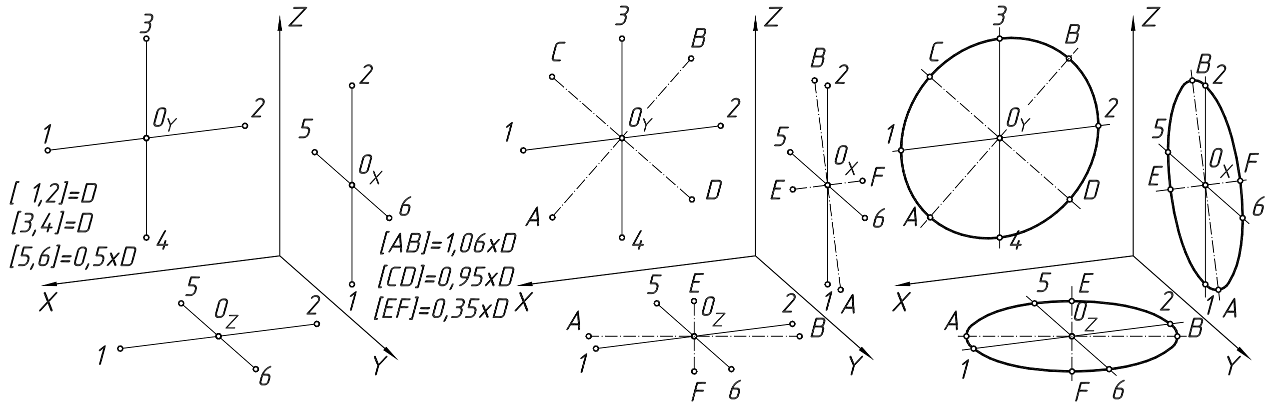



Figure 3.15 – Axonometrical projection of a figure

For the modeling of a rectangular dimetry circle (fig 3.16, a) which is in a co-ordinate plane (or in a plane level), first it is necessary to draw an axonometry of its center (points of $0_X$, $0_Y$, $0_Z$ (figure 3.8)), to draw through the obtained point lines, parallel to the proper two axonometrical axes (segment: [1, 2] = D; [3, 4] = D; [5, 6] = 0.5×D).




*a)* *b)* *c)*

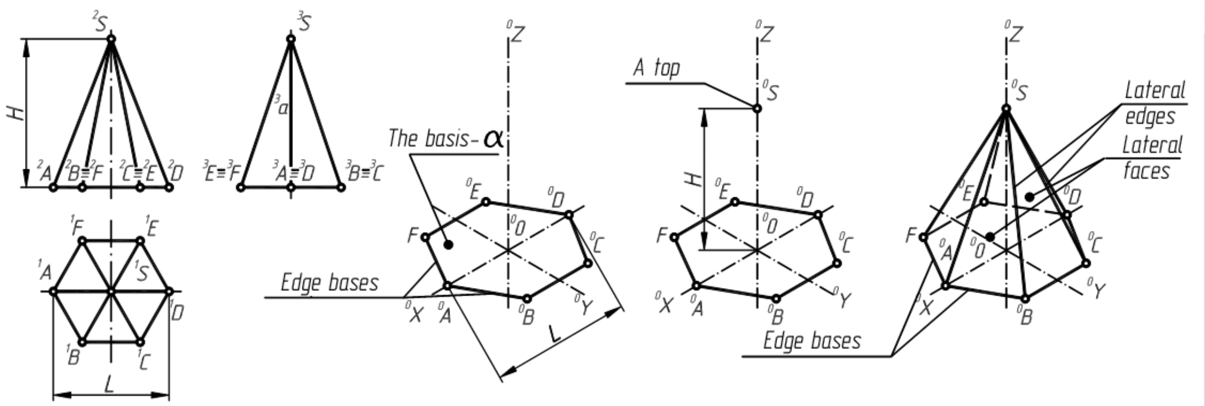
Figure 3.16 – The modeling of a rectangular dimetry circle

Then we draw the minor axis of an ellipse (segment [CD] = 0,95 × D (dash-dotted line) or [EF] = 0,35 × D) placed parallell to the axonometrical axis which doesn't exist in this plane, and also major axis (segment [AB] = 1,06 × D) which will be perpendicular to it (figure 3.16, b). The ellipse is traced on the eight points obtained by curve (figure 3.16, c).

### 3.3.2 EXAMPLES OF MODELING THE ISOMETRICAL PROJECTIONS OF SIMPLE FIGURES

**Modeling of rectangular izometry of a pyramid**

For a pyramid in figure 3.17, the axes of coordinates must coincide with its axes of symmetry, thus the beginning of coordinates - 0 will be in the center of the basis of a pyramid - α. At first draw isometric axes for the modeling the basis of a pyramid (figure 3.17, b). The basis of a pyramid is a plane figure which is drawn in obedience to description, to done before (figure 3.12). From a projection drawing we can determine the necessary coordinates of points and the location of a top of a pyramid – S (figure 3.17, c). Connect the top of a pyramid with points in basis, forming lateral edges and lateral faces (figure 3.17, d).

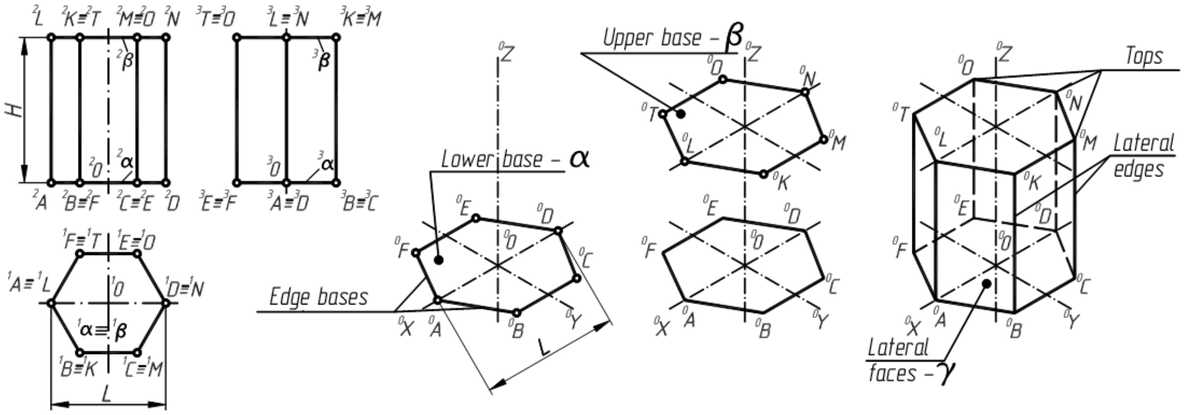



*a)* *b)* *c)* *d)*

Figure 3.17 – Rectangular izometry of a pyramid

**Modeling of rectangular izometry of a prism.**

For a prism in figure the 3.18 axes of coordinates must coincide with its axes of symmetry, thus the beginning of coordinates - 0 will be in the center of lower basis of a prism - α. At first isometric axes draw for the modeling the basis of a prism (figure 3.18, b). Upper and lower bases of a prism are a plane figure which is drawn according to the description done before (figure 3.12). From a projection drawing we determine the necessary coordinates of points and the location of upper base of a prism -β (figure 3.18, c). Connect points segments on upper and lower bases, forming lateral edges and lateral faces- γ (figure 3.18, d).

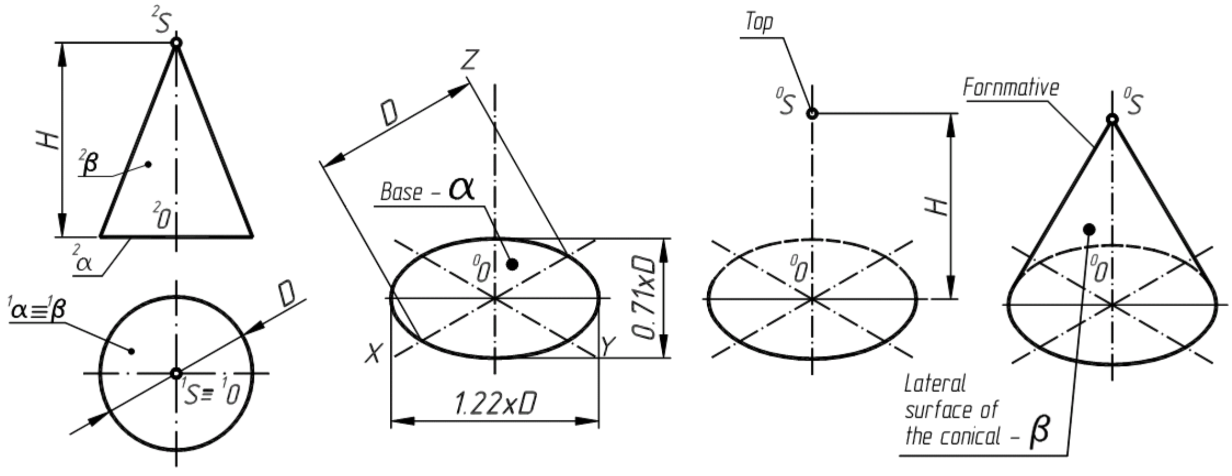



*a) b) c) d)*

Figure 3.18 – Modeling of rectangular izometry of a prism

**Modeling of rectangular izometry of a cone.**

For the direct cone (figure 3.19, a) axes of coordinates draw so that they coincided with the center of a circle in the basis, thus beginning of coordinates - 0 will be in the center of a circle. At first draw isometric axes for the modeling of a cone basis (figure 3.19, b). The basis of a cone is a circle, which is drawn in izometry according to the description done before (figure 3.13). From a projection drawing we determine the location of a top – S (figure 3.19, c). Connect the top of a cone with the segments of formative tangential to the elliptic curve (figure 3.19, d).

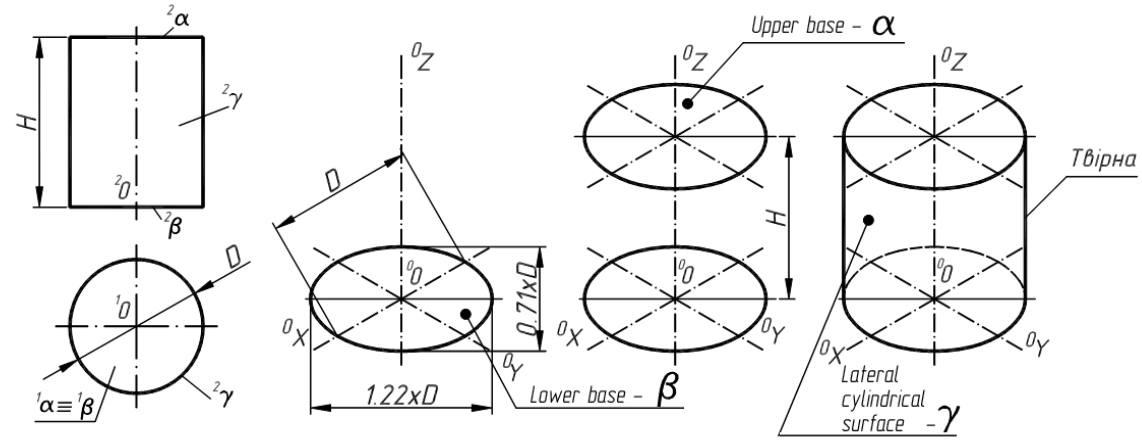



*a) b) c) d)*

Figure 3.19 – Modeling of rectangular izometry of a cone

**Modeling the rectangular izometry of a cylinder.**

For the direct cylinder (figure 3.20, a) axes of coordinates must coincide with the center of a circle in basis, thus beginning of coordinates - 0 will be in the center of a circle. At first draw isometrical axes for the modeling lower basis of a cylinder - β (figure 3.20, b). The basis of a cylinder is a circle which is drawn in izometry according to the description done before (figure 3.13). From a projection drawing we determine the location of a cylinder upper base - α (figure 3.20, c). Connect upper and lower bases with the segments of formative of tangential to the elliptic curves (figure 3.20, d).




*a)* *b)* *c)* *d)*

Figure 3.20 – Modeling the rectangular izometry of a cylinder

## QUESTIONS FOR SELFCHECK

1. Where are Axonometric projections used?
2. What types of axonometric projections do you know?
3. What are difference between dimetry and isometry?

# 4 JOINT
## 4.1 TYPES OF JOINT

Machines and mechanisms can be generally divided into component parts which form the unique functional system of the united elements and details.

Joints of details can be split-face and fixed.

Split-face joints allow to connect and disconnect details without a damage or plastic deformation of the both details.

Fixed joints are impossible to disconnect without a damage or plastic deformation of details of this connection (joints by welding, soldering, agglutination, press joints by riveting, etc.).

Split-face joints are divided into mobile in which the relative moving of connecting details (the key, splining but other) is possible, and immobile in which the connected details do not move in relation to each other (screw-thread joints by fixings, etc.). Let's consider sectional screw-thread joints. Examining this question it is necessary to find out basic determinations and classification of screw-threads. Basic determinations of screw-threads are resulted in State Standard 11708-66.

## 4.2 AN REPRESENTATION AND DENOTATION OF SCREW-THREAD ON DRAWINGS

A screw-thread is a surface formed at the spiral moving arbitrary plane a contour on the cylinder, conical or other surface of rotation.

All screw-threads are drawn conventionally on drawings, in accordance with the requirements of State Standard 2.311-68:

on a bolt (external thread): major diameter – by a mainline, minor – by a continuous thin in the distance not less than 0,8mm and no more to the size thread pitch from a thick mainline, on the left side view the minor diameter of screw-thread is shown by an arc, broken in an arbitrary place out of axial lines, length of arcs is ¾ circles;

in an opening (internal thread): minor diameter – by a continuous thick line, major – by a continuous thin line, on a left side view the major diameter of screw-thread is drawn by an arc on ¾ circles, the distance between is the same as for a screw-thread on a bolt .

The limits of screw-thread on the length of a bolt or an opening are drawn by a continuous thick line.

For all screw-threads (except of a pipe and one conical inch) conventional denotations are marked above the size line of major diameter. Pipe screw-threads, cylinder and conical are marked by the lines of foot-notes with pointers and shelves above which the conventional denotation of screw-thread is written. For a conical one inch screw-thread above a shelf the conventional denotation and standards on its basic parameters are written.

**A cylinder screw-thread is** a screw-thread on a cylinder surface, and **conical** on a conical surface. For implementation of screw-thread joints it is necessary to have two parts on one of which a screw-thread is on an external surface (external thread), and on the second – on internal surface (internal thread). A thread formed clockwise and moves along the ax of rotation from an observer is called a right-hand thread. A plane contour that moves anticlockwise along an ax from an observer forms a left-hand thread (LH).

A thread can be formed by spirally moving of one or a few identical plane contours which are located densely near each other along the ax of rotation. In the first case it is a single-start thread, in the second – a multiple-start thread (double-start thread or triple-start thread).

The thread profile is determined by the shape of the cutting tool. They are triangular, square, acme, round and others.

According to their purposes screw-threads can be fastener, motion (translating) (transformation of rotation of motion of one detail on straight line motion) and special.

Let's consider the basic parameters of screw-thread on the example of metric thread, shown in figure 4.1.

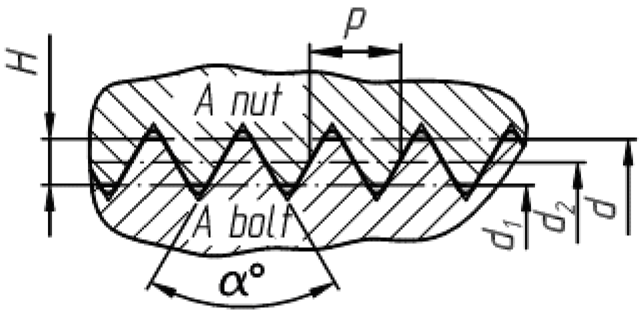



Figure 4.1 - Basic parameters of screw-thread

Parameters of a metric thread: d, $d_1$ - according to major and minor diameters of external and internal -threads, $d_2$ is a middle diameter of a screw-thread, $\alpha$ - a thread angle, P- a thread pitch, H- a height. The thread pitch P is a distance between two neighboring points of thread profile. A lead of thread t– is a distance on which one turn of a screw-thread surface will move along the ax of a screw-thread.

## 4.3 CLASSIFICATION OF THREADS

Threads are divided into: **standard** (metrical, pipe (cylinder and conical), one inch conical, trapezoidal and buttress), **special** and **non-standard** after the degree of parameters normalization. Standard threads are the most widespread.

For all standard and some special threads conventional denotations are foreseen. They consist of a letter, that marks a thread and nominal thread diameter, denotation of the tolerance zone or accuracy class of a thread. For a single-start thread a pitch is reflected additionally, and for a multiple-start thread – lead and pitch is marked by the letter P in handles, for example, 3 (P 1.5). Denotation of the left-hand thread is two letters LH.

### 4.3.1 METRIC SCREW-THREAD

A metric thread is the basic type of a fastener thread. The sizes of a metric thread are regulated by State Standard 9150- 2002, their profile (figure 4.2) – State Standard 9150-81, pitches –State Standard 8724-2002. The letter M is included in the conventional designation of a metric thread.

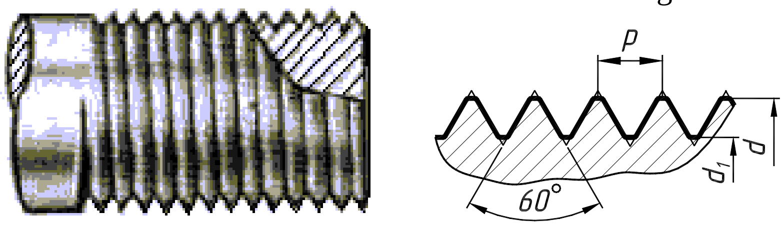



Figure 4.2 - Profile of a metric thread

The true form a screw thread is helical and it would take considerable time and labour to draw it. In actual practice, screw threads are shown by conventional methods.

External Threads—these threads in outside view are shown by means of two continuous thin lines drawn parallel to the axis, thus indicating minor diameter of the threads. The limit of the length of the thread is shown by a continuous thick line drawn perpendicular to the axis and up to the major or outside diameter of the threads. The run out of the thread is shown by lines drawn at an angle of 45° or 30° to the axis. Fig 4.3(a) shows an external thread conventionally. In the side view of the external threads, the minor diameter is represented by a part of a thin line circle about three quarters of the circumference.

Internal threads in section (Fig. 4.3 (b)) are shown by continuous thick and thin lines indicating respectively the minor and major diameters. The hatching lines are drawn crossing the thin lines.

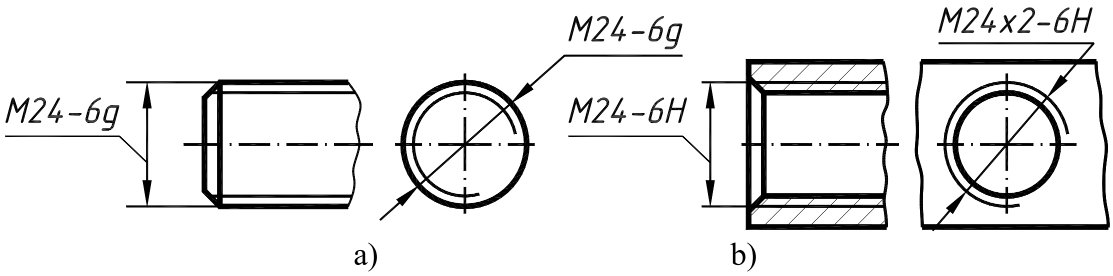



Figure 4.3 - Conventional representation of a metric thread:
a) on the bolt; b) in the opening.

Examples of conventional designation of metric thread with the nominal diameter of 24mm:

1. M24 – 6g – external, right-hand, with a coarse pitch and tolerance zone 6g;
2. M24x2-6H – internal, right-hand, by a fine pitch and tolerance zone 6H;
3. M24x3 (P1.5) LH- 6H – internal, double-start, with the fine pitch 1,5mm and 3 mm thread lead, left-hand, tolerance zone 6H.

Diameters and pitches of a metric cylinder thread of the general setting are shown in a table 4.1. Thread diameters of the first row have more advantages.

Table 4.1 - Diameters and pitches of metric cylinder thread of general application

| Diameter of thread, mm | | Pitch, mm | |
|---|---|---|---|
| 1th row | 2th row | coarse | fine |
| 6 | - | 1 | 0,75; 0,5 |
| 8 | - | 1,25 | 1; 0,75; 0,5 |
| 10 | - | 1,5 | 1,25; 1; 0,75; 0,5 |
| 12 | - | 1,75 | 1,5; 1,25; 1; 0,75; 0,5 |
| - | 14 | 2 | 1,5; 1,25; 1; 0,75; 0,5 |
| 16 | - | 2 | 1,5; 1; 0,75; 0,5 |
| - | 18 | 2,5 | 2; 1,5; 1; 0,75; 0,5 |
| 20 | - | 2,5 | 2; 1,5; 1; 0,75; 0,5 |
| - | 22 | 2,5 | 2; 1,5; 1; 0,75; 0,5 |
| 24 | - | 3 | 2; 1,5; ( 1 ) |
| - | 27 | 3 | 2; 1,5; 1; 0,75 |
| 30 | - | 3,5 | ( 3 ); 2; 1,5; 1; 0,75 |
| - | 33 | 3,5 | ( 3 ); 2; 1,5; 1; 0,75 |
| 36 | - | 4 | 3; 2; 1,5; 1 |
| - | 39 | 4 | 3; 2; 1,5; 1 |
| 42 | - | 4,5 | ( 4 ); 3; 2; 1,5; 1 |
| - | 45 | 4,5 | ( 4 ); 3; 2; 1,5; 1 |
| 48 | - | 5 | ( 4 ); 3; 2; 1,5; 1 |
| - | 52 | 5 | ( 4 ); 3; 2; 1,5; 1 |
| 56 | - | 5,5 | 4 ; 3; 2; 1,5; 1 |
| | 60 | (5,5) | 4 ; 3; 2; 1,5; 1 |
| 64 | - | 6 | 4 ; 3; 2; 1,5; 1 |

## 4.3.2 PIPE CYLINDER SCREW-THREAD

A pipe cylinder screw-thread is a fastener and it is mainly used for connection of water- and gas pipelines and armature. The thread profile is shown in fig. 4.4.

Conventional denotations of a pipe cylinder screw-thread consist of (fig.4.5): Latin letter G; a nominal conventional size in inches; an accuracy class of middle diameter and general denotation for a left-hand thread in case of need.

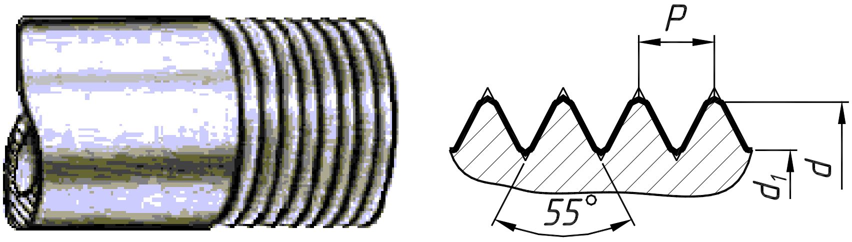



Figure 4.4 - Pipe cylinder thread profile

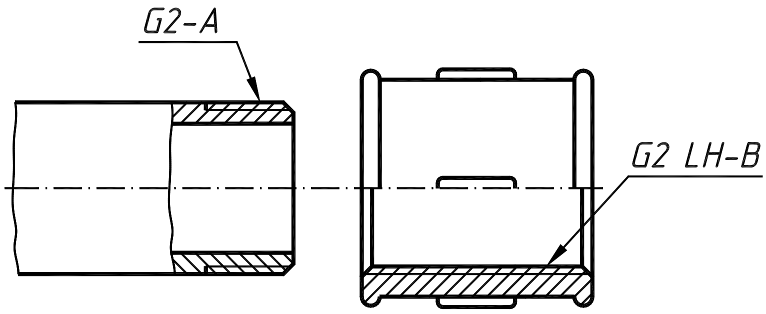



Figure 4.5 - The conventional drawing of a pipe cylinder thread:
*a) on a pipe; b) in an opening.*

There are two accuracy classes A and B. An examples of a pipe cylinder screw-thread conventional denotation with a nominal size of 1 inch are: G1–A (for the accuracy class A); G1LH – B (for the left-hand thread of the accuracy class B).

It is necessary to remember, that the size of a pipe cylinder thread is not measured on an external diameter – d. Unlike metric and other threads the nominal size of a pipe cylinder thread is marked in inches, here it approximately equals the internal diameter of a pipe, where a screw-thread is cut on. A pipe cylinder thread of the same size can be cut on as on pipes with the different pipe wall thickness as well as on a continuous bolt. Parameters of a pipe cylinder thread according to State Standard 6357-81 are shown in table 4.2.

Table 4.2 - Sizes of a pipe cylinder thread for diameters from 1/4” to 2”(first row)

| Conditional pass diameter of a pipe Dy | | Thread diameter, mm | | Thread pitch P, mm |
|---|---|---|---|---|
| in inches | in mm | External -d | Internal $-d_1$ | |
| 1/4 | 8 | 13.158 | 11.446 | 1.337 |
| 3/8 | 10 | 16.663 | 14.951 | 1.337 |
| 1/2 | 15 | 20.956 | 18.532 | 1.814 |
| 3/4 | 20 | 26.442 | 24.119 | 1.814 |
| 1 | 25 | 33.250 | 30.292 | 2.309 |
| 1 1/4 | 32 | 41.912 | 38.954 | 2.309 |
| 1 1/2 | 40 | 47.805 | 44.847 | 2.309 |
| 1 3/4 | 45 | 53.750 | 50.791 | 2.309 |
| 2 | 50 | 59.616 | 56.659 | 2.309 |

### 4.3.3 A PIPE CONICAL THREAD

A pipe conical thread is also a fastener and it is used for the higher requirements to sealing joints.

Screw-thread sizes are determined by State Standard 6211-81. A thread taper is 1:16 ($\varphi^{\circ}=1^{\circ}47'24''$). A thread profile is shown in fig.4.6. The size of a pipe conical thread and its diameter is measured in the so-called basic plane which coincides with the bearing face of the thread opening. They are fully identical with the analogical sizes of a cylinder pipe thread with the same conventional size in this plane. Consequently, these parts with a pipe conical screw-thread can be joined with the parts where the pipe cylinder thread of the same size is made.

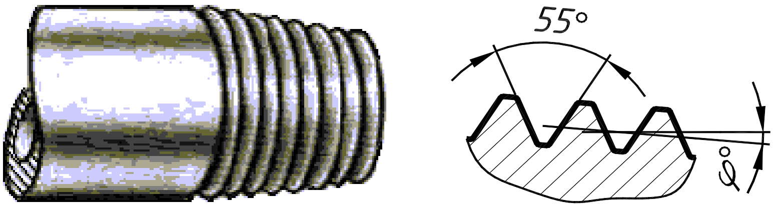



Figure 4.6 - Pipe conical thread profile

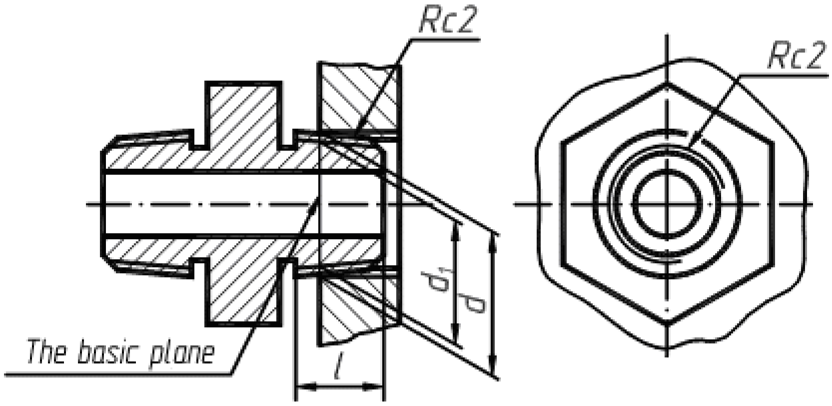



Figure 4.7 - The conventional drawing of a pipe cylinder thread

The conventional denotation of this thread (fig. 4.7) consists of the Latin letter R (for external thread) or $R_C$ (for internal thread), nominal size in inches and for the denotation of a left-hand thread in case of need. An example of the conventional drawing of a pipe conical thread in an opening with the size of 2 inches is $R_C2$.

### 4.3.4 TRAPEZOIDAL SCREW-THREAD

A trapezoidal screw-thread is motion (translating). It is mainly used for transformation of motion rotation on straight line motion. The sizes of a single trapezoidal screw-thread regulate State Standard 9484-81, and a multiple-thread is State Standard 2439-81. The thread profile is shown in fig. 4.8.

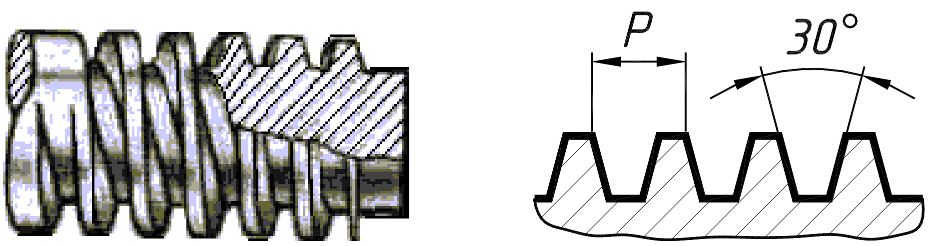
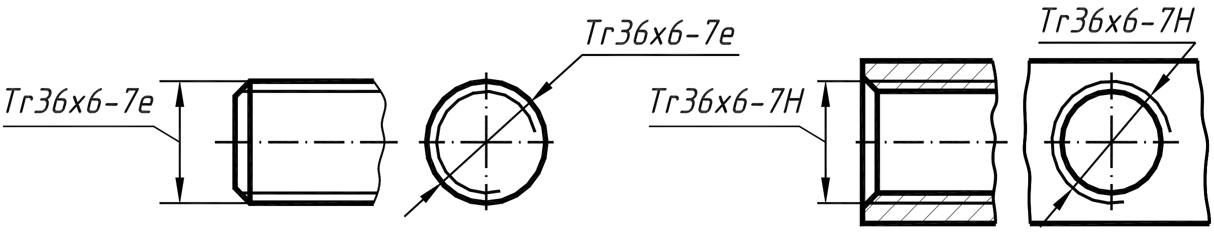



Figure 4.8 - A trapezoidal thread profile




*а)* *б)*

Figure 4.9 - Conventional drawing of a trapezoidal thread:
a) on a pipe; b) in an opening.

Denotation of a thread (fig.4.9) consists of the the Latin letters $T_r$ , external (nominal) diameter and other parameters in accordance with the general rules of marking the threads.

The example of the conventional denotation of threads is with the nominal diameter 36 mm:

1. Tr36x18(P6)LH-8H – triple thread with a thread lead 18mm and a pitch 6mm, internal, with the tolerance band 8H, left-hand;

2. Tr36x6-6g – a external thread with the tolerance band 6g and a pitch 6mm, right-hand.

### 4.3.5 BUTTRESS THREAD

A buttress thread is used as leading. It is used to transmit great power in one direction for example in jacks, presses, etc. Profile of a buttress thread is shown in fig. 4.10 according to State Standard 10177-82. The sizes of nominal diameters and pitches coincide with the proper parameters of a trapezoidal thread.

Thread denotations consists of the Latin letter S, external (nominal) diameter and other parameters according to the general rules of marking the threads.

Example of conventional denotation of a buttress screw-thread with the nominal diameter 80mm, the pitch 10mm, an external thread with the tolerance band 7h: S80x10-7h.

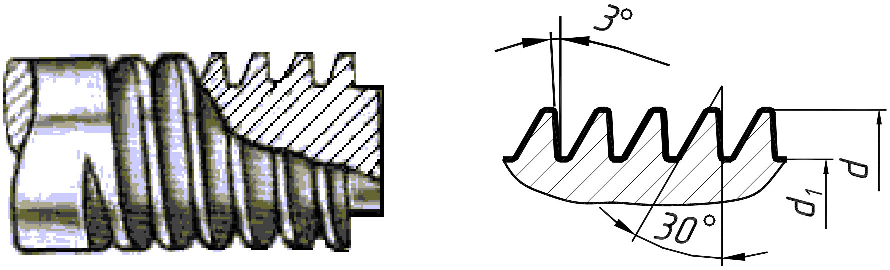
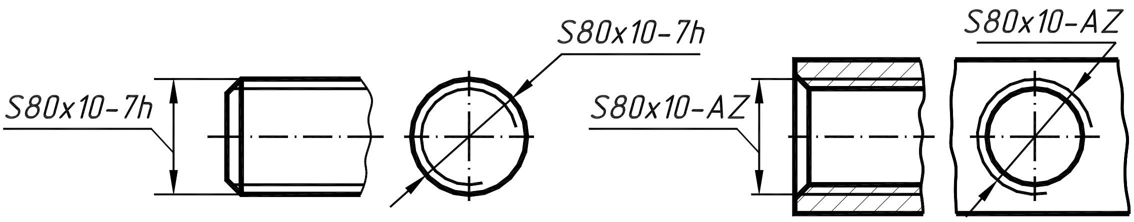



Figure 4.10 - A buttress thread profile




*a)* *b)*

Figure 4.11 - Conventional drawing of a buttress thread:
a) on the outside; b) in an opening.

### 4.3.6 SQUARE NON-STANDARD THREAD

The profile of a square non-standard thread (fig.4.12) is rectangular or square. The thread doesn’t have a conventional denotation, that is why all sizes of the thread (fig. 4.13) are marked on the drawing. It is used as a leading thread (for example, in jacks etc.)

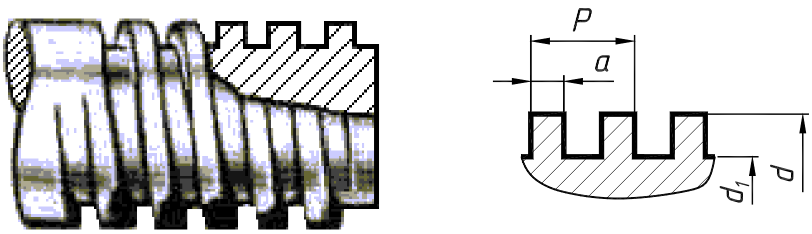



Figure 4.12 - Profile of a square non-standard thread

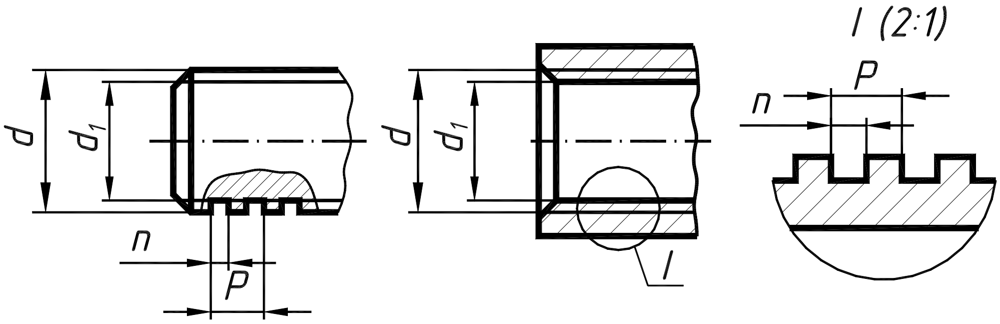



Figure 4.13 - The conventional drawing of a square non-standard thread

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### 4.3.7 SPECIAL THREAD

Special threads are threads with a standard profile that differ from standard threads in diameters or pitches, as well as thread with a non-standard profile (for example, a thread with a rectangular or a round profile). For the special thread with a standard profile write down the letters Sp before conventional denotation (for example, Sp M60x5-6g, where 5 is non-standard pitch). The dimensions of all of thread parameters fill in on a drawing for threads with a non-standard profile.

## 4.4 FIXINGS

The thread fixing are bolts, screws, studs and nuts. The form and sizes of fixings are regulated by the current standards.

As a rule, working drawing of the standardized fixings is not done and fixings are ordered on the basis of the conventional standard denotation. The conventional denotation of fixings consists of: the name of fixing, the instructions about the accuracy and the variant of implementation; the standard denotation of a metrical thread; the strength grade of a fixing material; the thickness of the corrosion resistant coating; the design standard.

Unscrew-thread fixings (washers, cotter-pins and other) are widely used in fixed thread joints. The most widespread designs of these fixings are also standardized, and they have conventional signs.

### 4.4.1 BOLTS

A bolt and nut comprises what is known as a screw pair. Such a pair is used for fastening together parts used in engineering construction. The parts can be separated. by screwing off the nut, the fastening is said to be temporary.

A bolt consists of two parts: a shank and a head. The shank is cylindrical and is threaded at the tail end for a sufficient length so as to effectively engage with a nut. The shape of the head depends upon the purpose for which the bolt is required. While considering the length of the bolt, the thickness of the head is not taken into account.

The most widespread construction of a bolt is hexagonal headed bolt. Bolts are made with normal, high and low accuracy.

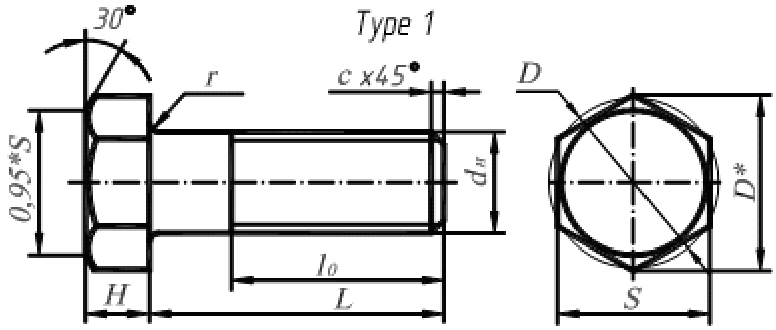


Figure 4.14 – Hexagonal headed bolt (type 1)

Example of conventional denotation of a bolt of normal accuracy, type 1, with the diameter of a thread 20 mm, a fine pitch 2 mm, by the tolerance zone 6g, a working length 100 mm, a strength class 5.8, without coverage according to State Standard 7798:2008:

**BOLT M20×2-6g ×100.58** State Standard **7798:2008.**

Bolts of types 2 and 3 are used for the connection of machines parts which are vibrating. It results in unscrewing of nuts and bolts. In fig. 4.15 the bolt of type 2 is shown - with opening for a split-pin and type 3 - with two openings in the head of bolt for wired connection of bolts group.

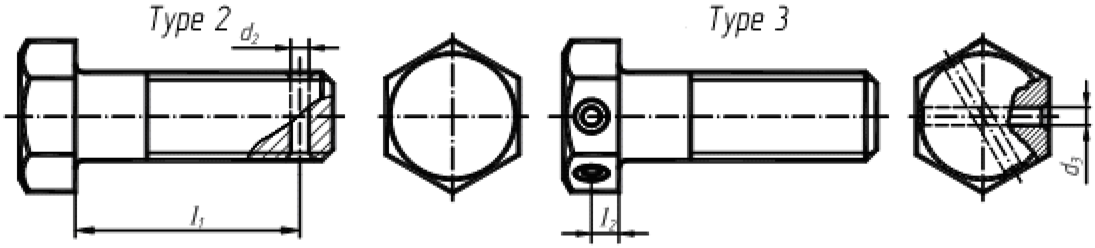


Figure 4.15 – Hexagonal headed bolt (type 2 and type 3)

Three verges of hexahedrons are shown on the front view of bolts and nuts. The drawings of a nut and a head of the bolt are started from the construction of the correct inscribed hexagon. The stage-by-stage construction of crossing lines of verges of a bolt head with the conical surface of chamfer on its face is shown in fig.4.16. At such construction the hyperbolical curves of crossing are simply drawn by the arcs of circles.

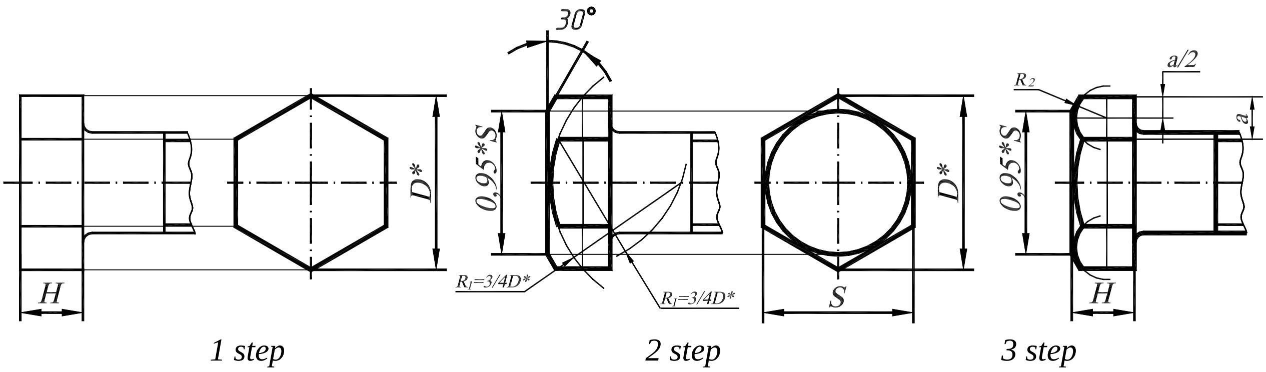


Figure 4.16 – The stage-by-stage construction of hexagonal headed bolt

Table 4.3 - The basic bolt sizes of normal accuracy are resulted in table 4.3.

| Nominal thread diameter $d_n$, mm | Pitch of a thread | | $S$ | $H$ | $D^*$ | $R$ no more | $D$ not less | $l_0$ | $c$ |
|---|---|---|---|---|---|---|---|---|---|
| | coarse | fine | | | | | | | |
| 16 | 2.0 | 1.5 | 24 | 10 | 27.7 | 1.2 | 26.5 | 36 | 2 |
| 18 | 2.5 | 1.5 | 27 | 12 | 31.2 | 1.6 | 29.9 | 42 | 2.5 |
| 20 | 2.5 | 1.5 | 30 | 13 | 34.6 | 2.2 | 33.3 | 46 | 2.5 |
| 22 | 2.5 | 1.5 | 32 | 14 | 37.0 | 2.2 | 35.0 | 50 | 2.5 |
| 24 | 3.0 | 2.0 | 36 | 15 | 41.6 | 2.2 | 39.6 | 54 | 3 |

The parameter $D^*$ determines the reference diameter of a circle described round a hexagon, and the parameter of $D$ regulates actual low-limit size hexagon diagonal for the real roller stock.

### 4.4.2 NUTS

Nuts are generally made in the form of hexagonal or square prism. Besides this, cylindrical and other forms are also used to suit the particular requirements. They have internal threads and hold the part by giving the tightening effect on the bolt.

The form of the external surface, the type of execution and the accuracy of manufacturing are determined for the standardized nuts. Three types of a nut are shown in fig.4.17. A metrical thread with coarse and fine pitches is used in standard nuts. Standard hexahedral nuts of different height are widely used.

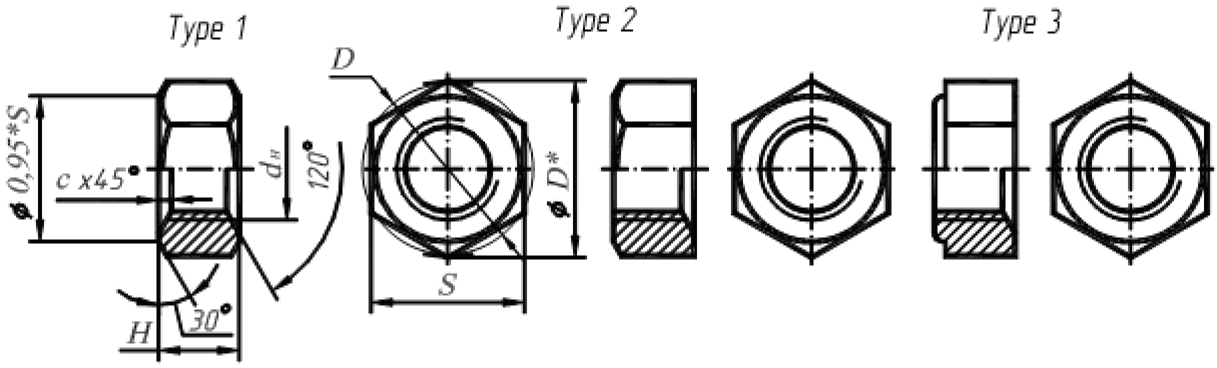



Figure 4.17 – Hexagonal nut.

The example of the conventional denotation of a nut (type 1), normal accuracy with the diameter of a metrical thread 12 mm, a coarse pitch, tolerance zone 7H, the strength class 5 and the coverage 02 (cadmium with chromating) 9 mkm thick:

Nut M12-7H. 5.029 State Standard 5915:2008.

The basic parameters of nuts are resulted in table 4.4.

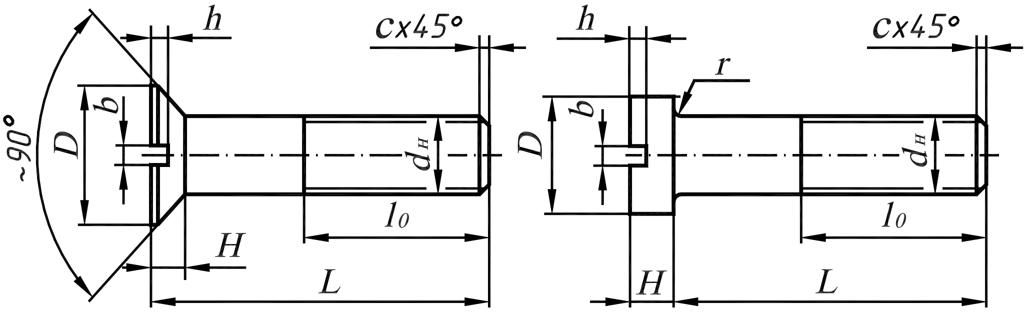
Table 4.4

| Nominal thread diameter $d_n$, mm | Pitch of thread | | $S$ | $H$ | $D^*$ | $D$ | $c$ |
|---|---|---|---|---|---|---|---|
| | coarse | fine | | | | | |
| 16 | 2.0 | 1.5 | 24 | 13 | 27.7 | 26.5 | 2 |
| 18 | 2.5 | 1.5 | 27 | 15 | 31.2 | 29.9 | 2.5 |
| 20 | 2.5 | 1.5 | 30 | 16 | 34.6 | 33.3 | 2.5 |
| 22 | 2.5 | 1.5 | 32 | 18 | 37.0 | 35.0 | 2.5 |
| 24 | 3.0 | 2.0 | 36 | 19 | 41.6 | 39.6 | 3 |

### 4.4.3 SCREWS

Screws are used where bolts are inconvenient to use. In the case of screws, the threads on the shank are continued to a distance from the head of the screw not exceeding two times the pitch of the thread for diameter up to 25 mm.

A screw is a threaded bar on the first side and a head of different forms on the second. Figure 4.18, a shows a countersunk head screw accoding to State Standard 17475:2008, and figure 4.18, b shows a cheese-head screw accoding to State Standard 1491:2008. The metrical thread of coarse or fine pitches with the tolerance zone 6g and 8g is done on a screw. As a rule, on a screwhead spline under a screwdriver is done. The basic parameters of countersunk head screws and cheese-head screws are resulted in table 4.5.




a) b)

Figure 4.18 – Screws.

The example of denotation of countersunk-head screw, with accuracy *A*, type 2, threads diameter 12 mm, a coarse pitch, length 45 mm, tolerance zone 8g, the strength class 5,8 without coverage:

*Screw A2.M12×45-8g.58 State Standard 17475:2008*

Basic parameters of countersunk-head screws are resulted in table 4.5, and cheese-head screws are resulted in table 4.6.

Table 4.5

| Nominal thread diameter $d_n$, mm | Pitch of thread | | *D* | *H* | *b* | *h* | *c* | *L* | Length $l_0$ depending on $l^*$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | coarse | fine | | | | | | | $l_0$ | $l^*$ |
| 12 | 1.75 | 1.25 | 21.5 | 6 | 3 | 2.5 | 1.6 | 22-85 | 30 | 42-85 |
| 14 | 2 | 1.5 | 25 | 7 | 3 | 3 | 1.6 | 25-90 | 34 | 47-90 |
| 16 | 2 | 1.5 | 28.5 | 8 | 4 | 3.5 | 2 | 30-95 | 38 | 55-95 |
| 18 | 2.5 | 1.5 | 32.5 | 9 | 4 | 4 | 2.5 | 35-100 | 42 | 59-100 |
| 20 | 2.5 | 1.5 | 36 | 10 | 5 | 4.5 | 2.5 | 40-110 | 46 | 65-110 |

Table 4.6

| Nominal thread diameter $d_n$, mm | Pitch of thread | | *D* | *H* | *b* | *h* | *c* | *r* | *L* | Length $l_0$ depending on $l^*$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | coarse | fine | | | | | | | | $l_0$ | $l^*$ |
| 12 | 1.75 | 1.25 | 18 | 6 | 3 | 2.5 | 1.6 | 0.6 | 22-85 | 30 | 35-85 |
| 14 | 2 | 1.5 | 21 | 7 | 3 | 3 | 1.6 | 0.6 | 25-90 | 34 | 40-90 |
| 16 | 2 | 1.5 | 24 | 8 | 4 | 3.5 | 2 | 0.6 | 30-95 | 38 | 45-95 |
| 18 | 2.5 | 1.5 | 27 | 9 | 4 | 4 | 2.5 | 0.6 | 35-100 | 42 | 50-100 |
| 20 | 2.5 | 1.5 | 30 | 10 | 5 | 4.5 | 2.5 | 0.8 | 40-110 | 46 | 55-110 |

### 4.4.4 STUDS

Studs are cylindrical numbers threaded at both ends.

A stud is a threaded bar on first end for screwing up in one of connecting parts, and threaded for a screwing on a nut on the second. Studs are mainly used in cases, when bolts and screws of large length are irrationally used.

The length of a thread end of $L_1$, for screwing up in a part depends on durability of the material of this part (table 4.7). The working length of a stud - *L* equals the part of its endlessly length, which is screwed up in a part. The length of cutting of a thread on the working end of a stud - $l_0$ is determined by its nominal diameter and is identical to the length of cutting of thread on a bolt (see table 4.3)

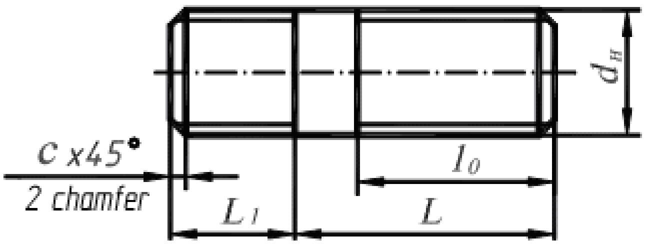



Figure 4.19 – A stud

Table 4.7

| Length $L_1$, mm | State Standard on a stud | Material of a part |
|---|---|---|
| $L_1=d$ | 22032:2008 | Steel, bronze, composition-metal, titanic alloys |
| $L_1=1,25d$ | 22034:2008 | Cast-iron |
| $L_1=1,6d$ | 22036:2008 | Cast-iron, the use of steel, bronze is assumed |
| $L_1=2d$ | 22038:2008 | Easy alloys, the use of steel is assumed |

The example of conventional denotation of a stud of normal accuracy for screwing up in the cast-iron part, with the diameter of a thread 16 mm, by the tolerance zone 6g, a working length 60 mm, a strength class 5.8, without coverage:

**Stud M16×60-6g.58 State Standard 22034:2008.**

A construction and sizes of studs of the general setting is regulated State Standards 22032:2008 – 22043:2008. The parameters of a metrical thread the same as for bolts, nuts and screws.

### 4.4.5 WASHERS

A washer is a cylindrical piece of metal placed between the nuts to provide smooth bearing surface for the nut to turn on. It spreads the pressure of the nut over a greater area. It also prevents the nut from cutting into the metal and thus, allows the nut to be screwed on more tightly. It is chamfered on the top of the flat surface.

A washer is a flat part with an opening without a thread. Plain, single coil spring washers and lock washers are the most widespread. Two types of plain washers are represented in fig.4.20. Basic parameters of plain washers according to State Standard 11371-78 are shown in table 4.8.

The example of conventional denotation of a plain washer (type 1) for a fixing part with a thread M20, with a thickness set in a standard (01), by coverage 01 (zinc with chromating) 6 mkm thick:

**Washer 20.01.016 State Standard 11371-78.**

Table 4.8

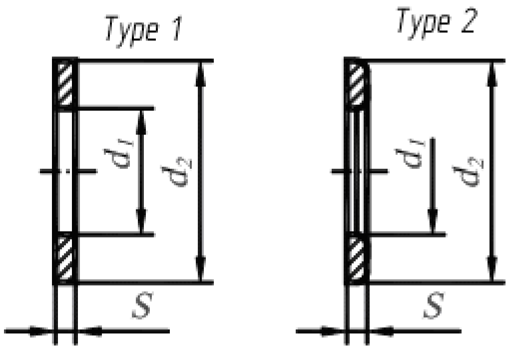


Figure 4.20 – Types of washers

| Nominal thread diameter $d_n$ | $d_1$ type | | $d_2$ | $S$ |
|---|---|---|---|---|
| | 1 | 2 | | |
| 16 | 17.5 | 17 | 30 | 3.0 |
| 18 | 20 | 19 | 34 | 3.0 |
| 20 | 22 | 21 | 37 | 3.0 |
| 22 | 24 | 23 | 39 | 3.0 |
| 24 | 26 | 25 | 44 | 4.0 |

## 4.5 THREAD JOINTS

Basic types of joints with the use of considered previously connecting elements are connection by a bolt, screw, stud, and also pipe joints. These types of joints (except of a pipe) have the three depictions: structural, simplified and conventional.

The structural depiction suits all structural elements of the parts of a joint.

The simplified depiction is used for details without chamfers, a thread is represented along the length of a bar of a thread part, a clearance between a bar and an opening is not shown.

A conventional depiction is used in those cases, when the diameter of a bar on a drawing less than 2 mm. State Standard 2.315:2008 is used for simplified joints.

Pipe joints are done only structurally.

### 4.5.1 BOLT JOINTS

A bolt joint consists of a bolt – 3, a nut –5 and a washer –3 (fig.4.21, a). There are two parts in the bolt joint also ($\delta_1$ and $\delta_2$ – their thickness).

At the structural drawing of a thread connection opening diameter equals $1.1\times d_n$ (where $d_n$ is a nominal diameter of a bolt thread). Actual working length of a bolt is found as a sum of the followings parameters: $L=\delta_1+\delta_2+H_n+S_w+0.25\times d_n$,
where $\delta_1$ and $\delta_2$ – the thickness of connecting parts, $H_n$ – the thickness of a nut, $S_w$ – the thickness of a washer, $d_n$ – the nominal diameter of a thread. The received sum is rounded to the nearest from the resulted standard row of workings lengths – $L$ at table 4.9.

Table 4.9

| Working length of a bolt $L$, mm | Threaded length $l_0$ according to the set nominal diameter of a thread $d_n$ | | | | |
|---|---|---|---|---|---|
| | 16 | 18 | 20 | 22 | 24 |
| 50,55,60,65,70,75,80 | 38 | 42 | 46 | 50 | 54 |

At the simplified drawing of a bolt joint for the calculation of working length of a bolt - $L$ the dependence is used:

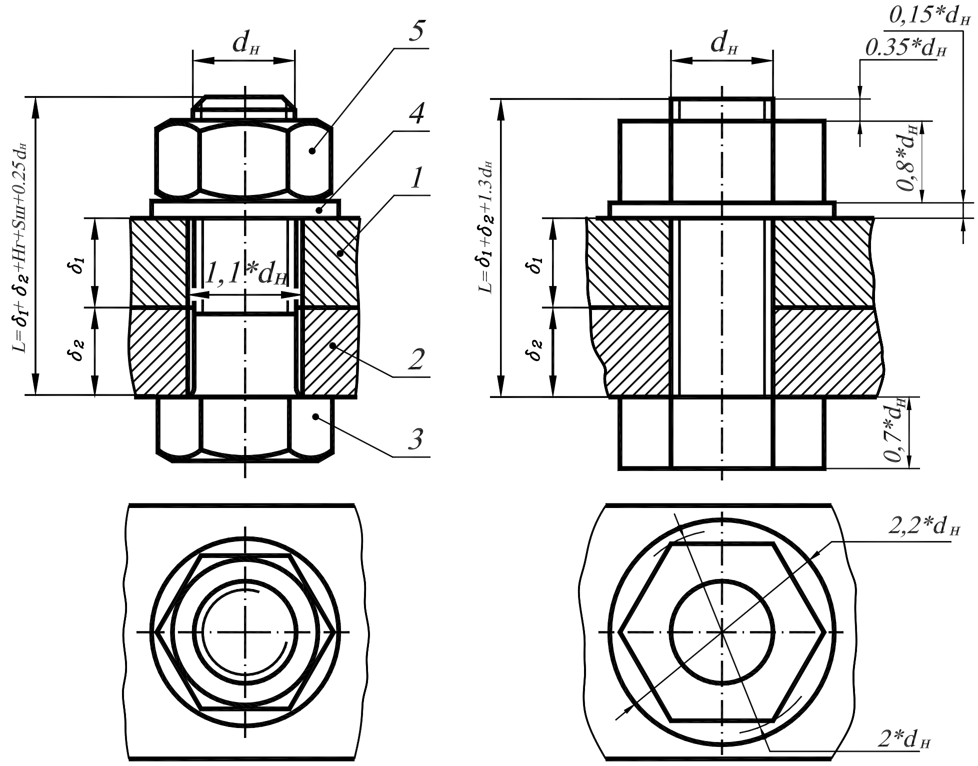
$$L=\delta_1+\delta_2+1{,}3\times d_n,$$

where $\delta_1$ and $\delta_2$ – the thickness of connecting parts, $d_n$ – the nominal diameter of a thread.

The parameter $1{,}3\times d_n$ approximately takes into account the structural sizes of the thickness of a washer, the height of a nut and stocked on length of a bolt. For the implementation of the simplified drawing of a bolt joint the followings correlations are used:

$D=2\times d_n$; $D_w=2{,}2\times d_n$; $H=0{,}8\times d_n$; $S_w=0{,}15\times d_n$; $h=0{,}7\times d_n$.

The structural drawing of a bolt joint is presented in figure 4.21, a and it is simplified – in figure 4.21, b.




a) b)

Figure 4.21 – The bolt joint

### 4.5.2 STUD JOINTS

A stud joint consists of a stud - 3 (figure 4.22), a washer - 4 and a nut - 5. An opening is shown in a part 1, its diameter equals $1,1\times d_n$ (where $d_n$ is a nominal diameter of a stud thread) at the structural drawing of a thread joint. Actual working length of a stud is found as a sum of the followings parameters:

$$L = \delta_1 + Hn + S_w + 0.25\times d_n,$$

where $\delta_1$ is the thickness of a connecting part, $H_n$ is the thickness of nut, $S_w$ is the thickness of a washer, $d_n$ is the nominal diameter of a thread. The received sum is rounded to the nearest from the resulted standard row of workings lengths - $L$ at table 4.10.

Table 4.10

Threaded length $l_0$ according to the set nominal thread diameter $d_n$

| Working length of a stud $L$, mm | $d_n$=16 | $d_n$=18 | $d_n$=20 | $d_n$=22 | $d_n$=24 |
|---|---|---|---|---|---|
| 35 | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | - | - | - |
| 40 | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | - | - |
| 45 | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | - |
| 50 | 38 | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ |
| 55 | 38 | 42 | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ | $l_0=L-0,5\times d_n$ |

This table shows the actual value of working length $L$ according to the threaded length $l_0$.

At the simplified drawing of a stud joint for the calculation of the working length of a stud - $L$ the dependence is used: $L=\delta_1+1,3\times d_n$,

where $\delta_1$ is the thickness of a connecting part, $d_n$ is a nominal thread diameter.

The parameter 1,3×$d_n$ approximately takes into account the structural sizes of the thickness of a washer, the height of a nut and stocked on length of a stud. For the implementation of the simplified drawing of a stud joint the followings correlations are used: $D=2\times d_n$; $D_w=2{,}2\times d_n$; $H=0{,}8\times d_n$; $S_w=0{,}15\times d_n$.

The structural drawing of a stud joint is shown in figure 4.22, and it is simplified in figure 4.22, b.

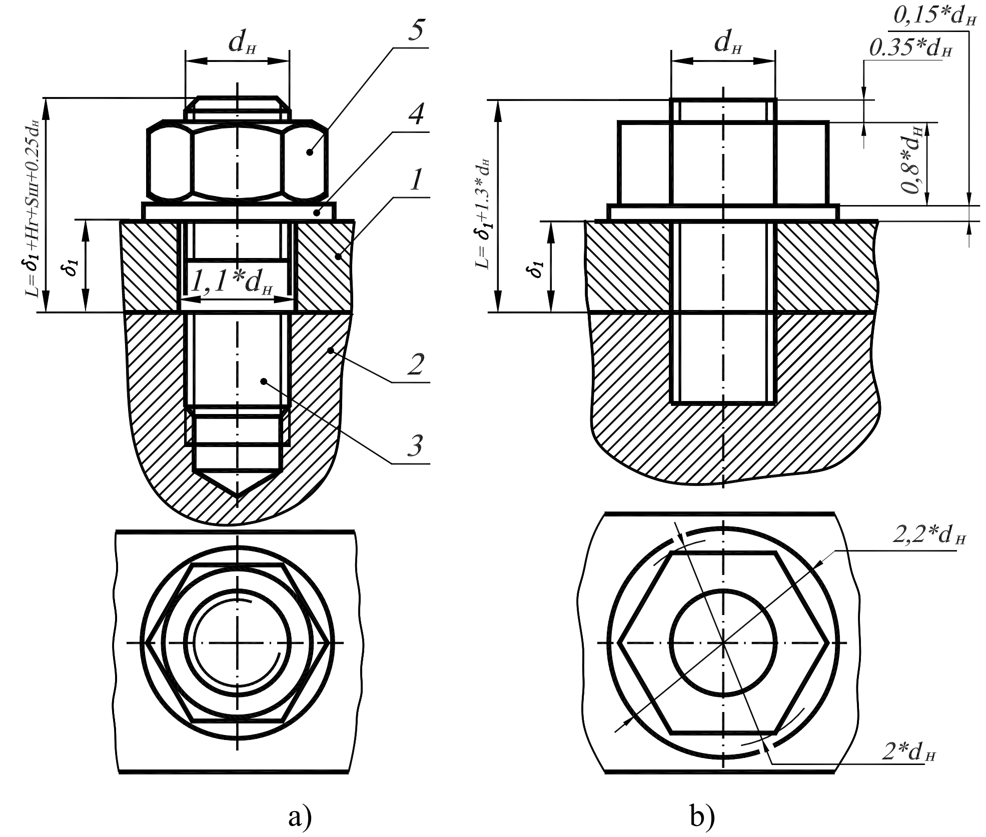



Figure 4.22 – The stud joint

The parameters of a stud jack are found according to the followings dependences:

$d_{opening}=0{,}85\times d_n$; $L_{opening}=L_1+0{,}5\times d_n$.

According to these parameters a stud jack is done in figure 4.23.

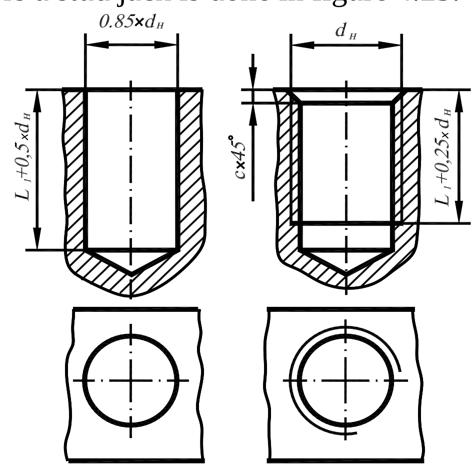



Figure 4.23 – The stud jack

#### 4.5.3 SCREW JOINT

The thickness of an overhead joining part and parameters of a screw are input data for the drawing of a screw joint. At the structural drawing of a screw joint (fig. 4.24, a, b, c) it is necessary to draw all structural elements of parts. The sizes of a thread, length of a screw and sizes of a base surface under a head fill in. A slot under a screwdriver is disposed under the corner 45° at the view from the face head. On the simplified drawing of a screw joint (fig. 4.24, d, e, f) the sizes of a thread and a length of a screw are marked. A slot under a screwdriver is represented an incrassate contour line. The thread opening under a screw is drawn like an opening under a stud.

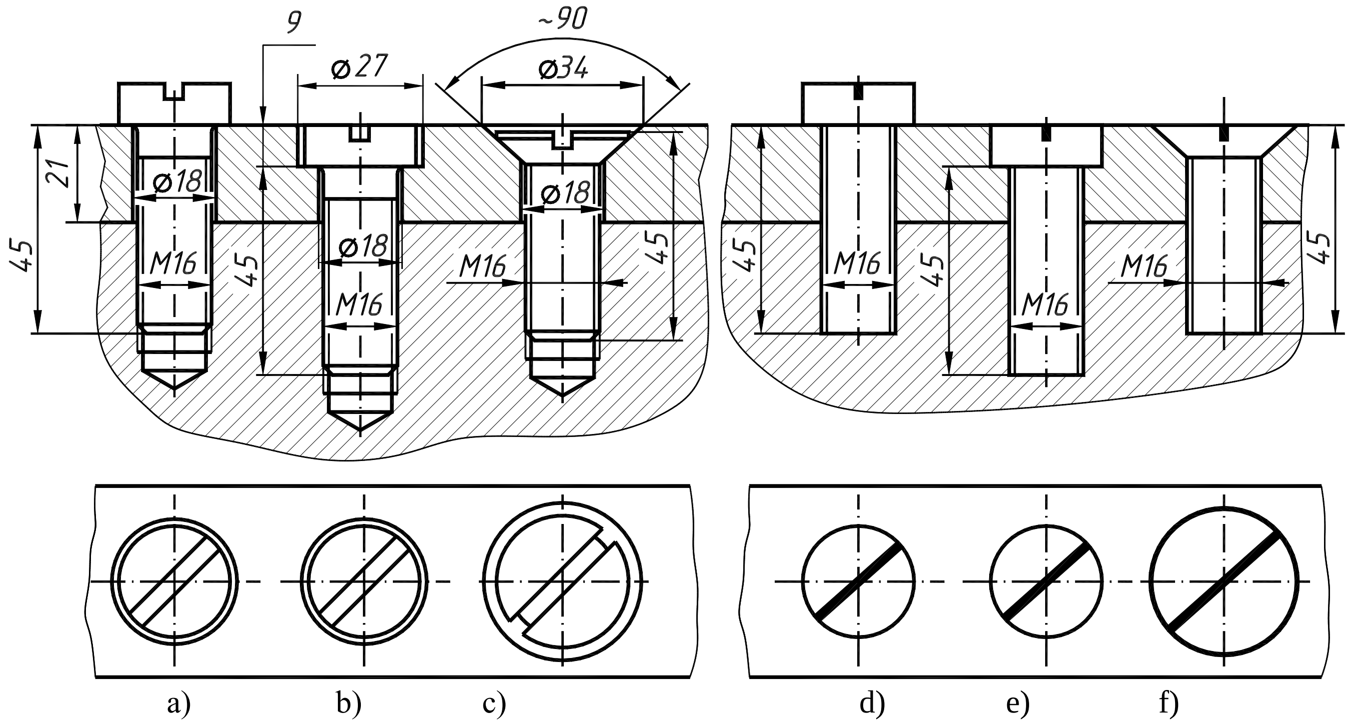



Figure 4.24 – The screw joint

The parameters of a base surface under a head of screw are regulated by State Standard 12876:2008.

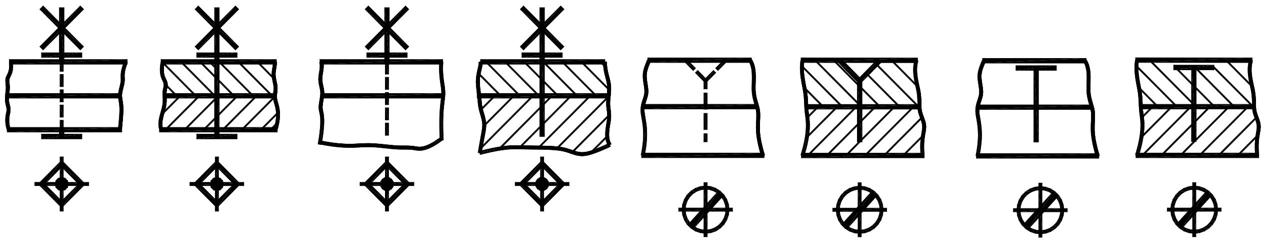
## 4.5.4 CONVENTIONAL DRAWING OF FIXINGS AND JOINTS

The conventional drawing of fixings (table 4.11) is regulated by State Standard 2.315:2008. Fixings for which on a drawing the diameter of a bar is equal 2 mm or less is shown conventionally. Conventional drawing and its sizes must give exhaustive and necessary information about the view of a joint and its components.

Table 4.11 - The conventional drawing of fixings

| Name of a part | View | Drawing | Name of a part | View | Drawing |
|---|---|---|---|---|---|
| Round-head and cheese-head bolts and screws | Main (front) | T | Nuts | Main (front) | × |
| | Top | ◇ | | Top | ◇ |
| | Bottom | • | Washers | Main (front) | — |
| Countersunk-head and oval-head screws | Main (front) | Y | | Top | |
| | Top | ⌀ | Studs | Main (front) |  |
| | Bottom | • | | Top | • |

In fig.4.25 the examples of conventional drawings of thread joints are resulted: a – by a bolt on a view and in a section; b – by a stud on a view and in a section; c – by a countersunk-head screw on a view and in a section; d –by a cheese-head screw on a view and in a section.



*a)* *b)* *c)* *d)*

Figure 4.25 – Conventional drawings of thread joints

## 4.5.5 PIPE JOINTS

Pipes are used to carry steam, water, gas, oil and many other fluids. The pipes for a particular use cannot be made of desired length. Therefore pipes of standard length are taken and joined together with the help of pipe joints of different types. Normally the pipes are made of cast iron, steel, copper and wrought iron, depending upon te pressure and temperature of the fluid to be conveyed.

A pipe cylinder or a conical thread is used for pipe joints. All parameters, including external diameter of a pipe thread, are determined according to conventional nominal sizes of thread in inches, which correspond the diameter of a pipe opening (in inches), if a thread is cut at the external surface of a pipe.

Thus, the external diameter of a pipe thread is always greater (fig. 4.5) than the conventional nominal size on two thickness of a wall pipe. Parameters of a pipe thread resulted in table 4.12.

It should be remembered, that an opening diameter in a pipe depends on the accuracy of its manufacturing and approximately corresponds the conventional nominal size of a thread in inches (1inch =25,4mm).

### 4.5.5.1 PIPES AND BRANCH PIPES

A basic parameter for pipes and connecting parts is a size of nominal bore Dy, that approximately equals the size of the internal nominal diameter of an opening pipe. Nominal bores are standardized. According to the State Standard 3262-75 the steel welded pipes for water- and gas pipelines, for the systems of heating are made galvanized and non-galvanized, normal accuracy of manufacturing and extra accuracy. These pipes are made from steel in accordance with State Standard 380-71 or State Standard 1050-74.

The structural sizes of the branch pipe in accordance with State Standard 3262-75 are shown in fig. 4.26.

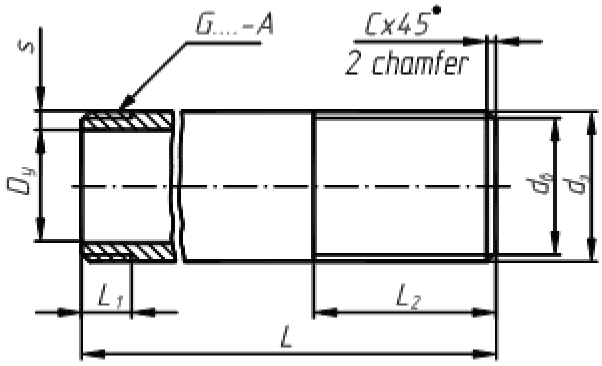



Figure 4.26 – The structural sizes of the branch pipe

The numerical values of parameters of a thread are resulted in table 4.12 according to the nominal bore Dy.

Table 4.12

| Nominal bore, Dy, mm | Thread G, inch | External diameter, mm | Internal diameter, mm | Thickness of a wall pipe, s, mm | | | $L_1$, mm | $L_2$, mm | L, mm |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Thin-walled | Normal | Thick-walled | | | |
| 10 | 3/8 | 16.663 | 14.951 | 2 | 2.2 | 2.8 | 8.5 | 46 | 105 |
| 15 | 1/2 | 20.956 | 18.532 | 2.5 | 2.8 | 3.2 | 9 | 58 | 120 |
| 20 | 3/4 | 26.442 | 24.119 | 2.5 | 2.8 | 3.2 | 10.5 | 64 | 135 |
| 25 | 1 | 33.250 | 30.292 | 2.8 | 3.2 | 4 | 11.0 | 75 | 150 |
| 32 | 1 | 41.912 | 38.954 | 2.8 | 3.2 | 4 | 13.0 | 85 | 160 |
| 40 | 1 | 47.805 | 44.847 | 3 | 3.5 | 4 | 15.0 | 85 | 160 |
| 50 | 2 | 59.616 | 56.659 | 3 | 3.5 | 4.5 | 17.0 | 85 | 160 |

The example of the conventional denotation of a steel non-galvanized pipe with the nominal bore 20 mm:

**Pipe 20 State Standard 3262-75.**

Pipe fittings are used for joining pipe different lengths and to provide changes of direction, branch connection at different angles or to effect a change in size. The fittings are made for screwed, flanged or welded connection.

A drawings and structural sizes of the pipe fittings is pointed below.

## 4.5.5.2 LOCK NUTS (STATE STANDARD 8961-75 )

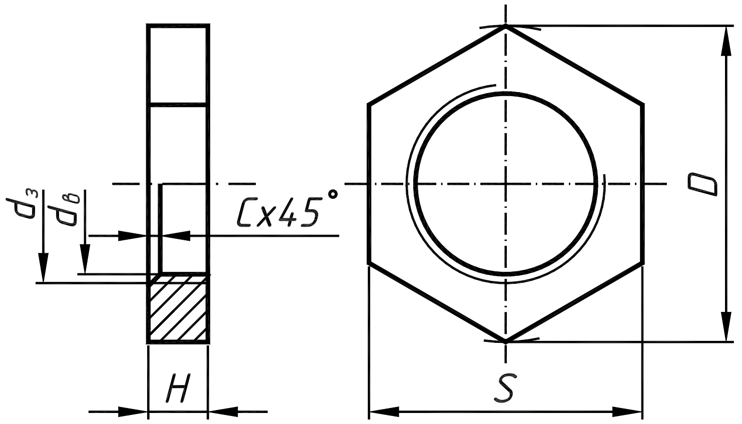


Figure 4.27 – Conventional drawings of lock nut

Table 4.13

| ***Nominal bore, Dy, mm*** | Thread G, inch | External diameter, mm | Internal diameter, mm | H, mm | D, mm | S, mm | Chamfer c, mm |
|---|---|---|---|---|---|---|---|
| 10 | 3/8 | 16.663 | 14.951 | 7 | 31,2 | 27 | 1 |
| 15 | 1/2 | 20.956 | 18.532 | 8 | 36,9 | 32 | 1,5 |
| 20 | 3/4 | 26.442 | 24.119 | 9 | 41,6 | 36 | 1,5 |
| 25 | 1 | 33.25 | 30.292 | 10 | 53,1 | 46 | 2 |
| 32 | 1 | 41.912 | 38.954 | 11 | 63,5 | 55 | 2 |
| 40 | 1 | 47.805 | 44.847 | 12 | 69,3 | 60 | 2 |
| 50 | 2 | 59.616 | 56.659 | 13 | 86,5 | 75 | 2 |

The example of the conventional denotation of a lock-nut with the nominal bore 20 mm: **Lock-nut 20 State Standard 8961-75.**

## 4.5.5.3 PIPE COUPLINGS (STATE STANDARD 8955-75)

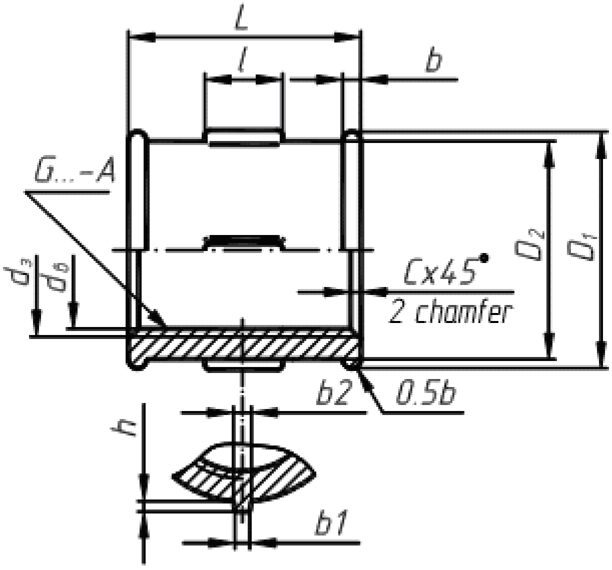


Figure 4.28 – Conventional drawings of pipe coupling

Table 4.14

| *Nominal bore, Dy, mm* | Thread G, inch | L, mm | l , mm | $D_1$, mm | $D_2$, mm | B, mm | $b_1$, mm | $b_2$, mm | h, mm | Number of ribs | Chamfer c, mm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 3/8 | 30 | 8 | 22 | 20 | 2 | 2 | 3.5 | 2 | 2 | 1 |
| 15 | 1/2 | 36 | 9 | 26 | 24 | 2 | 2 | 4 | 2 | 2 | 1,5 |
| 20 | 3/4 | 39 | 10.5 | 32.5 | 30 | 2.5 | 2 | 4 | 2.5 | 2 | 1,5 |
| 25 | 1 | 45 | 11 | 39.5 | 37 | 2.5 | 2.5 | 4.5 | 2.5 | 4 | 2 |
| 32 | 1 | 50 | 13 | 49 | 46 | 3 | 2.5 | 5 | 3 | 4 | 2 |
| 40 | 1 | 55 | 15 | 56 | 53 | 3 | 3 | 5 | 3 | 4 | 2 |
| 50 | 2 | 65 | 17 | 68.5 | 65 | 3.5 | 3 | 5 | 3.5 | 6 | 2 |

Note. Sizes of external and internal diameters are resulted in table 4.12.

The example of the conventional denotation of a pipe coupling with the nominal bore 20 mm: **Pipe Coupling 20 State Standard 8955-75.**

### 4.5.5.4 REDUCERS OR REDUCING COUPLINGS (STATE STANDARD 8957-75)

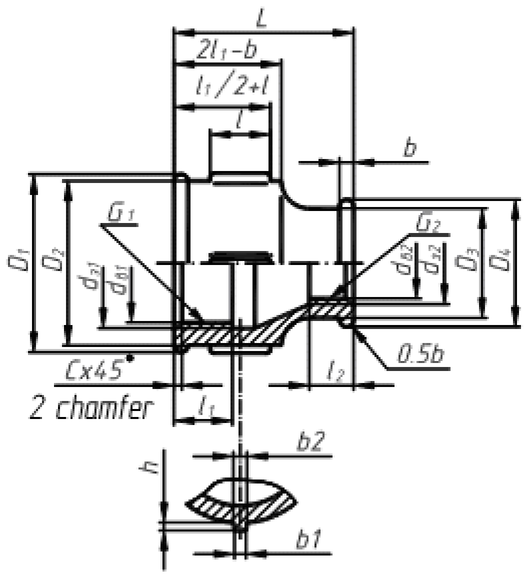



Figure 4.29 – Conventional drawings of reducing coupling

Table 4.15

| *Nominal bore, Dy, mm* | Threads $G_1xG_2$, inch | L, mm | l , mm | $l_1$, mm | $l_2$, mm | $D_1$, mm | $D_2$, mm | $D_3$, mm | $D_4$, mm | b, mm | $b_1$, mm | $b_2$, mm | h, mm | Number of ribs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20x10 | 3/4 x3/8 | 39 | 10 | 13 | 10 | 32 | 30 | 20 | 22 | 2 | 2 | 3.5 | 2 | 2 |
| 20x15 | 3/4x1/2 | 39 | 10 | 13 | 10 | 32 | 30 | 24 | 26 | 2 | 2 | 3.5 | 2 | 2 |
| 25x15 | 1 x 1/2 | 45 | 11 | 15 | 12 | 39 | 37 | 24 | 26 | 2 | 2 | 4 | 2 | 4 |
| 32x15 | 1 x1/2 | 50 | 13 | 17 | 12 | 48.5 | 46 | 24 | 26 | 2.5 | 2 | 4 | 2.5 | 4 |
| 32x20 | 1 x3/4 | 50 | 13 | 17 | 12 | 48.5 | 46 | 30 | 32.5 | 2.5 | 2 | 4 | 2.5 | 4 |
| 32x25 | 1 x 1 | 50 | 13 | 17 | 12 | 48.5 | 46 | 37 | 39.5 | 2.5 | 2 | 4 | 2.5 | 4 |
| 40x20 | 1 x3/4 | 55 | 15 | 19 | 13 | 55.5 | 53 | 30 | 32.5 | 2.5 | 2.5 | 4.5 | 2.5 | 4 |
| 40x25 | 1 x 1 | 55 | 15 | 19 | 13 | 55.5 | 53 | 37 | 39.5 | 2.5 | 2.5 | 4.5 | 2.5 | 4 |
| 50x25 | 2x1 | 65 | 17 | 21 | 15 | 68 | 65 | 37 | 40 | 3 | 2.5 | 5 | 3 | 6 |

The example of the conventional denotation of a reducing coupling with the nominal bore 20 mm: **Reducing Coupling 20 State Standard 8957-75.**

### 4.5.5.5 ELBOWS (STATE STANDARD 8946-75 )

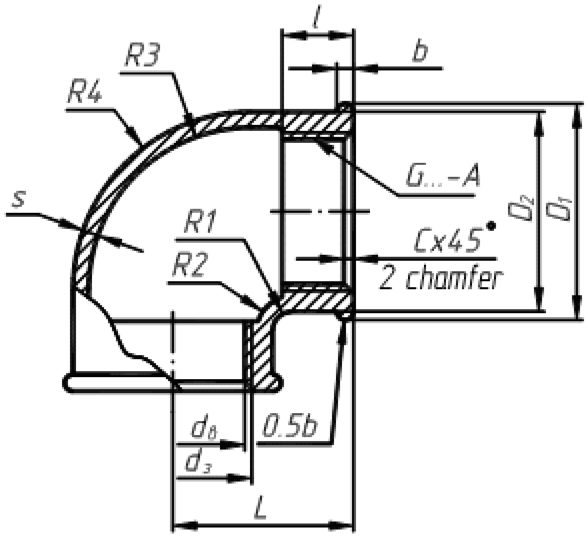



Figure 4.30 – Conventional drawings of an elbow

Table 4.16

| ***Nominal bore, Dy, mm*** | Thread G, inch | L, mm | l , mm | $D_1$, mm | $D_2$, mm | b, mm | ***$R_1$, mm*** | $R_2$, mm | $R_3$, mm | $R_4$, mm | S, mm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 3/8 | 25 | 10.0 | 24 | 22 | 2.0 | 4 | 6.5 | 23.5 | 26 | 2.5 |
| 15 | 1/2 | 28 | 12.0 | 28,6 | 26,6 | 2.0 | 2,7 | 5,5 | 26,5 | 29,3 | 2.8 |
| 20 | 3/4 | 33 | 13.5 | 34,9 | 32,4 | 2.5 | 3.3 | 6,3 | 32,8 | 35,7 | 3.0 |
| 25 | 1 | 38 | 15.0 | 42,1 | 39,6 | 2.5 | 3.2 | 6,5 | 39,5 | 42,8 | 3.3 |
| 32 | 1 | 45 | 17.0 | 52 | 49 | 3.0 | 3,4 | 7 | 49 | 52,6 | 3.6 |
| 40 | 1 | 50 | 19.0 | 59 | 56 | 3.0 | 3 | 7 | 55 | 60,5 | 4.0 |
| 50 | 2 | 58 | 21.0 | 70,5 | 67 | 3.5 | 2,5 | 7 | 67 | 71,5 | 4.5 |

The example of the conventional denotation of an elbow with the nominal bore 20 mm: **Elbow 20 State Standard 8946-75.**

### 4.5.5.6 TEES (STATE STANDARD 8948-75)

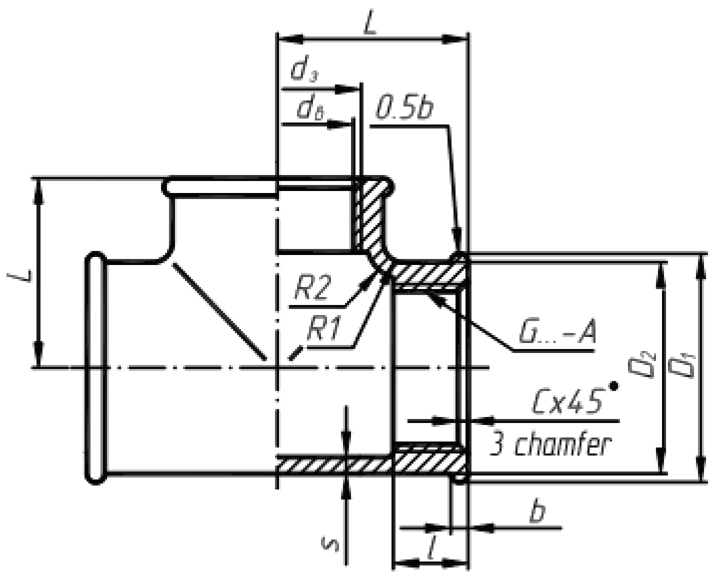



Figure 4.31 – Conventional drawings of a tee

Table 4.17

| ***Nominal bore, Dy, mm*** | Thread G, inch | L, mm | l , mm | $D_1$, mm | $D_2$, mm | b, mm | ***$R_1$, mm*** | $R_2$, mm | S, mm |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 3/8 | 25 | 10.0 | 24 | 22 | 2.0 | 4 | 6.5 | 2.5 |
| 15 | 1/2 | 28 | 12.0 | 28.6 | 26.6 | 2.0 | 2.7 | 5.5 | 2.8 |
| 20 | 3/4 | 33 | 13.5 | 34.9 | 32.4 | 2.5 | 3.3 | 6.3 | 3.0 |
| 25 | 1 | 38 | 15.0 | 42.1 | 39.6 | 2.5 | 3.2 | 6.5 | 3.3 |
| 32 | 1 | 45 | 17.0 | 52 | 49 | 3.0 | 3.4 | 7 | 3.6 |
| 40 | 1 | 50 | 19.0 | 59 | 56 | 3.0 | 3 | 7 | 4.0 |
| 50 | 2 | 58 | 21.0 | 70.5 | 67 | 3.5 | 2.5 | 7 | 4.5 |

The example of the conventional denotation of a tee with the nominal bore 20 mm: **Tee 20 State Standard 8948-75.**

The drawing of a joint is begun with the drawing of a pipe, then the view of connecting parts are drawn according to the sizes in tables (4.12 – 4.17). A pipe on the drawing is shown by not screw up in a connecting part on 2-4 mm (1-2 threads), that is why a thread on a pipe is at the face of the connecting part. Figure 4.32 shows the drawing of the pipe joint by a pipe coupling. An external thread on a pipe is drawn the same as on the bar of a bolt by a continuous contour line on the most diameter and by a continuous thin line on the internal diameter of a thread. Such view of a thread on a pipe will be in joint with other parts.

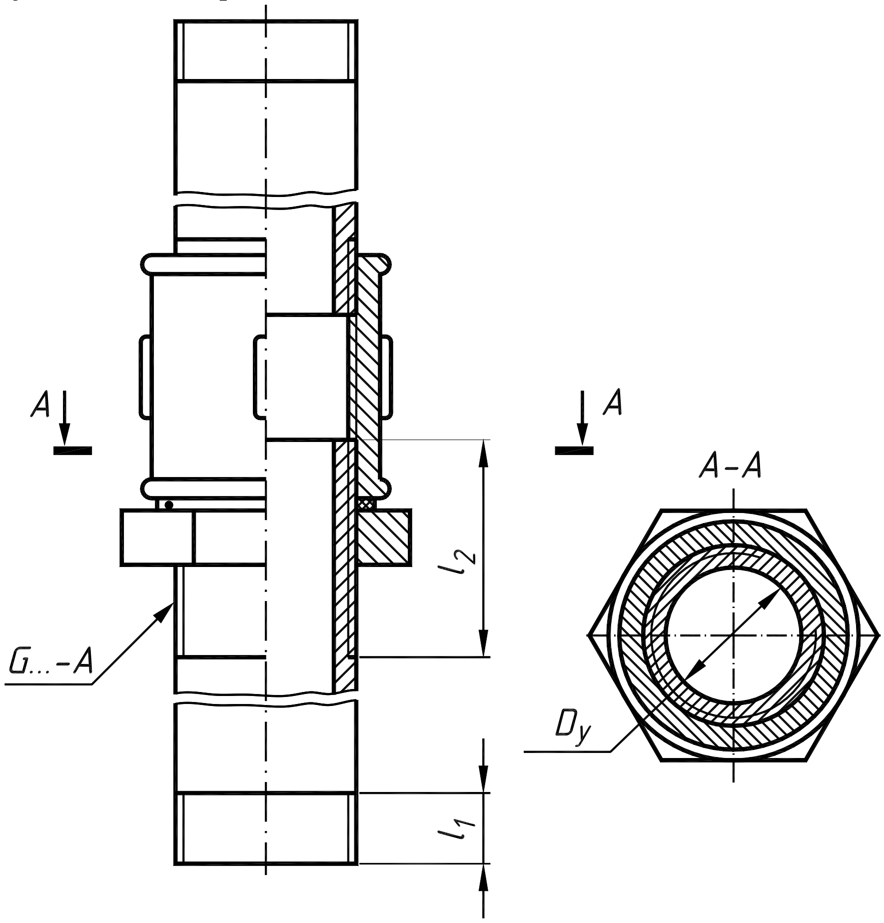



Figure 4.32 – Pipe joint by a pipe coupling

An internal thread in connecting parts remains unchanging only in the places not taken by the pipe.

## 4.6 PERMANENT JOINTS

As it was mentioned above, permanent joints are joints which are impossible to disconnect without the damage of connecting parts. Let's consider such types of joints, as joints by welding, soldering, cementing.

### 4.6.1 WELDED JOINTS

Welding is a permanent method for making joints. Welding has replaced riveting in many industries because of saving in labour as well as material and reduction in weight by the use of lighter plates and the elimination of all overlaps and rivets. Standard steel shapes, plates and bars may be welded together to make machine frame, bases, jigs and fixtures, etc. For joining of very high pressure steam pipes, welding is the only acceptable process. The aircraft, automotive and ship building industries have developed welding as a major fabricating method for aluminium magnesium and steel.

Welding is defined as the localized, intimate union of metal parts in the plastic or plastic and molten state, with the application of blows or mechanical pressure or the union of parts in the molten state without any pressure. There are three main methods of welding, viz., forge welding, electric resistance welding and fusion welding, which may further be classified as shown in Fig. 4.33.

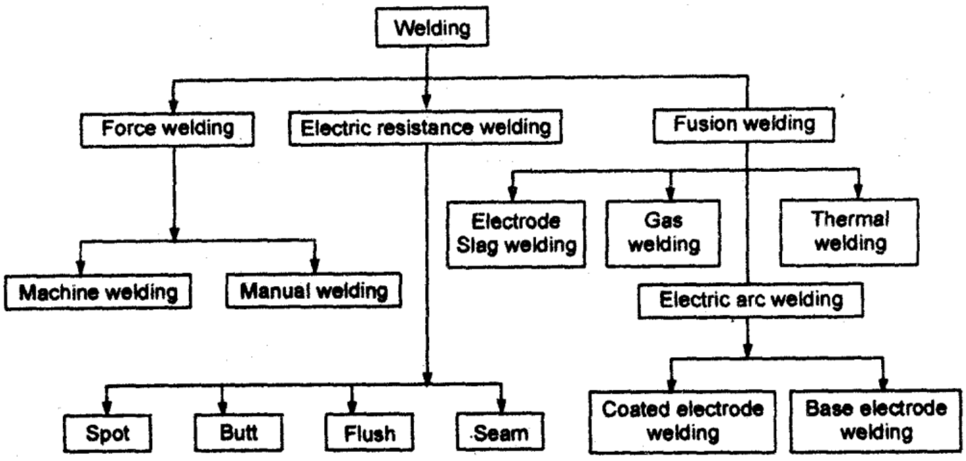



Figure 4.33 – Types of welding

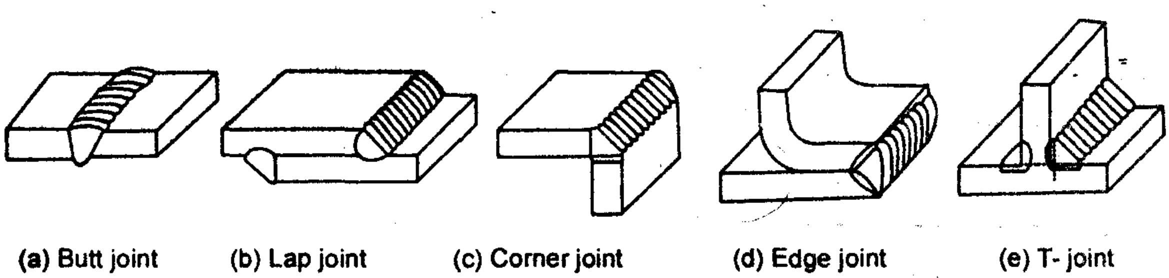
The most common welding used in manufacturing of machinery is arc welding but gas welding is also used.

Arc welding is carried out with the help of a voltaic arc between an electrode and welded parts.

The gas welding is conducted by flame of hot gas which is burned in the stream of oxygen.

At the resistance welding heating is carried out a heat which is selected at flowing of the powerful electric current through welded parts in the place of contact between them. The resistance welding is divided into butt and spot.

There are five basic form of welded joints, namely, edge, butt, lap, corner and tee. The various types of welded joints are shown in Fig. 4.34.



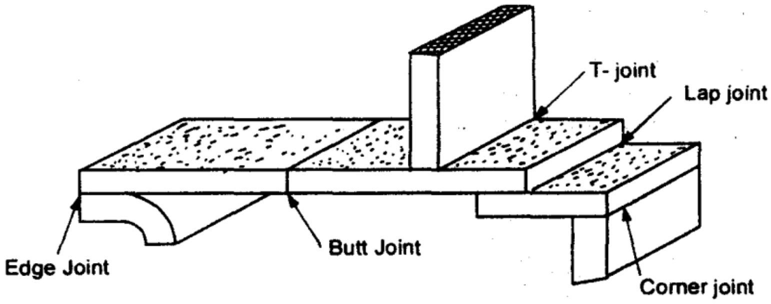



Figure 4.34 – Types of welded joints

1. Butt Joint-This type of Joint is used to join the ends of two plates, located in the same plane or 2 to 5 mm thick plates, the open square butt joint should be selected. But above 5 mm thickness, the joint with edge preparation on one or both sides may be recommended.

2. Lap Joint—It is used to join two overlapping plates such that the edge of each plate is welded to the surface of the other. This type of joint is suitable up to 3 mm thick plates.

3. Corner Joint-It is used to weld the edges of two plates this is suitable for both heavy and light gauges.This type of joint is commonly used in the construction of boxes, tanks, frames and other circular items.

4. Edge joint-The edge joint is used to join two parallel plates. This is generally used for sheet metal works.

5. T-Joint—T-Joint is used to join two plates, the surfaces of which are at right angle to each other. It is employed for thickness of plate’s up to 3 mm and is widely used in thin walled structures.

The weld is a part of the welded joint, formed in the place of a joint as a result of welding and which has structure, different from the structure of parent metal of the part**.**

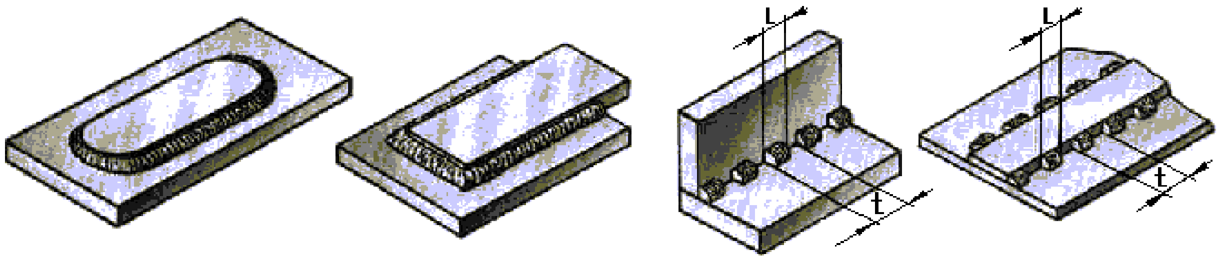
The welds are divided into types according to: duration, an external form, the form of edge preparation, the character of implementation.

According to duration the welds can be uninterrupted and interrupted**.** There are the uninterrupted – weld nonspaced on length (fig.4.35,a). Interrupted welds are the welds with intervals on length (fig.4.35,b).

Interrupted welds can be chain and staggered.

Chain weld is one (fig.4.35,c) or bilateral interrupted weld of T-Joint in which intervals are place1d for both sides of the wall against each other (not represented).

Staggered weld is a double-sided interrupted weld of T-Joint in which intervals on one side of a wall are placed opposite the welded areas of its second side (fig.4.35, d).

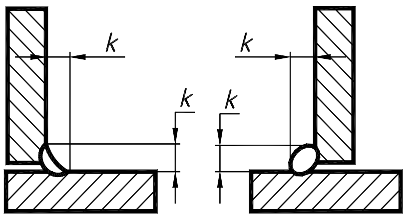



a) b) c) d)

Figure 4.35 – Uninterrupted and interrupted welds

Some corner joints, T- joints and also lap joints are characterized by the size of leg *K* (fig.4.36).

A leg weld is the shortest distance from one surface of welding parts to the border of a corner weld and the surface of another weldable part.




*a)* *b)*

Figure 4.36 – A leg weld

The form of edge preparation depends on the thickness of welding parts, the position of a weld in the space and other information. A bevel angle is an angle α between the bevel edges of weldable parts (fig.4.37).

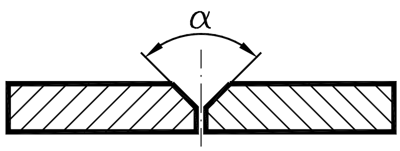
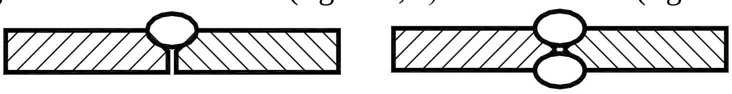



Figure 4.37– A bevel angle

The way of making a weld depends on the thickness of weldable parts and technical conditions of welding. Welds are one-sided (fig.4.38, a) and two-sided (fig.4.38, b).



a) b)

Figure 4.38 – One-sided (a) and two-sided (b) welds

In the welds of the welded joints there are the obverse and reverse sides. The obverse side of the weld is that from which welding is done (fig.4.39).

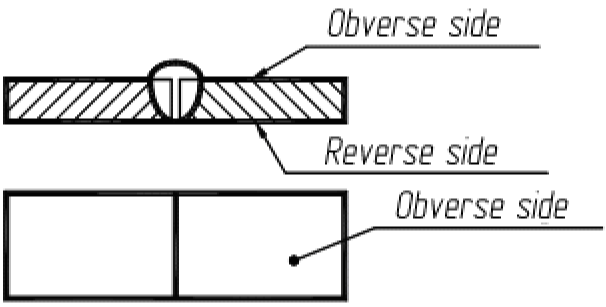
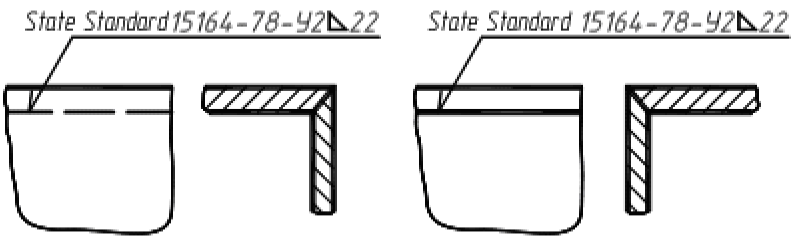



Figure 4.39 – Obverse and reverse weld sides

In accordance with State Standard 2.312-72 welds of the welded joints regardless of the method of welding are : visible – by a continuous mainline *S* thick (fig.4.40, b), invisible – by a stroke line s/2 thick (fig.4.40, a).




*a)* *b)*

Figure 4.40 - Welded joints

The visible single welded points regardless of the method of their welding are conventionally marked with the sign «+», which is drawn by continuous mainlines (fig.4.41). Invisible single points are not shown.

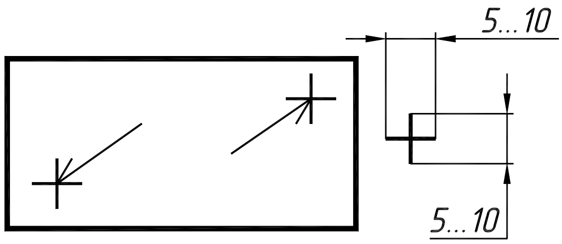
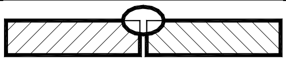
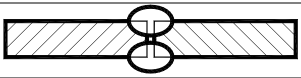
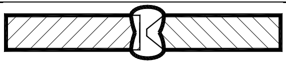
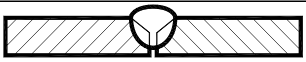
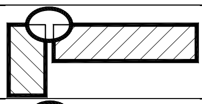
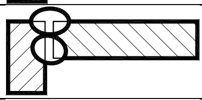
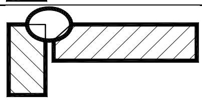
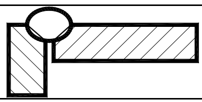
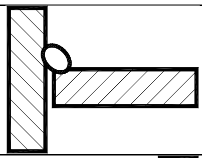
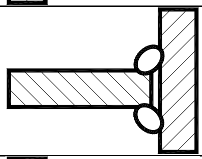
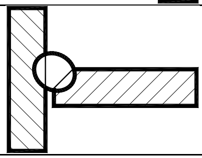
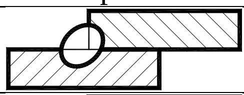
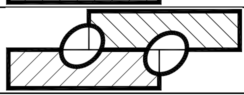


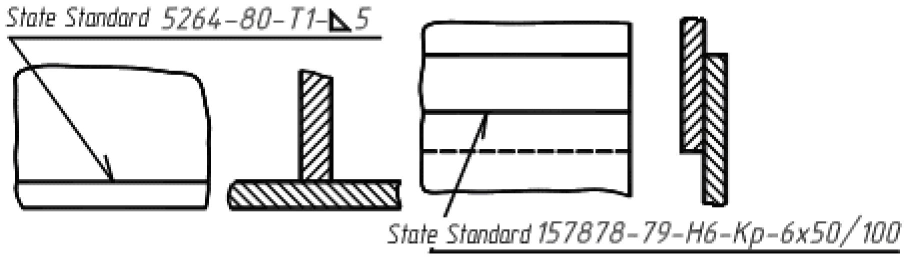
Figure 4.41 – The visible single welded points

To point the place of welds location of the welded joint utillize a line – foot-note with an one-sided pointer is used, which is drawn by a continuous thin line s/3...s/2 thick. The inclination of a line is foot-notes to the line of weld is recommended to draw under the angle of 30°-60°. To the line – foot-notes a horizontal point is joined of the same thickness where the complete description of welding is given.

Table 4.18 shows denotations of weld basic types of arc welding according to State Standard 5264-80.

Table 4.18

| The form of edge preparation | The way of making a weld | Form of weld section | Thickness of welding parts, mm | Conventional designation of the weld | Length of a leg weld, mm |
|---|---|---|---|---|---|
| | | Butt joint | | | |
| Weld without bevel edge | One-sided |  | 1-6 | C2 | |
| Weld without bevel edge | Two-sided |  | 2-6 | C4 | |
| Weld bevel one edge | Two-sided |  | 4-26 | C5 | |
| Weld bevel two edge | One-sided |  | 3-50 | C15 | |
| | | Corner Joint | | | |
| Weld without bevel edge | One-sided |  | 1-6 | U2 | |
| Weld without bevel edge | Two-sided |  | 2-6 | U3 | |
| Weld bevel one edge | One-sided |  | 4-26 | U6 | |
| Weld bevel two edge | One-sided |  | 12-60 | U9 | |
| | | T-Joint | | | |
| Weld without bevel edge | One-sided |  | 2-30 | T1 | 3-8 |
| Weld without bevel edge | Two-sided |  | 2-30 | T3 | 2-8 |
| Weld bevel one edge | One-sided |  | 4-26 | T6 | |
| | | Lap Joint | | | |
| Weld without bevel edge | One-sided and interrupted |  | 2-60 | H1 | |
| Weld without bevel edge | One-sided |  | 2-60 | H2 | |




a b

Figure 4.42 – The example of T-Joint (a) and interrupted lap welded joint(b)

The example of T-Joint T1 is shown in fig.4.42 (a). It is weld without bevel edge, two-sided, with length of a leg weld 5 mm.

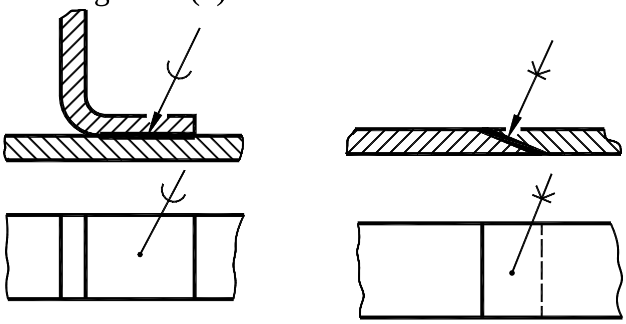
The example of an interrupted lap welded joint H6 is shown in fig.4.42 (b). Width of a weld is 6 mm, length of a weld is 50 mm., pitch of a joint is 100 mm.

### 4.6.2 SOLDERED AND GLUED JOINTS

A conventional views and drawings of soldered and glued joints are in State Standard 2.313-82.

The place of joints of parts must be represented by a continuous line 2S thick.

For drawing of the soldered and glued joints conditional marks are used which put on lines – leader by a continuous mainline: C- for a soldering, K- for glued joints. The soldered joint is shown in fig. 4.43 (a), glued joint – in fig. 4.43 (b).



a b

Figure 4.43 – Drawing of the soldered (a) and glued (b) joints

Joints, executed on the closed line, must be marked by a circle with diameter from 3 to 5 mm, drawing a thin line (fig.4.44). The sizes of joints and denotation of roughness of the surface should be pointed out on drawing of a soldered joint in case of necessity.

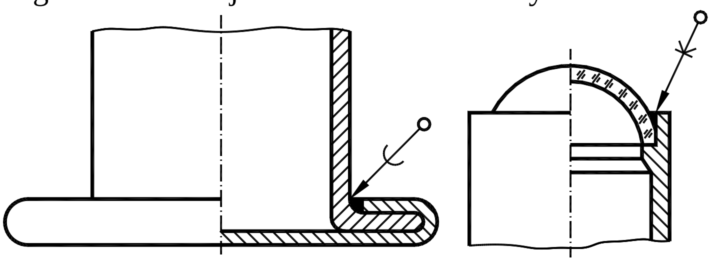


Figure 4.44 – Joints, executed on the closed line

### QUESTIONS FOR SELFCHECK

1. What types of joints do you know?
2. What is a screw-thread?
3. What types of screw-thread do you know?
4. What thread fixing do you know?
5. Classification welded joints.

# 5 GENERAL INFORMATION ABOUT PRODUCTS AND DRAFTS
## 5.1 INFORMATION ABOUT STATE STANDARDS

After the State system of standardization of Ukraine normative documents for standardizations divide into such categories: State Standards of Ukraine; branch standards of Ukraine; standards of scientific and technical and engineerings societies and unions of Ukraine; technical regulation of Ukraine; factory standards. The state standards of the former USSR (abbreviation is GOST) on territory of Ukraine are acknowledged intergovernmental and keep the same abbreviation.

In obedience to the intergovernmental agreement accepted in 1992 years part of operating standards of the former USSR is taken to implementation, including the existent standards of the Unified system of designer document (ESKD), which was entered from January, 1, 1971. In 1996 year the order of national Standard of Ukraine is bring System of designer document into an action (SKD) (State Standard 3321 – 96).

SKD is the complex of terms and determinations of elements and basic concepts of designer document which is made and apply organizations and enterprises of Ukraine.

Main setting of SKD State Standard 3321 – 96, as well as ESKD, to set the unique terms and determinations of basic concepts of designer document, governed and position in relation to the order of development, registration and appeal of designer document which is developed and used organizations and enterprises.

The national standard of Ukraine accepted classification of normative documents for standardizations, which answer International Standard Organization (ISO).

## 5.2 PRODUCTS AND THEIR COMPONENT PARTS

In accordance with State Standard 2.101 - 68 product is any object or set of objects production, subject making on an enterprise. Products, depending on their setting, divide by the products of basic production (products, intended for realization) and auxiliary production (products, intended for the own needs of enterprise). The followings types of wares are set: a) details; b) assembly units; c) complexes; d) complete sets. Depending on a presence or absence of component parts of products divide on: **a) unspecified** (details) - not having component parts; **b) specified** (assembly units, complexes, complete sets) - consisting of two and more component parts.

**A DETAIL** is name product, made from homogeneous on the name and brand of material, without application of assembly operations.

An assembly units is product, component parts of which connect between itself on an enterprise by means of assembly operations (screwing together, stave, welding etc.), for example: car, machine-tool.

**A COMPLEX** is two and more specified products, not connected by on an enterprise-manufacturer assembly operations, but the associate operating functions intended for implementation, for example: production shop-automaton, ship, boring apparatus.

A **complete SET is** two and more than products, not connected by on an enterprise-manufacturer assembly operations and being a set products which have the general operating setting of auxiliary character, for example: complete set of awaiting-parts, complete set of instrument etc.

Any products can be made only on the basis of certain designer documents. Graphic and text documents, which determine composition and device of product and contain necessary information for his development, making, control, formal acceptance, exploitation and repair, behave to the designer documents. The different types of drafts behave to the graphic documents, circuitrys. In them there is graphic information about product.

Graphic documents are subdivided into the followings kinds: **A detail design of DETAIL** is a document, containing the view of detail and other information necessary for its making and control. **Assembly drawing** is a document, containing the image of assembly unit and other information, necessary for its assembling (making) and control. **A draft of GENERAL VIEW** is a document, determining the construction of product, co-operation of its component parts and explaining principle of work of product.

**Overall Drawing** is a document, containing the contour (simplified) view of product with overall, locational and joinings sizes.

**Circuit** is a document on which component parts of product and connection between them are rotined as conventional images or denotations . Text designer documents are documents, containing information about product as texts which can be presented in form tables, lists etc. To the text designer documents behave, in particular:

SPECIFICATION (document, determining composition of assembly unit, complex or complete set);

Technical regulation (document, containing requirements to product, its making, control, formal acceptance and delivery, which beside the purpose to specify in other documents), and also different LISTS**, TABLES, etc.** using for development, in a production, exploitation and repair of products.

State Standard 2.103 – 68 divided designer documents into design and detail depending on the stages of development.

Preliminary design and contract design belong to design project. The incoming in a technical project drafts of general views are contained by basic data for implementation of detail documents - specification**,** assembly drawing**,** detail design etc. Concordantly State Standard 2.103 - 68 the followings stages of development of designer document are set:

1. Draft proposalis an aggregate of designer documents, containing the analysis of different variants of possible decisions of requirement specification of customer, feasability studies of the offered variants, patent search etc.

2. Preliminary design is an aggregate of designer documents, which must plug in itself of principle structural decisions, givings the general picture of device and principle of work of product, and also information, determining setting, basic parameters and overall sizes of the developed product.

3**.** Contract design **-** aggregate of designer documents, which must contain final technical decisions, givings the complete picture of device of the developed product and basic data for development of working document. A technical project serves as foundation for development of detail designer document.

4. Detail designer documents **is** an aggregate of designer documents, intended for making and tests of pre-production model, adjusting party, serial (mass) production of products.

## QUESTIONS FOR SELFCHECK

1. What types of standards do you know?
2. What product is?
3. What detail is?
4. What complex is?
5. How are graphic documents subdivided?

# 6 DETAIL DRAWINGS AND SKETCHES OF PARTS

## 6.1 REQUIREMENTS TO THE DETAIL DRAWINGS AND SKETCHES OF A PARTS

Detail Drawing — A machine usually consists of several parts. A part is called an element or detail. The detail drawing gives the complete information for manufacture of each of the separate part. It is mainly meant for shop floor.

The detail drawing of a part is a designer document, which contains the representation of a part and other information, necessary for its making and control.

A freehand sketch is a drawing made without the use of drawing instruments. In afreehand sketch, all the rules of graphic language are as rigidly observed as a scale drawing. Freehand sketches are not to any scale but they should be in good proportion according to the shape of the object. Freehand sketch is an important tool for an engineer or a draughtsman and is useful in various applications.

A sketch is a draft of temporal character, intended for the non-permanent use, executed, as a rule, from a hand, without the observance of scale, but with the maintainance of proportion of elements of a part.

A detail drawing and a sketch must contain:

a) minimal, but sufficient number of representations (views, sectional views, sections) which fully find out the form of a part;

b) all necessary sizes;

c) denotation of roughness of all surfaces;

d) information about material, heat treatment, coverage which a part must have before assembly etc.

The basic requirements to the detail drawings and sketches of parts are following:

1. A separate drawing is done on every part on formats according to State Standard 2.301-68. A title block of a drawing must be done according to State Standard 2.104-68.
2. Conventional denotation of material is in the title block. It consists of the name of material, its grade and a standard, for example for parts from steel «Steel 20 State Standard 1050-88», «St 3 State Standard 380-2005», for parts from the cast iron « Gray Cast Iron State Standard 1412-85», for parts from the bronze «Br. OCS 3-12-5 State Standard 6713-79» etc.
3. The mass of a part is put in title block in kilograms, not marking the units of measuring.
4. The scale of representation on the detail drawing s is chosen according to State Standard 2.302-68.
5. The detail drawing s, as a rule, are done on all of the parts which form an article. Separate drawings on the following parts are allowded to not do: a) made of cutting-off high quality rolled section; b) permanent joints (welded, soldered etc.), if the design of parts is simple and do not require more than three-four sizes, which are drawn on the assembly drawing.
6. Sizes and denotations of roughness of surfaces a part must have before the assembly of a product are marked on the detail drawing or sketch.

## 6.2 TECHNIQUE OF SKETCHING

It is recommended to do sketches on a graph paper or section paper, as it facilitates the projecting connection. Sketches are done due to all rules for the detail drawing s of parts.

The following steps should be followed to make orthographic sketches.

**Step I.** Study the object carefully and decide the views which describe the shape of the object best. Note the symmetry of the object from drawing the centre lines. Forgetting the details note the length, width, height and their proportions.

**Step II.** Decide upon the views (sections) to be drawn and sketch the centre lines for them planning the proportions. A special attention is paid to the choice of the main view. It must give the complete picture of a form and sizes of a part taking into account technology of its making.

**Step III.** To choose a format in accordance with State Standard 2.301 - 68, to do title block. The size of a format is chosen according to complication and sizes of a part taking into account the possibility of the increase of a view in comparison with the nature for complicated and small parts and the decrease for simple in a shape and large parts.The sketch should not be too small otherwise it is not clear and dimensions cannot be placed on it.

**Step IV**. Draw the rectangles or squares in which the views are to be sketched and sketch the outline of every feature by firm lines. To draw axial lines. Mark the reference points to show lengths, widths, heights, curve lines, circles, etc.

**Step V.** Lightly sketch the object, drawing circles first and then horizontal, vertical and sloping straight lines in that order. Sketch in the required dotted lines for hidden features of the object. To draw the visible contour of a part by continuous lines, beginning with the basic geometrical forms and keeping the projection connection and proportion of elements of a part on all depictions (fig. 6.1, a).

**Step VI.** To draw the necessary sectional views, sections by thin lines (fig. 6.1, b). Finish all the lines of the views and rub out lines which are not required. To depict previously missed small elements: grooves, chamfers, fillets etc.

**Step VII.** To shade sectional views, sections. To mark sectional views, sections (fig. 6.1 c). Add the necessary dimensions and notes. To draw extension and dimension lines. The sizes of external elements are placed, as a rule, from the side of a view, and the sizes of internal – from the side of sectional view. Overall dimensions must be marked. To mark the roughness of surfaces, according to State Standard 2.309 – 73.

**Step VIII.** To delete unnecessary lines, point a sketch (fig. 6.1, d). To fill the title block and write down technical requirements. Column «Scale» in the title block for sketches is not filled in. Then have a final look to correct any inaccuracy or to add any omissions.

The example of the completed sketch is shown in figure 6.2.

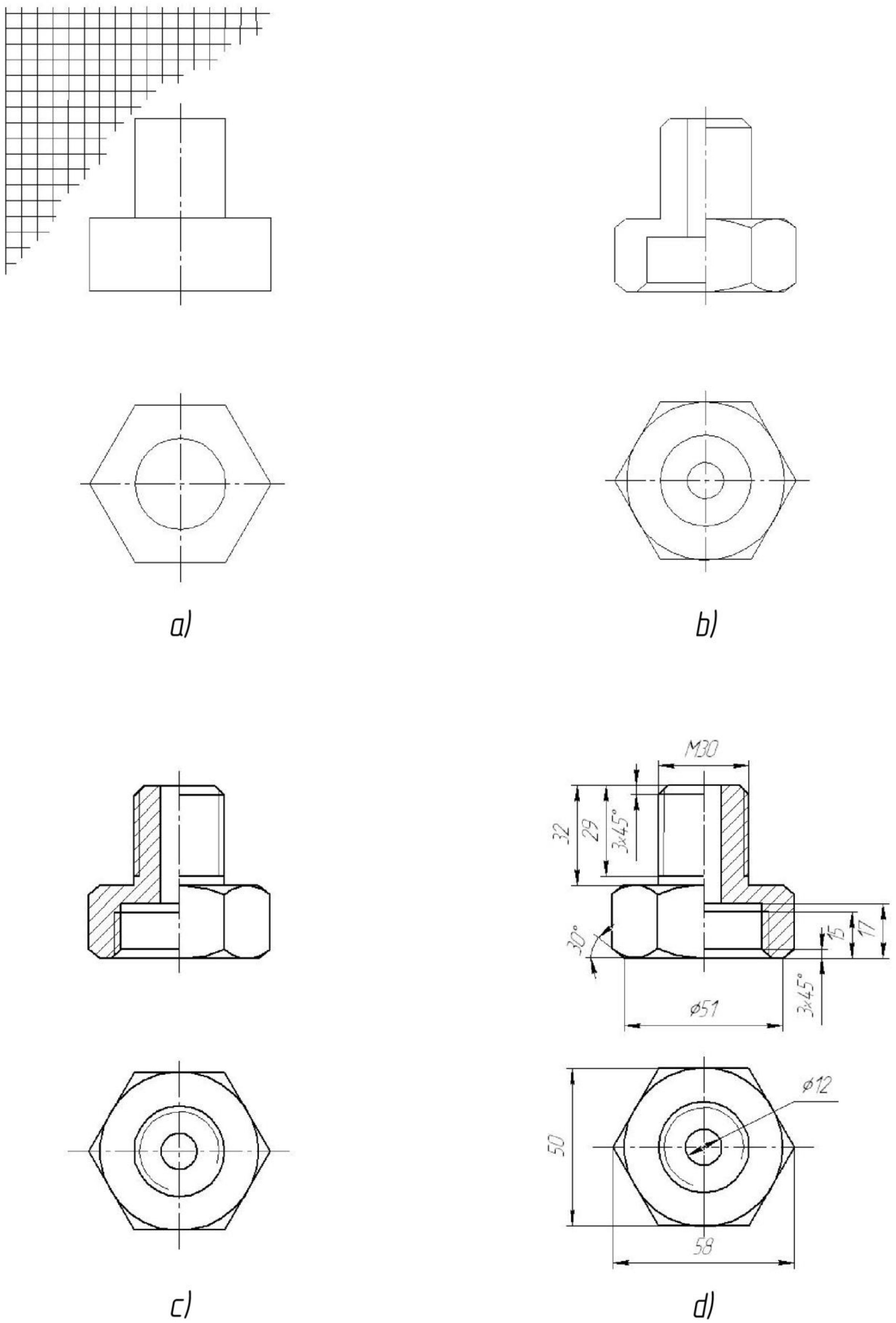



Figure 6.1 – Technique of sketching

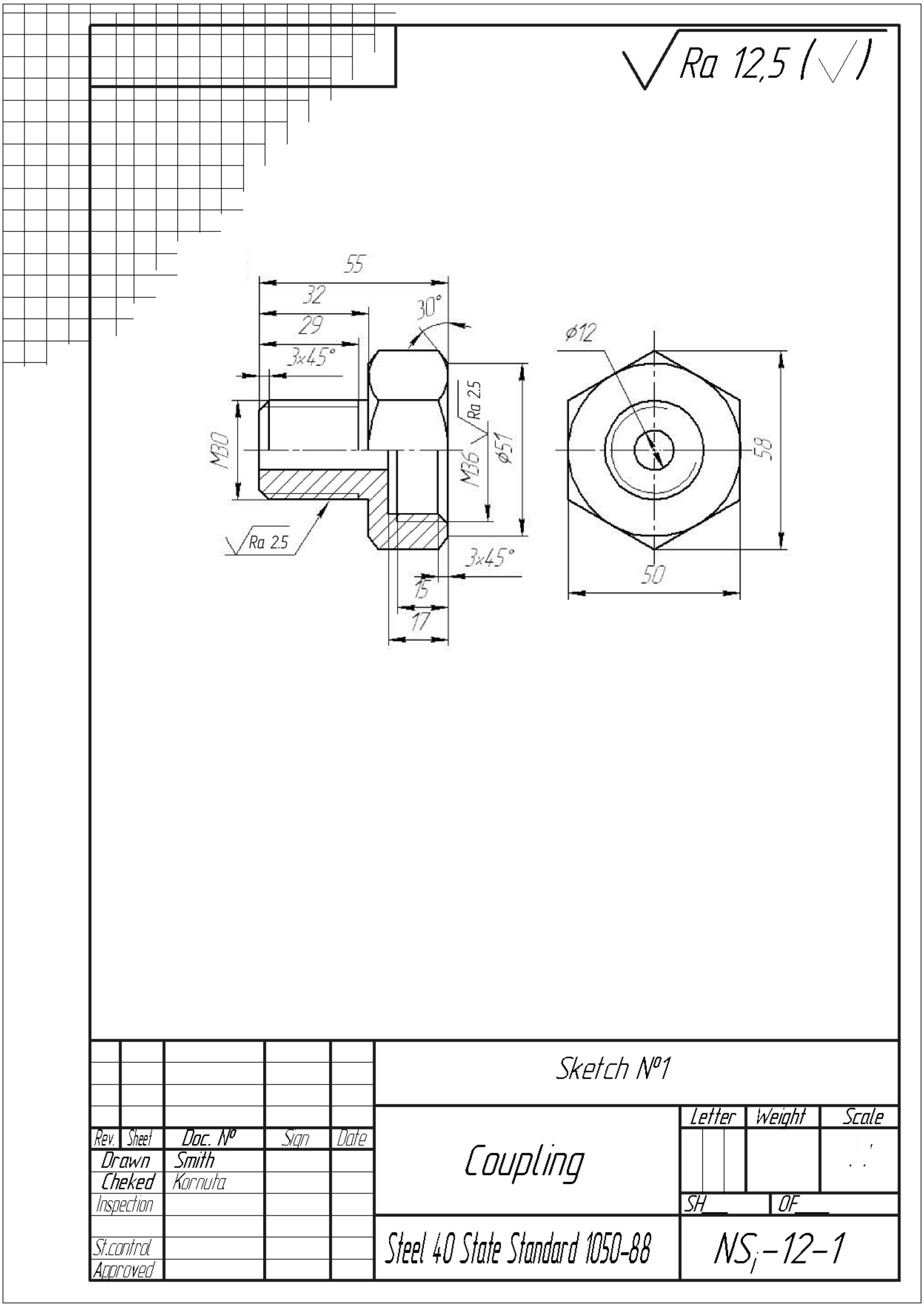



Figure 6.2 –The example of the sketch «Coupling»

### 6.3 DENOTATION OF ROUGHNESS OF SURFACES

The roughness of surfaces of the parts is marked on sketches and detail drawing s by conventional signs.

The roughness of surface is the aggregate of inequalities in the form of profile peak and profile valley which remain on the surface of the part as a result of the influence of a cutting instrument. For setting norms and evaluation of roughness of surface State Standard 2789-73 set six parameters among which the parameters of Ra are mainly used in practice (arithmetical mean deviation of the profile) and Rz – ten-point height of irregularities.

The roughness of surfaces on the drawings is shown according to State Standard 2.309-73 one of three signs: the sign, shown in figure 6.3 is used, when a designer does not set the type of treatment of surface; the sign, shown in figure 6.3 b is used for surfaces, got by a deplating material, for example, turning, drilling, milling; the sign, shown in figure 6.3 c is used for surfaces, got without a deplating material, for example, casting, die forging, rolling etc.

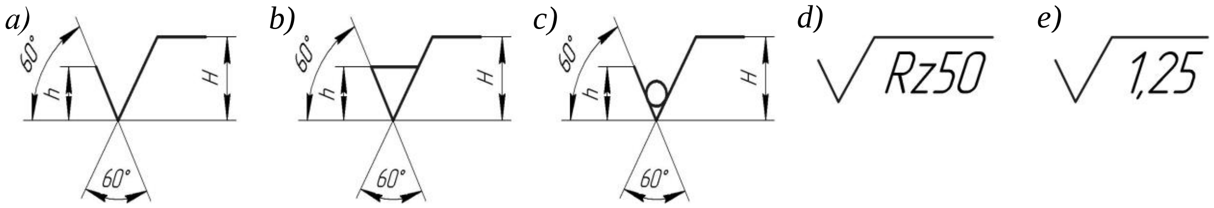



Figure 6.3 – The signs for roughness of surfaces

The height of *h* signs (fig.6.3) must be approximately equal the height of numbers of size numbers, and height *H=(1,5-3)h* . The thickness of lines of these signs equals the half of thickness of continuous mainline.

Denotations of roughness of surfaces are marked on a contour lines, extension lines, or on the shelves of line-foot-notes; when there is no space, it is allowed to write them on dimension lines.

If all surfaces, indicated on the drawing, have an identical roughness, its denotations are marked in the upper-right-hand corner of drawing, and no signs are put on the depiction. Sizes of this sign must be approximately 1,5 times more than on a drawing (fig.6.4, a).

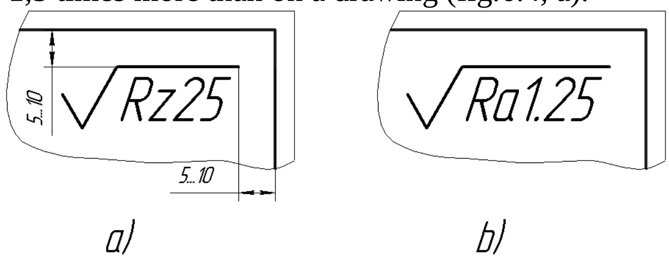



Figure 6.4 – Sizes of this roughness sign

If the roughness of surfaces on the drawing is not identical, in upper-right-hand corner, after general denotation of identical roughness (for most surfaces), the sign of less size is put in brackets (fig.6.4, b). It means that all surfaces which have no signs of roughness on the depictions must have roughness, indicated in the upper-right-hand corner.

### 6.4 MAKING THE DETAIL DRAWINGS OF PARTS FROM SKETCHES

Unlike sketches the detail drawings of parts are done in a scale with the exact observance of sizes with the help of drawings instruments.

To make the detail drawings it is necessary:

- to analyze preliminary the sketch of a part, in accordance with State Standard 2.302-68 choose the scale of a view and a drawing format ;
- to draw a frame and title block on a format;

- to make the final chart of arrangement of drawing, i.e. to mark the places of basic and additional depictions;
- to draw the axes of symmetry, central lines, to draw the contours of depictions, to draw sectional views, sections, to draw extension and dimension lines;
- to check up the drawing and remove unnecessary lines, to outline a visible contour by a continuous thick mainline, to hatch sectional views and sections;
- to mark sizes and signs of roughness of surface, to fill title block and technical requirements.

Example of the sketch of the part «Captive Nut» is shown in fig.6.5, and its detail drawing is shown in fig.6.6.

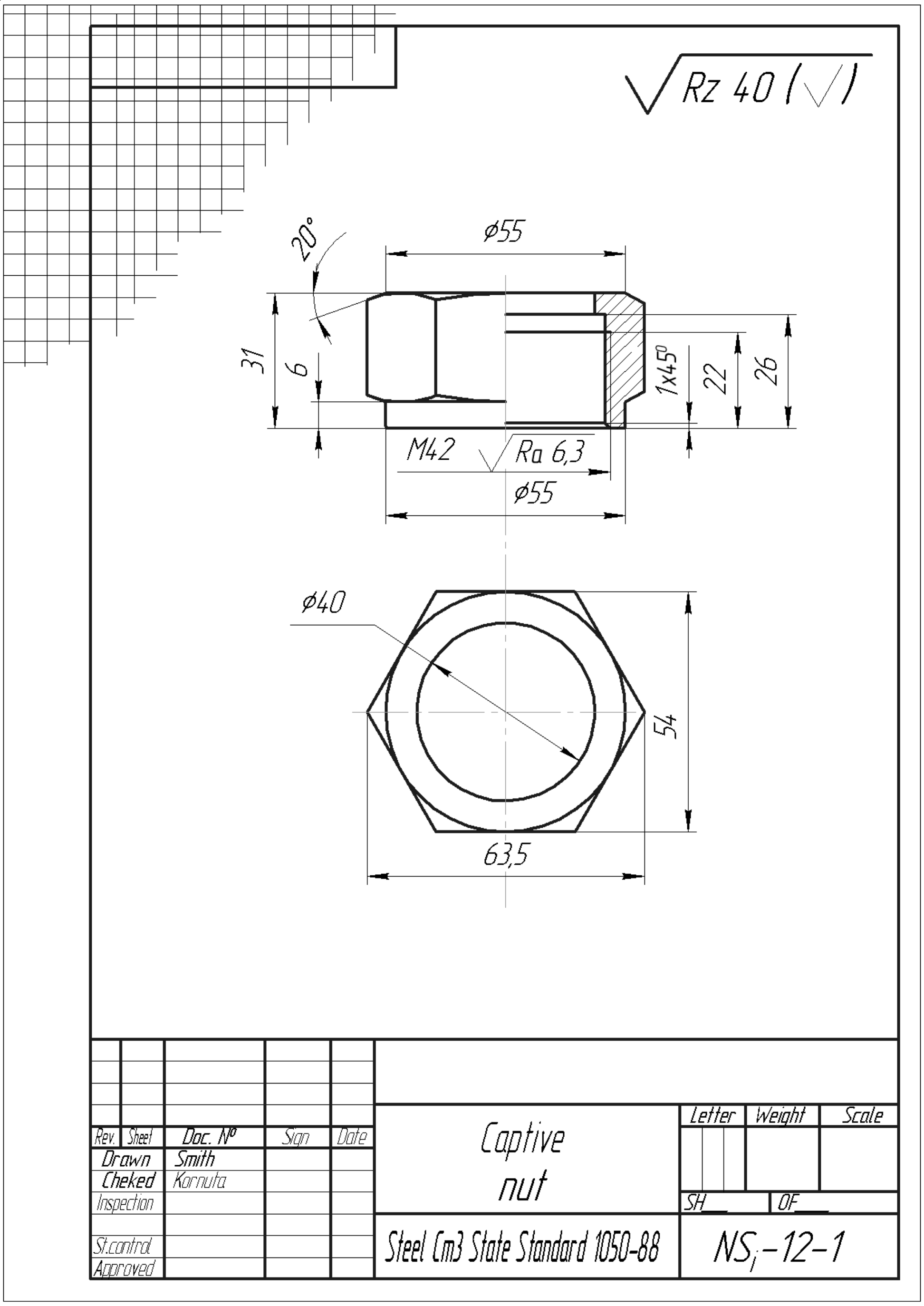



Figure.6.5 – The sketch of the part «Captive Nut»

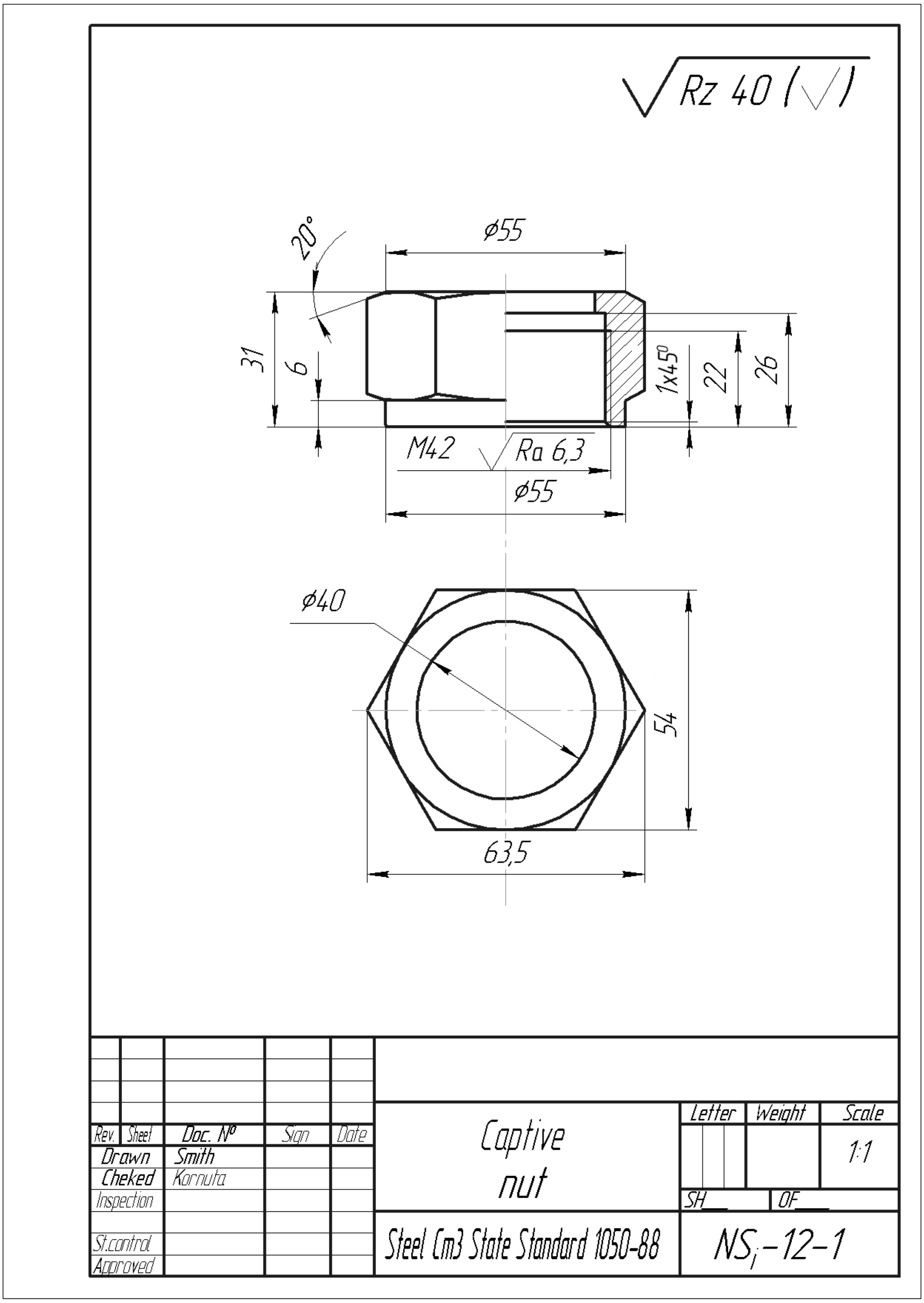



Fig.6.6 – The detail drawing of the part «Captive Nut»

## QUESTIONS FOR SELFCHECK

1. What is detail drawing of a part?
2. What is a sketch?
3. What is the basic requirements to the detail drawings and sketches?
4. What steps should be followed to make sketches?
5. Denotation roughness of surfaces of the parts.

# 7 ASSEMBLY DRAWINGS

Assembly drawing shows how the components or parts must be assembled to form the complete machine or device. The assembly drawing shows the different parts in their relative positions. An assembly drawing furnishes the following information:

a) One main view to show the best assembly.

b) Selected overall dimensions and important centre to centre distance.

c) Identification of different parts on assembly drawing.

d) Necessary sectional views.

e) Part list, notes, titles, etc.

An assembly drawing is a document, which contains the representation of assembly unit and other information, necessary for its assembly and control. An assembly drawing must give the complete information about an article construction, interaction of parts, that belong to it, and there is a technical document during implementation of assembly operation and acceptance of an article.

An assembly drawing must contain:

A) representation of an assembly unit, which gives an idea of placing and interconnection of its separate parts;

B) sizes and other parameters and requirements, which are carried out and controlled in the process of an assembly of an article, pointing about the method of connection of parts of an article;

C) part number of component parts of an article;

D) basic descriptions of an article;

E) overall, setting dimension, conjunctive and reference dimensions (fig.7.1).

## 7.1 MAKING ASSEMBLY DRAWING

1. Necessary and sufficient amount of representations are determined thus, the external and internal elements of an article were fully exposed on an assembly drawing.

2. The scale of a drawing is determined depending on complication of an article and its sizes, a paper format is chosen according to State Standard 2.301-68. A frame and title block are drawn.

3. Overall rectangles or circles are marked for placing of representations and the axes of symmetry are drawn.

4. Necessary sectional views, sections, additional representations are drawn. If any sectional view is to be drawn, fix the position of the cutting plane and find out the parts through which cutting plane passes. Difficult parts are drawn simultaneously on all of representations of an article.

5. Other parts are drawn.

6. The executed drawing is checked up, the lines of visible and invisible contours are drawn, sectional views and sections are shaded. Change hatching directions in adjacent sectioned components.

7. Extension and dimension lines are drawn and size numbers are marked.

8. Part numbers of component parts of an assembly unit are marked.

9. A title block is filled in, technical requirements and technical description of an article is shown in case of necessity.

If an article is designed in a shape of a symmetric figure, it is recommended to combine the half of view with the half of the proper sectional view. Fixing, keys, connecting rods, axles and shafts in a longitudinal section are drawn undissected. Such elements, as spokes of fly-wheels, pulleys, gear-wheels, thin walls as stiffening ribs are cut, but are drawn unshaded, if a cutting plane passes along an ax or a long side of such element.

Shadings of one part in sectional views on different representations are drawn under one angle, maintaining the identical interval of shading. Shadings of contiguous parts are drawn in different directions.

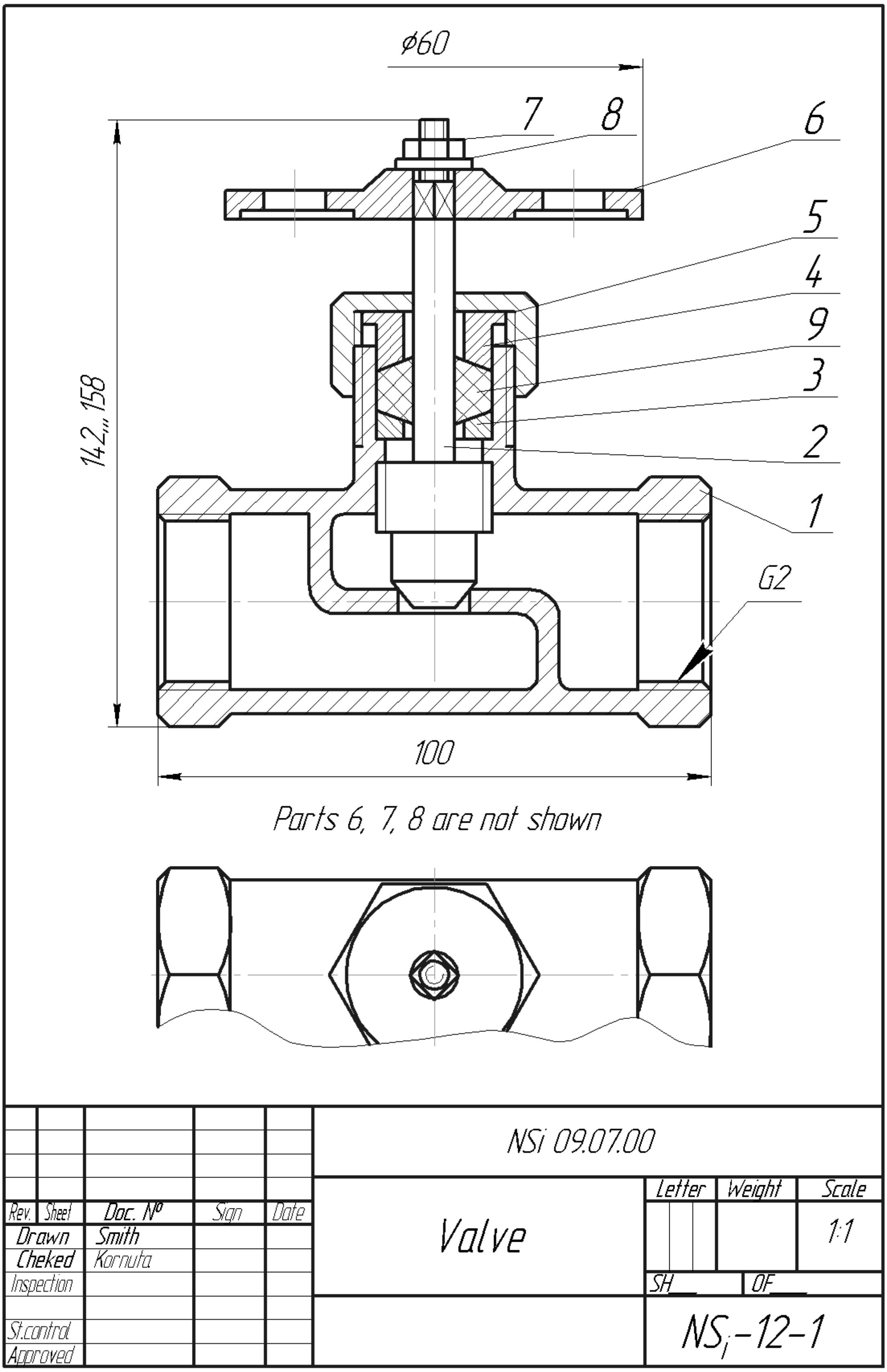



Figure7.1 – Assembly drawing

| Format | Zone | Poz. | Code Identification | Description | Quantity | Remarks |
|---|---|---|---|---|---|---|
| | | | | Documents | | |
| | | | NSia.1201.07.00 AD | Assembly Drawing | | |
| | | | | Parts | | |
| | | 1 | NSia.1201.07.01 | Housing | 1 | |
| | | 2 | Nsia.1201.07.02 | Spindle | 1 | |
| | | 3 | Nsia.1201.07.03 | Wheel | 1 | |
| | | 4 | Nsia.1201.07.04 | Bushing | 1 | |
| | | 5 | Nsia.1201.07.05 | Captive Nut | 1 | |
| | | 6 | Nsia.1201.07.06 | Flywheel | 1 | |
| | | | | Standard Parts | | |
| | | 7 | | Nut M8.5 St.Standard 5915-70 | 1 | |
| | | 8 | | Washer 8 St. Standard 11371-78 | 1 | |
| | | | | Materials | | |
| | | 9 | | Fiber Packing AP5.4 State Standard 5152-88 | 0.1 kg | |

| Rev. | Sheet | Nº doc | Sign. | Date | NSia.1201.07.00 | | | |
|---|---|---|---|---|---|---|---|---|
| Drawn | | | | | Valve | Letter | SH__ | OF__ |
| Checked | | | | | | | | 1 |
| St.control. | | | | | | NSia-12-1 | | |
| Approved | | | | | | | | |

Figure 7.2 – A parts list

An assembly drawings are done, as a rule, with simplifications and conventions.

## 7.2 SIMPLIFICATION AND CONVENTIONS ON ASSEMBLY DRAWING

It is allowed not to show on an assembly drawing:

A) chamfers, fillets, grooves, collars, cuts and other small elements;

B) clearances between a bar and an opening;

C) covers, fly-wheels, handles, hoods, if it is necessary to show the parts of an article closed by them. Thus the proper record, for example, «Fly-wheel ref.6 is not shown» is done above the depiction;

D) visible component parts of articles or their elements, are located behind a spring.

## 7.3 PART NUMBER

All component parts of an article are numbered in accordance with the part number (item number, reference character), indicated in the parts list of this assembly unit. The part number is pointed out on those representations on which a part is designed as visible, giving advantage to basic views or to sectional views.

The part number is marked on the shelves of lines of foot-notes which are drawn by thin lines. The part number is put on a drawing once as a rule and is placed parallell to the title block.

## 7.4 PARTS LIST

A parts list is a document, which determines the composition of an assembly unit, complex or an assembly, necessary for making designer documents (fig.7.2).

A parts list is done on separate sheets A4.

In general case a parts list consists of the followings sections:

1.Documents. 2.Complexes. 3.Assembly units. 4.Parts. 5.Standard articles. 6.Other products. 7.Materials. 8.Assemblies.

The presence of those or other sections is determined by the composition of an article. The name of every section is pointed out as a title in the column «Name» and it is underlined.

The section «Documents» consists of documents which make the basic complete set of designer documents.

The section «Assembly units» consists of assembly units which directly belong to a part construction.

Non-standard parts are put down in the section «Parts» which are included in an article. They are put down according to the increasing of part numbers.

The section «Standard articles» consists of standard articles (bolts, studs, nuts), made in accordance with State Standards.

The section «Materials» consists of materials which are directly included in an article.

The vertical columns of parts list are filled in that way:

– The column «Format» contains denotations of format where the drawing of a part is done;
– The column «Area» is filled in only for drawings, divided into areas;
– The column «Part Number» points the numbers of parts in the sequence of recording them to the parts list. For sections «Documentation» and «Assemblies» this column is not filled in;
– The column «Denotations» consists of denotations of designer documents on all documents and articles, put down to the parts list;
– Additional information, which belong to articles, documents, materials, brought to the parts list is indicated in the column «Note».

## 7.5 DIMENSIONS IN THE ASSEMBLY DRAWING

The followings dimensions are marked in the assembly drawing of an article:

1. Overall dimensions, which characterize height, length and width of an article or its the greatest diameter. If one of these dimensions is changed after wards the shipment of mobile parts, thus, dimensions in extreme positions of mobile parts are shown on the drawing.
2. Fixing or assembly dimensions, necessary for correct connection of parts, located in direct connection in an article.
3. Setting and conjunctive dimensions, which determine dimensions of elements, due to them an article is installed or joined to another article.
4. Operating dimensions which show some calculation and structural descriptions of an article.

The dimensions of separate parts or their elements are not shown in the assembly drawing.

## QUESTIONS FOR SELFCHECK

1. What is assembly drawing?
2. What must assembly drawing contain?
3. How making assembly drawing?
4. What are part numbers?
5. What dimensions we should put in the assembly drawing?

# 8 READING AND DETAILED DRAFTING OF ASSEMBLY DRAWINGS

## 8.1 READING OF ASSEMBLY DRAWINGS

To read an assembly drawing means to understand setting, structure, principle of work of the represented article. Thus co-operation, methods of connection and shape of every part are taking into consideration.

The name of an article and the scale of a representation are finded out after title block. Due to the representations and parts list by the part numbers we determine from what parts and what amount article consists of, what kind of parts are drawn on every representation, how they are joined and co-operated. Thus a special attention should be paid to fragmentary views, sections, and detail sections.

Having found out the setting of an assembly unit and principles of its work, the geometrical shape of separate parts are analyzed. For this purpose all representations of a part on the drawing should be attentively learned, projection connection between representations, position of cutting planes with the help of which sectional views and sections are executed by should be found out. It should be remembered that shading of sections of the same part is identical on all of representations.

The final stage of reading a drawing is to determine the sequence of assembling and disassembling of an article.

The main place while reading the assembly drawing occupies the study of a shape of every separate part.

When determining a geometrical shape of a part it should be remembered that it can't be fully found out from the representations. It is explained by the presence of general view of an article of row of simplifications, legalized standards, on the drawing.

So chamfers, fillets, grooves and similar elements are not drawn on the drawings of general view. But these elements must be drawn on detail drawings of parts.

## 8.2 DETAILED DRAFTING OF ASSEMBLY DRAWING

Detailed drafting is drawing of separate parts according to the drawing of an assembly unit.

It is recommended to begin the process of detailed drafting with drawings of basic parts of an article. The drawing of every part is done in the following order.

1. Read the assembly drawing thoroughly. Do not concentrate too long on one part, but pass on to the adjacent part and come back to first part, if necessary. Determine the minimum number of views required to adequately represent each part. Locate the sectional planes, if necessary.To choose main view. It must give a complete picture of a shape and sizes of part.

2. To set the location of sectional views, sections, auxiliary views and other representations on the drawing; thus unnecessarily to adhere to the same location, as on the drawing of general view.

3. To choose a scale for the representation of a part, according to State Standard 2.302 - 68.

4. Separate small elements on a part are advisable to draw as detail sections.

5. To choose necessary format according to State Standard 2.301 - 68.

6. Use the following sequence for drawing:

– Draw the axes of symmetry and block in the overall dimensions of the views;
– Draw the main outlines;
– Make sectional views and sections, and cross-hatch them;
– Draw the dimension lines and arrow heads;
– Put in the dimension figures and check the dimensions of mating parts.

7. To put denotation of roughness of surfaces. One of the most important moments in the process of implementation of the detail drawing of a part is dimensioning and designation of roughness of its surfaces. Putting the denotations of roughness of surfaces of a part should be done according to State Standard 2.309 - 73.

7. Size numbers which are put on the drawing and which are characterized dimensions are determined by measurement of the representation of a part on the drawing of general view taking into account a scale. While putting size numbers the special attention should be taken to the sizes of

surfaces which are joined. Arrangement of representations, location of size net, denotation of sizes, sections, roughness and other inscriptions, must be executed taking into account the rational use of the field of drawing.

8. Drawing of a part is completed by filling in the title block.

The example of the completed detail drawing is shown in fig.8.1

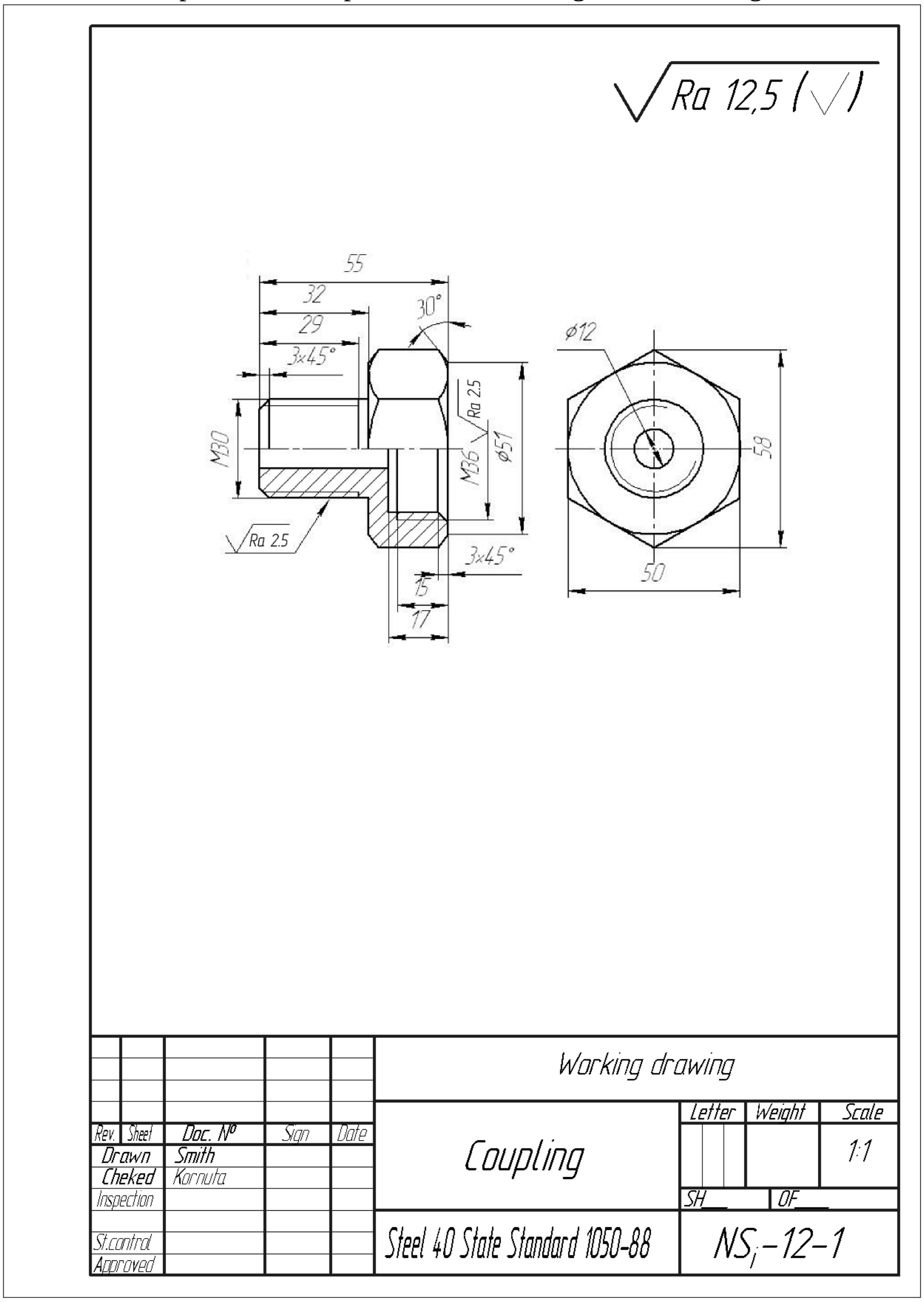



Fig. 8.1 – The example of the completed detail drawing

**QUESTIONS FOR SELFCHECK**

1. What is reading assembly drawing?
2. What order reading assembly drawing is?
3. What is detailed assembly drawing?
4. What order detailed assembly drawing is?

# 9 COMPUTER GRAPHICS
## 9.1 PRESENTATION OF GRAPHIC INFORMATION IN A COMPUTER

Computer graphics is creation, storage and treatment of objects models and their reflection with the help of computer technique.

Basic tasks of computer graphics are:

- Inputting data to a computer which initially has a graphic form or determines it;
- Treatment, optimization of descriptions, storage, defence, transmission of local and global networks of this information facilities;
- Outputting data from a computer in a graphic form.

The fundamental theory of analytical and differential geometry, vectorial algebra, sketch geometry and technical drawing, counts, numeral methods of solution of mathematical tasks, methods of optimization, recognition of patterns, artificial intelligence is fixed in basis of computer graphics.

## 9.2 COMPUTER GRAPHICS USING

Computer graphics is used in different spheres of human's activity: industry, economy, medicine, public institutions, educational establishments. The list of its using is extraordinarily wide and grows continually, how become more accessible and more powerful the personal computers.

The basic classes of the systems of computer graphic arts and the leading industries of their practical application are: business, scientific, engineering and illustration computer graphics.

The systems of business computer graphics are mainly used in the spheres of business, marketing, management, economic calculations. These systems are intended for visual graphic presentation of information, i.e. drawing of the graphs, charts and diagrams (graphic examples of different data).

The systems of scientific computer graphics are intended for dynamic graphic visualization of the process and the results of carrying out of scientific experiments, automated planning of scientific and scientific – technical tasks, forming of scientific documentation (mathematical, chemical, physical formulas), researches of geographical, geological, geohydrological, seismological, ecological, meteorological, astronomic and other natural objects, processes, phenomena and systems, oil-and-gas exploring and production activity, computer cartography and etc.

The systems of engineering computer graphics are intended for automation of drawing-graphic and designer works in the process of products planning.

The systems of illustration computer graphics are intended for creation and artistic processing of computer depictions (pictures, geographical cards, multimedia, WEB, etc.).

Typical cases of computer graphics using are:

*Cartography.*

Computer graphics are used for presentation of geographical and other natural phenomena with a subsequent exact recreation them on a paper or a tape. Most distribution this aspect of computer graphics got at created geographical and relief maps, maps of weather and isolines, oil-and-gas exploring maps or maps of population density.

*Automation of drawings and designer works*

In computer-aided designs (CAD) computer graphics is used for planning the systems of mechanical, electric, electromechanics and electronic devices. Difficult complexes and structures (for example, buildings, power plants, basket of cars, fuselage of airplanes, corps of ships and them insides), electric charts, public-call networks and COMPUTER networks refer to such systems. The ultimate goal of the automated planning is an issue of drawings of parts, assembly units and assembly drawings. Considerable attention is paid to interactive work with the model of the system or its components. A mathematical model is interpreted the designing program which periodically gives out information about the conduct of the system under various conditions. After completion of the process of object planning, the additional programs will be able to conduct treatment of project database with the purpose of preparation, necessary on the different stages of making the object of technical documentation, such as complete sets of designer and technological documentation.

*Design and making of animated cartoon*

Animation made with the help of computer and demonstrate the conduct of various real or modeled objects in time become more popular. They allow to learn the mathematical models of the most various phenomena which are examined by science, for example, the flow liquids, nuclear and chemical reactions, physiology systems and deformation of constructions on-loading, by visual presentation of model's conduct under various conditions. Various trainers are the second use of the computer making animated cartoon. They allow to generate not only the immobile world where an object moves but also such special effects, as clouds, fog, smog, nightly fires, and also other objects of the most various shapes and sizes which move due to their course. Computer graphics is widely used in the creation of feature films and publicity video, saturated 3D-effects.

*Management processes*

If trainers enable the user to socialize with the model of the actual or imaginary world, there is a necessity to work in the interactive mode directly with some aspects of the real world in many cases. Displays at the oil-processing factories, power-stations or at any other productions allow to imagine visually information from the sensing elements placed in the most essential points of the system. Such reflection of information allows to operate different processes quicker and more effective.

*Automation of office works and electronic publication*

Computer graphics for forming and distribution of information in administrative establishments is being widely used. It helps it is possible to make traditional printing documents (hard copy), "electronic" documents which consist not only of phototypography but also tables, graphs and other illustrative two-dimensional information.

*Art and advertising*

The joint aim of computer art and advertising is a desire facilities of computer graphics to express the main content of depiction by means of computer graphics and a desire to pay attention to it by aesthetically pleasant depictions. One of the most modern and economically effective mean of the use of computer graphics in this field is making of sliding seats for presentation of commercial, scientific and educational information.

## 9.3 TYPES OF COMPUTER GRAPHICS

Three basic principles of presentation of graphic images – bit-mapped graphics, *vector* and *fractal* graphics are developed and successfully used. Mathematical models of images are the basis of this or another method. For a bit-mapped graphics there is the array (matrix) of numbers which describe co-ordinates and colour parameters of every point of a picture, for vector graphics there are mathematical formulas which describe geometrical figures (objects) a picture is formed. Fractal graphic art operates mathematical formulas too, and they describe not separate geometrics, but a process of automatic generation of image by equations.

A bit-mapped graphics is applied, mainly, in the development of electronic (multimedia) and publishing editions. For coding a picture is broken up to small monochrome parts. All colors, used in an image, are numbered, and for every part the number of its color is written down. Memorizing the sequence of location of parts and the number of color for every part, it is possible to describe any picture.

Figure 9. 1 – A bit-mapped graphics

Illustrations, used by a bit-mapped graphics, are rarely created by hand with the help of computer programs. For this purpose illustrations are used more often, prepared by an artist on a paper or pictures which then are digitised on a scintiscanner (fig. 9.1). Therefore most graphics editors, intended for work with bitmap illustrations, are oriented not on the creation of images, but on their treatment.

Programmatic facilities for work with **vector graphics** on the contrary appointed, in the first turn, for creation of images and less for their treatment. In the vectorial method of coding geometrical figures, the curves and lines which make a picture are saved in memory of a computer as mathematical formulas and geometrical abstractions, such as a circle, a square, an ellipse and similar figures. By mathematical formulas it is possible to describe various figures. Exactly vector graphics is used in different computer-aided designs for making and editing of various technical document at implementation of project-designer works (fig. 9.2). Vector graphics is also widely used in advertisings agencies, designer bureaus, editorial offices and publishing houses. Designer works, based on application of fonts and simplest geometrical elements decide facilities of vector graphics far simpler.

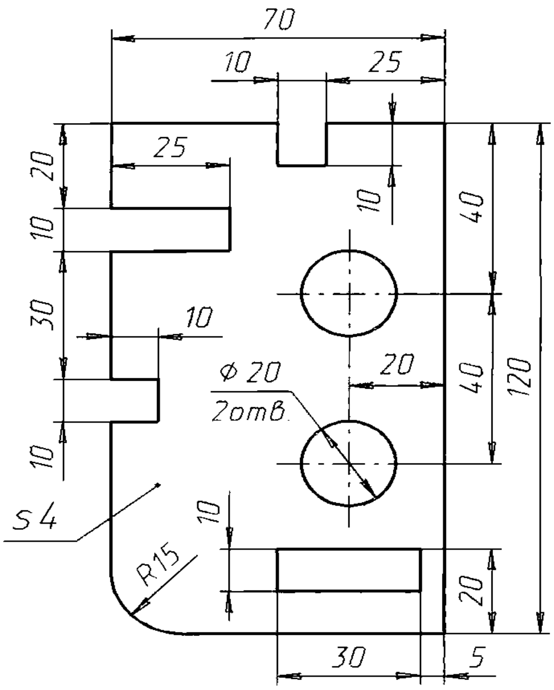



Figure 9. 2 – Vector graphics

Programmatic facilities for work with **fractal graphics** are intended for *the automatic generation of images* by mathematical calculations. Creation of fractal artistic composition consists not of drawing or registration, but in *programming.* Fractal graphics arts is rarely applied for creation of printing or electronic documents. The ability of fractal graphic art to design images often is used for the automatic generation of unusual illustrations (fig. 9.3). Fractals are used for representing trees, bushes, designing hypsography or sea surface and etc. in machine graphic art. Fractal geometry is irreplaceable during the generation of artificial clouds, mountains, sea surface. From the point of view geometry, the method of easy presentation of complex objects which shapes look like natural is actually found, because a lot of objects of organic and inorganic nature have fractural properties.

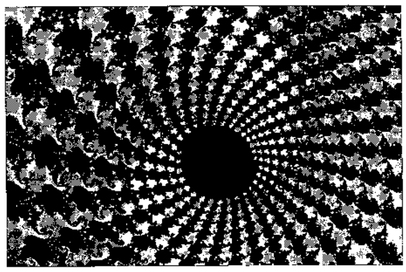


Figure 9. 3 - Fractal graphics

9.3.1 BIT-MAPPED GRAPHICS

The principle of coding graphic information in a bit-mapped graphics have been discovered and used by people for many centuries before computers, monitors and scintiscanners. These principle drawing "on cells" are productive methods of transferring the image from a preparatory cardboard on the wall, intended for a fresco. Such directions of monumental and applied art, as a mosaic, stained-glass window, embroidery: in each of these technics the image is made from discrete and coloured elements as a rule.

A computer bitmapped image is represented in the form of rectangular matrix, every cell of which is represented by a coloured point. Being digitised the images is divided into such little cells, that man's eye does not see them, perceiving the whole image as a unit. A scale got its name of a raster card, from the English word «bitmap», and its single element (a square cell) is named a pixel (from English PICture ELement). A pixel is the smallest element bitmap display which has the address. A bitmap card is a set (array) of three of numbers: two first values are the co-ordinates of pixel on a plane, the third determines its color. With the help of bit-mapped graphics it is possible to represent and pass all range of nuances and thin effects, the real image possesses. Bitmapped image is near to the picture as it allows precisely reproduce basic descriptions of a picture: luminosity, transparency and depth of sharpness.

According to the structure bitmapped images consist of great number of small coloured points. Every pel, as a pebble in a mosaic, is independent from each other. However, the amount of colors in nature is endless, similar colors are numbered by identical numerals. In dependence of the amount of used colors, it is possible to code a more or less realistic image. It is clear, that less colors are in the picture, less numbers are used, and it is more simple to code the image. Only black and white colors are used in the most simple case. For representation of every pixel in a black-and-white picture one bit is enough. A bit is minimum unit of computer's memory which can keep a value 0 or 1. While working with color it is obviously not enough. However approach to the coding of the colored images remains unchangeable. Any picture is broken up to pixel, i.d. small parts, each of them has its color. The amount of information which describes color of a pixel determines the depth of color. The more information determines color of every point in a picture, the more variants of color exists. If we set the size of a pixel, we can restore the coded picture without any problems. Without defining the size of a pixel, it is impossible to make an image on the basis of the coded information. However the sizes of pixels are not used in practice, but two other sizes are set: size of picture and its discriminability. A size describes physical sizes of an image, i.d. its height and width. It is possible to set sizes in meters, millimetres, inches or any other sizes. But in computer graphics a size is usually set in pixels. Being reflected on the monitor and typed on the printer every pixel appears as a separate point, if the equipment does not do any special transformations. Old monitors, with large grain of kinescope, shows a big picture, and on the modern printer which uses small points, a picture will be very little. And what kind of picture must be in fact? The discriminability of an image is set up for this purpose. A discriminability is a closeness of placing pixels which form an image, i.d. the an amount of pixels on the set segment. More frequently all a discriminability is measured in the amount of points on an inch - dpi (Dot Per Inch). To reflect pictures on the monitor a discriminability from 72 dpi to 120 dpi is used. While typing the most widespread discriminability is 300 dpi, but for high-quality imprints on the modern coloured printers it is possible to use greater discriminability.

The bitmapped images are more often by the scan-out of pictures and other images, by a digital photo camera or by “fascination” of a shot of video survey. Lately for introduction of bitmapped images to the computer digital photo- and video cameras have been widely used. Bitmapped images can be received directly in the programs of bit-mapped graphics.

When scanning-out an image the scintiscanner breaks up a picture to the great number of small elements (pixels) and forms a raster picture. Color of every pixel is written down in computer’s memory by the certain amount of bits. If a picture possesses a discriminability of 800x600, these numbers represent the amount of pixels for horizontal lines (800) and for vertical lines (600). The more pixels are in an image, the best its discriminability is on the screen. The number of colors necessary to paint a separate pixel is determined as two in the degree of N, where N is an amount of bits which keep colour information about a pixel. In a contrasting black-and-white picture every pixel is encoded by one bit. Eight bits image allows to have 256 colors, and 24 bats provide more than 16 million colors in the image, that enables to work with the images of professional quality. Depending on the discriminability of the monitor, images which have 640x480, 800x600, 1024x768 and more pixels can be on the screen. Therefore, large amount of information is the basic problem for using bitmapped images.

Bitmapped images have another very substantial drawback: it is difficult to increase or to diminish them to scale. When diminishing a bitmapped image a few nearby points grow into one, that’s why legibility of small objects on the depiction is being last. The increase of an image makes these points bigger. No additional objects can be seen when increasing a bitmapped image. When increasing a graphic image the size of every point is increased, that’s why a step effect appears. Making an attempt to turn an image slightly, for example with clear vertical striolas, on a small corner, clear lines grow into "steps" and without an increase. It means that at any transformations (turns, down-scaling, inclinations and other) in a bit-mapped graphics it is impossible to do without distortion (it is dictated discrete nature of image).

Nevertheless than bitmapped images are widely used in the computer engineering, because they have certain advantages — simplicity and, as a result, the possibility of technical realization of automation of introduction process (digitisings) of graphic information. There is the developed system of peripheral devices for introduction photos, sliding seats, pictures, water-colours and other graphic originals. These peripheral devices are continually improved, giving possibility of more adequate transformation of images on financial transmitters (paper, to tape et cetera) in a digital form.

No less important advantage of pixel graphic arts there is a possibility to create and process photo-realistic images. It is possible to get picturesque effects, for example, fog or haze, to represent the thinnest nuances of color, create a perspective depth and unsharpness, washed out etc.

Therefore photographs and pictures, entered in a computer, are stored exactly as bitmapped images. Most pictures in a world computer network the Internet is also bitmap files.

### 9.3.2 VECTOR GRAPHICS

In order to avoid the problems which arise when using bitmapped images a vectorial method of coding images was invented.

In the vectorial method of coding geometrical figures, curves and lines which make a picture are saved in the computer’s memory as mathematical formulas and geometrical abstractions, such as a circle, a square, an ellipse and similar figures. For example, to code a circle, it is not needed to be broken up to separate pixels, but it is necessary to memorize its radius, coordinates of a center and color. For a rectangle it is enough to know the size of sides, its location and color of sketching. Various figures can be described with the help of mathematical formulas. Some simple figures (geometrics) are used to draw more difficult pictures.

Any image in a vectorial format consists of great number of components which can be edited independently from one another. These parts are named objects. Therefore, sometimes vector graphics is named object-oriented. To combine several objects, it is possible to create a new object, that is why objects can have a complicated appearance. For every object, its sizes, curvature and location are stored as numerical coefficients. Due to this there is a possibility to scale an image with the help of simple calculations, simple multiplying of graphic elements. Thus quality of image remains without changes. For example, when scaling a segment coordinates of supporting points are transferred, but sizes of points which fill an interval between these key points of a segment remains unchangeable. Only number of these points are changed. Therefore, unlike the increasing segment of bit-mapped graphics a vectorial segment remains clear and of high-quality. Figure 9.4 shows the increasing segment made with the help of bigmap on the left figure 9.4, shows this segment made with the help of vector graphics on the right figure 9.4. Using vector graphics, it is possible not to think what we do: prepare a miniature emblem or draw two-meter transparency. We work with a picture quite identically in both cases. At any moment we can scale an image to any sizes without the loss of quality. The vectorial programs are irreplaceable in those areas of graphic arts, where the maintenance of high-quality and clear contours - in design, technical drawing, drawing-graphic and designer works is very important.

a b

Figure 9.4 – Increasing segments made with the help of bigmap graphics (a) and vector graphics (b)

No less important advantage of vectorial method of coding images is that the graphic files of vector graphics have a considerably smaller size, than the files of bit-mapped graphics. It is related to the fact that not an image is stored but some important data, in particular coordinates of supporting and managing points, using which the program reproduces an image for the first time. In addition, a description of colors increases a file size slightly, as given data about color identical to the whole object.

But on the other hand, vector graphics has some drawbacks to be mentioned.

The substantial drawback is programmatic dependence, as there is no principle possibility to create the unique standard format which would allow to open freely any vectorial document in any vectorial program.

As in a bit-mapped graphics a basic display element is a point, so in vector graphics a basic display element is a line which is named a vector, and it got its name from it – vector graphics.

Clearly, there are lines in a bit-mapped graphics, but there they are considered as combinations of points. For every point of line in a bit-mapped graphics one or some barns of memory are taken (the more colors can have points, the more barns are selected for them. Accordingly, the longer raster line, the more memory it occupies. In vector graphics the amount of memory, which needs to be selected a line does not depend on the sizes of a line, as a line appears in the form of formulas and to be more exact in the form of several parameters.

## QUESTIONS FOR SELFCHECK

1. What are basic tasks of computer graphics?
2. Where are computer graphics using?
3. What types of computer graphics do you know?
4. Describe bit-mapped graphics.
5. Describe vector graphics.