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DIMENSIONING OF THE PARTS CONTAINING SURFACES OBTAINED BY PRIMARY SHAPING PROCESSES

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Dimensioning should determine necessary dimensions for functioning and manufacturing of parts, by a correct definition of required values for geometrical characteristics like dimensions, shape, and relative position.

Keywords: dimensioning, raw part, machined part

1. Introduction

Constructive characteristics of finished parts are influenced by both functional and technological characteristics. Functional characteristics are related to functional requirements imposed by the functions of parts within assemblies. Technological characteristics are imposed by the requirement of efficient machining of raw materials for obtaining finished parts. Constructive characteristics include material characteristics, geometrical characteristics, and coating and protection characteristics [1].

Geometrical characteristics relate to dimensions, shape (macro-geometrical and micro-geometrical), and relative position. Geometrical characteristics generally referred in part drawings are dimensions and roughness [2 to 7, 10]. As a result, dimensioning of parts must be in concordance with functional and technological requirements claimed to the part [1, 6, 7].

To meet their functional requirements, surfaces of parts have to be designed and manufactured with particular or general specifications on their accuracies for dimensions, shapes, and relative positions [2 to 9].

For obtaining the part within a manufacturing process, part dimensions are processed during manufacturing operations such as: primary shaping, machining, inspection, assembly etc. Raw parts need machining operations like turning, milling, drilling, grinding, honing etc. [1, 3, 7] in order to increase their geometrical accuracy.

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Through analyzing the dimensioning of several part drawings in order to plan parts manufacturing processes, many deficiencies have been observed. These deficiencies relate generally to the dimensioning of parts having raw, unprocessed surfaces, which are obtained through primary shaping processes like casting, forming, injection etc. This paper tries to correct the observed deficiencies, with the help of a conclusive case study.

2. Datums and datum systems

A part is formed from various elementary geometrical entities (cylindrical, conical, spherical, parallelepiped etc.) with different shapes, dimensions and relative positions. An elementary geometrical entity is defined by surfaces, edges (curves), vertices. The intersection of geometrical entities results in the creation of supplementary edges (curves) and vertices. As a result, the part is defined by three types of elementary geometrical entities: surface, edge, and vertex [1].

Both during the creation of the part technical drawing and during the production of the part, the dimensional and geometrical accuracy of geometrical elements such as surfaces, edges, vertices must be established with the help of geometrical references called *datums*.

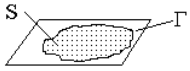
The datums are point type (P), line type (Δ) or plane type (Γ), theoretical, geometrical elements which are associated to surfaces, edges or vertices of parts in order to facilitate the determination of their relative position.

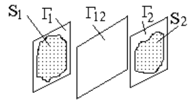
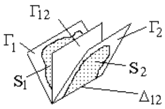
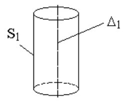
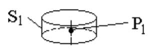
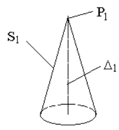
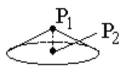
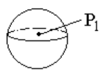
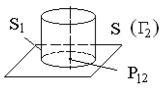
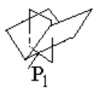
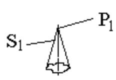
Generally, the relative position of surface, curve (edge) or vertex geometrical elements cannot be defined in space with only one datum and as a result the use of several datums must be taken into consideration. The number and structure of datums associated to a geometrical element for determining its position in space forms the *datum system* associated to that element.

Examples of datums and datum system attached to surface, edge or vertex geometrical elements are shown in table 1 [1].

Table1

Datums and datum systems attached to the geometric elements

Type of geometric element	Shape of the element			Datums and datum systems associated to the geometric element	
				Proper datums	Group datums
Surface	1	Plane		Γ	-

	2	Two parallel plan surfaces		Γ_1, Γ_2	Γ_{12}
	3	Two intersecting plane surfaces		Γ1, Γ2	Γ_{12}, Δ_{12}
	4	Long cylindrical surface (with length 1.5 times larger than diameter)		Δ_1	-
	5	Short cylindrical surface (with length 1.5 times shorter than diameter)		P_1	-
	6	Long conic surface (with length 1.5 times larger than diameter)		P_1, Δ_1	-
	7	Short conic surface (with length 1.5 times shorter than diameter)		P_1, P_2	-
	8	Spherical surface		P_1	-
Edge	1	Two intersecting plane		Δ_1	-
	2	Cylindrical intersecting with a plane		P_{12F}	-
Vertex	1	Three intersecting plane		P_1	-
	2	Cone vertex		P_1	-

Categories of datums and datum systems

The classification of the datums and of the datum systems associated to the geometrical elements can be performed depending on various criteria as follows [1].

Depending on the type of datum:

- Point datums, P;
- Line datums, Δ;
- Plane datums, Γ.

Depending on the complexity of the geometrical elements (EG):

- Datums and datum systems associated with elementary geometrical elements (spherical, cylindrical, plane, conical etc.);
- Datums and datum systems associated to the complex geometrical elements. For a cylindrical part, which has a key slot formed by the surfaces S_1, S_2, S_3, the datum system attached to this complex geometrical element is formed by the planes Γ_{12} and Γ_3 (Fig. 1).

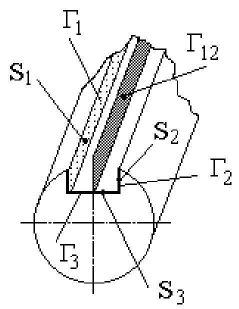


Fig. 1. Datum system attached to a complex geometrical element

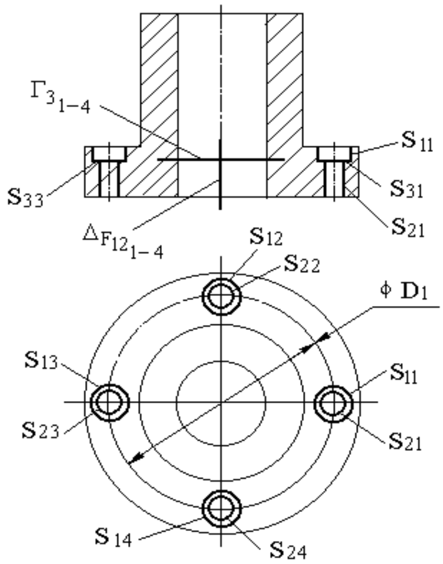


Fig. 2. Datum system attached to a group of complex elements

- The datums and the datum systems associated to complex geometrical elements groups [1]. For a flange-type part, which has four holes, geometrical elements formed by surfaces S_{11}, S_{12}, S_{13}, S_{14}, S_{21}, S_{24}, S_{31}, S_{34} have a datum system consisting in the line $\Delta_{F12_{1-4}}$ and the plane $\Gamma_{3_{1-4}}$ (Fig. 2).

3. Dimensioning of parts

Both during the creation of the part technical drawing and during the production of the part the dimensioning datums will be used.

We will take into consideration a part which contains both processed and raw surfaces.

There are [4 to 7]:

- Functional dimensions, which represent important dimensions for the fulfillment of the functional purpose of the part (will be written directly on the technical sheet, and not through the aggregation of other dimensions);
- Non-functional dimensions, which refer to dimensions which are not essential for fulfilling the functional role of the part (are necessary for determining the geometrical shape of the part);
- Auxiliary dimensions, which refer to dimensions written for informational purposes, for avoiding certain calculation, for determining the maximum dimensions of the part (will be written between brackets without tolerances).

The functional dimensions will be written first, followed by non-functional and auxiliary dimensions.

As a result, the following dimensions will exist on the part: dimensions between the datums attached to the raw surfaces; between the datums attached to the processes surfaces; between the datums attached to the processed surfaces and the datums attached to the raw surfaces. The dimensioning datums can be attached to the processed or raw geometrical elements. The processed surface has a higher precision than a raw surface.

By taking this into consideration, how a part must be dimensioned? We will propose the following rule: *dimensioning in the order in which the surfaces are obtained during manufacturing stages* (primary shaping, machining, etc.), by respecting the functional dimensioning and the other rules. The raw surfaces must be dimensioned in respect to other raw surfaces and not to processed surfaces which will be obtained subsequently through processing. The processed surfaces must be dimensioned in respect to other processed surfaces, and a part of them must be dimensioned in respect to raw surface. It can happen that a processed surface is dimensioned in regard to several raw surfaces, which is incorrect because not all dimensions can be fulfilled at the same time (there are several dimensioning datums). The dimensions are set between the datums attached to the respective surfaces.

For a correct dimensioning, datums related to X, Y, Z linear directions or to A, B, C angular directions must exist, both for raw and machined surfaces. However, there are always dimensions that connect datums on raw surfaces with machined surfaces.

To prove the above ideas, dimensioning of an example part will be analyzed and improved, as it is representative for this purpose.

For the example part in Fig. 3, a dimensional chain is formed on Z direction, which will be analyzed. The functional dimension on this direction is dimension 152. For dimensioning the S1 surface, dimensions of 20 (S2) and 60 (S3) were used:

$$\begin{aligned} \Gamma_{S1} &\xleftrightarrow{\quad 20 \quad} \Gamma_{S2} \\ \Gamma_{S1} &\xleftrightarrow{\quad 60 \quad} \Gamma_{S3} \end{aligned} \qquad (1)$$

The use of two dimensions in this case is incorrect because surface S1 (ΓS1) is obtained through machining after both surfaces S2 and S3.

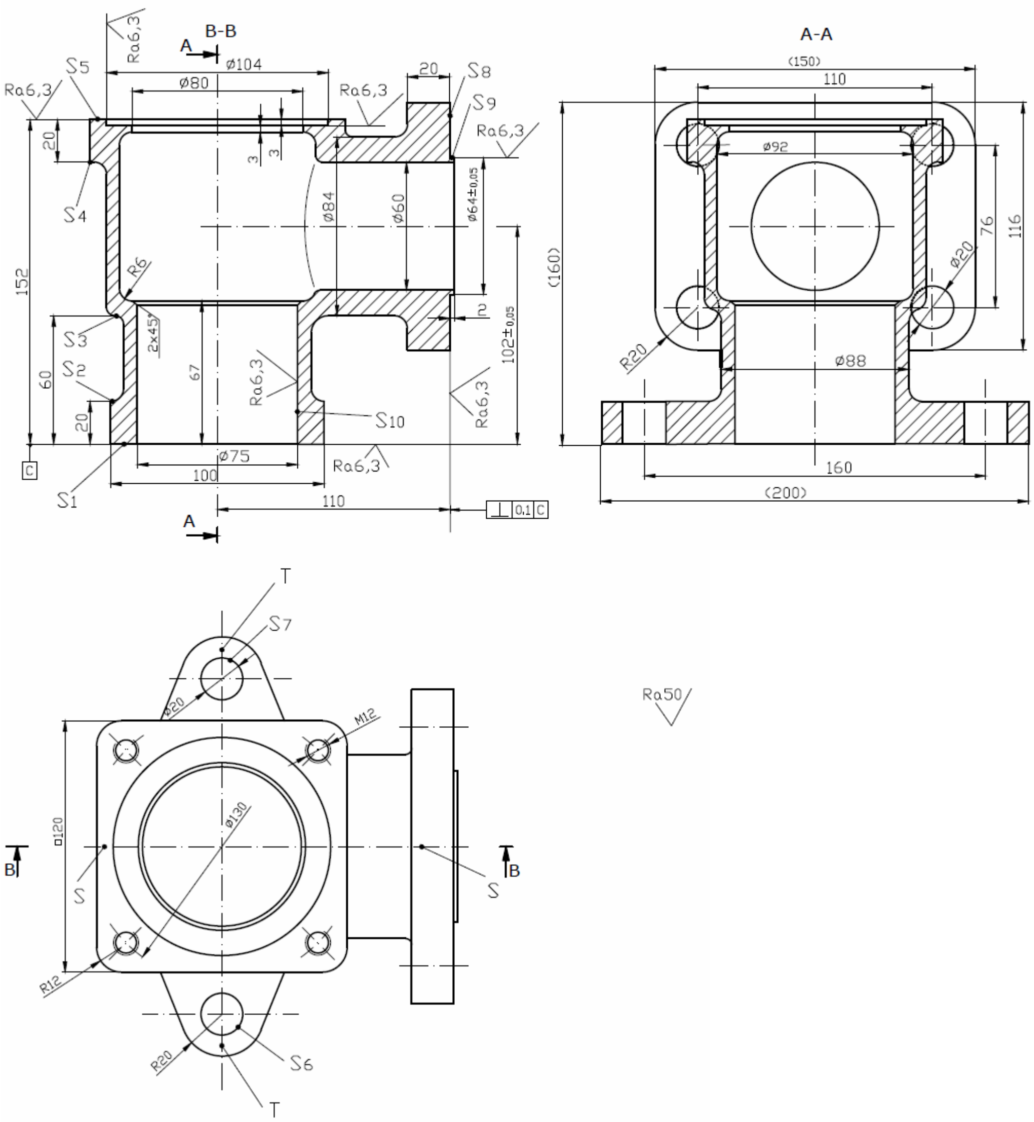


Fig. 3. Existing dimensioning of “Socket” part

For the dimensioning of the S_5 surface, two datums were also used:

$$\Gamma_{S5} \xleftrightarrow{\quad 20 \quad} \Gamma_{S4}$$
$$\Gamma_{S5} \xleftrightarrow{\quad 152 \quad} \Gamma_{S1} \qquad (2)$$

This is also wrong, because of the same reason presented above.

For the S_8 (Γ_{S8}) surface, the dimensional datum system consists of Γ_{S1} (S_1) and Γ_T- Γ_T:

$$\Gamma_{S8} \xleftrightarrow{\quad \perp 0{,}1 \quad} \Gamma_{S1}$$
$$\Gamma_{S8} \xleftrightarrow{\quad 110 \quad} \Gamma_{T\text{-}T}. \qquad (3)$$

The $\Gamma_{T\text{-}T}$ is an imaginary plane and can be defined as being a plane perpendicular on the S_1 surface which contains the axis of the short cylindrical surfaces S_{10} and S_7. As a result, the plane $\Gamma_{T\text{-}T}$ can be written as follows:

$$\Gamma_{T\text{-}T} = \perp \Gamma_{S1} \text{ U } P_{S10} \text{ U } P_{S7}. \qquad (4)$$

Surface S8 is dimensioned in respect to surfaces S1, S10, S7 which were previously processed, and as a result the dimensioning datum system for the datum attached to the surface S8 is:

$$\text{SBC } \{ \Gamma_{S8} \} = \{ \Gamma_{S1,} P_{S10,} P_{S7} \}. \qquad (5)$$

Surface S9, which is a short cylindrical surface, has the following dimensioning datums:

$$\Delta_{S9} \xleftrightarrow{\quad 102 \pm 0{,}05 \quad} \Gamma_{S1}$$
$$\Delta_{S9} \xleftrightarrow{\quad \equiv \quad} \Gamma_{S\text{-}S}. \qquad (6)$$

The plane $\Gamma_{S\text{-}S}$ can be described with:

$$\Gamma_{S\text{-}S} = \perp \Gamma_{T\text{-}T} \text{ U } P_{S10}. \qquad (7)$$

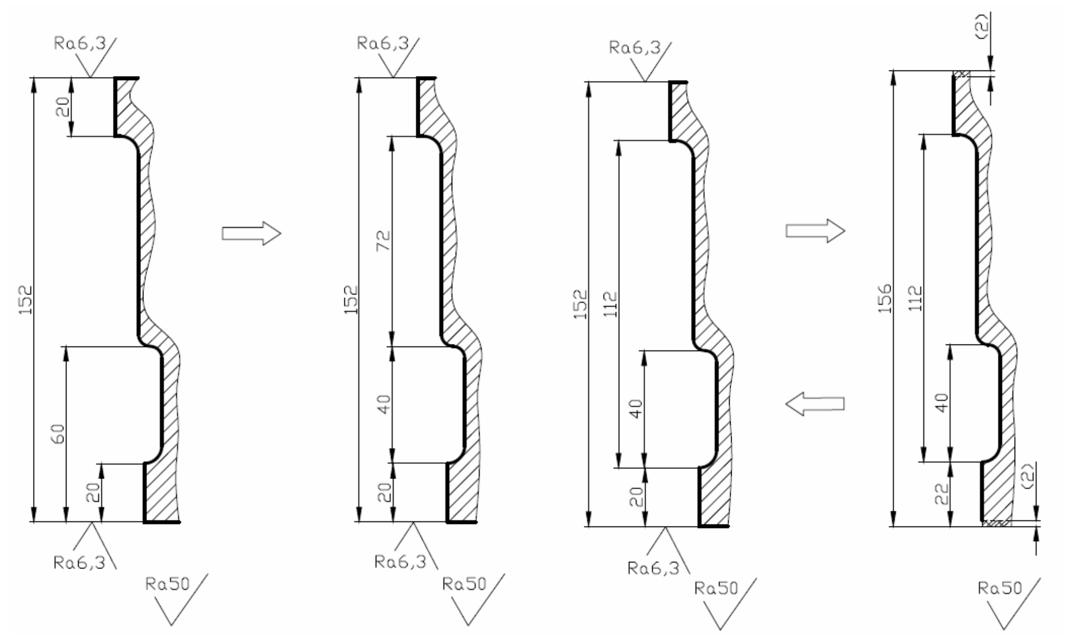
The dimension datum system for the datum attached to the surface S_9 is the same as for surface S_8 with the note that in the first case the plane Γ_{S1} can be determined through a parallel plane, as follows:

$$\text{SBC } \{ \Delta_{S9} \} = \{ \Gamma_{S1}, P_{S10}, P_{S7} \}. \qquad (8)$$

As a result, in figure 4.a the existent dimensioning is presented. By taking into consideration that the processed surfaces cannot be dimensioning surfaces for the raw surfaces, the dimensioning method presented in figure 4.b is proposed. After machining of surface S_1, the surface S_5 will be machined. For S_1 surface, the dimensioning datum is the plane attached to the surface S_2, Γ_{S2}. This resulted from the requirement to fulfill two dimensions:

$$\begin{array}{c} \Gamma_{S2} \xleftrightarrow{\quad 20 \quad} \Gamma_{S1} \\ \Gamma_{S5} \xleftrightarrow{\quad 152 \quad} \Gamma_{S1} \end{array} \tag{9}$$

The dimensioning of finished part (Fig. 4.b) and of the raw part (figure 4.c) will be performed in such a manner that the raw surfaces are dimensioned in respect to the raw surfaces (dimensions 40 and 72), that raw surfaces are connected with machined surfaces (final dimension 20 and dimension 22 for raw part), and that surfaces to be machined are interconnected (final dimension 152 and dimension 156 for raw part).



a) initial dimensioning of finished part

b) proposed dimensioning variants for finished part

c) proposed dimensioning of raw part

Fig. 4. Outside dimensioning

The dimensioning of the interior surfaces will follow the same rules.

Taking into consideration functional role of the part and the dimensioning rules and considerations from above, a proposal for dimensioning of the part is presented in figure 5.

To obtain example part in figure 5 from a raw part primarily shaped by casting, a machining process with three operations can be used. Drafts of machining operations are presented in Figs. 6, 7 and 8. Symbol “X” in Figs. 6, 7 and 8 indicates the surfaces associated to dimensional datums of machined surfaces.

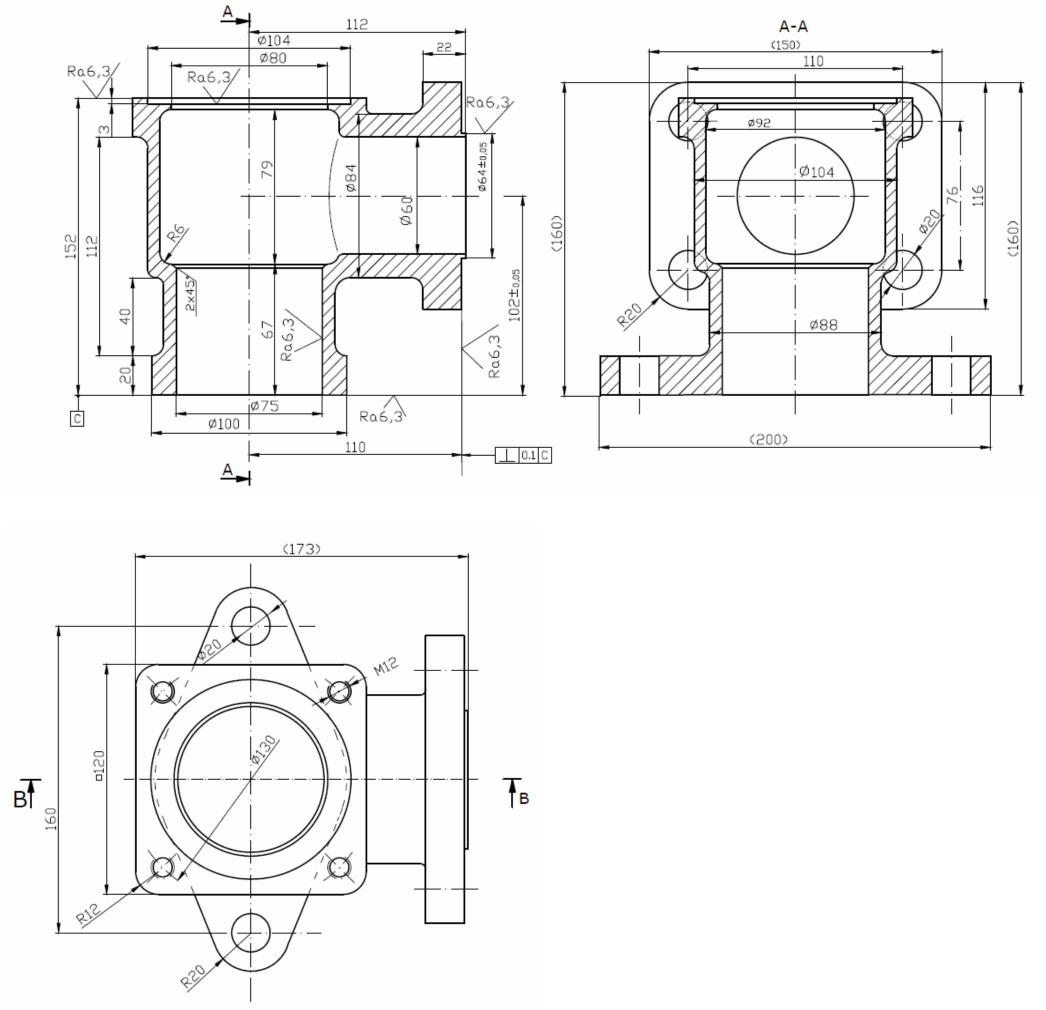


Fig. 5. Proposed dimensioning of “Socket” part

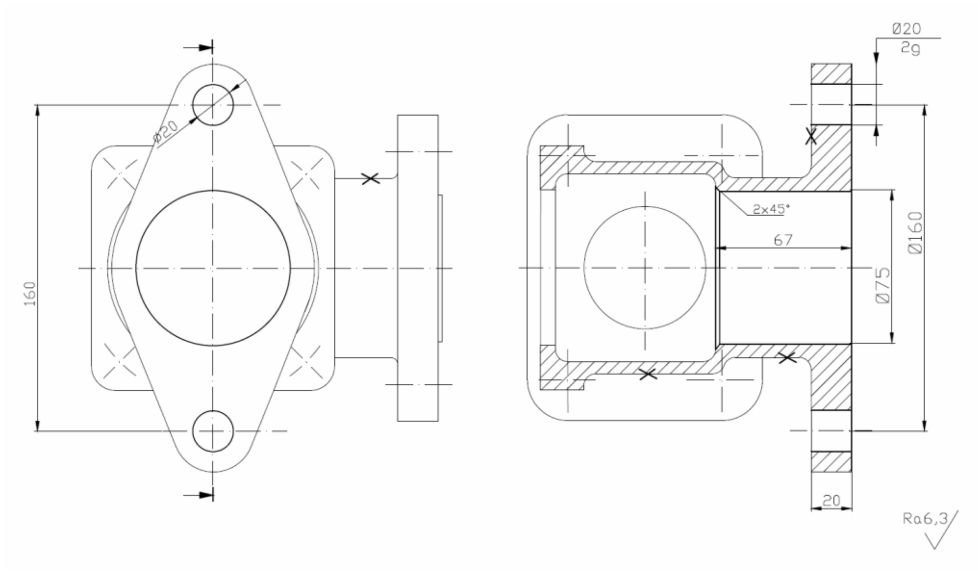


Fig. 6. Draft for the first machining operation of “Socket” part

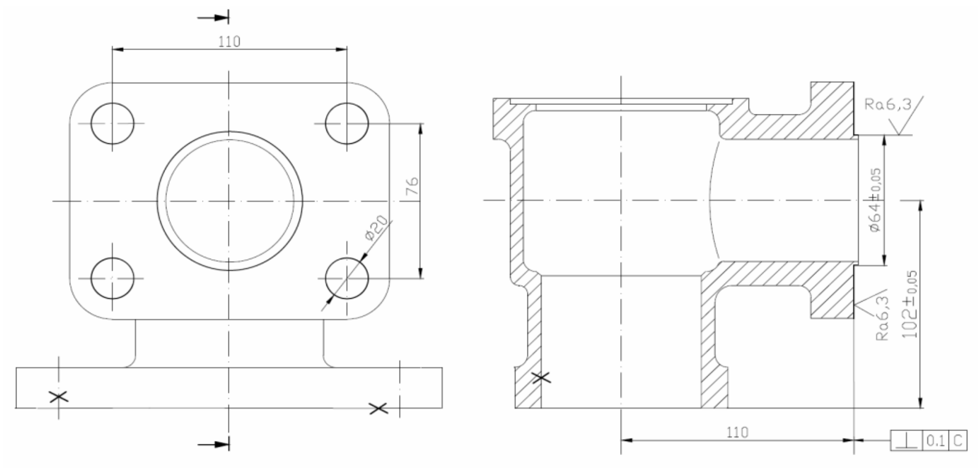


Fig. 7. Draft for the second machining operation of “Socket” part

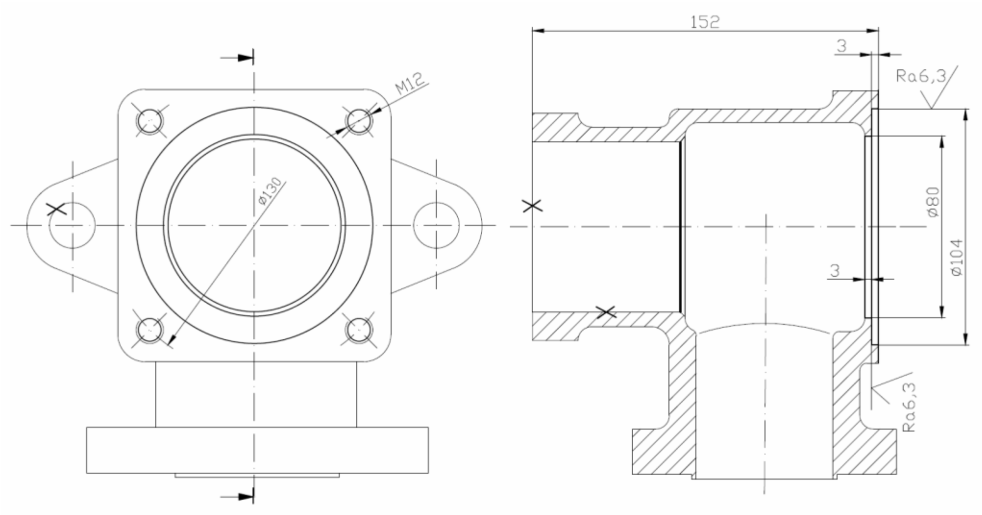


Fig. 8. Draft for the third machining operation of “Socket” part

After the last operation in the process, all dimensions of the part in figure 5 are obtained as specified.

4. Conclusions

If the finished part has raw surfaces, these surfaces must be dimensioned in respect to other raw surfaces. Machined surfaces must be dimensioned mostly with respect to other machined surfaces and, only if necessary, in relation with raw surfaces. However, a machined surface can have only one raw datum in a direction, all other datums being associated to already machined surfaces. Dimensioning of a machined surface with respect to several raw datums is incorrect because raw surfaces are obtained previous to machined surface and, accordingly, these dimensions cannot be obtained in machining process.

For a correct dimensioning, datums related to X, Y, Z linear directions or to A, B, C angular directions must exist, both for raw and machined surfaces.

It is recommended to use as raw datums for the first machining operation some exterior or interior, adjacent surfaces, with large dimensions and high geometrical accuracy.

R E F E R E N C E S

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