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DESIGN AND ECONOMIC JUSTIFICATION OF GROUP BLANKS APPLICATION

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Within the manufacturing process planning, blanks are either selected or designed, respectively forms of input material for the manufacture of products. Reviewed in this paper are three types of group blanks: group castings, group forgings manufactured by closed die forging and free forging, and group blanks manufactured by pressing melted metal in casts. The paper also presents requisites for design and evaluation of economic justification of group blanks application.

Key words: group blanks, design, economic justification

Dizajn i ekonomska opravdanost primjene grupnih pripremaka. U okviru projektiranja tehnoloških procesa vrši se izbor ili projektiranje pripremaka, odnosno oblika ulaznog materijala za izradu proizvoda. U radu se prikazuju osnovne vrste grupnih pripremaka kao što su grupni odljevci, grupni otkivci proizvedeni u zatvorenim kalupima i hladnim zapreminskim oblikovanjem, slobodnim kovanjem, kao i grupni pripremci proizvedeni prešanjem rastopljenog metala u kalupima. U radu se, također, daju podloge za projektiranje i ocjenu ekonomske opravdanosti primjene grupnih pripremaka.

Ključne riječi: grupni pripremak, dizajn, ekonomska opravdanost

INTRODUCTION

High market demands regarding versatility, quality, design, prices and terms of product delivery, impose complex tasks on the metalworking industry. Meeting high demands, especially in low-batch, frequently changing production programs, requires constant development and improvement of production and process planning.

Such goals can be met not only through development and application of flexible manufacturing, but also through application of highly integrated systems for product design, and process planning [1].

Modern technological production preparation models involve the systems for conceptual design of products and process planning, CAPP systems for macro and micro process planning, technological database and knowledge base as well as the systems for process planning simulation and optimization [2, 3].

In addition, technological production preparation requires development and design of various technological solutions, such as special devices and equipment, fixtures, tools and blanks, what increases complexity, especially in the case of low-batch production [4].

Conceptual process planning to use CAPP systems also requires determination of blanks. Blanks can be standard or special. As part of special blanks, group blanks will be the subject of this investigation.

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BASIC TYPES AND CHARACTERISTICS OF GROUP BLANKS

In low-batch manufacturing of products and product components, application of group blanks, in comparison with standard and special blanks, brings significant advantage regarding costs of machining.

The most widely used group blanks in the metalworking industry are manufactured by casting and bulk forming. Group castings are most often produced by pressure casting, centrifugal casting and sand mold casting.

The most important factor in the design of group blanks for pressure casting is the tool, i.e. the mold. The materials for group catsings, manufactured by pressure casting, most often include alloys of aluminum, zinc, magnesium, copper and tin-lead.

In manufacture of group blanks by centrifugal casting the key influence on the formation of part groups have their dimensions, shape and material. An example of a centrifugal cast group casting, used for manufacture of a group of alloyed cast iron cylinder liners, is shown in Figure 1.

Group blanks which are manufactured by bulk forming technologies (cold forming, closed die forging and free forging) are also frequently used. They are manufactured from the group of steels which are suitable for these types of manufacturing technologies. Shown in Figure 2 is an example of group blank manufactured by cold bulk forming, while Figure 3 shows an example of group blank manufactured by closed die forging. Rational application of this types of group blank demands extensive unification of part shapes, dimensions and materials.

Group blanks can be manufactured by pressing molten metal in appropriate tools, i.e. molds. Efficient application of this type of blanks requires extensive unification of part shapes and dimensions for the same kind of material.

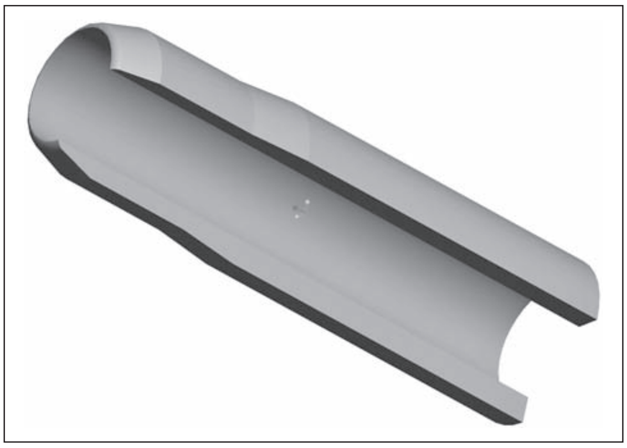


Figure 1 Group casting for the production of a group of cylinder liners [5]

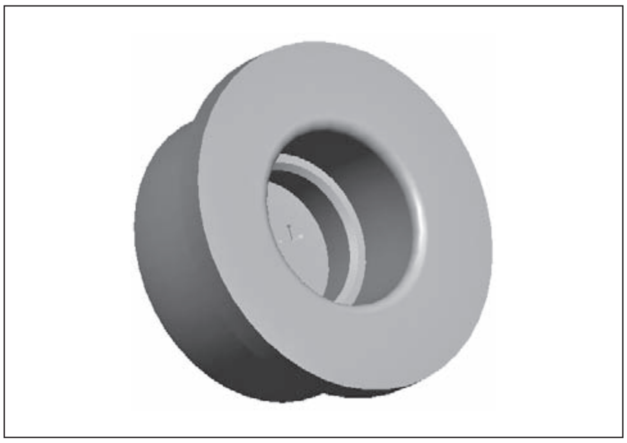


Figure 2 Group blank manufactured by cold bulk forming

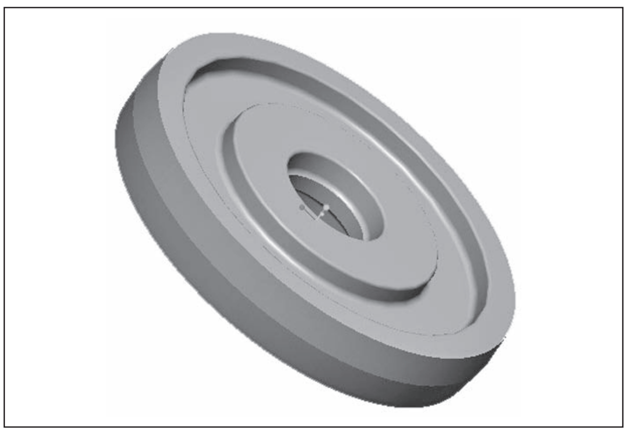


Figure 3 Group blank manufactured by closed die forging

Requirements for the design of group blanks

Based on the short review of characteristics of particular types of group blanks, it can be generally concluded that development and design of group blanks demand analysis, classification, and grouping of low-batch production parts, including the following critical information:

- Shapes and dimensions of parts,
- Material and
- Volume of production.

Similarity of shapes, range of dimensions and material unification, are among the most critical factors which affect the forming group of products (parts) for which the group blanks are designed. The grouping of as many parts as possible enables greater effects of group blanks application.

When designing and modelling group blanks it is necessary to take into account shapes and dimensions of all parts within a particular group, as well as the machining allowances. In this way, the group blank allows each part to be machined, while at the same time performing well in manufacture, especially considering the tool life.

The parts which belong to particular groups, the modelling and detailing of group blanks must also conform to the design rules for castings, forgings, and blanks for cold bulk forming and pressing of melted metal [6 - 8].

Material utilization rate

Group blanks material utilization rate is one of the parameters which contribute to the value of manufacturing process, Figure 4.

Group blanks material utilization rate, defined by the quantity of removed chip, is one of important criteria for the forming of part groups and is often kept at 90 %, with respect to each part form the group [10].

Group blanks material utilization rate (η_i) is calculated based on the mass of a particular part from the group (m_i), and the mass of the determine group blanks (m_p), i.e.:

$$\eta_i = \frac{m_i}{m_p} \cdot 100 \qquad (1)$$

In addition to the data which define the group forming, the Group blank material utilization rate is also one of the critical criteria for group forming and group blank design.

Within a research dealing with the advancement of process planning for gear box manufacturing in a production system, 27 gear groups were formed for which group forgings were designed based on the h_i^3 90 % criterion. One of the gear groups is shown in Table 1, while the appropriate group forging is shown in Figure 5.

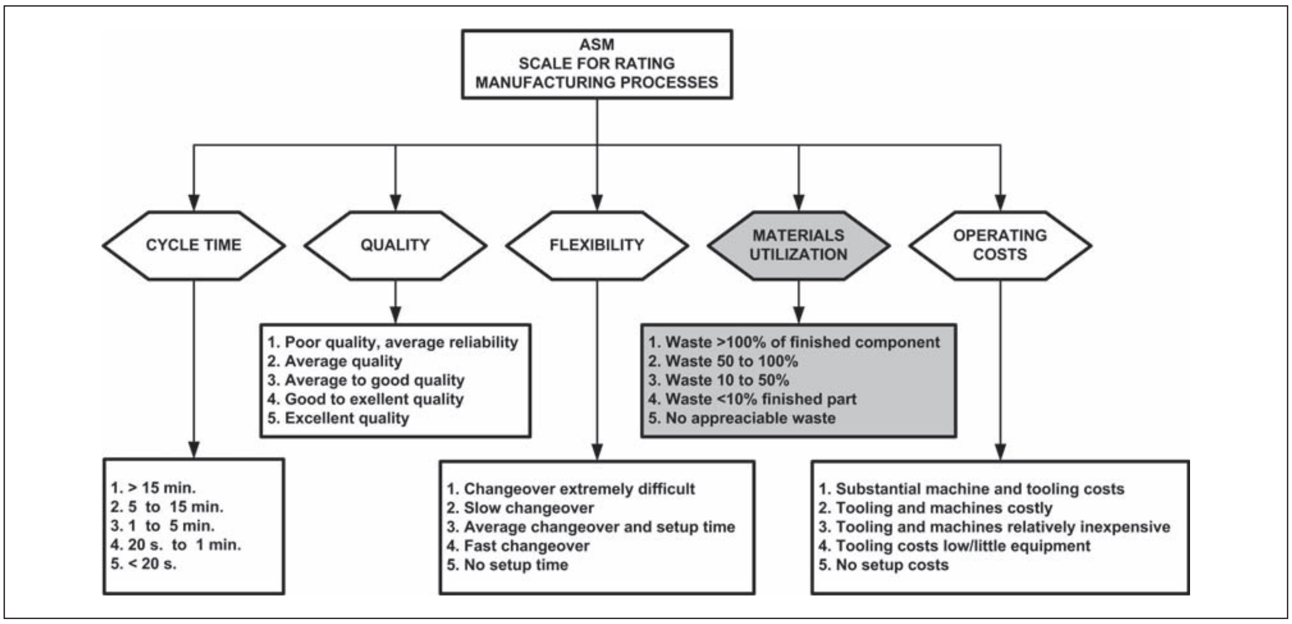
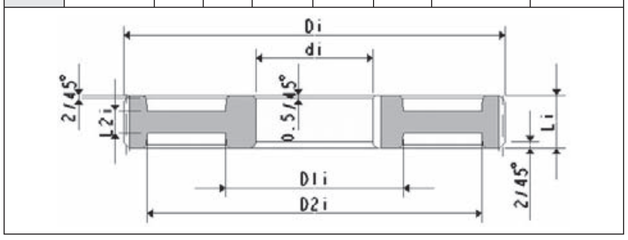


Figure 4 Parameters of manufacturing process in the metalworking industry (Rating: 1-poorest; 5-best) [9]

Table 1 **A gear group with data**

No.	Gear dimensions						Qi	mi
	Di	di	Li	D1i	d2i	L2i	(pcs/yr)	(kg/pc)
1	123,65	38	17	57	109	7	1 728	1,41
2	123,65	48	17	72	109	7	1 423	1,32
3	122	48	17	72	107	7	1 271	1,28



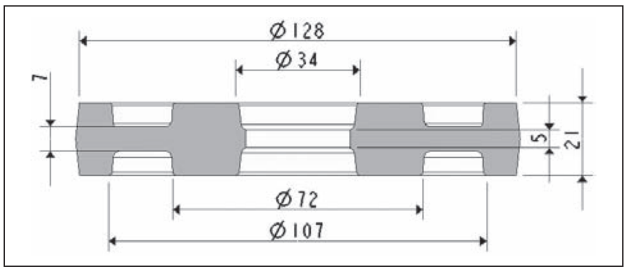


Figure 5 Group forging for the gear group from Table 1

Engineering drawings of the group forging also incorporate machining allowances, required heat treatment, etc. [10, 11].

ECONOMIC JUSTIFICATION OF GROUP BLANKS APPLICATION

To evaluate economic justification of group blanks application, beside the material utilization rate it is also necessary to take into consideration other parameters of manufacturing process, such as cost effectiveness, i.e. manufacturing costs [12]. A better solution can be obtained through comparison of manufacturing costs for group blanks and standard blank.

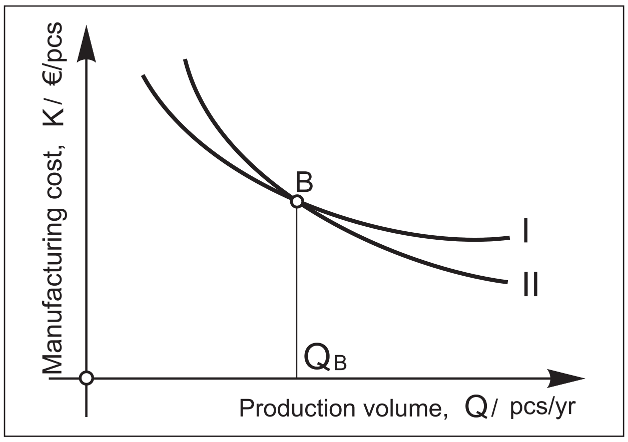


Figure 6 Diagram of the total manufacturing costs per product unit, for two blank variants [13]

In everyday manufacturing, the boundary production limit – defined by the break-even point at which the manufacturing costs are even for standard blanks (variant I) and group blanks (variant II) – can be used as a criterion for economic justification of group blanks application, Figure 6.

Limits of group blanks applicability

Generally speaking, manufacturing costs consist of fixed and variable costs. The first group of costs does not depend on the production volume (Q), while the second group is proportional to the production volume [14].

To calculate the limits of cost-efficient application of group blanks and standard blanks, in terms of production volume (Q_B) (Figure 6), the manufacturing costs per product unit are expressed as [13]:

$$K = \frac{C_A + K_{TP}}{Q} + \frac{K_{PP}}{z} + C_P + K_o \qquad (2)$$

where:

- C_A - costs of tool for manufacturing blanks,
- K_{TP} - costs of technological preparation,
- K_{PP} - costs of repeated manufacturing,
- z - batch size,
- C_P - costs of blanks, tool costs excluded,
- K_0 - direct costs of machining per unit product, proportional to the times of machining processes, they include operator costs, machine tool costs, tool costs, and other direct costs.

At point B, the manufacturing costs are equal for both types of blanks, while the boundary production volume (Q_B) equals:

$$Q_B = \frac{(C_A + K_{TP})_{II} - (C_A + K_{TP})_I}{\left(\frac{K_{PP}}{z} + C_P + K_o\right)_I - \left(\frac{K_{PP}}{z} + C_P + K_o\right)_{II}} \qquad (3)$$

When calculating (3) it is sufficient to include manufacturing costs (K_o) just for those machining processes which differ for the two blank types under consideration. In addition, it should be emphasized that one of the possible methods for the calculation of costs, i.e., machining times for these operations, is based on the data for the group representatives.

The representative product for a particular group is selected based on ABC analysis, that is, by determination of quantity, mass and value ratios for particular parts from the group. In the case of the gear group presented in Table 1, part number 1 was selected as the representative part. For this part, the relevant data for two types of blanks were calculated: variant I pertains to hot rolled bar, Ø130 mm, while variant II pertains to group forging, Figure 5. The data are given in Table 2.

Table 2 **The data on required times and machining costs for the representative part, for two blank variants**

Times and costs of machining processes	Blank variants		
	I		II
	Cutting-off	Turning	Turning
t_k (min/pcs)	7	21	16
K_0 (€/pcs)	1.9	5.2	4

Based on the data presented in Table 2, as well as the adopted values for the rest of the parameters in expression (3), the boundary production volume of Q_B = 778 (pcs/yr) was calculated. This volume defines the boundary of economic justification for application of the two considered blank types for manufacture of the gear group.

CONCLUSIONS

Group blanks in low-batch production of wide range of products allow significant increase of economic efficiency.

The application of group blanks in low-batch production allows reduction of the number of manufacturing flows, while increasing the efficiency of production planning and management. The proposed method for the determination of economic justification of group blanks application can be efficiently used for process planning and process planning improvement.

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