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# ANALYSIS OF EXISTING TECHNOLOGIES FOR MANUFACTURING LARGE-MODULAR GEARS

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**Abstract.** The article presents an analysis of existing technologies for the production of large-modular gears. As is known, large-modular gears are widely used in industry. The results of experimental studies show that in open gear mechanisms of ore crushers, these gears are subject to premature repair. The results of the conducted experimental studies show that the loading conditions of large-sized and large-modular gears are such that their calculation should differ significantly from the calculation of general mechanical engineering gears, their stress state has been studied in sufficient detail, and the calculations have been consistently standardized.

**Keywords.** gears, metalworking, mechanical engineering, manufacturing, processing, gear cutting tool, technology, drum, mill, process, gear wheels

## INTRODUCTION

The decisions of the Government of the Republic for the coming years set the task of providing for the accelerated development of mechanical engineering and metalworking, increasing the output of mechanical engineering and metalworking products, as well as raising the technical level and quality of mechanical engineering products, automation equipment and devices, significantly increasing the efficiency and productivity of manufactured equipment, its reliability and durability.

This ultimately contributes to the task of ensuring further technical progress in our society, implementing a broad program to improve the people's well-being. A large place in ensuring the fulfillment of this task is given to machine tool manufacturing, which plays a key role in all branches of mechanical engineering production. Only by using modern high-performance machine tools can we achieve accelerated growth in labor productivity, savings in metal, and an increase in the quality of products as a whole.

One of the important elements of each machine and machine is gear transmissions, the quality of which largely determines the quality of the products obtained from the machine, as well as the reliability and durability of the machine and mechanism itself. The manufacture of gear transmissions is one of the complex and labor-intensive production operations. In our country, various gear wheels of various sizes and purposes are manufactured. Such a wide distribution of gear transmissions places increased demands on their economical use, increased service life and reliability.

## LITERATURE REVIEW

Given the specific scale of production, large module gear wheels are produced in single copies or small series. In this regard, their manufacture occurs using metalworking equipment with manual control, which causes a large number of transitions. When using such equipment, the best results in terms of accuracy and processing productivity are achieved by the rolling method during tooth milling with worm cutters. The use of the copying method on such machines for finishing is limited by the low accuracy of the machine's indexing mechanisms [1].

Geometric parameters for gear-cutting tools are usually assigned based on the calculation of minimal distortions of the tool profile during regrinding, and not based on the properties of the material being processed, which is typical for most other types of metal-cutting tools. Therefore, traditional types of gear-cutting tools have imperfect geometry, which significantly limits their durability. The use of hard alloy as a tool material is difficult due to the low speed range of the equipment used and the labor intensity of manufacturing hard-alloy shaped tools. All this does not allow the use of modern highly efficient processing methods in technological processes and ensuring the degree of accuracy of the processed gears better than the eighth degree of accuracy according to GOST 1643-81 [2].

**DISCUSSION**

Large-sized and large-module gear transmissions are widely used in industry. For example, drum mills designed for grinding various ores, coal and other raw materials are equipped with open gear transmissions, the tooth module of which is *m* = 20 ... 34 *mm*, the width of the toothed rim *b* = 600 ... 1000 *mm*, and its diameter reaches 12 *m*. The toothed rim of drum mills is mounted directly on the journal or on the mill drum, which causes significant end and radial runouts. Due to the fact that open gear transmissions of drum mills are adjustable, installation inaccuracies are inevitable. The listed factors lead to significant unevenness in the load distribution along the length of the contact lines.

Experimental studies show that in open transmissions of ore-grinding mills there is incomplete contact of the teeth along the length of the contact lines. The analysis carried out shows that the loading conditions of large-sized and large-module gear transmissions are such that their calculation should differ significantly from the calculation of general mechanical engineering transmissions, the stress state of which has been studied in sufficient detail and the calculation of which is standardized [3].

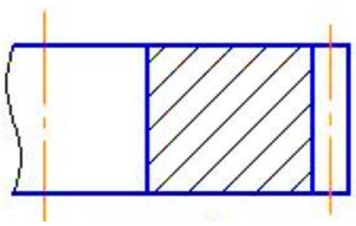
cylindrical gear wheels of external engagement with straight and oblique teeth are cut by copying and rolling methods.

the copying method is used for rough and finish cutting of teeth with disk modular and finger cutters on universal milling machines with a single division. This method has low productivity and accuracy (9-10 degree according to GOST 1643-81). It is used for the manufacture of small batches of wheels or spare parts, as well as for processing cylindrical and chevron wheels of a large module.

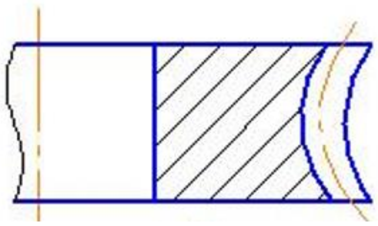
**RESULTS**

The rolling method is the most common in the production of gear wheels. On gear-cutting machines, worm cutters are used in continuous division to cut cylindrical spur and helical gear wheels with standard (Fig. 1, *a*), conical (Fig. 1, *b*) and barrel-shaped teeth (Fig. 1, *c*), worm wheels (Fig. 1 *g*), spline shafts with involute and straight-sided profiles, double-crown wheels (Fig. 1, *d*), etc.

The use of multi-start hobs in gear milling with axial, radial-axial and other feeds is one of the means of increasing productivity. In order to rationally use the advantages of multi-start hobs, it is necessary to comply with certain conditions. The number of starts of the hob cutter should not be a multiple of the number of teeth of the machined wheel. Errors in the start of the cutter cause an error in the pitch of the wheel teeth during milling, which cannot always be eliminated in subsequent operations. It is known that when gear milling with multi-start hobs, the workpiece rotates faster relative to the cutter in a direct dependence on the number of starts. This is the main advantage of multi-start hobbing.



*a*)



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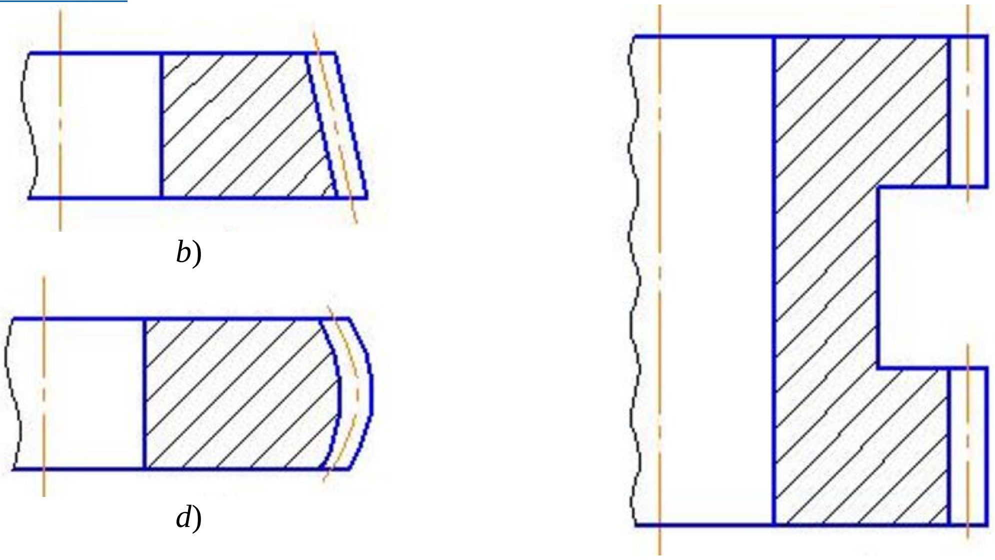


**Fig. 1. Gears cut on a gear hobbing machine**

However, with an increase in the number of cuts that form the profile of the gear teeth, the accuracy of the teeth decreases proportionally. Therefore, with an increase in the number of cutters, it is advisable to increase the number of their chip grooves. An important condition is also a non-multiple ratio of the number of cutter starts to the number of its chip grooves.

The use of multi-start worm cutters of an assembled design is significantly limited. The rectilinear arrangement of the chip grooves, due to the design of the cutter, at a lifting angle of more than 6° is the cause of negative cutting angles on one of the side faces of the cutter tooth. To avoid this, it is necessary to increase the diameter of the cutter, which reduces its productivity.

Formula for determining the number of starts of assembled worm cutters:

$$K_{max} \approx \frac{D_e}{10m_e}, \quad (1)$$

where, $m_e$ – is the module of the hob cutter, *mm*;

$D_e$ – is the diameter of the hob teeth, *mm*.

Modern rigid CNC machines help to expand the scope of application of multi-start milling cutters. Thus, for subsequent shaving or grinding, solid 6-7-start milling cutters with 15-17-chip flutes and a cutting length of up to 200 *mm* are used. Milling with diagonal feed is carried out on special machines. The worm cutter moves at an angle to the axis of the wheel being processed. This method is used in large-scale and mass production for processing wheels with wide toothed rims, a package of wheels and wheels with increased hardness, when it is necessary to have a long period of resistance of the cutters during the cutting process.

With diagonal feed, compared to axial feed, the conjugation of tooth profiles (cut lines are not located along the tooth, but at an angle) of spur gears during rolling is improved; therefore, this method is also advisable for gears whose teeth are not subsequently subjected to finishing, for example, for pump gears. In diagonal gear hobbing, it is economical to use long and precise cutters. The ratio of tangential and axial feed depends on the capabilities of the machine and the useful length of the hobbing cutter and is within the range of 1/9 ... 1/3. If good conjugation of teeth is required, then the ratio of tangential St and axial so feeds should be.

$$\frac{S_T}{S_o} \geq \frac{m\pi}{b}, \quad (2)$$

where, $m$ – is the module of the gear wheel, *mm*;

$b$ – is the width of the gear rim, mm.

The diagonal milling method is used to produce straight-sided and involute spline shafts with special cutters, which must have a slight taper to ensure a fixed fit, as well as for toothed tracks with a slight barrel shape along the tooth width.

Example of machining a gear wheel made of chrome-molybdenum steel using the two-pass method (*m* = 4 *mm*, *z* = 50; *α* – 30°; *β* – 0°; *b* = 32 *mm*): tool - two-pass worm cutter made of high-speed steel with titanium nitride coating. Cutting modes:

– cutting speed ½ *v* = 50/80 *m*/*min*;
– axial feed ½ *S* = = 3.6/2 *mm*/*rev*;
– main time T = 2.3 *min*.

**CONCLUSION**

The results of the theoretical and experimental studies aimed at increasing the efficiency of mechanical operations of tooth processing of large-module gears allow us to draw the following conclusions:

During tooth processing of large-module gears, a significant share of the accuracy balance (up to 70-75 %) is made up of dynamic errors determined by fluctuations in cutting forces. It has been shown for the first time that due to regular changes in cutting forces, the nature of which is determined by the kinematic features of each tooth processing operation, the dynamic errors that are formed on each tooth are mainly systematic, rather than random.

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