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Short Report
Краткое сообщение

Improving operation of a drawing mill

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Abstract. The report considers the purpose of drawing mills and possible violations of the technological process associated with the design flaws of drawing mill drive. We analyzed the design of a planetary gearbox with a common carrier used in the drive of the stretching drum of a drawing mill. During the operation of such a transmission, there are disadvantages: due to the imbalance of links of the mechanism relative to the central axis, additional dynamic forces arise. This design transmits movement from the leading link to the carrier only through one satellite, the teeth of which perceive all the force transmitted by the torque, which reduces the reliability of the gearbox and the drive as a whole. The design of a three-satellite balanced self-aligning planetary gearbox, free from these disadvantages, is described.

Keywords: drawing mill, drive, planetary gearbox, torque, dynamic force, carrier, satellite, reliability

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Совершенствование работы волочильного стана

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Аннотация. В сообщении рассматривается назначение волочильных станов и возможные нарушения технологического процесса, связанные с недостатками конструкции привода волочильного барабана. Проведен анализ конструкции планетарного редуктора с общим водилом, используемым в приводе протягивающего барабана волочильного стана. В процессе работы такой передачи возникают недостатки: из-за неуравновешенности звеньев механизма относительно центральной оси возникают дополнительные динамические силы. Такая конструкция передает движение от ведущего звена на водило лишь через один сателлит, зубья которого воспринимают всю силу, передаваемую крутящим моментом, что снижает надежность редуктора и привода в целом. Описана конструкция трехсателлитного уравновешенного самоустанавливающегося планетарного редуктора, свободного от указанных недостатков.

Ключевые слова: волочильный стан, привод, планетарный редуктор, крутящий момент, динамическая сила, водило, сателлит, надежность

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Drawing represents the fourth stage of metallurgical production and is used to create cold-drawn products such as wire, shaped profiles, and tubes. The process involves pulling an initial billet through a tapered channel in the drawing die under the influence of a pulling force. This reduces the cross-section of the material, shaping it to match the die's outlet. Drawing dies are manufactured with high precision using tungsten carbide hard alloys.

The drawing process is performed in a cold state with mandatory lubrication. The stability of the drawing process, product quality, and scrap generation largely depend on the application of the external force needed to execute the operation. This force is supplied by the drum of the drawing mill, which is typically driven by an electric motor through a cylindrical gearbox. The drum drive system plays a critical role in influencing friction conditions in the die, ensuring stable load application during acceleration and steady-state operation, and ultimately determining the overall feasibility of the drawing process [1; 2].

Currently, the drawing process is used to produce wires, small-diameter tubes, and certain types of specialized profiles. The primary equipment for this operation is the drawing mill, whose main components include the die and the stretching drum. The drum receives rotation from an electric motor via a gearbox [3; 4].

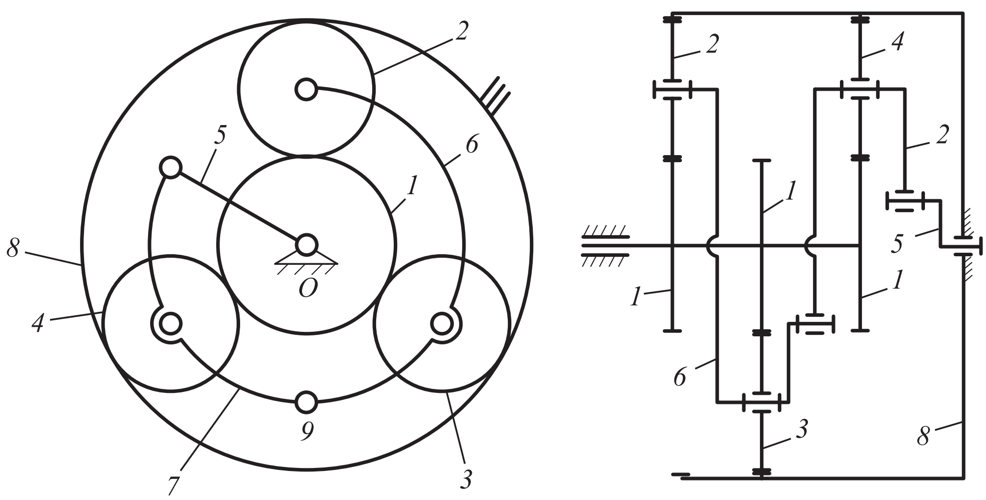
An analysis of the AZTM VN 2-550 drawing mill, operated in the steel rolling shop of EVRAZ United West-Siberian Metallurgical Plant JSC (EVRAZ ZSMK), identified the need for modernization to extend its service life and enhance productivity. The modernization involved replacing the existing drive system – comprising two bevel gears, a cylindrical gearbox, and a belt transmission – with a three-satellite planetary gearbox, model MPO-1M-10-5.74-7.5/250 [5].

However, the newly installed three-satellite planetary gearbox with a common carrier exhibited significant shortcomings. The imbalance of the transmission components relative to the central axis caused additional dynamic forces. Furthermore, the design transmitted motion from the driving link to the carrier through a single satellite, whose teeth bore the full torque-transmitted load. These drawbacks reduced the reliability of the gearbox and the drive system overall [6; 7]. Consequently, critical technological challenges remained unresolved, such as shortening profile changeover times, achieving smooth acceleration to steady-state drawing speeds, and reducing the occurrence of breakages.

To address these shortcomings, researchers at the Siberian State Industrial University developed a design for a three-satellite balanced self-aligning planetary gearbox [8] (see Figure).

The three-satellite planetary gearbox consists of a central input drive wheel (1), satellites (*2 – 4*), an output link (carrier) (*5*), three-pair articulated levers (*6*, *7*), and a central wheel with internal teeth (*8*), around which motion occurs. Since the mass centers of the three-pair articulated levers are located along the axes of the satellites they connect, the system becomes balanced, reducing dynamic forces in the gear meshing zones.

The three-satellite balanced planetary gearbox operates as follows: rotation from the electric motor is transmitted to the central input drive wheel (*1*), which evenly transfers motion to all satellites (*2 – 4*) through the three-pair articulated levers (*6*, *7*) connected with the output



a *b*

General view (*a*) and kinematic scheme (*b*) of a balanced three-satellite planetary transmission:
1 – central input drive wheel; *2 – 4* – satellites; *5* – output link (carrier);
6, *7* – three-pair articulated levers, which are connected with satellites *2 – 4* and with the carrier *5* by five rods;
8 – central wheel with internal teeth; *9* – additional hinge

Общий вид (*a*) и кинематическая схема (*b*) уравновешенной трехсателлитной планетарной передачи:
1 – центральное входное ведущее колесо; *2 – 4* – сателлиты; *5* – выходное звено (водило);
6, *7* – трехпарные шарнирные рычаги, которые пятью шарнирами соединены с сателлитами *2 – 4* и с водилом *5*;
8 – центральное колесо с внутренними зубьями; *9* – дополнительный шарнир

link (carrier) (*5*). In this process, the torque from the central input drive wheel (*1*) is uniformly distributed among all satellites.

The mobility of the developed gearbox design is determined using P.L. Chebyshev's formula:

$$W = 3n - 2p_5 - p_4,$$

where W is the degrees of freedom (mobility) of the mechanism; n is the number of links; p_5 and p_4 are the numbers of fifth-class (hinge) and fourth-class (gear meshing) pairs.

The kinematic chain of the transmission contains seven links ($n = 7$), connected by seven hinges ($p_5 = 7$) and six gear meshes ($p_4 = 6$). Substituting these values yields $W = 1$. This indicates that the planetary transmission is statically determinate, and all three satellites reliably participate in transmitting power from the central wheel to the output link. This reduces forces and, consequently, stresses in the gear teeth.

Integrating the three-satellite balanced self-aligning planetary gearbox into the drawing mill drive system can significantly reduce profile changeover times, lower scrap rates and downtime caused by breakages, increase drawing speed, and enhance the overall productivity of the drawing mill.

Conclusions

The analysis of the drawing mill operation revealed that to improve its productivity, the drive of the drawing drum must be modernized. The developed design of the drawing mill drive, featuring a three-satellite balanced self-aligning planetary transmission, extends the service life, reduces profile changeover time, increases drawing speed, minimizes equipment downtime due to failures, and decreases scrap rates, thereby enhancing the overall productivity of the mill.

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A. G. Nikitin – formation of the basic concept, formulation of conclusions, scientific guidance.
A. R. Fastykovskii – revision of the text, correction of conclusions, discussion of the experiments.
S. P. Gerasimov – performing the experiments, writing the text.

Вклад авторов

А. Г. Никитин – формирование основной концепции, формулирование выводов, научное руководство.
А. Р. Фастыковский – доработка текста, корректировка выводов, обсуждение экспериментальной части.
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