Kontemporary directions and methods of studying bevel gears working in mining machines drives

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Súčasné smery a metódy výskumu kužeľových ozubených prevodov určených pre pohony banských strojov

Jedným zo smerov zabezpečenia vysokej spoľahlivosti a životnosti súčasných banských strojov je optimalizácia konštrukcie ich kužeľových ozubených prevodov, ktoré tvoria dôležitý prvok ich pohonných systémov. Táto optimalizácia sa musí dotýkať celého rozsahu „technologického zabezpečenia“, vo fázach: projektovanie, výroba a využívanie. Musí byť založená na výsledkoch vývoja systému, ktorý berie do úvahy príslušné optimalizačné kritériá a metódy pre ich teoreticko-praktické overenie.

Príspevok sa zaoberá kritériami hodnotenia kužeľových ozubených prevodov z hľadiska odolnosti voči zmenám, tribologickej stálosti, dynamického, vibračno-akustického a termického stavu. V príspevku je tiež prezentovaný hierarchický systém overovania kritérií pomocou experimentov. Tento systém tvoria: modelové výskumy javov a procesov, testy konštrukčných uzlov, ako sú ozubenie, ložiská a tesnenie, standové testy skutočných kužeľových ozubených prevodov, ako aj prevádzkový výskum.

Kľúčové slová: *banské stroje, kužeľový ozubený prevod, výskum*

Introduction

The technological life of industrial machines and equipment, including toothed gears consist of three basic subsequent phases:

- design and construction,
- manufacturing and assembling,
- use.

During the design and construction phase, a concept is developed, accompanied by technical solution (technical documentation) that defines in detail the functional, geometrical, material, strength and durability factors.

During the manufacturing and assembling phase, the object receives its material form, reflecting technical and technological design, so that it fulfils its usage assumptions.

During the use phase, which consists in applying a given machine or equipment in order to carry out a specific technological process, we specify the following characteristic periods: the period of using, i.e. execution of useful work, and the period of renewal, i.e. restoration of lost usage characteristics.

For toothed mining machines gears it is possible to predict functionality and durability [1] with the use of a structured system of theoretical and experimental studies at any of the above-mentioned phases.

Studying toothed gears in contemporary mining drives

Development in highly efficient mining machines related to the increase in the unit capacity of drives requires an appropriate set-up of studies on toothed gears, accounting for main and specific criteria of their use evaluation. (fig. 1) As shown in figure 1, the the execution of main and specific technical criteria is there to guarantee fulfilment of the primary condition, i.e. safe use of the gear, which is part of the machine or equipment drive system.

ASSESSMENT CRITERIA

MAIN TECHNICAL CRITERIA
- *reliability*
- *durability*
- *efficiency*

-intensity of wear
- thermal status
- vibration and acoustics status

DETAILED TECHNICAL CRITERIA
- functionality of technological process
- execution
- work dynamics

- PRIMARY CRITERION –
SAFETY OF USE

Fig.1 Use assessment criteria for toothed gears used in mining machines and equipment drives.

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Methods of studying toothed gears

In the view of the above-mentioned criteria, a system of gears studies can be developed and divided into a theoretical analysis, based on the mathematical modeling and computer simulation of processes and phenomena as a function of construction, technological and use characteristics, and experimental studies carried out at one of the following levels, which constitute a hierarchy [2], [3]:

- studies of real objects (in this case: toothed gears),
  - in machines and equipment (use studies),
  - in special work stands (stand studies),
- studies on real objects models in smaller scale or for a representative sample of type and volume (tests of strand studies),
- model experimental studies based on identifying elementary phenomena and processes (e.g. generating dynamic and thermal induction, tribological use, fatigue et cetera).

Examples of such approach to studies, related to tribological studies of various technical objects are presented in figures 2 and 3 [4].

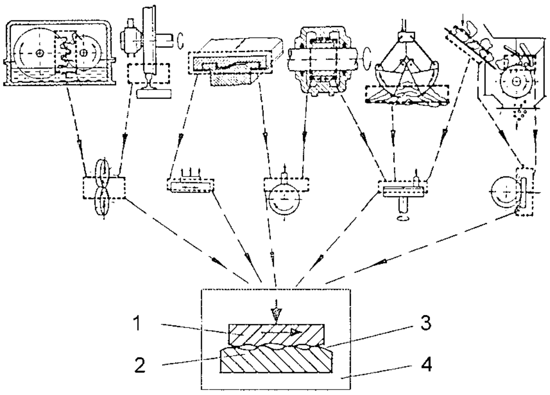

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Fig.2 Structure of system tribological studies of various technical objects: 1, 2–specimen, 3–lubricant, 4 – surroundings.

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Fig.3 Presentation of structured studies of toothed gears in a car drive.

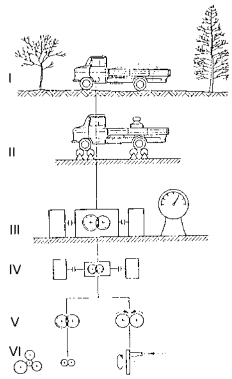

Figure 2 presents subsequent phases of studies, starting from object studies, specific construction nodes and identification of elementary phenomena on ‘small’ elements (samples) of the experimental model, while figure 3 shows a hierarchical structure of use studies (I), stand studies (II, III) and laboratory studies (IV, V, VI).

Each level of studies execution brings specific cognitive findings (mainly in model studies) and application findings (stand and use studies).

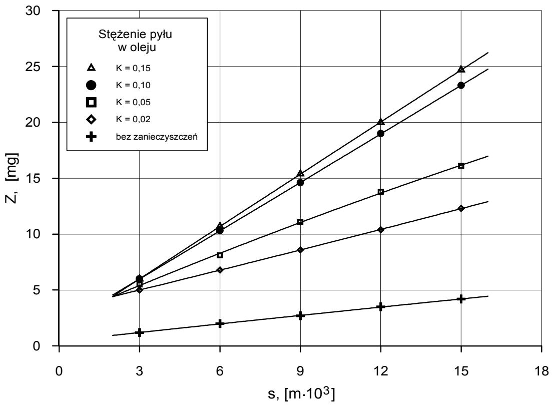

Fig.4 Dependence of summary abrasive wear of cylindrical samples on the friction path for various levels of coal dust concentration in oil VG-200 with the slag contents of 21.34%.

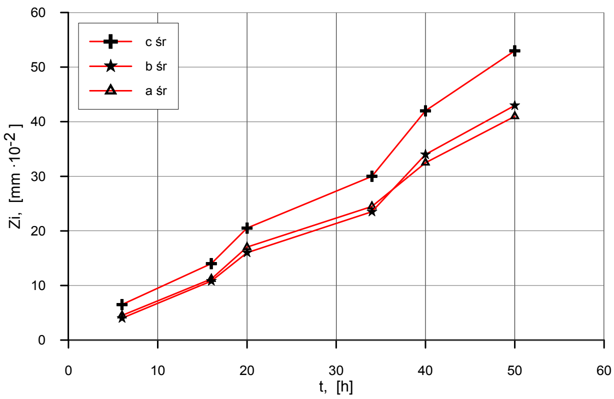

Fig.5 Dependence of abrasive wear of testing wheel teeth on testing time at the closed-power stand with load M = 60 Nm. Lubrication: oil VG-220 contaminated with coal dust of the concentration of 5% and slag concentration of 21.34%; $a_{śr}$, $b_{śr}$,$c_{śr}$ – use for: tooth heads, partition diameter area, tooth foot.

As an example, figure 4 shows the impact of coal dust concentration in gear oil VG-220 on the abrasive wear in cylindrical samples with a turning and sliding contact (kinematic model of teeth co-operation with evolving teeth profile), while figure 5 presents the results of abrasive wear of model toothed wheels teeth, i.e. results obtained at experimental stand studies [5]. It is worth mentioning that in one case information was obtained from the wear as a function of oil contamination concentration, while in the second case information was obtained on the wear along tooth profile, which has an important impact on conclusions related to teeth decreasing resistance to breaking).

Examples of results generated in broader stand studies [6] of a high-capacity planetary gear are an illustration of temperature distribution along a cooling water jacket as a function of gear working time. (fig. 6).

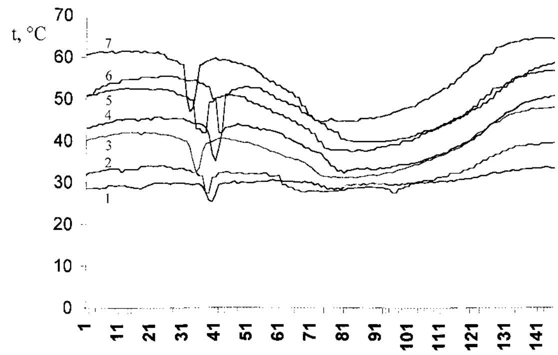

Fig. 6 Temperature distribution along the cylindrical surface of the water jacket in a planetary gear (160 kW) as a function of time at a closed-power stand. The temperature distribution graph was obtained using of a thermal-vision camera.

This figure presents dynamics of gear warming, with the application of water cooling system of a flow equal to roughly 2 dm^3/min, and it also shows uneven heat consumption, i.e. areas of small cooling efficiency. It should also be mentioned that the problem of thermal status becomes a key issue in the construction of high-capacity toothed gears and hence it becomes a subject of broad scientific analyses [7], [8].

Conclusions

The implementation of new high-capacity mining machines requires the use of reliable high-quality efficiency and durable gears in their drives. A fulfilment of these criteria is related to the need of optimising construction models of gears during the phases of designing, manufacturing, assembling and optimisation of their use.

Optimisation should be based on a system of hierarchical structure of theoretical and experimental studies. This system consists of:

- model studies of elementary phenomena and physical processes with the use of computer simulation and laboratory experiment ,
- test studies of gear construction nodes (pitch, bearing, sealing, etc.),
- gear studies (real models) carried out as stand and use studies.

Each element of the system provides us with a specific collection of findings and partial conclusions. However, only a total and closed analysis allows to obtain a technical object that fulfils the reliability, durability and efficiency criteria.

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