dislocations (1,50 %). Other nervous system injuries (0,65 %) are the rarest in this group. During the whole period of study there were no cases of poisoning. No consequences of toxic impact, of injuries, burns, freezing or any consequences of head injuries were detected. On the whole in the period from 2003 to 2011 the level of occurrence of poisoning and injuries in the main office team changed very little. Since 2009 there has been a tendency to the level decreasing, however at the same time the index of temporary inability to work among the employees has been increasing.

Based on the results of the work, the following conclusions have been drawn:

1. The long-term average annual morbidity rate is 84,35 cases of TLWA and 752,80 days of loss of working ability per 100 employees, and in accordance with Y.L. Notkin's scale dated 1977 is close to the average level of TLWA.

2. Respiratory diseases are the leading pathology of the main office of the studied petrochemical company. They account for 63,49 % cases of TLWA and 48,21 % of total disability. The second rank place is occupied by musculoskeletal diseases, their percentage in the total structure of TLWA on the basis of the number of cases per 100 employees and on the basis of the number of disability days is 9,3 и 9,74 % respectively.

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MINIMIZATION OF BACKLASH IN THE THREADED CONNECTIONS IN BORING CUTTING TOOLS

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The article is devoted to modeling of precision treaded connections in SolidWorks software. Experiments were carried out to reduce the backlash in threaded connections of boring tools.

In metalworking boring heads are widely used for making precise holes. They allow to set the size of the tool with high precision and to achieve high-precision machining and quality. The possibility to control the size of the tool can improve processing efficiency by reducing tooling costs and improve performance through the use of modern tool materials as cutting teeth such as hard metal, mineral ceramics and superhard materials that allow the use at higher cutting mode [1].

Progressive tools are adjustable single-blade boring prefabricated heads, equipped with replaceable indexable carbide inserts.

Figure 1 shows an example of a structure of a typical single-tooth boring head for boring holes in the range 30 ... 150 mm.

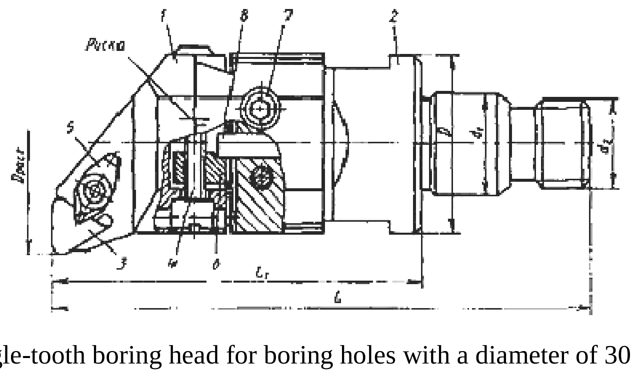

Fig. 1. Single-tooth boring head for boring holes with a diameter of 30 ... 150 mm

These heads consist of a head body 2 on the front side of which there is a corner recess of the «dovetail». In the recess a tool holder 1 is accurately placed, it has a possibility of radial displacement. In based tool holder a replaceable indexable carbide insert 3 is mounted, it has triangular or tetrahedral shape with rear corners. A plate fastening according to its design is performed using a stuck 5 and a screw or screws through the hole in the plate.

Geometric parameters of the insert: entering angle $\varphi = 90$ ° for triangular plate and 75 ° for tetrahedral plate, front angle $\gamma = 0$, rear angle $\alpha = 8 – 10$ °.

The housing of the head is provided with an adjusting screw 4. Along the screw 4 the guide rail 6 moves, which serves to focus the holder 1. When the screw 4 rotates the guide rail 6 acts on the pin 8, and the holder 1 is moved in the radial direction, thereby ensuring accurate adjustment of the head to the desired size treatment. After setting the required size, the holder 1 is firmly fixed in the slot due to the elastic deformation of the body 2 while tightening the screw 7. To create a possibility for deformation of the «dovetail» type groove the housings have a longitudinal slot. The housing and the holder are hardened to HRC 32-40. Accuracy of adjustment available in the operating conditions of up to ± 0,01 ± 0,02 mm depends on the diameter and experience of an operator.

On the basis of analysis of boring tool structures it can be concluded that in modern engineering boring tools can be divided into boring cutters, microbur and boring heads.

Tools with indexable inserts in accordance with GOST 19042-80 or ISO 1832 (it could be also found forms of indexable inserts that differ from these standards) are most common nowadays. It helps to improve reliability of cutting tools, intensify cutting modes, and provide quick-tool change in case of wear, which is especially important for automated production.

The most promising direction in boring tool design and application is creation of instrumental systems based on a modular principle.

Particular attention is paid to the construction of unites for micrometric adjustment and moving cutting blades, as well as cartridges or cutting blocks.

One of the main problems of these systems is their lack of rigidity and accuracy due to the presence of more joints than in the solid tool. One of the most effective ways to improve the accuracy of the blocks is to use elements for adjusting the dimensions of cutting tools, such as microbur. But the main drawback in the design of microburs and other instrumental system blocks having a micrometer screw as a regulatory element is a gap in the micrometer screw pair. Reducing instrument inaccuracies in setting the size by means of the micrometer screws is made by imparting the preload in the threaded connection, however, a question of influence of microbur design parameters to create necessary interference, and thus the precision and rigidity in the connection, has not been studied enough.

There are many ways to make the preload in the micrometer screw connection of microbur. This variety is shown most thoroughly in the patent №2349426 [2].

According to this patent the boring head consists of a micrometer screw, playing the role of the tool holder 1. On one end of the tool holder 1 there is a groove for indexable insert 2, fixed, for example with a clamp 3 with help of screw 4, and on the other end a key 5 is set. The key 5 can slide along the keyway of a mandrel 6 and prevents rotation of the tool holder 1 around its axis. A limb 7 and a bushing 8 are conjugated with tool holder 1. The limb 7 is set in the rotatable housing 9. A vernier 10 is made at the end of the housing 9 for precision adjusting of the tool holder 1. Between the sleeve 8 and the housing 9 an elastic member 11 is mounted (Fig. 2).

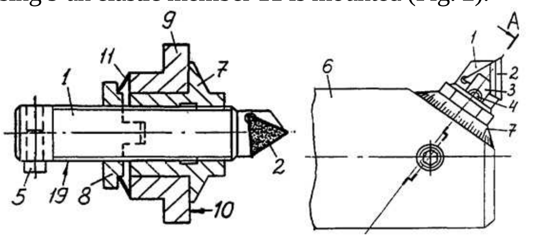

Fig. 2. Boring head assembly and section view

The elastic element 11 can be made as diaphragm spring, curved washer or wavy washer. The elastic element 11 can also be made as one part with sleeve 8 as: a diaphragm spring (Fig. 2) with rolling bearings 12, a slotted spring (Fig. 3) with an abutment surface 13 on the housing 9, etc.

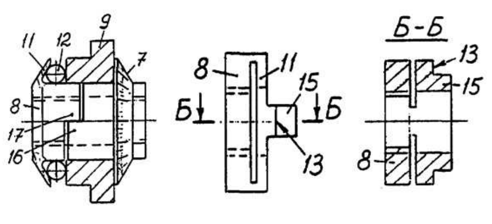

Fig. 3. Elastic elements

The limb 7 interacts with the sleeve 8 (transmits torque) through slots 14 and ridges 15, performed respectively in limb 7 and sleeve 8. Shoulders 16 and 17 may also transmit torque (Fig. 3) due to halved cutouts at the ends in limb 7 and sleeve 8, respectively. In the central limb opening 7 excluding threads precise circular recess 18 is made as a cylindrical inner surface with diameter d (Fig. 4).

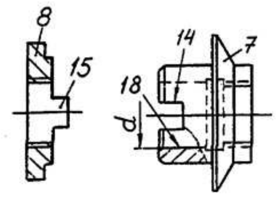

Fig. 4. The limb with a circular recess

In the tool holder 1 the thread tops are processed (cut) without violating the average diameter of the thread and the diameter d of the recess18, and form an outer cylindrical surface 19 of diameter d (Fig. 5).

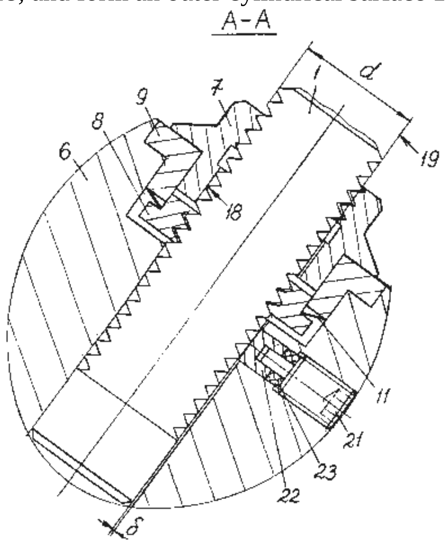

Fig. 5. Boring head. Cut A-A

However, the resilient member in the form of a slotted spring is the easiest to manufacture.

During the projecting process and development of the new boring instruments with micrometer adjustment of the cutting blade the main task was to solve the problem with clearance adjustment (to reduce to the necessary size) in the thread connection of the boring head. It was revealed that some factors influence the clearance size, namely the parameters of the slots on the housing of the bushing and the stresses of prior pressing or wedging (for prior preload).

A plan-matrix of the complete factorial experiment (CFE) was done for the purpose of estimation of slots influence on the accuracy of the thread connection. In our case there were three factors: width of the slot, step and depth of the slot. To reduce the number of models we used two levels of each factor. Thereby we had 8 models [4]. The plan-matrix of CFE is shown in table 1.

Table 1 – Plan-matrix of CFE

Sample #	The width of the slot, mm	The step of the slot, mm	The depth of the slot, mm
1	1	1	18
2	1	1	21
3	1	1,5	18
4	1	1,5	21
5	1,5	1	18
6	1,5	1	21
7	1,5	1,5	18
8	1,5	1,5	21

This connection was subjected to structural analysis using the built-in SolidWorks tools. Wedging of bushing slots and simultaneous pressure on the axis of the screw inside the bushing were modeled (Fig. 6, 7).

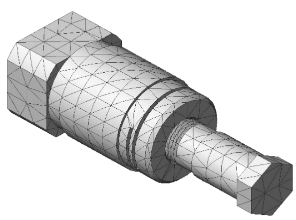

Fig. 6. Screw-bushing connection divided into finite elements in SolidWorks

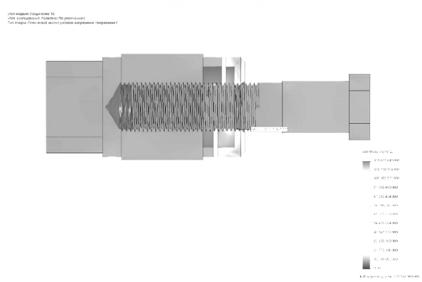

Fig. 7. Map of the stress distribution obtained in SolidWorks

After analyzing the connections using the finite element method, we can conclude that during the slots wedging and the simultaneous action of an axial force on the screw (component of the cutting force) prior preload is formed on the split bushing. This happens at certain values of slots wedging force and it is sufficient to minimize gaps and backlash in the threaded pair.

After the research and calculations had been done using SolidWorks software, experiments were conducted on natural samples of split bushings.

During the experiment split bushings were wedged with the help of measuring plates, and then the torque in the threaded connection was measured by means of screwing and unscrewing of the screw (Fig. 9).

Fig. 9. Measurement of torque with a torque wrench

After analyzing the structure using finite element method in the program SolidWorks, you can draw preliminary conclusions about the acceptability of such a compensation of gaps in the threaded connection of micrometer screws in precision cutting tools. However, due to the nature of calculations in SolidWorks Simulation it is impossible to model a situation of split bushing compression and the following screwing the screws. Thus, further modeling was carried out on real models. During experiments it was found that threaded connections moments occur at the same step and width of slots, but at a more favorable depth of slots. However, when the width of slots equals to two steps of the thread and the step of slots equals to two steps of the thread, the bushing changes from the elastic deformation into the plastic deformation zone. Thus, we can conclude that the slots on bushings should be no more than 1.5 steps of the thread and have a maximum depth (for a square in cross-section).

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