GENERAL AND SPECIFIC REQUIREMENTS FOR THE DEVELOPMENT OF NEW HAMMER DRILLING MACHINES

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ABSTRACT. The paper examines the general and specific requirements for the development of hammer drilling machines. They operate under a strong dynamic regime, so too many requirements must be met when designing them. The study aims to clarify these issues in order to help designers in choosing parameters and constructive schemes. A particular attention is paid on the selection of the air distribution device, the rotation mechanism, the start-up device, the fines removing device, the feed and maintenance device, the fittings and the smoothness classes of the various parts.

Keywords: machine, stroke, hammer

ОСНОВНИ ИЗИСКВАНИЯ ПРИ РАЗРАБОТВАНЕ НА НОВИ ПРОБИВНИ МАШИНИ С УДАРНО ДЕЙСТВИЕ

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РЕЗЮМЕ. В работата са разгледани общите и специфични изисквания при разработване на пробивни машини с ударно действие. Те работят при силно изразен динамичен режим, поради което при конструирането им трябва да се спазват твърде много изисквания. С работата се цели да се изяснят тези въпроси, с което да се подпомогнат конструкторите при избора на параметри и конструктивни схеми. Специално внимание е отделено на избора на въздухоразпределителното устройство, механизмът за въртене, пусковото устройство, устройството за отстраняване на ситнежа, устройството за подаване и поддържане, сглобките и класовете на гладкост на различните детайли.

Ключови думи: машина, удар, чук

Introduction

The process of construction is one of the main activities in the designing of each new product. At the beginning of the design, some basic technical parameters are usually set under operational conditions. The new machines must comply with the normative documents.

Typically, the choice of a constructive solution does not have an unambiguous solution, so these issues should be clarified very well in respect to different types of machines.

In the present paper the basic requirements for the design of new modern hammer drilling machines are examined. These machines include drills and hammers mounted on a manipulator (Mitrev, Minin I., 2017, Nedyalkov P., 2003), submersible pneumatic hammers, rock breaker and pneumatic hammers. The drilling machines operate in a highly dynamic mode. Some of them are used as hand-held machines (Minin I., 2017), others work on manipulators and carriages. Their principle of operation and the way of work set too many requirements on them. It is not enough to know only the general construction requirements of these machines. If the constructor is not well acquainted with the theory and practice of drilling, he cannot create a good drilling machine. In practice, there are many examples for irrelevant constructive decisions due to the lack of knowledge on the problems.

Requirements for machine design

Before the construction, it is necessary to do some research in our and foreign literature sources. The constructions of the drilling machines, implemented and operated in the industry, must be known, their technical level and the possibilities for using the advantages of the new machines should be assessed. It is important to strive for a succession and a unification. New elements must be developed when there is no possibility of using the existing ones and when this leads to an essential improvement of the machine. The hammer drilling machines have been used for more than 150 years and it could be considered that the rational constructive solutions for their individual mechanisms are well known.

The assignment specifies the mass, frequency and energy of the stroke [Minin 2], the relative metal capacity and the energy consumption. These parameters comply with the current standard. The parameters are selected with some reserve in order to fulfil the standard and to provide better qualities of the new machines. The progressiveness of the new construction is mainly determined by the relative metal capacity, the energy consumption and the characteristics of vibration and noise. The rest of the parameters are selected depending on the purpose of the machine and its operational

mode. The technical parameters are determined after calculation using the known methodology (1.2).

The choice of the constructive scheme is one of the most important stages of the designing process. The tolerable errors at this point can devalue the construction and make the model morally outdated from the very beginning. We will focus on this problem in more detail, as many errors are made regularly when choosing a constructive scheme.

The air distributor and the rotation mechanism have the greatest influence on the performance of the machine.

As it is known, independent and dependent rotations through front and rear mechanisms are used for the drilling hammers.

An independent rotation should be used on all the machines that work on manipulators and carriages. Only the independent rotation can provide great drilling speed rate. This requirement is often outstepped. A typical example of this are the Russian hammers KC-50 and these of Atlas Copco-BBD-120. They are heavy drilling machines that work on manipulators. The first ones have a rear rotating mechanism and the other ones - a front one. The dependent rotation cannot provide a sufficient torque, an impact power and a drilling speed rate. There are several drilling machines with an independent rotation of the following companies: Permon - Czech Republic, VKS90VM, from Russia – ПК-60, ПК-75, БГА-1, of Atlas Copco – BBE-51 and BBE-53, of USA – PRR-123, PR-143, VS-40M, Ingersol Rand-URD-474, URD-550, Finland, Tamrok-L-400, 500, 800, 1000, 2000, 4000, Germany, Hausherr – ДК7ЕСА and others.

The independent rotation is unsuitable only for manual drilling machines, as thus their mass increases. Some constructions such as these of Atlas Copco, Russia and others are known, but they have not found a widespread application. The independent rotation could find some application in the manual hydraulic drilling machines. Engines and rotation reducers with small sizes and mass are used for the rotation mechanism. The hand-held drilling machine must have a mass up to 25-28 kg, which is not difficult to be achieved with the hydraulic mode.

For the modern hand drilling machines (Djobov, 2017), both types of dependent rotation are used - front and rear. With a rear rotation are almost all of the Russian drilling machines - ПР – 24, ПР – 25, ПР – 27, ПР – 30, ПТ- 29, ПТ- 36, ПП-54В and others, some of the companies Holman - England, Permon - Czech Republic, Ingersol Rand, Tamrok and others. Almost all of the models of Atlas Copco, some models of Flotman, Hausher, Demag, Bohler and others are with a front rotation.

The older drilling machines are predominantly with a rear rotation.

The rear rotation mechanisms set less requirements on the construction, mainly in terms of accuracy classes of surface roughness. The mechanism is not difficult for exploitation and its life-long service is better. This, however, deplete its advantages. Its deficiencies are of great significance. First of all, the excess increase of the drilling machine mass has to be noted - a very important indicator for the hand-held drilling machines. This is due to the filling of the cylinder with many details compiling the rotating mechanism. It is not rational the drilling bore located in the front to be rotated by a mechanism located at the rear of the hammer. It is not necessary to fill the whole distance along the machine length with parts that weigh on, complicate and increase the cost of the construction.

In the case of hammer drills with a front rotation mechanism, the machine consists of fewer details. The details of the rotation mechanism are located at the front of the hammer and have a lightweight and simple construction. Therefore, the mass of the machine is from 5 to 8 kg less.

Another disadvantage of the rear rotation mechanism is the poor design of the stroke mechanism in respect to the power supply. The shape of the piston could not be sustained in energy terms. The piston is of a small length. On the other hand, the requirement for consistence of the piston sectional length could not be complied. To accommodate the rotating chuck at the rear of the piston, its cross section and its mass increase. All of this leads to the occurrence of peak loading rates in the drilling tool when the stroke is transmitted and the duration of the contact between the piston and the tool decreases. For these reasons, at the drilling machines with a rear rotation the drilling tools break more often, and the energy conversion efficiency is smaller.

The front rotation mechanism provides good possibilities to use pistons with a longer length and equal section along the entire length. For the alignment of the cross section, the rear of the piston is straightened up, thus achieving its weight reduction. Additional volume is added with this straightening to the rear chamber, which helps to reduce the rear air buffer and also to reduce vibrations and increase the active motion of the piston.

A ratchet mechanism is used in all constructions with a dependent rotation. For both rotation mechanisms, the constructions are well-worked and should not be changed. In the lighter models, two ratchet tappers are used, and in the medium and heavier ones - four. At an even number of tappers, the number of teeth of the ratchet wheel gear should be odd. Furthermore, the kinematics of the ratchet mechanism need to be designed so that the individual tappers could operate in sequence, not at the same time. This reduces the amount of reverse rotation of the tool at the end of the reverse motion. The novelty that is recommended is the simultaneous coupling of the ratchet tappers, placed oppositely, two by two. Thus, a more symmetrical load on the rotor nodes is achieved, maintaining the coaxiality of the machine, and the piston is moving with a smaller resistance.

The rotation angle of the instrument should be selected depending on the scales in which it will be operated. The optimisation of this parameter is of great importance as it leads to an increase in the drilling speed rate without an additional energy consumption. In a modern construction, this reserve must be used and imposed still into the design. The machine must be produced with several kits of pistons and rotating sleeves. They are identical in design. They differ only on the helical cannels inclines. The machine produced in this way will operate at a different rotation angle of the tool when changing the kits. Depending on the operational conditions, the assembly kits will be ordered to provide the maximum drilling speed rates without any change in the energy consumption. With the optimisation of the rotation angle, an average increase in the drilling speed rate of about 25% and a significant reduction of the consumption of compressed air could be reached. In addition, the presence of the same machine with several sets of pistons and a rotating sleeve will allow the most suitable combination to operate with to be determined for the particular conditions. This idea has not been realized for any construction, neither in Bulgaria nor abroad.

Considering its easy realization, this reserve for improvement of the indicators should be used for each new construction.

The rotation mechanism should provide very light and smooth rotation of the tool for a whole turnover and along the entire length of the cylinder. The rotation should be without retention and with minimal friction loss. This can be achieved by using a soft and heat-treated springs, sufficient smoothness and coaxility of the friction surfaces, an observation of the prescribed assemblies and good lubrication of the parts. The construction of the tappers must be symmetrical and must allow their reversal turning at a wear on the one side. It is best the tapers to be made of rolled material.

Another very important issue to consider when choosing a construction scheme is the type of air distribution device. There are too many studies on this topic, and that is why we will not discuss the problem in detail, as only the most general rules and assessments will be given.

The machine's faultless and economical operation depends on the air distribution device. At its selection, the following issues should be considered: the movement of the distributing element should be small, should not induce throttling of the fluid, the channels should be of sufficient cross-section and without unnecessary bends.

The simplest in construction, safety of operation and with a high energy conversion efficiency is the self-distribution device. This device is becoming more and more applicable. It should be preferred for short-motion fast-impacting machines.

The valve distribution device is relatively simple and safe to operate with. Some of its disadvantages are the presence of a buffer in front of the piston at the end of the working motion and the uneconomic air flow due to the opening of the outlet due to the displacement of the valve. Various designs of valve distribution devices are known. The best features are those in which the valve is supported and does not move the whole. The swinging valve requires the smallest force and moving time, therefore the disadvantages of the valve distribution are minimised. The valve distribution is mainly applicable for different drilling machines.

The slide shutter air distribution is complicated in construction and unsecure for operation. The distributor is in a joint by two or three surfaces, which places a greater demand on the joints and roughness of the surfaces. Closed volumes are formed in the shutter slide box that are not well flowed by the fluid, so the shutter gets dirty quickly. For the new constructions, it is necessary to provide better drainage of all chambers around the shutter, even if some loss of fluid occurs. On the other hand, this distribution provides economical discharge of the compressed air due to the pre-displacement of the slide shutter because of the outlet opening. In addition, at the end of the two motions, the buffer in front of the piston is absent or minimised. The slide shutter air distribution increases the cost of the product, so it is recommended for heavier long-motion machines. The greater cost of the machine in this case is compensated by the lower operating costs.

The design of the distribution device must ensure good lubrication of the machine. It is best to lubricate the details that are up-flown with compressed air. There are problems mainly with the lubrication of the parts of the rotation mechanism and the chuck. They are most easily resolved by diverting a flow-part of the blown air to the front of the machine. This is most easily done by opening the outlet shortly after opening the slit channels. Thus, from the front chamber of the cylinder through the slit slots, a sufficient amount of compressed air will flow out to spread on the front of the machine.

There are less requirements for the rest of the mechanisms of the drilling machines. Let's take a look at them too.

The starting device must have sufficient permeable capacity and density to ensure the normal feeding of the chambers with minimal losses. This is not observed for various constructions. The inlet is narrowed or it does not match well with the opening of the starting faucet and rear cover lid.

The fines removal device is with a central water supply. Various automatic devices are used to start and stop water. During the operation, these devices very quickly get out of order and they are replaced with a shut-off valve. In case of such a problem with the new construction, it is better still at the designing stage to abandon the spectacular but unsafe mechanisms and to predict a simple shut-off valve. Thus, the appearance of the new construction would not worsen. The safety of the machine is of greater importance.

The maintenance and the feeding devices must be selected or constructed together with the drilling machine. For hand-held machines, it is best to use a double-acting stand. Their management can be from the stand itself or from the hammer. The hammer-management is easier. During the operation only one of the worker's hands is occupied. This reduces the harmful impact of vibrations. On the other hand, however, the construction is complicated. Such management may be envisaged if the level of the plant-producer is good enough.

In addition to the specific requirements listed here, the standard requirements must also be observed. Also, standardised, purchased and formerly acquired in the production process products have to be used, to limit the nomenclature of threads, slits, attachment sizes, coatings, assortment of used materials, interchangeability.

It is difficult to accurately calculate the drilling machines. Therefore, the next stages of design are the most important - the manufacturing of the test sample, its testing and the specification of the construction. This is a very important stage and it is worth most in terms of time and costs. No modern design can be created without a precise implementation at this stage.

It is desirable for the design to be as technological as possible and to contain a minimum number of details. The simplicity is an indication of the craftsmanship of the construction. For the drilling machines, it is necessary to exclude any excesses and the efforts need to be focused on increasing the safety of the machine. In this sense, the intention for simplification could not be considered as an indication of an outdated constructive solution. The constructor must also take into account the capabilities of the manufacturer.

The roughness classes and joints are determined by the operating conditions of the mechanisms. For the parts that operate together, the following limits for the roughness classes may be recommended: 0,63 - 0,16 / 0,63 - 0,16 - for couplings cylinder - piston, cylinder - guiding sleeve, cylinder - air distributor, cylinder - ratchet wheel gear: 1,25 - 0,32 / 1,25 - 0,32 - for front body - intermediate body, cylinder - rear cover lid, air distributor - rear cover lid, 1,25 - 0,32 / 2,5 - 0,63, for cylinder - valve box cover lid, cylinder - valve box sleeve.

Joints with guaranteed clearance and tightness are used for the drilling machines. With a guaranteed clearance are the

joints between the cylinder and the piston H7-H8 / g6-f7; guiding sleeve- piston, chuck, front body - H7 / f7-e8; front body - intermediate body - H7 - H8 / g6 - h6; cylinder – distribution device corps - H7-H8 / h6-h7; cylinder - valve box cover lid - H7-H8 / f9; cylinder - sleeve of the valve box; cylinder - ratchet wheel gear, cylinder – rear cover lid - H7-H8 / f6-f8; cylinder - intermediate body, cylinder - air distributor, air distributor - rear cover lid - H7 / g6-h6. With a guaranteed tightness are the joints between the body and the guiding sleeve - H7 / r6 and between the chuck and the chuck sleeve - H7 / x6.

As it could be seen from the presented material, the construction designing of drilling machines is a complex task that sets too many questions to the constructor. The design of a modern drilling machine can be done only with a basic knowledge of the drilling technique. This paper is an attempt to clarify the main issues that arise in the design and acquisition of new drilling machines.

Conclusions

1. The frequency and energy of the stroke, the relative metal capacity and the specific energy consumption are set in the design process of new drilling machines. They must comply with the current standards.

2. The air distributor and the rotation mechanism have the greatest influence on the performance of the machine.

3. A possibility for optimisation should be provided for the modern machines through the selection of an appropriate rotating angle of the tool for the various operational conditions.

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