MACHINES

Influence of Nonmetallic Inclusions on Endurance of Percussive Machines

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Abstract—Based on the results of the industrial testing of downhole hammers with underreamers and on the analysis of the influence exerted by nonmetallic inclusions in steel on the steel fatigue endurance under the impact load, it has been shown that the stringer-type nonmetallics greatly aggravate the steel endurance both under compression and bending, although have no effect on the steel hardness and strength indexes.

Keywords: downhole hammer, drill bit, borehole, nonmetallic inclusions, endurance, reliability

It is simple and efficient to make large diameter holes by reaming out a small diameter, pioneer hole using light weight drilling machines. For example, downhole hammer P150, designed at the Institute of Mining SB RAS (IM SB RAS) in the 1990s and batch-produced by the Serovsky Machine Plant (SMP), found application in mines of Russia and the former USSR countries in the capacity of an underreamer in driving holes for water passes or for backfilling. In 2008 EVRAZRUDA Co. started to use P150 hammer equipped with a 250-mm diameter underreamer in blasthole drilling, with the appropriate designer’s service.

Downhole hammers are placed in a confined environment and therefore are to be maximum small in size, also they must possess high impact effect to break hard rocks. The most stressed elements of hammers operate at their strength limit. Thus, the choice of material to manufacture hammer elements and the selection of the manufacturing technology are extremely important.

Russian plants produce a variety of percussion machines for the mineral mining and construction industries at the moment. The materials such machines are made of should satisfy exclusive standards. For instance, percussive mechanisms, such as a striking bar or a bit, must have high hardness index and yield limit to retain geometrical dimensions. Percussive elements can be thermally strengthened depending on their size and impact energy: small component parts are usually subjected to heat hardening and then low-temperature tempering [1]; large-size elements exposed to high impact load undergo surface impregnation, namely, casehardening, and then low-temperature tempering.

Being of equal performance, Russian machines are usually exhibit low reliability and operational life. High performance indexes of machines manufactured by leading foreign companies ensue from high durability steel. Recent testing of P150 hammers in Russia revealed noticeable reduction in life of the machines, which forced the Institute of Mining, SB RAS (IM SB RAS) to initiate a research into the quality of materials the hammers are made of, at the Novosibirsk State Technical University, Division of Materials Sciences in Engineering. The present article’s authors have set a task to find out whys of the low reliability operation of Russian percussive machines and to develop the machine material selection guidelines. The research was carried out on the parts of the broken striking bars of different hammers.
1. MATERIALS AND METHODS OF THE RESEARCH

The test materials were different steels manufactured in Russia, USA, Germany, Japan and Sweden, in the form of samples cut from component parts of percussive machines.

Operation conditions of percussive elements were simulated on an electromagnetic facility for multiple ram compression of rectangular samples with stress raisers (Fig. 1). The samples 35 mm long, 10 mm wide and 23 mm thick had 1-mm deep stress raisers on their sides. Accelerated by electromagnetic coil 4 (see Fig. 1), striking bar 1 delivered a blow to sample 6. After de-energizing, compressed spring 2 brought the striking bar to home position. The loading cycle was then repeated. The impact tests were carried out at 500 blows per minute; blow energy was 7 J. The task was to measure time to complete failure of a sample (life of the sample), and the time of origination of fatigue cracks and their velocity. The sides of samples were polished to measure lengths of the growing fatigue cracks.

Metallographic observation of steels and measurement of fatigue crack lengths were accomplished using light microscope Carl Zeiss AxioObserver A1m. Shapes and size of nonmetalics in steels were assessed by comparing unetched polished sections with longitudinal fibers with etching scales. Fractographic investigation of broken surfaces of the samples used electron-scan microscope Carl Zeiss EVO 50, equipped with microspectrum analysis add-on EDS X-Act to determine elemental composition of the nonmetalics. Chemical composition of the test steels was assessed on optical emission spectrometer ARL 3460. The compositions of the test steels are described in Tables 1 and 2. Besides, the samples were strengthened by heat hardening with low-temperature tempering in the range of 100 to 600°C later on to obtain different structures of the samples.

![Fig. 1. Physical configuration of the fatigue-impact test facility: 1—movable stop; 2—striking bar; 3—return spring; 4—electromagnetic coil; 5—holder; 6—sample.](image)

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<th>Manufacturer</th>
<th>Steel grade</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>V</th>
<th>S</th>
<th>P</th>
<th>Cu</th>
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<tr>
<td>Bosch (Germany)</td>
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<td>Makita (Japan)</td>
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<td>0.44</td>
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