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OPTIMIZATION OF THE HYDRAULIC PART OF SLURRY PUMPS TO INCREASE EFFICIENCY AND REDUCE ABRASIVE WEAR

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Centrifugal slurry pumps for conveying highly abrasive slurries with a high content of solid particles are of great interest for mining and metallurgical enterprises, energy facilities and other industries. OJSC Bobruisk Machine-building Plant (a subsidiary of HMS Group JSC) is a major manufacturer of slurry pumps. It is working now on improvement its slurry pumps design to meet the present-day requirements. The main aim of the work is optimization of pump hydraulic parts in order to increase their efficiency and reduce abrasive wear. This paper presents the results of the work for calculation and optimization of the slurry pumps flow paths.

KEY WORDS: slurry pumps, high efficiency, abrasive wear, solid particles, hydro transport

1. INTRODUCTION

The range of centrifugal slurry pumps manufactured by OJSC Bobruisk Machine-Building Plant includes 26 unit sizes with flow rates up to 5000 m^3/h and heads up to 71 m. The most widely used slurry pumps for metallurgical and energy enterprises in Russia and CIS countries have flow range from 400 to 1900 m^3/h. Operation conditions for these slurry pumps vary widely:

- pH hydrogen index between 6 and 12;
- Slurry density (S_m) up to 2.5 t/m^3;
- Temperature up to 70° C;
- Volume concentration of solid particles (C_v) up to 40%;
- Solid particles size (*d50/d85*) up to 35 mm.

Analysis of failures and statistics of the pump's wet parts lifetime reveals that 80% of Russian-made slurry pumps operate in non-optimal regimes, which results in intense abrasive wear of their flow paths parts (Figure 1), increased temperatures of their bearing and excessive vibration (European Association of Pump Manufacturers 1999, 2001).

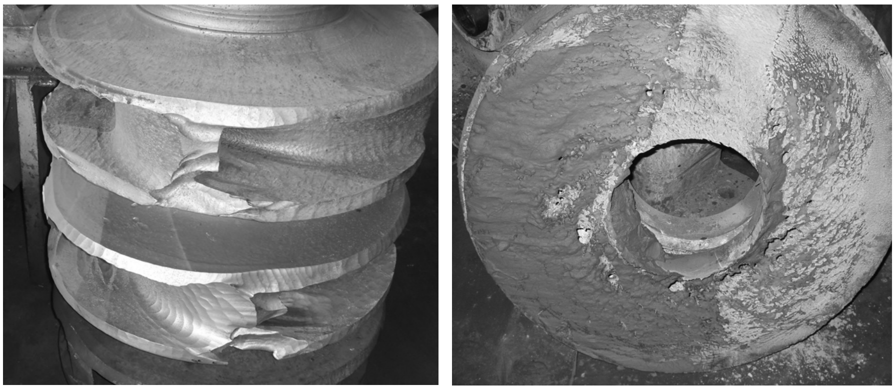

Fig.1 Flow path parts of GrT 1250/71 pump after 500-700 hours of operation

2. TASK DESCRIPTION

Centrifugal slurry pump reliability and efficiency improvement was the primary objective of the research. The research targeted finding out the optimal operation ranges and design of the new hydraulic parts with a higher efficiency rate. The research was based on the GrT 1250/71 pump as the most popular model. These pumps work with flow range 800-1200 m^3/h and head up to 60 m in many ore concentrating mills and thermal power plants (concentration of solid particles 15%<C_w>40% wt., average particle size 150 µm<*d85*>400 µm, slurry specific gravity SG_s>1.4, unrounded angular particles). Operation of the GrT 1250/71 pumps in such conditions leads to intense wear of its flow path parts (Figure 1) and increased energy consumption due to low efficiency (operation in low efficiency zone). The pump's wet parts lifetime usually does not exceed 1500 operation hours – much less than lifetime of similar slurry pumps of world leading pump manufacturers.

Many previous research works [1-5] showed that extensive flow vortexes in flow path channels are wear concentrators. The vortexes are induced often by centrifugal pump operation far away from best efficiency point (*BEP*), i.e. in non-optimal regimes in zones with low efficiency. It creates various operation problems [6-8] (cavitation, increased vibration, high bearing temperature). In accordance with general worldwide practice (American National Standards Institute 2011, K. C. Wilson, G. R. Addie, A. Sellgren, R. Clift 2005, Johann Friedrich Gülich 2008, 2010), the optimal operation range for centrifugal slurry pumps must be 0.3…1.4*Q_{BEP} or narrower in more difficult operating conditions:

- For light and medium duties (solid particles concentration C_w<20% wt., average particle size *d85*<150 µm, slurry specific gravity SG_s>1,4, rounded, non-angular particles) – the operation range must be within 0.3…1.3*Q_{BEP} for high-head pumps and 0.5…1.4*Q_{BEP} for low-head pumps;
- For heavy duties (solid particles concentration 20%< C_w >50% wt., average particle size 150 µm<*d85*>400 µm, slurry specific gravity SG_s >1,4, unrounded, angular particles) – the operation range must be within 0.7…1.2* Q_{BEP} for low-head pumps;

- For super heavy duties (solid particles concentration C_w>35% wt., average particle size *d85*>400 µm, slurry specific gravity SG_s>2.0, angular particles) – the operation range must be within 0.8…1.1*Q_{BEP} for low-head pumps.

Another cause of vortexes is non-optimal geometry of the pump flow part. Depending on the operation conditions, the flow path geometry should be changed (applying impellers with different numbers of vanes, different discharge path profile, etc.) in order to minimize vortexes. These factors and their combinations, selected depending on the operation conditions, help making the slurry pumps more reliable and efficient.

3. METHODS AND SOLUTIONS

The optimal ranges of centrifugal slurry pump operation and optimal flow path geometry have been determined using computer-aided flow simulation (ANSYS CFX) and by numerically studying the flow path in *PumpLinx* software. The *PumpLinx* calculation took into account the flow in the impeller channels. Axial gap and real surface roughness were both simulated, i.e. the numeric experiment simulation was brought as close to real pump conditions as possible (Figure 2).

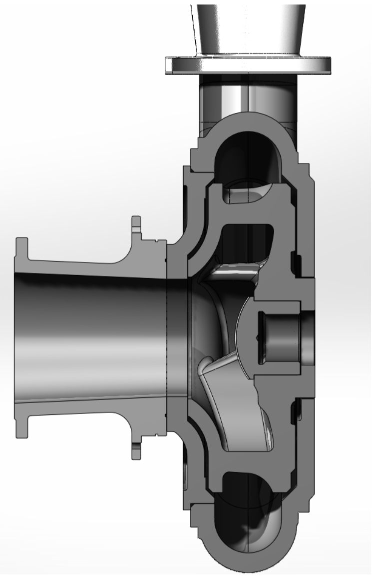

Fig.2 Hydraulic parts of GrT 1250/71 pump

The calculation conditions were as follows:
- Stationary modes with different impeller's axial gaps (S_{seal}=0.5; 1.5; 3.0 mm),
- Non-stationary modes for different flows Q=750, 1375, 1900 m^3/h with axial gap S_{seal} =0.5 mm,
- Rotation speed n=1000 rpm,

- Temperature t=20° C,
- Fluid density ρ=998 kg/m^3.

The pump's characteristics obtained in the numeric experiment with stationary and non-stationary modes are shown on Figure 3.

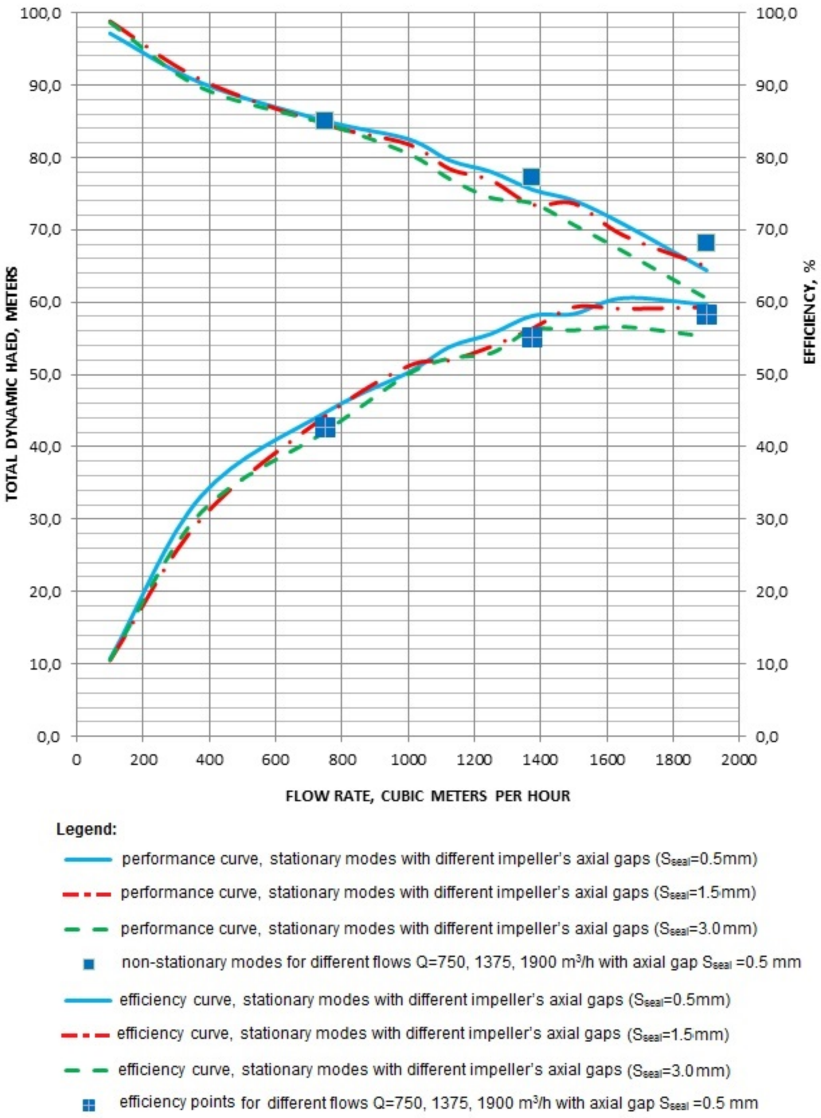

Fig.3 Comparison of numeric calculated characteristics and test results

The numeric experiments have calculated the velocities distribution in the pump flow path and show graphically the places of possible wear due to increased velocities and vortexes (Figures 4-6).

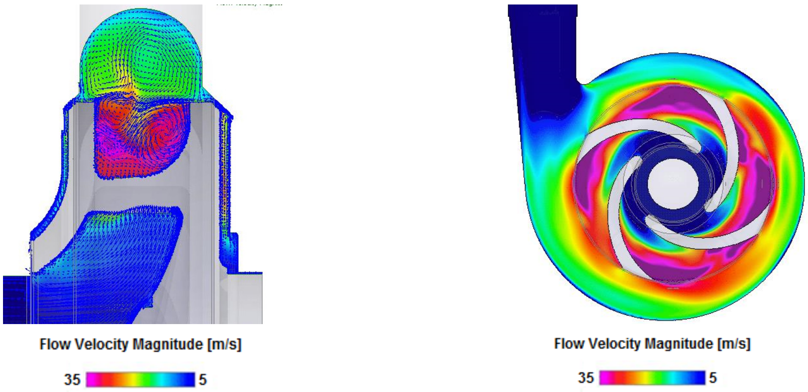

Fig.4 Flow in the hydraulic parts of GrT 1250/71 pump at Q=750 m^3/h

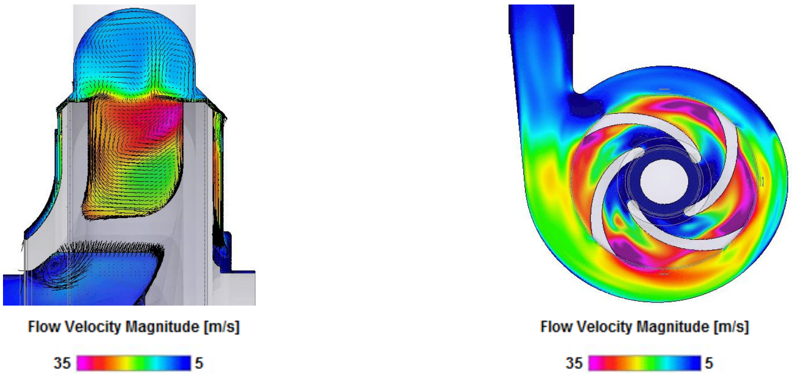

Fig.5 Flow in the hydraulic parts of GrT 1250/71 pump at Q=1375 m^3/h

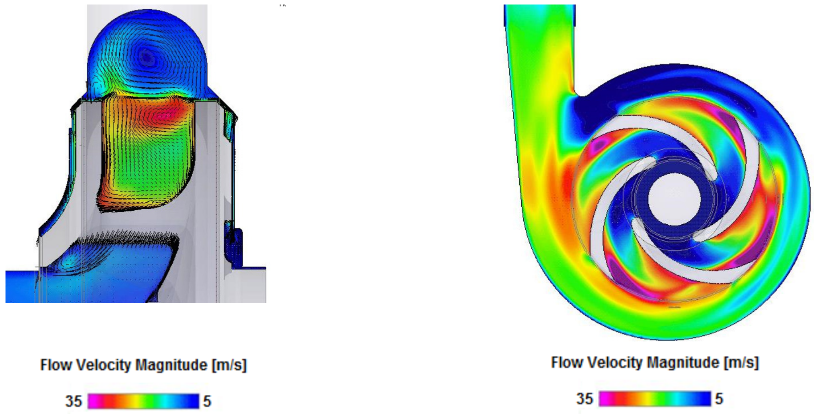

Fig.6 Flow in the hydraulic part of GrT 1250/71 pump at Q=1900 m^3/h

4. CONCLUSIONS

Calculations using *PumpLinx* software visualize clearly the vortexes zones in the flow part of GrT 1250/71 pump operating in selected modes, which are 90-95% the same as the actual wear places in the flow parts of slurry pumps at real operation. When GrT 1250/71 operates at flow rate Q=750 m^3/h (0,4*Q_{BEP}), it is seen clearly that this mode results in increased abrasion rate of the pump’s inner casing and impeller due to high velocities of the flow (more than 25 m/s). In real operation, it will lead to intensive abrasive wear already after 500 hours of continuous operation (Figures 1 and 4). When the pump operates at flow rate Q=1375 m^3/h (Figure 5), vortexes are reduced due to better flow profile in the impeller channels and inner casing discharge way. The flow velocities are near their optimal values, so wear intensity decreases. The increased wear is present still in one zone of the pump casing discharge way (flow velocity of 15-17 m/s) and on the of the impeller vane tips (up to 30 m/s). The Q=1900 m^3/h flow mode (Figure 6) was found to be the optimal one, with flow velocities evenly distributed in the pump’s casing (10-15 m/s), and impeller vane tips velocities reduced to 15-20 m/s.

This research for optimization of slurry pump flow parts, to increase their efficiency and reduce abrasive wear, has revealed:

1. The need to strictly limit the application ranges of slurry pumps depending on their operating conditions.
2. The need to design new hydraulic parts of slurry pumps with higher efficiency for specific operating conditions.

The implementation of the above solution will help:

1. To increase the lifetime of flow paths by up to 6 times;
2. To increase slurry pump efficiency by up to 10%;
3. To reduce slurry pump lifecycle cost by up to 15% due to longer *MTBR* (Mean Time Between Repairs).

The results of this work have been applied in the design of new slurry pumps by OJSC BMBP (subsidiary of HMS Group).

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