INVESTIGATION OF THE WEAR PATTERNS OF CENTRIFUGAL PUMP 8 GR-8 PARTS IN THE CONDITIONS OF "KAZAKHMYS" CO. ORE-DRESSING PLANT

ИССЛЕДОВАНИЕ ЗАКОНОМЕРНОСТЕЙ ИЗНОСА ДЕТАЛЕЙ НАСОСА 8 ГР-8 В УСЛОВИЯХ ОБОГАТИТЕЛЬНОЙ ФАБРИКИ КОРПОРАЦИИ "КАЗАХМЫС"

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Abstract: *The paper considers centrifugal pumps 8 Gr-8, component of the hydro-transport of the ore-dressing operation line, which pumps abrasive hydro-mixtures (pulp). The pumps working conditions are described and the results from wear measurement of the impeller, wear plate and housing are shown for different operation times. The wear patterns of the examined parts are determined and the causes for their intensive wear and the methods of its reduction are identified.*

Keywords: WEARING, CENTRIFUGAL PUMP, ABRASIVE HYDRO-MIXTURES

1. Introduction

Abrasive wear of materials is fundamentally technical and economic important [3, 5, 9]

The processing equipment of the ore-dressing plants/enterprises operates in conditions of intensive hydro-abrasive wear. The hydro-abrasive wear is characterized by change of the dimensions and geometric shape of the parts caused by the impact of the fluid (pulp) [7]. On the surface of parts acting in hydro-abrasive environment there are sections comparatively uniformly worn and sections where the disruption has the appearance of separate depressions or continuous caverns, i. e. general and local wear is observed.

Generally, the consequences of the hydraulic machine wear by the hydro-abrasive environment are in two directions. First, the technological and energy indicators deteriorate (reduced productivity and efficiency; increased loss of valuable components and electric power consumption). Second, the realization of repair works to remove the consequences of wear require considerable expenditures for labor, materials, spare parts [5] and leads to interruption of the operational process.

Centrifugal pumps are one of the most vulnerable to wear components of the hydro-transport systems [5, 10].

Generally, the fluid flow in the pump channels is turbulent [1, 2]. Furthermore, intensive whirling is formed in the flow that determines the pulsations of the abrasive particles contained in it. In consequence of the turbulence and whirling the moment speeds of the particles can be changed in arbitrary direction. As a result of that the solid particles strike upon the surface of the parts at different attack angles thus causing their wear.

The intensity of pump parts wear is greatly affected by the presence or absence of cavitation [1, 5]. In the presence of cavitation the parts durability sharply decreases. The impeller blades of the centrifugal pumps are damaged by the cavitation usually on the suction side. The wear intensity grows along the direction of the impeller blade trailing edge. If the trailing edges are tapered they could be subjected to very intensive cavitation damage.

Together with the impellers damage, the hydrodynamic cavitation may cause also failure of pump static parts, mainly the walls of the housing spiral channels and the wear plates, particularly in the place of assembly of the wear plates to the housing lid [3, 5].

As a result of the pulp hydro-abrasive impact on the surface of the parts their intensive wear is realized by cutting, similar to grinding. Simultaneously, the abrasive particles hitting the parts cause fatigue phenomena in the surface layer which in the long run results in its damage [4].

Purpose of the present paper is to present the results from investigation of the wear process in centrifugal pump components operating in hydro-abrasive environment.

2. Wear of pump 8Gr-8 components

The present paper considers centrifugal pumps 8GR-8 [6], component of the hydro-transport of the ore-dressing operation line in the Zhezkazgan deposit. The pumps operate with abrasive hydro-mixtures (pulp) of solid substance volume content up to 30 – 40 % and density to 2800 kg.m-3. The permissible size of the solid inclusions in the pulp is to 6 mm for metal impeller pumps.

Table 1 presents the exploitation conditions of this operation line.

Table 1: *Exploitation conditions of the operation line*

Ore-dressing stages	Lifetime, hours	Physical composition of the transported material	
		% content of solid particles in the feeding	Solid material fraction
1 processing	About 300	55 -60	Size 10 mm to 5%
2 processing	About 750	55-60	Size 1,6 mm to 8 %
3 processing	About 900		
For the pumps of "pumping-over"		60-65	Size 0,6 mm to 10%
For the pumps separating the final products		50-55	Size 0,21 mm to 25 %

It is investigated the wear of pump 8Gr-8 parts (made of wear resistant iron Cr28 Ni2) from the Ist processing, i.e. after unloading the material to be dressed from the bar-and-rod mills, at 50-55% solid particles content in the feeding from the 10 mm fraction. The average operational lifetime of the parts is not more than 300 hours at coefficient of utilization 0,97. Wearing resistance of iron Cr28 Ni2 is thanks of allow 28 – 30 % Cr and 1,5 – 2,0 % Ni. The parts are molded and heath treated, cut by rapid-cut-steel tool [10].

The impeller (Fig. 1) wears most intensively in the place of material outgoing from the barriers (the blades), after that (Fig. 2 and Table 1) the nearest to the suction point sectors (surfaces A) and the sectors next to the wear plate (surfaces B). This is explained by the fact, that sector A is bilaterally subjected to wear by the abrasive components.

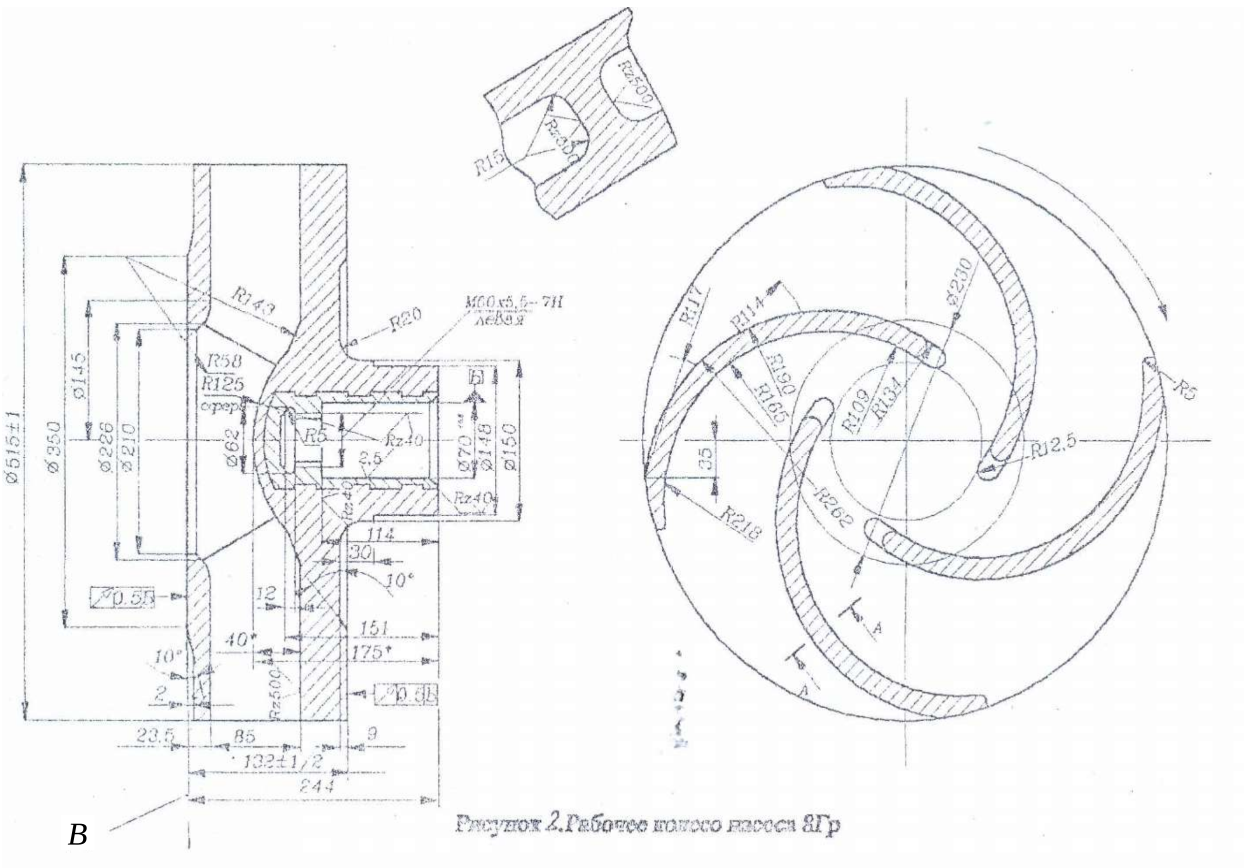

Fig. 1: *Pump 8Gr-8 impeller*

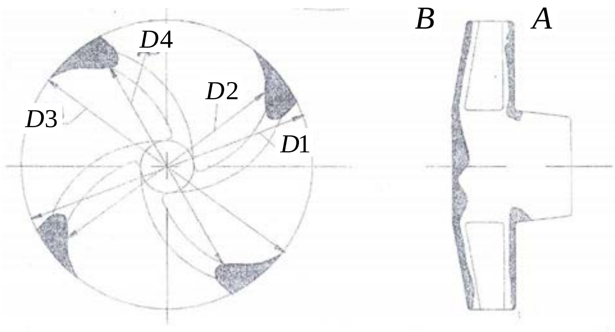

Fig. 2: *Areas/zones of impeller wear*

Table 2: *Results of measuring the impeller of pump 8Gr-8*

No. of pump	D1, mm	D2, mm	D3, mm	D4, mm
1	510	508	515	481
2	509	505	510	479
3	512	507	513	501
4	502	506	511	475
5	509	506	507	490

In case of critical wear, i.e. sharp decrease of pump productivity, the surface A is completely worn, the barriers are 45-55 % worn and surface B – more than 50%. The wear of the blades is in the shape of cavities, which shows the non-uniformity (inhomogeneity) of the material and its irregular distribution in the operation zone. In some areas of the impeller local wear prevails which after 900 work hours of the pump has led to perforation of the material of the shroud and hub plates in the zone between the blades. Such holes have also appeared on the blades – in the middle part and on the boundary between the blades and the hub plate.

Table 3: *Results of measuring the thickness S of surface A along diameter*
∅ 515 mm

Number of measurement	Thickness *S*, mm	Deviation from the nominal value δ, mm
1	2	3
1	11,47	12,03
2	14,005	9,495
3	15,40	8,1
4	16,75	6,75
5	17,005	6,495
6	17,5	6,0
7	17,70	5,8
8	17,75	5,75
9	17,95	5,55
10	18,25	5,25
11	18,96	4,54
12	19,005	4,495
13	19,55	3,95
14	19,94	3,56
15	20,004	3,496
16	20,18	3,32
17	20,75	2,75
18	21,03	2,47
19	21,65	1,85
20	21,78	1,72
21	22,05	1,45
22	22,37	1,13
23	22,5	1,0
24	22,85	0,65
25	23,20	0,3

The greatest wear is in the place of blades assembly to the hub plate (Fig. 1, section A). Table 3 presents the results of measuring the thickness of section A along diameter ∅ 515 mm.

The measurement of the thickness S of surface A provides 25 values: from 0,3 to 12,03 mm. It is most expedient to break the zone of results scattering (12 mm) into 12 sections of 1 mm. The mathematical treatment of the results of the measurements is shown in Table 4.

Table 4 Treatment of the results of the measurements

No. of interval	Limits of interval, mm		Middle of interval, x_i, mm	Frequency, m_i	$x_i m_i$	$m_i x_i''$
	Over	To (incl.)				
1	0,00	1,0	0,5	4	2	4
2	1,0	2,0	1,5	3	4,5	20,25
3	2,0	3,0	2,5	2	5,0	25,00
4	3,0	4,0	3,5	3	10,5	110,25
5	4,0	5,0	4,5	2	9,0	81,00
6	5,0	6,0	5,5	3	16,5	272,25
7	6,0	7,0	6,5	2	13,0	169,00
8	7,0	8,0	7,5	1	7,5	56,25
9	8,0	9,0	8,5	2	17,0	289,00
10	9,0	10,0	9,5	1	9,5	90,25
11	10,0	11,0	10,5	1	10,5	110,25
12	11,0	12,0	11,5	1	11,5	132,25
Sum				**25**	**116,5**	**1359,75**

Because of the limited measurement results during the treatment of the results, instead of the mathematical expectation and dispersion, their approximate estimations are obtained – the empirical average *x* and empirical dispersion *S''*, respectively, which characterize the average result of the measurements and the degree of results scattering [8].

(1) $$x = \frac{x_i m_i}{n} \sum_{i=1}^{n} x_i$$

were

$$x = 116,5/25 \approx 4,66 \text{ mm}$$

$$S'' = m_i x_i'' / M_i - x$$

$$S'' = 1359,75/25 - 4,66 = 32,67 \text{ mm}$$

As soon as the first hours of operation in the looseness between the impeller and wear plate (that is no more than 2 mm) abrasive material from fractions up to 2 mm starts to get in causing uniform wear of the whole circumference of both surfaces. After that, when the impeller is worn along the diameter E4, in the base of the barriers between surface B and the impeller, fraction bigger than 2mm gets in and causes clearly expressed wear band along the diameter 510 – 515 mm. After some time the wear band width increases to 60 – 65 mm and penetrates in depth of the plate to 8 mm.

The plate wear in the bottom part and in the pressure zone is deeper than in the other places (Fig. 3) and it is examined in three tentatively defined zones. For zone C of about 20 – 25 mm width the wear is approximately 25 % of the initial thickness; for zone D of about 75 – 80 mm width – 35 – 55 % and for zone E (the remaining part) – not more than 20 %. In the bottom part of zone C – in the area of feeding the characteristic wear is up to 50 – 60 % of the initial thickness which is due to the non-uniform material density and its different sliding speed over the pump work surfaces.

The main wear of the pump housing (Fig. 4) is in the area of material entering the work zone and in the area of material outgoing to the main pipeline. The impeller wear zone in the point of suction is more uniform along the whole circumference of ∅ 200 mm, the wear band being 40 – 45 mm wide, but the wear in the suction bottom part is a little greater with increase of size and depth on the pressure side (zone F). The next in wear intensity sector is the base of the outlet pipe orifice (zone G). The wear in this zone leads to appearance of punctures and housing failure. The intensive wear in zone G is due to bilateral wearing of the zone (sides a and b) by the material turbulent motion. Side a wears during raking up the material by the blades and side b – during its delivery to the pipeline. The housing wears as well in the place of assembly under the wear plate ∅ 53O +0,14 in the bottom part of the pressure side and along the whole circumference.

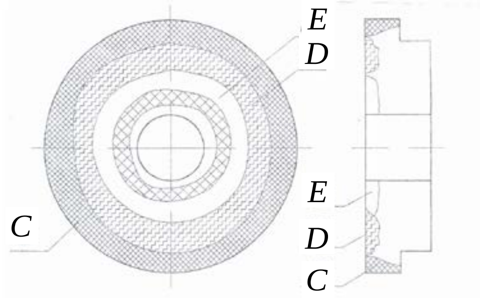

***Fig. 3**: Areas/zones of plate wear*

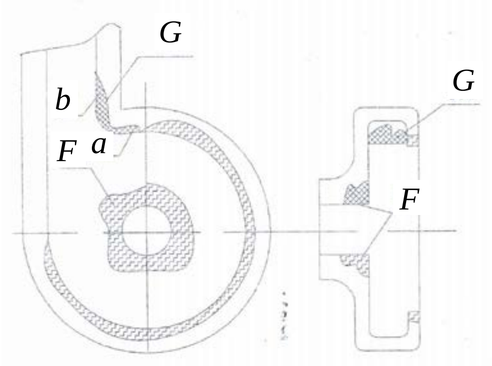

***Fig. 4:** Areas/zones of housing wear*

3. Analysis of the results

Taking into account the above said observations on the parts as well as on the pump as a whole, diagrams of operation lifetime are made (Fig. 5, 6, 7) for the considered parts of wear resistant iron on the base of data about 5 pumps. These diagrams show that:

- The impeller, plate and housing of one and the same pump have different operational lifetimes;
- The non-uniform distribution of the material different fractions, i.e. its different density, and the non-uniform speed of these fractions in the impeller work zone results in failure of the whole pump because of one part, most often because of the housing.

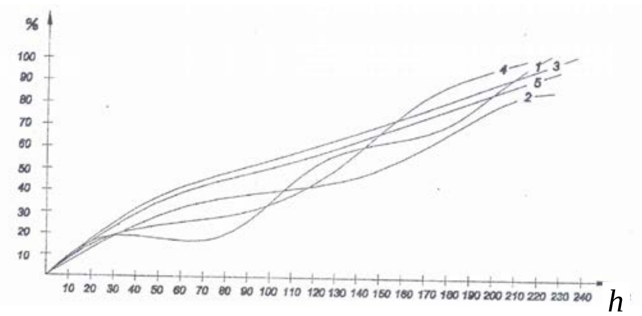

***Fig. 5:** Impeller wear depending on operation time (lifetime) measured for 5 pumps*

Therefore, the performed investigations for finding out the patterns of friction and wear of pump 8Gr-8 parts in the conditions of “Kazakhmys” Co. ore-dressing plant permit to make the following conclusions:

1. The transported material has high abrasivity which acts differently on the different sectors (zones) of the considered parts (impeller, wear plate and housing);

2. The statistical method of determining the empirical characteristics and the mathematical treatment of the measurement results provide possibility to determine with satisfactory accuracy the values of the actual size deviation from the nominal one, which characterize the magnitude of wear. In this case, the average deviation of the wear plate thickness is $\delta = 4{,}66$ mm.

3. The high degree of wear of the pump parts is due to the inadequacy of the chemical composition and mechanical properties of the material, iron, as well as due to the non-uniform distribution of its components during casting the parts.

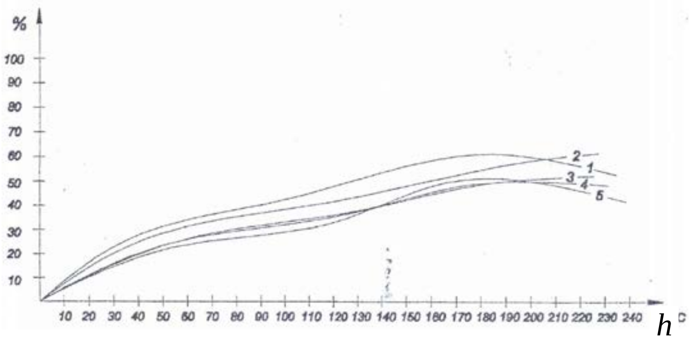

Fig. 6: *Plate wear depending on operation time (lifetime) measured for 5 pumps*

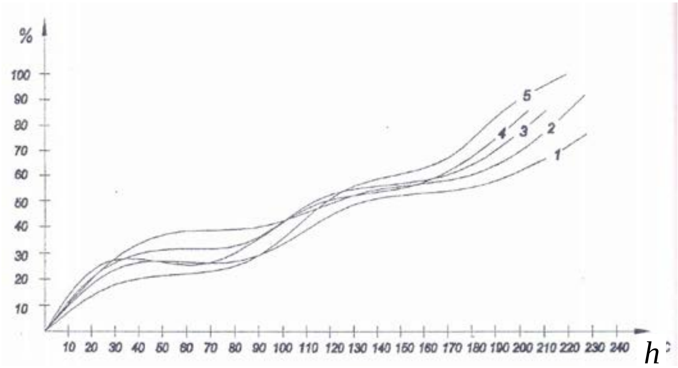

Fig. 7: *Housing wear depending on operation time (lifetime) measured for 5 pumps*

4. Conclusion

Analysis of the pump 8 Gr-8 and the presented results of the measurement of wear of the impeller, wear plate and housing, worked in hydro-abrasive environment shows that the efficiency of this type hydraulic transport does not match its capacity due to the high labor intensity in the operation of the equipment, high wearing of the parts and low average lifespan of the pump.

It was found that the main reason for the inefficiency of the pump 8 Gr-8 is the wear of the pump impeller, resulting in increase of vibration and reducing the pressure characteristics. To reduce the wear is recommended:

- Pump operation in the range of at least wear;
- Switch to impellers open and semi-open type;
- Choice of durable materials for parts

5. References

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