Development of a Progressive Design of a Ground Centrifugal Pump

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Abstract. The processes and technologies of gas-flame surfacing of metal powders are considered, promising modern gas-thermal methods for creating a hardened surface layer of machine parts are established. The use of a specific surfacing method from the considered ones is due to the production conditions, the number, shape and size of the surfaced parts, the permissible share of the base metal in the surfaced, technical and economic indicators, and for restorative surfacing – the amount of wear. The choice of the type of deposited metal and, consequently, the grade of the filler material is made in accordance with the type of working loading of the deposited part. Therefore, when choosing the type of deposited metal, they focus on the prevailing type of wear. Based on the conducted studies of the gas-thermal method of applying wear-resistant coatings, a new design of the impeller of a centrifugal ground pump has been developed.

Keywords: gas-thermal spraying, centrifugal ground pump, surfacing, metal powders.

Introduction. Kazakhstan has huge mineral deposits, entire industries for the extraction and processing of various mineral raw materials have been formed for their development and, as a rule, has a large fleet of mining and processing machines, and these are machines for the extraction of coal, various ores, oil and more. These machines work in harsh conditions, under heavy shock loads and corrosion, when working in aggressive environments [1-4].

Under these conditions, machine parts have intense wear and quickly fail, disrupting the technological process of enterprises. The engineers of these enterprises are faced with the task of increasing the service life of machinery and equipment (combines, drilling tools, transport equipment and equipment for processing (grinding of extracted useful raw materials)).

Therefore, a whole industry for the repair of parts of heavy-loaded machines and aggregates has been formed in Kazakhstan. Enterprises engaged in the extraction and processing of mineral raw materials have a large fleet of equipment, machines and mechanisms that are subject to intensive wear. Thus, in the mining industry, during the extraction and processing of rock, ground pumps are used to transport mineral raw materials through the technological cycle of crushing rock and extracting minerals from them (copper, lead, iron, aluminum, etc.).

The parts of the ground pump used in the technological cycle are subjected to intensive wear, since the transported water medium contains a solid particle of fossil with a concentration of up to 45 percent [5].

Figure 1, 2, 3 shows fragments of parts of the ground pump after a full cycle of operation.

Table shows data on the service life of the soil pump.

As can be seen from Table 1, the service life of the soil pump in conditions of aggressive wear is very short and the operation of which requires the introduction of new technologies to create wear-resistant metals applied to worn surfaces [6, 7].

Consequently, only one area for the processing of mineral raw materials, has a large fleet of ground pumps, is the object of our research. Therefore, the creation of parts having a wearable surface with predetermined properties in terms of strength, corrosion resistance and resistance to aggressive acids. Also, it can be said that in any other industry – oil, construction, metallurgical, in which there are large volumes of mechanisms experiencing heavy loads and intensive wear.

Research methods. To increase the service life of heavily loaded parts, in conditions of intense wear, there are a number of ways in the industry to ap-
ply wear-resistant coatings on them, one of which is gas-thermal surfacing or spraying of superhard powders.

Based on the conducted studies of the gas-thermal method of applying wear-resistant coatings, we have the opportunity to develop the design of the impeller of a centrifugal ground pump of a new design and the possibility of patenting it [8].

The invention relates to pump engineering, namely to the designs of impellers of centrifugal ground pumps.

The impeller of a centrifugal pump is known, containing a disk and blades made in the form of a gummed frame made of a rubber-fabric material [9].

The disadvantage is the low wear resistance due to the presence of stressed zones along the en-

Figure 1 – Impeller of the soil pump 8Gr-8:
    a – new impeller; b, c – worn impeller

Figure 2 – 8Gr-8Gr pump armor plate:
    a – after operation, b – new

Figure 3 – Wear of the 8Gr-8 ground pump housing
tire working surface of the blade formed under the impact of solid particles, which contributes to the destruction of the frame made of rubber fabric in randomly probabilistic places of contact with solid particles.

It is also known that the impeller, taken by us as a prototype, is a centrifugal ground wheel containing disks and blades located between them with a working one profiled from the entrance to the exit along an epicycloid and with the back side profiled along a logarithmic spiral [10].

The disadvantage of the technical solution is the insufficient wear resistance of the pump due to the fact that even the presence of appropriate profiling of the working and back sides of the blade with a change in the angle of entry and exit does not eliminate the impact of repeated collision of solid particles with the blade. Especially in the exit area, which intensifies the destruction of the blade in this contact zone.

The technical objective of the proposed solution is to increase the wear resistance of the impeller of the ground pump, by reducing the intense impact of solid particles at the outlet of the working side of the blade, due to the predominant transformation of the impact of solid particles on its surface, as well as the design of the impeller is collapsible for the purpose of further surfacing on the working surfaces of the blades of the wear-resistant layer by a gas-thermal method.

The technical result is achieved by the fact that the impeller of the centrifugal ground pump is made collapsible, and contains the leading and driven disks, and the blades located between them with the working, profiled from the entrance to the exit along the brachystochrone, and with the rear, profiled along the logarithmic spiral sides, while the blades are made for one with the leading disk, on the working surfaces that have been coated with wear-resistant coatings made by a gas-thermal (plasma) method.

Figure 4 shows the impeller – a longitudinal section and a view of it from above.

The impeller of the centrifugal pump contains a drive disc 1 with blades (winglet) 2 made on it, a driven disc 3 connected to the winglet with pins 6 and for fixing the driven disk, screws 4, spring-loaded washers 5 are made in it.

To increase the wear resistance of the impeller and the ground pump, in general, wear-resistant coatings are deposited on the working and rear surfaces of the blades, when the driven disk 3 is removed (disassembled). After gas-thermal treatment, the impeller is assembled with the driven disk 3, by means of pins 6 and coupling screws 4 with a spring-loaded washer 5, in pre-drilled in it and the shoulder blades of the hole. Wear-resistant coatings 8 on the working and back sides of the blades, obtained by the gas-thermal method, is an alloy of alloying elements of steels with iron, based on the standard PG-Zh40 alloy with the inclusion of chromium boride CrB₂ ligatures in it to increase the strength of the deposited layer. The optimal composition of the chromium boride CrB₂ ligature introduced into the composition of the new surfacing alloy PG-Zh40, it was found that in order to obtain a hardness of the deposited metal equal to 450-600 NV, it is necessary to introduce it into the coating composition within 10%, of the total mass, %.
The impeller of the centrifugal ground pump works as follows.

The angle $\alpha$ of the entrance of the blades from the working side 7 is 35-45°, the angle $\beta$ of the exit from this side is 12-17°, and the angle $\gamma$ of the installation of the blades from the back side 8 is constant along the length of the blade and equal to 20-25°, and the profile of the blades from the working side 7 is made according to the brachystochrone, and from the back – according to the logarithmic spiral. The angles $\alpha$, $\beta$ and $\gamma$ were determined as a result of tests that showed that at these angles there is minimal wear during pumping of the abrasive medium.

When solid particles in the composition of the hydraulic mixture enter the impeller, they move along trajectories depending on the shape of the blades. For blades with the specified profile, the solid particle collides with the working side at the initial site and after rebounding from the surface moves in the inter-blade channel to the exit, gradually reducing the speed. Since the point of impact lies at a small radius of the wheel, where the circumferential velocities are small, the impact force and the destructive effect on the blade are insignificant. Further, the particle of the hydraulic mixture passes the wheel without repeated collisions with the blade. The blade, shaped in accordance with the specified angles, is characterized by an increased radial directivity of the flowing inter-blade channels at the inlet and a reduced one at the outlet. With an increase in the angle $\alpha$ above 35°, the inlet section is in the path of the flow of solid particles, which causes an inevitable collision of particles with the blade in the region of low speeds. A decrease in the angle $\beta$ of less than 17° contributes to the free passage of solid particles through the inter-blade channel without repeated collisions with the blade after their rebound from the blade at the inlet section. The brachystochronous shape of the working side 7 of the blade ensures smooth coupling of the input and output parts of the blade with the specified input and output angles. The blade of the working surface 7, made in the form of a brachystochrone, otherwise we can say that this is a «rapid descent» curve.

The blade formed as a result of a combination of a logarithmic spiral and a brachystochrone has a wing-shaped shape, which increases efficiency due to the creation of hydrodynamic lift.

On the working surfaces of the blades, on the working side made according to brachystochrone and on the back side according to a logarithmic spiral, wear-resistant coatings made of self-fluxing alloy PG-Zh40 are applied in a gas-thermal way, with the addition of chromium boride $\text{CrB}_2$ to the strengthening additives, which significantly increases the service life of ground centrifugal pumps.

**Scientific results and their discussion.** The originality of the technical solution lies in the fact that on the working side of the blade profiled by brachystochrone, an increase in the wear resistance of the pump is ensured, thanks to the smooth merging of flows...
with the working and back sides, which eliminates or significantly reduces the disruptive edge phenomena behind the wheel blades with a reduction not only of losses in the pump, but also the practical elimination of contact destruction of the working side during collision with solid particles after they bounce off the blade at the entrance area and as they move towards the exit. In addition, there is an increase in the reliability of the pump due to a decrease in the intensity of vibration phenomena, as static pressure pulsations decrease. Moreover, the impeller of the pump is made collapsible, after removing the driven disk with a wing, a wear-resistant coating is applied by gas-thermal methods, due to the openness of the blades of a complex shape, the application of a gas-thermal coating becomes easily accessible.

The use of a self-fluxing PG-Zh 40 alloy, with the introduction of chromium boride CrB₂ into the composition of strengthening additives, makes it possible to create a deposited layer of high hardness and corrosion resistance.

During spraying, the plasma jet serves as a source of heating, melting and acceleration of coating particles. The electric energy consumed by the arc, turning into thermal energy, is spent on heating the plasma-forming gas, melting and partial evaporation of the sprayed material, as well as on heating the plasma torch and losses to the surrounding space. Part of the heat generated by the plasma and particles enters the product by heating it. The efficiency of using plasma energy when applying powder coatings is largely determined by the design of the plasma torch.

It is much more difficult to use plasma energy in the case of powder spraying. The search for ways to increase the efficiency of heating powders in plasma-trons for coating has been going on for many years. To date, designs of plasmatrons have been developed that have a thermal efficiency close to or even slightly higher compared to the efficiency of the wire spraying process.

The greatest efficiency can be achieved by introducing powder particles into the arc discharge column. However, such an input is difficult due to the high mobility in the anode region of the discharge. The physical picture of the interaction of a solid particle with an arc discharge column is currently not clear enough. However, observations show that in the case of powder injection near the cathode, the particles do not move along the axis of the nozzle and the plasma flow, but are located between the central part of the flow and the walls of the nozzle channel.

In argon plasma, the mass flow rate of gas and its heat content along the flow section are extremely unevenly distributed, and the main energy transfer does not occur along the nozzle axis.

Thus, it can be assumed that the movement of the powder when it is fed near the cathode occurs in the highest enthalpy region of the plasma, which improves its heating. The latter is especially important for low-power plasma flows. When the powder is fed through one hole, it occupies only a part of the high-enthalpy zone of the plasma jet.

Conclusions. The processes and technology of gas-flame surfacing of metal powders are considered, promising methods of gas-thermal methods for creating a hardened surface layer of machine parts are established. Based on the conducted scientific research of the gas-thermal method of applying wear-resistant coatings, a new design of the impeller of a centrifugal ground pump is proposed.

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Ортадан тепкіш топырақ сорғысының прогрессивті конструкциясын жасау

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Металл унтақтарын газбен жалынмен балқыту процестері мен технологиялары қарастырылған, машина бөлшектерінің қатайтылығы мен қатайтылығына, техникалық-экономикалық көрсеткіштерге, ал қалпына келтіру үшін – тозу мөлшеріне байланысты. Балқытылған металдың түрін, демек, толтырғыш материалдың маркасын таңдау балқытылатын бөліктің жұмыс жүктемесінің түріне сәйкес жасалады. Сондықтан, балқытылған металдың түрін таңдағанда, олар тозудың басым түріне назар аударады. Тозуға төзімді жабындарды қолданудың негізінде ортадан тепкіш топырақ сорғысының жұмыс дөңгелегінің жаңа конструкциясы жасалды.

Кілт сөздер: газотермиялық бүрку, ортадан тепкіш топырақ сорғысы, балқыту, металл ұнтақтары.

Разработка прогрессивной конструкции грунтового центробежного насоса

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Рассмотрены процессы и технологии газопламенной наплавки металлических порошков, устано-новлены перспективные современные газотермические методы для создания упрочненного поверхностного слоя деталей машин. Использование конкретного способа наплавки из рассмотренных обусловлено условиями производства, количеством, формой и размерами наплавляемых деталей, допустимой долей участия основного металла в наплавленном, технико-экономическим показателям, а для восстановительной наплавки – величиной износа. Выбор типа наплавленного металла и, следовательно, марки присадочного материала производится в соответствии с видом рабочего нагружения наплавляемой детали. Поэтому при выборе типа наплавленного металла ориентируются на преобладающий вид износа. На базе проведенных исследований газотермического способа нанесения износостойких покрытий разработана новая конструкция рабочего колеса центробежного грунтового насоса.

Ключевые слова: газотермическое напыление, центробежный грунтовый насос, наплавка, металлические порошки.