Fundamental Wear and Treatment Investigations of Laser-Coated Pump Parts

Ariunbolor Purvee [1], Gunther C. Stehr [2], Battsengel Baatar [1], Purevdorj Batkhuu [3]
[1] German Mongolian Institute for Resources and Technology, Ulaanbaatar, Mongolia
[2] HTW Dresden University of Applied Sciences, Germany
[3] Erdenet Technology School, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia
Email: ariunbolor@gmit.edu, gunther.stehr@htw-dresden.de, battsengel@gmit.edu.mn, batpuje@gmail.com

***Abstract*—This paper describes the technologies and results from a study to investigate a suitable means to protect high chromium white cast iron from further wear. This work focuses on the precondition for the feasibility testing of laser cladding with metal matrix composite powders for the wear protection of impeller blades of slurry pumps. Investigations of selected powder mixtures and different treatment parameter setups were conducted using test plates. During the process of laser cladding the pumps, factors affecting success included: the very raw surface quality of the blades; very high tolerances of the parts; possible defects within the cast iron substrate; and general weldability of the cast iron material due to chemical composition. In comparison between the part surfaces as cast and after the cleaning using sandblasting, the measurements show strong differences in the chemical composition. The measurement results are strongly dependent on the measurement position, surface condition, and laser power. Based on our results, an industrial trial was conducted to compare the wear behavior of the claddings with untreated high chromium white cast iron. An evaluation of the lifetime of the laser-coated pump parts in the mineral processing industry is underway, which results will be published separately.**

***Index Terms*— laser cladding, chromium white cast iron, wear, powder systems**

I. Introduction

Pump and material design are areas in engineering that have been studied for decades. This paper focuses on the results of various designs and materials used in the laser cladding of centrifugal pumps.

A centrifugal pump uses rotational energy from an electric motor to generate centrifugal force. This outwardly-directed force delivers the material internally, along a direction that is perpendicular to the shaft. GrAT pumps are one type of centrifugal pump [1]. A GrAT pump, and the units based on them, are designed to pump high-abrasive slurries (sand, gravel, ore flotation products, etc.).

GrAT pumps are centrifugal horizontal, single-stage cantilevers that send axial slurry to the impeller. The pressure connection is adjustable in increments of 30 degrees in the plane perpendicular to the axis of the shaft. The impeller of a GrAT-1400/40 is a closed type of impeller. The material of the flow-through parts (impeller, inner casing, and cover plate) is made of wear-resistant ICH28N2 cast iron. The GrAT 1400 slurry centrifugal pumps are used to move and lift copper ore and water mixture in a mineral processing plant. The operating lifetime of a pump is very low; between 212 and 350 hours. During one year, more than 300 pumps are taken out to be rebuilt in a repair plant. Most of them fail due to the wear of the main elements, especially of the impeller. The costs of replacement are estimated at several million USD annually; therefore, it is important to extend the working time of the pumps. Cladding the pumps by means of laser coatings is one method.

This research focused on the preconditions necessary for the feasibility testing of laser cladding with metal matrix composite powders for the wear protection of impeller blades of slurry pumps. It was conducted by testing the coated parts under actual industrial conditions to compare wear and lifetime against the uncoated parts. In this study, 3 of 4 blades of the impeller were clad with different powder systems, and the cover plate with one powder system. The process and results of varying laser claddings for wear protection of the impeller blades and a cover are presented.

A. Selection of Laser Cladding and Materials

Laser cladding is a surface modification procedure. It uses a powerful laser beam to deform the coating material and a thin substrate layer, to form a coating without pores and strata. This process can be used to cover a large area by overlapping individual tracks; however, it is the ability to protect small localized areas that makes it unique. The wide range of materials that can be applied, and its suitability for treating small areas, make laser cladding particularly suitable for adapting surface properties to local operational requirements. This opens up a new perspective for materials developed on a surface.

The processes of laser deposition differ in the method of supplying the coating material. In two-step processes, a thin layer of material is applied onto the substrate, for example, in the form of a suspension or a coating applied by thermal spraying, and then melted using a laser beam.

In one-step processes, the material is continuously fed into a laser-generated molten bath, usually in the form of a

Manuscript received August 2, 2021; revised November 11, 2021.

doi: 10.18178/ijmerr.11.3.166-173

powder. The laser shell formed by injecting powder surpasses the alternative processes and is the only one that has found practical application, because it is more energy efficient and provides better control and reproducibility of the process. The laser envelope has found relatively wide application for: protecting materials from wear, corrosion and oxidation; for applying self-lubricating coatings and thermal barriers; and for restoring expensive industrial components. Other applications that have significant potential are: non-equilibrium synthesis of modern materials; the development of alloys; and the manufacture of almost pure forms in free-form [2], [3]. In practice, here is not much effort underway to test either laser welding, or cladding of high chromium white cast iron. This material, in general, is considered to be un-weldable as a result of the thermal affected zones / danger of cracks due to the high content of alloy elements.

Several technologies were selected to investigate a suitable method for further wear protection of high chromium white cast iron (Table I).

TABLE I. SELECTED LASER TECHNOLOGIES FOR WEAR INVESTIGATIONS

Technology	Description	Purpose
Laser glazing	Surface melting of high chromium white cast iron, 0.5 mm depth	To increase surface hardness, reduce wearing of the state-of-the-art material, eliminate the need for additional material for cladding or welding
Laser welding	Joining of two different materials, 2mm plates a) Cast iron with cast iron b) Cast iron with steel	To join a high chromium, white iron hardfacing cover, to steel or iron substrates
Laser cladding	Surface protection layer (6 mm) ofa) metal-ceramic compound b) Stellite® 1* c) Stellite® 21**	To cover the surface with coating materials containing high amounts of carbides

*Stellite® 1 contains a high proportion of hard, wear resistant primary carbides; **Stellite® 21 consists of a CoCrMo alloy matrix containing dispersed hard carbides which strengthen the alloy

B. Hardness and Wear Resistance

In Table II, the chemical composition analysis, hardness, and wear rate of the Laser cladding is shown, in comparison to the high chromium white cast iron material (HCWI). The metal-ceramic material's wear rate is the minimum compared to the other materials.

TABLE II. CHEMICAL COMPOSITION, HARDNESS AND WEAR RATE

Type	Chemical Composition, %								Hardness	Wear rate
	Fe	Cr	Mn	Ni	Co	Mo	W	V	HRC	g/min
HCWI	65.1	30.9	1.06	1.42	0.08	-	-	0.23	55.0	0.0080
metal-ceramic	31.9	19.6	0.5	46.6	0.6	-	-	-	54.4	0.0042
Stellite® 1	2.12	27.8	-	0.48	63.1	-	5.5	-	42.8	0.0370
Stellite® 21	3.0	27.0	1.23	2.59	59.4	5.3	-	-	35.2	0.1900

Fig. 1 shows the complexity of the wear behavior regarding the measured macro-hardness, using the Vickers test procedure (HRC) [4].

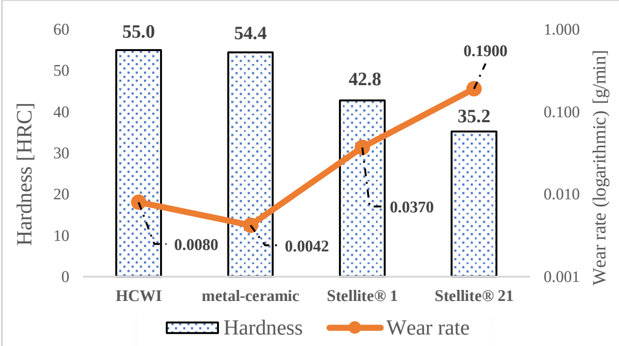


Figure 1. Hardness and wear rate of HCWI vs. Laser cladding

As expected, the high chromium white cast iron material, as the state-of-the-art solution, provides a high hardness level, due to the finely distributed chromium carbides and high wear resistance. The selected metal-ceramic compound could reduce the amount of wear to half, even though it has the same macro-hardness level of approx. 54÷55 HRC.

II. RESULTS OF POWDER MATERIAL SELECTION FOR LASER CLADDING

The base material is a highly alloyed cast iron with high hardness for high wear resistance. The weldability is related to the high carbon and chromium content and is very difficult [5]. It is therefore not suggested. Due to high roughness and geometrical tolerances a further challenge is the cladding on the non-machined casted surface. The XRF (X-ray fluorescence) measurements show strong differences in the chemical composition in comparison between the part surfaces as cast, and after the cleaning using sandblasting. The measurement results are strongly dependent on the measurement position and surface condition shown in Table III.

TABLE III. CHEMICAL ANALYSIS OF TEST PLATE, IMPELLER AND COVER PLATE

Element	*ИЧХ 28Н	Chemical content, % (Bruker XRF)					
		as cast			sandblasting		
		Test Plate	Impeller	Cover plate	Test Plate	Impeller	Cover plate
Fe	base	65.9	68.1	61.2	71.6	76.8	67.8
C	2-2.5	Not measurable by XRF spectrometer					
S	≤ 0.08	5	<0.1	<0.1	<0.1	0.6	0.6
P	≤ 1	0.1	<0.1	<0.1	<0.1	<0.1	0.2
Mn	0.5-1	0.4	0.3	1.2	0.3	0.2	0.8
Cr	25-30	25.5	28.5	26.4	22.8	19.8	20.8
Si	0.7-1.4	1.1	0.3	5.3	2.7	0.5	5.5
Ni	1.5-3	1.2	1.5	0.7	0.9	1.4	0.5

*Reference

For the coating systems, two different tungsten carbide types, with angular and spherical shapes, were selected. Two NiBSi-alloys, with different chemical compositions, were chosen for the matrix material: a P1 powder with higher Cr- and C content, and a P2 powder, without Cr and a low C content (Table IV). During the laser cladding procedure, the powders were combined with a mixture of 60% carbide and 40 % matrix alloy.

TABLE IV. SPECIFICATIONS OF THE SELECTED POWDER SYSTEMS

Powder systems			Particle size [µm]	Hardness
PS1	Matrix1	P1	50-150	~ 52 HRC
	Carbide1	SWSC	50-150	~ 2500 HV
PS2	Matrix1	P1	50-150	~ 52 HRC
	Carbide2	WSC	50-180	~ 2500 HV
PS3	Matrix2	P2	50-150	50 HRC
	Carbide1	SWSC	50-150	~ 2500 HV

SPECIFICATIONS OF THE SELECTED POWDER SYSTEMS (CONT.)

Powder systems	C	Si	Cr	Ni	B	Co	Fe	W
P1	0.45	4	10.5	base	2	-	3	-
SWSC	~4	-	-	-	-	-	-	96
P1	0.45	4	10.5	base	2	-	3	-
WSC	~4	-	-	-	-	-	-	96
P2	<0.1	3	-	base	3	-	<2	-
SWSC	~4	-	-	-	-	-	-	96

Note: PSpe-Powder Specification; SWSC-spherical shaped cast tungsten carbide; WSC-angular shaped cast tungsten carbide; SWSC-spherical shaped cast tungsten carbide. – duplicate; Note: HV-Vickers Pyramid Number.

For an explanation of the degree of success of the coatings, the hardness ratio between the copper ore particles and the part materials (coatings) plays and important role (Table V).

TABLE V. HARDNESS LEVEL AND RATIO OF ABRASIVE MATERIAL VS. PART MATERIAL/COATINGS

Powder Systems	**Hardness Level [HV*]**	**Hardness Ratio *r***
Copper Ore	~ 200 … 800	./.
HCWI	~ 500 … 600	0.6 … 3.0
Coating Matrix PS1	~ 550 … 720	0.7 … 3.6
Carbides PS1	~ 2500	3.1 … 12.5
Coating Matrix PS2	~ 550 … 720	0.7 … 3.6
Carbides PS2	~ 2500	3.1 … 12.5
Coating Matrix PS3	~ 520 … 720	0.6 … 3.6
Carbides PS3	~ 2500	3.1 … 12.5

The surfaces of the impeller (Fig. 2-3) and the cover plate (Fig. 4-5) were cleaned by blasting with steel chips, because grinding was not successful. Regarding the casting technology used in the industrial field, the surface of the parts is very rough (Fig. 6-7).

Figure 2. Impeller, as cast, before cleaning

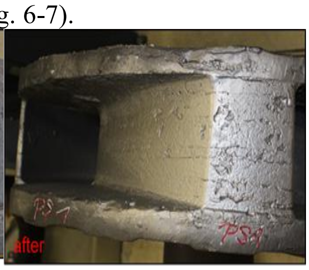


Figure 3. Impeller, after cleaning by blasting with steel chips

Figure 4. Cover plate, as cast, before cleaning

Figure 5. Cover plate, after cleaning by blasting with steel chips

Figure 6. After blasting, impeller surface

Figure 7. After blasting, cover plate surface

The machine setup (Table VI) for the Laser cladding procedure uses a high-power diode laser source with up to a 20kW laser power output. The handling system is driven by a KUKA KR60 robot system [6].

TABLE VI. MACHINE SETUP FOR LASER CLADDING

Setup	**Parameter**
Machine	KUKA KR60 robot
Laser	Laserline LDF diode laser with 20kW max. laser power
Optics	Laserline OTS 2, 400 mm focusing length
Laser spot size	10 mm diameter
Powder nozzle	COAX power line ring slit, 20 mm working distance
Powder feeder	GTV-Twin, matrix and carbide powder in different powder lines
Protection gas	Argon

For the parameter study, a series of flat sample plates (100x100x30 mm) made by the high chromium white cast iron material is used. Single track (Fig. 5a) and area (Fig. 5b) cladding tests were performed with different parameter sets (Table VII) and different laser power levels.

a)

b)

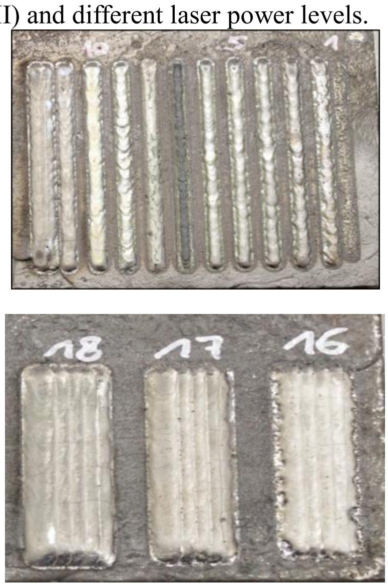


Figure 8. Impeller a) as cast, before cleaning; b) after cleaning by blasting with steel chips

TABLE VII. PARAMETER SETUP FOR CLADDING TESTS

Parameter	Value
Laser power	2.0- 6.0 kW
Powder feed rate total	80 g/min
Powder feeder 1 (carbide)	48 g/min
Powder feeder 2 (matrix material)	32 g/min
Speed	300-2000 mm/min
Pitch	4 mm
Protection gas flow	20 l/min

During the test runs, the lateral speed and the powder feed rates were adjusted to reach approx. 2.5-3 mm coating thickness in one layer. Additionally, different laser power levels were tested to influence the adhesion, penetration and track shape (Table VIII).

TABLE VIII. CLADDING TESTS WITH DIFFERENT LASER POWER

Track No.	Powder system	Laser power [kW]	Penetration & track shape
#16	PS1	2.5	Bad
#17	PS1	3.7	Good
#18	PS1	6.0	Good

With a final parameter setup (Table VII) and a fixed speed of 550 mm/min, cladding samples with all 3 selected powder systems, using two different laser power levels, were performed to prepare the metallographic investigations (Fig. 6). The cross section can be performed just by water jet cutting because the materials are too hard for a standard cutting process (grinding machine). The industry field wire cutting was not possible due to non-metallic inclusions (carbon, manganese sulfides) in the cast iron (Fig. 7).

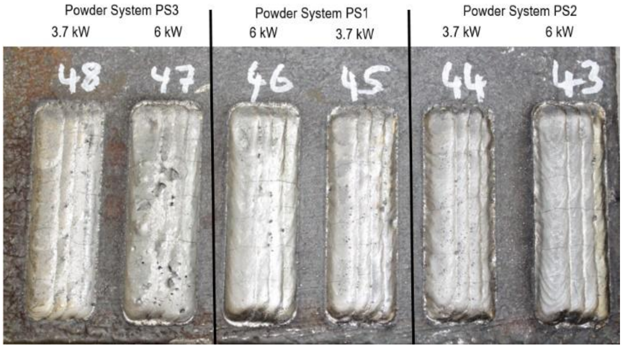


Figure 9. Cladding tests with different powder systems and laser power

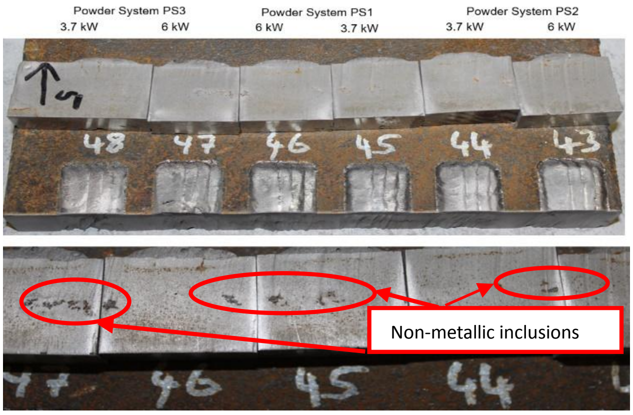
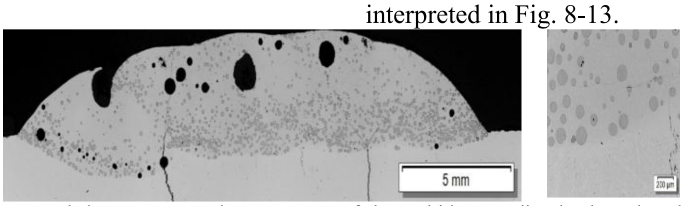


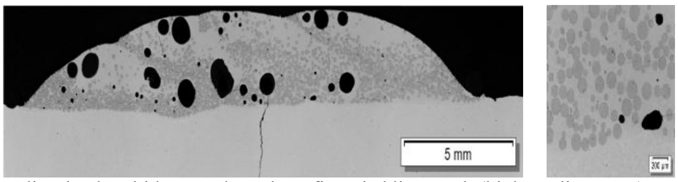
Figure 10. Cross section preparation of laser cladding

The metallographic investigations of the laser cladding of the three selected powder mixtures using two different laser power levels (6 kW and 3.7 kW) are shown and interpreted in Fig. 8-13.



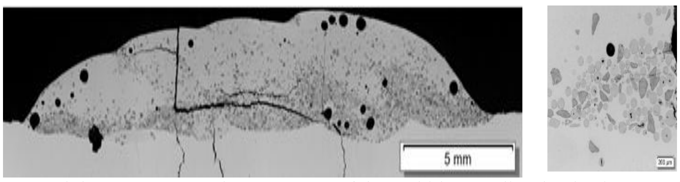
Too much laser power: a large amount of the carbides are dissolved->reduced wear resistance

Figure 11. Cross section #46, PS1, Laser power 6 kW



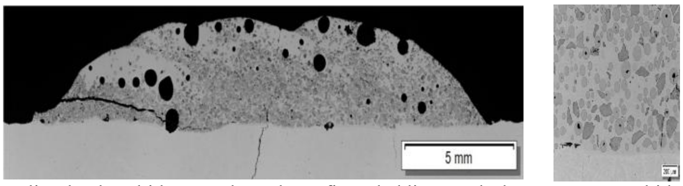
No dissolved carbides, cracks only at first cladding track (high cooling rates)

Figure 12. Cross section #45, PS1, Laser power 3.7 kW



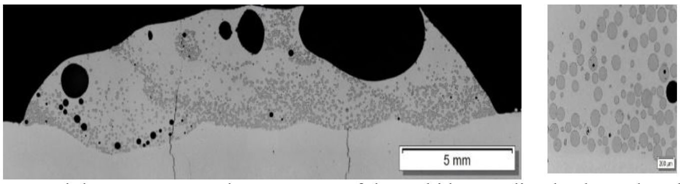
Too much laser power -> a large amount of the carbides are dissolved-> increased hardness and brittleness of the matrix -> increased cracking, reduced wear resistance (note: unplanned mixture of angular and spherical carbides)

Figure 13. Cross section #43, PS2, Laser power 6 kW



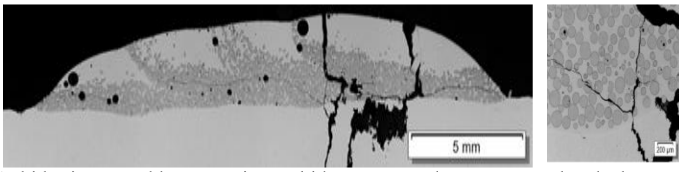
No dissolved carbides, cracks only at first cladding track, homogenous carbide distribution (note: unplanned mixture of angular and spherical carbides)

Figure 14. Cross section #44, PS2, Laser power 3.7 kW



Too much laser power -> a large amount of the carbides are dissolved-> reduced wear resistance

Figure 15. Impeller a) as cast, before cleaning; b) after leaning by blasting with steel chips



Carbides intact and low porosity, carbides are strongly concentrated at the bottom of the coating -> ratio between matrix to carbide is low -> horizontal cracks initiated, cross section shows a large inclusion in the cast iron -> critical for weldability

Figure 16. Impeller a) as cast, before cleaning; b) after leaning by blasting with steel chips

The hardness profile from the coating into the substrate (sample #45, PS1, Laser power 3.7 kW, Fig. 17) shows the typical variation between higher values when a carbide is measured, and lower values when the matrix is measured.

III. Discussion of Powder Material Selection for Laser Cladding

From these metallographic investigations of cladding, we can conclude that:

- The parameter sets with 6 kW laser power cause too high of energy input, causing the carbides to be dissolved and become diluted
- The parameter sets with 3.7 kW laser power show no, or fewer dissolved carbides. This should be used for the next tests and cladding on real machine parts.
- All samples show some porosity; the reasons could be the cladding on the cast surface and the high carbon content of the cast iron.
- PS1 samples show more porosity but the better distribution of the carbides, and PS2 samples show lower porosity, but with PS3 samples, the carbides concentrate at the bottom of the coating, and the high coating thickness has an influence.”

To finalize the cladding tests with the flat sample plates, all three selected powder variations were used to coat an area of approx. 90 x 45 mm with the optimal parameter setup, shown in Table IX. Fine cracks in the cladding materials indicates the internal stress of the claddings.

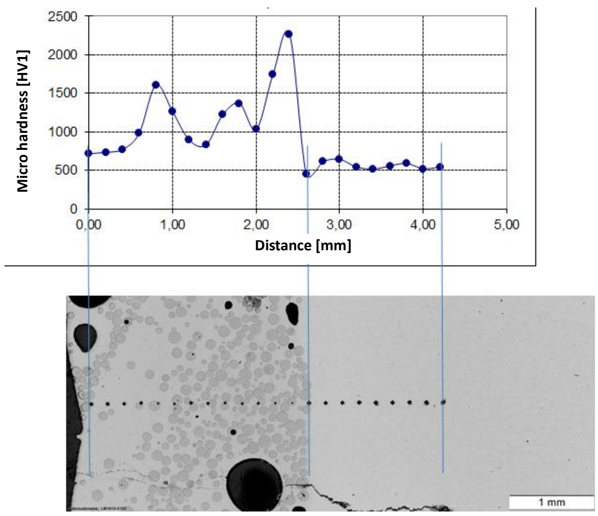


Figure 17. Impeller a) as cast, before cleaning; b) after cleaning by blasting with steel chips

TABLE IX. Selected Parameter Setup for Cladding of Actual Industrial Parts

Parameter	Value
Laser power	3.7 kW
Powder feed rate total	80 g/min
Powder feeder 1 (carbide)	48 g/min
Powder feeder 2 (matrix material)	32 g/min
Speed	550 mm/min
Pitch	4 mm
Protection gas flow	20 l/min

Fine cracks in the cladding materials indicate the internal stress of the cladding using powder systems PS1-PS3 shown Table IV (Fig. 18-20).

Figure 18. Cladding test area using Powder System 1

Figure 19. Cladding test area using Powder System 2

Figure 20. Cladding test area using Powder System 2

For the industrial trial, three out of four blades were coated to have the opportunity to compare the wear behavior of the cladding with the untreated high chromium, contain white cast iron (Fig. 18-20). The programmed cladding strategy is shown in Fig. 18. There are 3 blades coated with different coating power systems (blade PS1, blade PS2 and blade PS1) and -as a reference- one blade (blade 0) remains uncoated. The blades are coated following a programmed cladding strategy for an impeller, by a robot arm, with the tools path programmed by a specialized software system (SKIM DCAM CAD) shown in Fig. 21. It should be noted that there are large differences between a virtual CAD model created using CAD drawings, and the real-life geometry of the part (especially the radius between the blade and the sidewall). It was impossible to find the reference point for the coordinate system on the real part. Therefore, the tool paths were programmed by teaching the robot manually. The coating process is shown in Fig. 22.

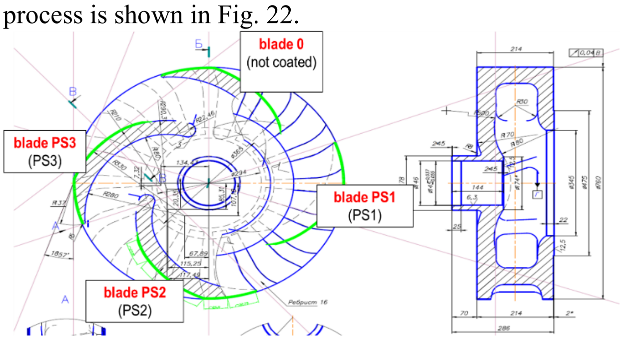


Figure 21. Cladding strategy of the impeller

Figure 22. Impeller cladding

For cladding the cover plate, only Powder System 3 was used. The cladding strategy was ring-shaped, starting from inside to outside (Fig. 20-21). The cladding time was approx. 180 min. (laser 'on' time).

Geometrically, the cover plate is much easier to coat because it is a simple disk shape. But unfortunately, many problems occurred during the cladding procedure. The coating at the inner area cracked, and delamination was found (Fig. 20-21). The reasons for this could be:

- repair welding in the past on the cover plate
- preheating necessary
- horizontal cracking

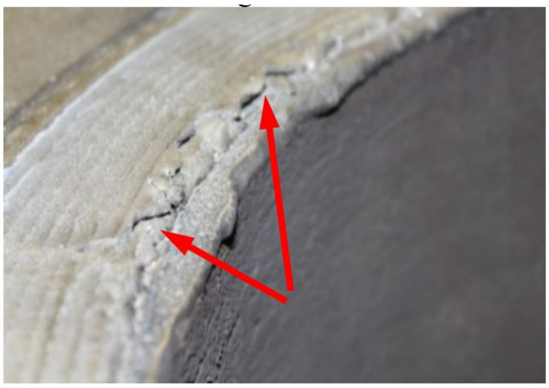


Figure 23. Cladding of cover plate (delamination of the coating)

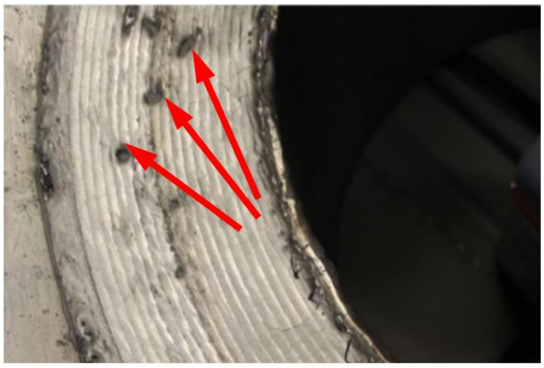


Figure 24. Cladding of cover plate (pores in the coating)

Additionally, the coating shows some holes or open pores (Fig. 20-21). The reasons could be:

- casting defects
- pollution in the cast iron
- carbon or manganese-sulfide inclusions

For repair, the delaminated cladding layer areas were removed by hammer and chisel (Fig. 22, Fig. 23). Then, in a second step, a re-cladding with two layers was conducted:

- 1st buffer layer: only PS3 without Carbides (thickness ~1.0 mm)
- 2nd hard-facing layer: Powder System PS3 (thickness ~1.5 mm)

After re-cladding, the bonding of the coating was much stronger than Fig. 20-21, but still some cracks and holes were detectable (Fig. 24). To repair the leftover pores, the holes were filled with a single laser beam (Fig. 25).

Figure 25. Removed laser cladding at inner area

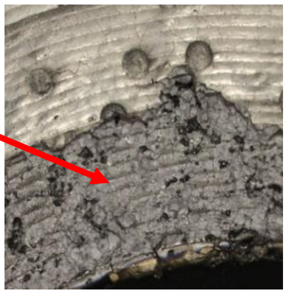


Figure 26. Detail of removed laser cladding

Figure 27. Re-Cladding of cover plate

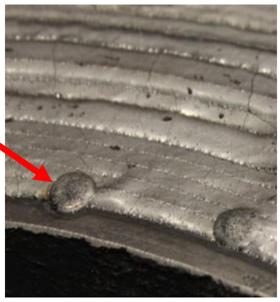


Figure 28. Repair of holes with single laser beam shot

After repairing all effects of the impellers and cover plates, these parts should be mounted and operated in the processing plant.

IV. Conclusions

Three different types of powder systems were introduced into the pump parts. During a real-life trial, each powder system showed individually different performances. Comparison between powder systems, which characteristics from each other in terms of hardness, roughness, and grain size, supported the effort to gain more information on the actual performance results. Uncertainties like tearing and unwanted vortices on the cover plate occurred. To use material hardness and wear resistance to higher efficiency, we need to cover all surfaces with different thicknesses, depending on wear rate of the part being studied.

After coating, the three parts could be assembled before the usage. If all areas affected by wear could be coated, a much more suitable substrate material for the welding/coating process could be selected.

Finally, the test shows that further process optimization is necessary to improve the coating quality. The following steps are suggested for further investigation:

- use ductile buffer layers to improve the adhesion and reduce cracking
- use preheating techniques, e.g., induction heating, to improve the adhesion and reduce cracking
- for the cover plate, the use of a rectangular spot cladding head could be beneficial, e.g., cladding with COAX11V6 with 45 mm cladding track with lower cooling rates.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Professor Gunther C. Stehr is the project leader Professor Ariunbolor Purvee, Professor Purevdorj Batkhuu, Professor Battsengel Baatar are as project members. Professor Ariunbolor conducted the research; Professor Gunther C. Stehr analyzed the data; Purevdorj Batkhuu and Professor Battsengel Baatar wrote the paper and all authors had discussed and approved the final version. The corresponding authors are Professor Ariunbolor Purvee and Professor Gunther C. Stehr.

Acknowledgment

The authors would like to thank the Mongolian Ministry of Education, Culture, Science and Sports for funding this project. For their active contribution and cooperation in this project, we would like to thank the Erdenet Mining Corporation employees (Dr. B. Chinzorig, Mr.B. Baasansuren, and Mr. Khosbayar).

We would also like to thank Prof. Dr.E. Beyer, Prof. Dr. C. Leyens from the Fraunhofer Institute for Material and Beam Technology and the Institute of Material Sciences, Dresden University, Germany and the Faculty of Engineering at the German Mongolian Institute for Resources and Technology for their important contributions and technological support as well as for the investigations regarding the materials.

References

[1] "Pumps GRAT, GRAK and GRAU. buy in Ufa," Construction Equipment. [Online]. Available: https://ru.all.biz/en/pumps-grat-grak-and-grau-g1796468 (accessed Aug. 10, 2021).

[2] M. M. N. Frøjk, N. F. H. Bjergmark, R. L. Bjerg, R. Gomila, and P. Valero, "Metal to composite: Redesign of centrifugal pump impeller," in *Proc. The 8th Student Symposium on Mechanical and Manufacturing Engineering*, pp. 1–8, 2020.

[3] S. Zanzarin, "Laser cladding with metallic powders," *Trento*, 2015.

[4] B. D. P. G. etc Animesh Das, "Rockwell hardness lab report," Shibpur, 2005.

[5] I. Arnardóttir and L. Daghini, "Analysis on steel composition and its Effect on weld quality," Stockholm, Swedish, 2014.

[6] M. M. Khruschov, *Principles of Abrasive Wear*, Elsevier Sequoia S.A, 1974.

Ariunbolor Purvee She is a professor and the program coordinator of Energy and Electrical Engineering at the German-Mongolian Institute for Resources and Technology. Sha has a teaching and working experience in both of higher education and industries in Mongolia for more than 28 years. Her research fields are online condition monitoring of electrical motors, power quality, dynamic simulation based on MATLAB and product simulation based on engineering statistics. More detail information is from the link: https://www.gmit.edu.mn/eng/member/14

Gunther C. Stehr has been studying Mechanical Engineering at Freiberg university, Germany, and received his Ph.D. degree in Mechanical Engineering in the field of tribology and wear investigations. After working in a company and a research institute for applied sciences in the field of industry tools and materials for more than 11 years, he moved to Fraunhofer-Institute for Material and Beam Technology (IWS) Dresden, Germany. Here, he was responsible for LASER cladding systems as well as thermal coatings for industry applications. In 2015, he was promoted to the Dean of Engineering Faculty at the German-Mongolian Institute for Resources and Technology (GMIT) in Ulaanbaatar, Mongolia. Since 2019, he is working as Professor for Mechanical Design and Machine Elements at University of Applied Sciences (HTW) in Dresden, Germany. LinkedIn: https://www.linkedin.com/in/gunther-stehr-79459591/

Battsengel Baatar Battsengel Baatar is a professor of Chemistry at the German-Mongolian Institute for Resources and Technology. She received. Her Ph.D degree in Chemistry in Institute for Technical and Macromolecular Chemistry of RWTH Aachen, Germany. Her research fields are mineral and electrochemical processing. She has been working in higher education institutes for more than 20 years. More detailed information is from the link: https://www.gmit.edu.mn/eng/member/3

Purevdorj Batkhuu is a professor at the Mechanical Department of Erdenet Technology School, the Branch of Mongolian State University of Science and Technology. He has 29 years of teaching and research working experience in the field of Materials Science and Processing. His research fields are “Structure and Properties of Wear Resistant Materials such as High Chromium White Cast Iron and High Manganese Steel”, “Wear process and Refurbishing technology of mining machinery parts”, “Hard facing technology”. He completed a project related to the study of Mechanical Properties and Microstructure of High Chromium White Iron (ICH28N2) treated by laser deposition in South Dakota School of Technology and Mining, the USA in 2016-2019.