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# RECONDITIONING OF COMPRESSION MOULDS BY LASER CLADDING

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**Abstract:** This research addresses to the reconditioning of a compression mould used in automotive industry for manufacturing of rubber seals. The reconditioning process have been carried out using an CW Coherent diode laser with a maxim in power of 1000 W and a cladding head made by PRECITEC, manipulated by means of an CLOOS robotic arm synchronised with a rotational table. The NiCrBSiFeC powder (commercialised as Oerlikon Metco 15E) was used as filler material for repairing the MOULD STEEL 1.2738. Crack free and dense coatings were obtained with similar hardens and wear resistance of the base material. The samples were analysed by optical and electron microscopy and by EDS micro chemical analyses.
**Keywords:** automotive industry, rubber seals, reconditioning process, compression mould, laser cladding

## 1. INTRODUCTION

Nowadays, the laser cladding process is well known as the preferred repair technology for pistons, shafts, mouldings parts and so forth. Compression or injection moulding and die castings are the most used technology for fabricate small parts of metals and non-metals alloys, polymers, thermoplastics and composite materials.

Unconcerned the used materials, the forming process is characterised by repeatable cycles of fast heating and cooling of the moulds which conduct to a premature wearing of the moulds cavities and active parts.

The die-casting moulds and injection moulds durability is directed influenced by different factors such us: thermal stress due heating and cooling, abrasion wear, impacts, corrosion wear, adhesion wear during the casting extraction [1, 2, 3]. All these factors have a negative impact to the lifetime of the casting/injection moulds with direct consequence on the quality and production rates of the components and to the final production costs. According to Chen [4], 80 % of the mould and dies used in the automotive industry will be repaired/reconditioned during the production life-spam. In the automotive industry, up to 15% of the total production cost of components fabricated by moulding and casting is related with the durability and the lifespan of the mould and dies [5]. Moreover, an unexpected failure of a mould/die can produce lots of under-quality casted pieces and production delays with further increasing of production costs.

Today, the fast production requirements of the automotive industry impose new methods to improve and to repair the mould and die components from the production lines. Conventional reconditioning techniques (TIG welding, MIG/MAG welding, thermal spraying, flame brazing) have been replaced by the laser technology which is the current solution for restoring damaged components from aeronautics [6, 7, 8, 9], automotive [10] and other industrial fields [11]. The laser technology through his characteristics of local fast heating and cooling is used for surface re-melting, laser cladding, laser alloying and laser heat treatments with minimal heat affected zones of the processed component. From all the available techniques, the laser cladding with injected powder have the most potential for reconstruction of complex 3D active parts and cavities of worn mould and dies.

Advantages, such us improved bonding of the coated material and substrate, easy automatization and high precision and low heat input resulting in low distortion of the repaired parts validates the laser cladding as an innovative repair technology. Moreover, the laser cladding benefits from the unlimited possibilities of alloyed powder recipes that can be designed for any specific repair situations [12, 13].

Thanks to these advantages, laser cladding is still the subject of numerous repair and reconditioning studies involving metal matrix composites, amorphous coatings, ceramics and gradient claddings. Kattire et all [14], use an CW CO2 laser to optimise the process parameters for CPM 9V cladding on H13 tool steel for die repair applications. Enhance of the die life is reported due to the hard vanadium carbide and low dilution. In a similar study [2], AISI H13 steel damaged by fatigue cracks was repaired by laser alloying with cobalt- and iron-based powders. The preplaced powder technique was successfully used to surface re-melting and block all the cracks retained on the original surface. Using the same laser cladding process studies are conducted for restauration of aviation parts such us Ni superalloy turbine blades. As particular case, the Ni superalloys with 9% Ti/Al are hard to recondition due to the high reactivity of the titanium with oxygen promoting solidification cracking and grain boundary liquation cracking. Guijun Bi [15] repairs damaged Ni super-alloy jet engine blades by laser cladding with NiCoCrTiAlMoV and use a closed-loop process control system to regulate the laser power in order to no overheat the melt pool and the blade. Good results are reported due to the precise control of the input process parameters.

In this study, various compression moulds used for manufacturing of rubber sealings have been chosen for restauration. Aims of the study is to present the feasibility of the reconditioning process for the active edges of a compression mould.

The mould is fabricated by MOULD STEEL 1.2738 (AISI P20+Ni). The materials compatibility, microstructure and mechanical behaviour is discussed.

## 2. MATERIALS AND METHODS

### — Requirements

Moulds and dies used in the automotive industry are subjected to premature wear due to the repeated moulding cycle time, heating-cooling and ejecting the piece. Fatigue, thermal shocks, corrosion and abrasion are several sources that can damage the moulds. Even mistakes in manipulation, overheating or using of tools to remove sticky parts can be sources of major damage of moulds. Figure 1 exemplifies two compression moulds with medium signs of wear on the active edge.

Figure 1. Examples of compression mould with signs of wear

### — Materials

It must be noted that for local reconditioning of the compression mould, the coated material, besides metallurgical compatibility with the mould material, must have low cracking susceptibility, low melting temperature in order to not overheat the entire mould and good machinability after the deposition. For this reason, it was be chosen an alloy with lower hardness but with very good milling proprieties necessary for remanufacture the active sharp edges.

The coating material for reconditioning the P20 steel was Metco 15 E. The chemical composition of the powder and base material are presented in table 1.

Table 1. Chemical composition of the powder and base material

| Material | Element wt. (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C % | Ni% | Cr% | B% | Si% | Fe% | Mn% | Mo% | P% | S% |
| P20 + Ni | 0.44 | 0.98 | 1.94 | - | 0.28 | 94 | 1.32 | 0.17 | 0,01 | 0,02 |
| Metco 15 E | 1 | Bal | 17 | 3.5 | 4 | 4 | - | - | - | - |

### — Methods

The experimental reconditioning of the compression moulds has been realised using a CW diode LASER, Coherent 1000, with a maximum output power of 1000 W. The laser beam was focused (200 mm focal length) by a Precitec YC 50 cladding module manipulated by means of a robotic arm CLOOS synchronised with a rotation table. The powder was preheated (70°C) and delivered through a Thermatech AT-1200HPHV feeding device.

The optimal parameters for the laser reconditioning have been chosen considering our previous study [16, 17]. Depending on the wear signs and the desired clad geometry have been used different parameters for each ring edge (table 2).

Table 2. Laser cladding parameters used for the reconditioning process

| | Laser power [W] | Power density [kW/cm²] | Cladding speed [cm/min] | Powder feed rate [g/min] |
|---|---|---|---|---|
| R1 (ring edge 1) | 450 | 14.33 | 24 | 4.5 |
| R2 (ring edge 2) | 450 | 14.33 | 22 | 4.5 |
| R3 (ring edge 3) | 450 | 14.33 | 20 | 4.5 |

After the reconditioning process, the moulds have been sectioned and prepared for metallographic analyses by grinding, polishing and etching with 1:3 $HNO_3$ / HCl reagent. A LEICA DM ILM LED optical microscope and a SEM: Quanta FEG 250, FEI (The Netherlands) at 30 kV for electron microscopy and EDX with Apolo SSD: detector, (EDAX Inc. US) for quantification of the chemical elements have been used for sample examination. The hardness testing was performed ex-situ by a MICROMET – 5124VD Buehler micro-durometer capable of loads from 0,5 gf up to 2000 gf.

## 3. RESULTS AND DISCUSSIONS

The laser cladding capability to repair compression moulds is demonstrated by partially or complete repair by laser cladding of four compression moulds used for manufacturing of calliper piston ring gasket. These types of moulds are used in the hot compression mouldings process designated for the automotive industry. As previously stated, the active edge of the mould is subjected to impact and adhesion wear due to the open-close cycle of the moulding process.

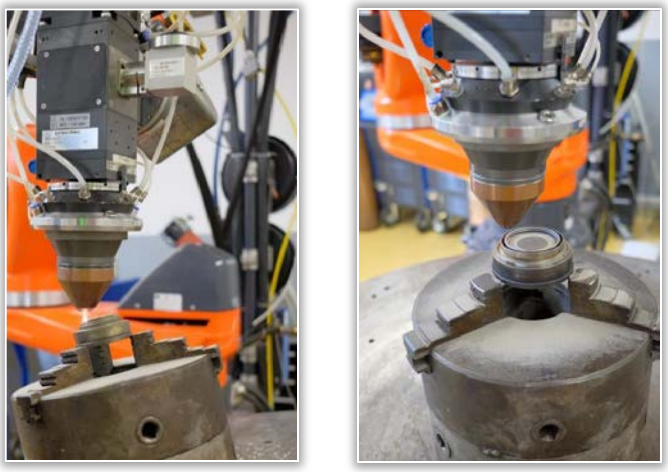
Figure 2. Compression mould during the reconditioning process

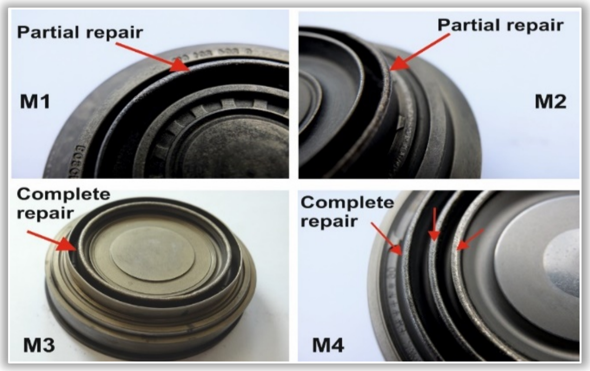


Figure 3. Compression mould after the reconditioning process

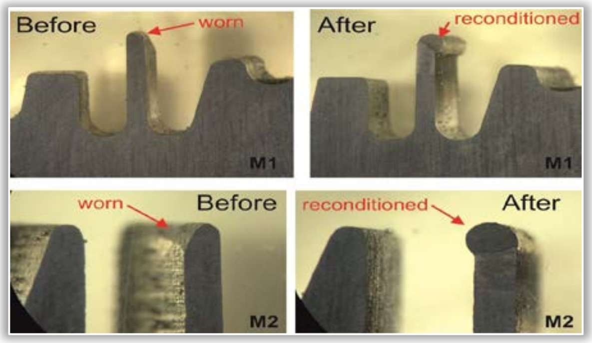


Figure 4. Cross section of moulds M1 and M2, Before and After the reconditioning process

In the figure 3 is presented the appearance of different compression moulds (male and female side) after the laser cladding reconditioning process. In the case of M1 and M2 moulds only a partial repair of the active edge was necessary and moulds M3 and M4 were reconditioned on the entire ring edge. The cross-section profile of the reconditioned edge of moulds M1 and M2 are presented in figure 4. For better understanding of the reconditioning process, the M4 mould will be further analysed and discussed in this study. One single track has been laser cladded on each ring edge of M4 mould and as it can be seen in figure 5, the coated material is uniform without visible defects or unmelted powder particles. Cladding speed of 20, 22 and 24 cm/min was chosen in order to not overheat the ring edges but in the same time to obtain a good adhesion with the substrate.

Each ring edge has been repaired with adapted speed in accordance with the ring shape geometry and depth of the worn marks. Figure 5 shows at different magnifications the cross-section profile of the three edges, R1, R2 and R3, which have been repaired. The cladded layer is free of cracks and present a good bonding with the mould substrate. The coating is dense and present a typical Ni based superalloy microstructure composed of columnar dendrite with the growth direction perpendicular on the base material. Only in the case of R3 edge, a well-defined non-interference line (planar growth) between the two materials is visible. This edge was repaired using a lower speed therefore a higher temperature and thermal gradient was created during the laser processing producing the planar growth at the bottom of the melted pool (fig. 5 h).

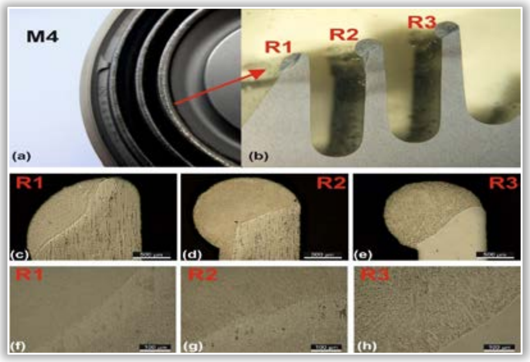


Figure 5. Cross section of the reconditioned ring edge of mould M4

The SEM analyses of the ring edge R2 is presented in the figure 6. The details show the diffusion zone characterised by the pronounced dendrite formation with pyramidal growth in the direction of the thermal gradient. The dendrite formations are smaller and uniform distributed in the Ni matrix on the upper part of the coating where the distance from the interface with the substrate increase.

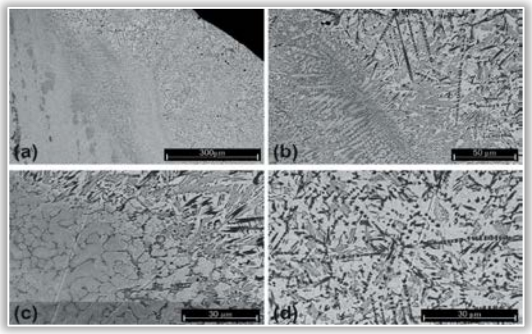


Figure 6. SEM micrographs of the reconditioned ring edge R2 from figure 3

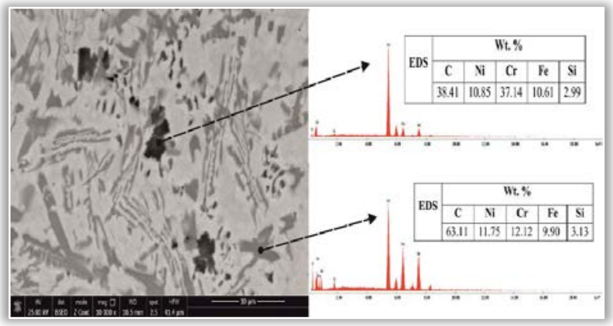


Figure 7. EDS analyses of different phases identified on the clad cross-section (ring edge R2)

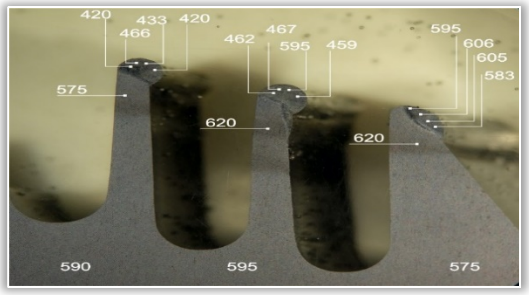


Figure 8. Results of the microhardness testing of the mould M4. Indicated values are Vickers microhardness tests results at 200 g load: HV02

The EDS micro chemical analysis indicates the presence of hard phases distributed in the nickel-iron matrix. The high amount of iron is resulted by the mixing and diffusion phenomena with the substrate. In the figure 7, it can be seen several darker areas that indicates, according with the EDS results, the presence of phases rich in C and Cr, chromium carbides that are embedded in the Ni-Fe matrix. The presence of hard phases ensures the hardness and wear resistance of the coating.

The hardness of the cladded layers is influenced by the microstructure, grain size and dilution with the substrate. Figure 8 show the microhardness values measured on the coating, heat affected zone and base material of the mould 4 (M4). The highest hardness (~ 600 HV02) is registered on the R1 ring mainly due to the low dilution with the material. The obtained hardness is in accordance with the technical specification of the Metco 15E alloy deposited by laser cladding. In the case of R2 and R3 cladded area, the microhardness is with almost 150 units lower mainly due to the diffused iron from the substrate. The heat affected zone is hardened and have 620 HV02 compared with the base material characterises by a microhardness of 575-590 HV02.

## 4. CONCLUSIONS

Laser cladding with coaxial powder injection is a suitable technology for reconditioning of moulds/ dies used for injection or compression moulding processing. Dense and crack free cladded layers can be fabricated by this reconditioning technique and by parameters optimisation and fine-tuning the desired coating geometry can be obtained. The Metco 15 powder is well suited to be used as filler material due to his corrosion and wear resistance capabilities.

The following conclusions were derived from the exposed experimental study.

- Low heat affected zone can be achieved by using a reduced laser power
- Good metallurgy between Ni17Cr4Fe4Si3.5B1C coating and P20 + Ni steel was observed without signs of segregation or microcracks at the materials interface
- Comparable harness with the base material were obtained by optimising the process parameters.
- Laser cladding is a promising technology for reconditioning of moulds and dies, with reduced repairing time and prolonged exploitation time of repaired parts.

Further investigation will be carried out for testing the repaired moulds in exploitations conditions.

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