Laser Cladding and Alloying for Refurbishing Worn Machine Parts

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ABSTRACT

The subject of this research is to develop a technique for refurbishing worn machine parts by applying a new material to the eroded surfaces with the aim not only of replacing the worn out material but of obtaining surface layers with better service characteristics than those of the original part. Among possible ways of applying additional material to the eroded surfaces, cladding and surface alloying can be named. An infrared continuous CO₂ laser with a maximum power of 8 kW was used in the investigation. The laser was equipped with an optical system and a computerized table that allows rotation of the specimen as well as its movement in three directions with a wide range of travel velocities. A direct injection of an alloying powder in the laser beam melted zone at the specimen surface was explored as a way of surface cladding. The powder used for this purpose was a cobalt-base alloy, “Stellite”. The thickness and composition of the cladded layers vary significantly with irradiation conditions. A low content of iron (1%) in a cladded layer indicates that a significant amount of Stellite powder can be homogeneously introduced.

1. INTRODUCTION

Modern industrial applications require parts with special surface properties, for example, high corrosion and wear resistance and hardness. As a rule, alloys possessing these properties are very expensive and their utilization would drastically increase the cost of the parts. The most effective and economical approach to improving the ability of machine part and component surfaces to withstand harsh environments and high surface stresses is by creating surface layers that possess a high level of corrosion and wear resistance. In this way unique service characteristics can be obtained, such as a combination of high surface hardness with high impact strength of the bulk material. This approach can also be effectively applied for refurbishing worn machine parts.

Surface cladding and alloying can be produced by using a high-power laser. The difference between cladding and alloying is in the concentration of bulk material in the laser-treated surface layer. The layer treatment can be performed in such a way that the melting of the substrate surface will be limited to a minimum depth in order to provide a good fusion bonding between the laser clad material and substrate. As a result, laser cladding can produce surface coatings whose composition and properties are determined primarily by the clad material.

Alloying material can be introduced in the laser-treated area either from predeposited layers /1-4/ (for example, from painted or electroplated layers) or directly from sheets, wires or powders /5-8/. A direct powder injection into the melt pool produced by the laser beam on the substrate surface seems to be the most flexible and convenient technique. Its main advantage is a wide spectrum of alloys that can be deposited either by using the chosen alloy in a powder form or by injecting a mixture of different powders that would give the required composition. Another advantage that should be mentioned of this type of laser cladding is that it can be performed as a one-step procedure, without any preliminary surface preparation.

2. EXPERIMENTAL PROCEDURE

Irradiation was performed by using an infrared continuous CO₂ laser (Type ML-108, MLI Laser Ltd.) with wavelength 10.6 μm and maximum power 9 kW. The laser beam was focused with a lens having a working...
diameter of 70 mm and a focal distance of 500 mm. At this geometry a displacement from the focal plane by 7 mm increases the beam spot diameter at the treated surface by 1 mm. An industrial powder feeder Meteo 4MP was used for powder injection. Laser cladding experiments were performed on rods of SAE 4340 steel; a cobalt alloy Stellite 6 in a powder form was used as the alloying material, with argon as a carrier gas. The rod specimens were fixed at a computerized table that enabled rotation of the specimens as well moving them in three directions (Fig. 1).

The interaction between laser-beam, injected powder and rotating specimen results in the formation of a laser-clad stripe on the specimen surface that consists of the remelted volume of the bulk material together with the melted alloying powder (Figs. 2 and 3). The complicated form of melt penetration into the bulk is determined by the mode of power distribution within the laser beam. The used laser is characterized by a "ring" power distribution (TEM 01 mode) which results in the observed profile of the melt zone. A combination of specimen rotation and its movement in the axial direction allows treatment of the whole surface of the rod. The surface pattern obtained in this case (Fig. 2b) looks like a series of stripes, but in fact it represents a single spiral stripe wound on the rod surface. As a rule, the relation between the width of the melt zone and the rate of specimen advance in the axial direction is chosen in such a way that a partial overlapping of adjacent stripes is obtained.

The following conditions were varied during laser cladding experiments: beam power; beam travel velocity over the specimen surface (by changing specimen rotation speed); overlapping of adjacent stripes (by changing specimen speed in the axial direction); powder feeding rate (by changing carrier gas pressure); the size of the surface area to which injected powder is applied (by changing the distance between the feeder
nozzle and specimen surface) and also the incident angle of powder injection. All rods were machined prior to laser treatment in order to obtain a clean, bright surface having approximately the same reflectivity in all experiments.

3. RESULTS AND DISCUSSION

Fig. 4 presents cross-sections of two specimens that were treated under the same conditions except that the specimen in Fig. 4a was treated without powder injection. As can be seen, surface remelting did not take place in this specimen, although it is observed in Fig. 4b. The results confirms a known observation /1/ that powder injection increases beam power absorption and facilitates substrate melting.

The effect of the beam power on the depth of substrate melting depends on the rate of powder feeding. When the feeding rate is low, the increase of beam power results in a deeper melt zone and non-uniform thickness of the clad layer (Fig. 5). As a result, the content of the bulk material in the clad layer is also increased. At a high feeding rate (Fig. 6), an increase of beam power results in a higher thickness of the clad layer due to an increased melting of injected powder, whereas the substrate melting is not significantly affected. In this case, obviously, a lower dilution of the clad layer with the bulk material can be expected. It should also be noted that the content of the alloying element in the clad layer is uniform through the layer thickness (Fig. 7).

Under certain conditions the clad layer has an undulating surface and, as a result, a non-uniform thickness (Fig. 8a). This is undesirable because the required surface machining will remove a significant part of the clad layer. The undulating thickness appears when the region where the powder is injected is narrower than the width of the melt zone. Therefore, there are two ways of improving the quality of clad layers in this case, namely, either by diminishing the width of the melt zone or by increasing the distance between the nozzle of powder feeder and the specimen layer or, alternatively, by increasing the nozzle...
that a coarse porosity can appear in the clad layer if the ratio of the width of the remelt stripe to the thickness of the clad layer becomes relatively low (less than five according to /6/). In this case, the coarse pores are observed at the interface between the clad layer and the substrate, at regular intervals that correspond to the distance between successive beam runs (so-called “inter-run” porosity). To avoid this kind of porosity, the injection angle should not exceed 45 degrees. Repeated laser cladding can be successfully used as a way of obtaining a thick clad layer with a very low content of bulk elements in the surface layer. In our experiments the Fe content at the surface of clad layers was less than 1%.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

5. UK Patent No. App. 84 25716, Quantum Laser Corp., USA.
