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Effect of Diode Laser Surface Alloying of Commercial Tool Steel

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Abstract. The following review paper is a synopsis of the fundamentals of laser remelting and alloying, outlining some of its benefits compared with conventional heat treatment techniques of hot-work tool steel X40CrMoV5-1. A selective review of the experimental research carried out in this area is presented. The aim of such treatment was to harden and alloy the steel surface which had been previously coated with the paste consisting of the tungsten carbide and the inorganic binder. Development of the surface layer was observed in which one can distinguish the remelted zone, heat-affected zone and the transient zone. Occurrences of the un-melted tungsten carbide grains were observed in the structure and the increased tungsten content compared to the native material, whose variable concentration is connected with the molten metal fluctuation in the pool during alloying. The fine grained, dendritic structure occurs in the remelted and alloyed zone with the crystallization direction connected with the dynamical heat abstraction from the laser beam influence zone. It has the important cognitive significance and gives grounds to the practical employment of these technologies for forming the surfaces of new tools and regeneration of the used ones.

Keywords: Manufacturing and Processing, Heat Treatment, Laser, Alloying, Tool Materials.

1. Introduction

The moulding cast allows the performance of a lot of quantity of components with high-level complexity, fulfilling the mechanical specifications required, with a medium-low relative prices. The material of our study is steel used to make a lot of components of mechanized, as dies for moulding cast for example (Mateos *at al.* 2000). The design and the service-behaviour of the steel die are the most important factors in order to achieve the required specifications in moulding cast. These factors not only control the final dimensions and tolerances but even the surface finish. The thermal stress producing by hot-cooling cycles promotes little cracks which make the life of the die shorter (Jervis 1997). One die costs almost one million dollar and needs from months to years to be made. Improvements in the steel make better final components, but also a longer life of the die (Kusiński 1995, 1997, 2000). If the die has a longer life, the costs will be lower and also the energy consumption. The hot-work steel X40CrMoV5-1 is one of the most used steels to make dies because of its good properties in thermal fatigue, corrosion and wear away resistance. That is why the hot-work tool steel X40CrMoV5-1 is very used to cast aluminium, magnesium and their alloys (Bonek 2013, 2014). Figure 1 shows how is applied the laser technology in the automotive industry for different applications. The main advantages of using laser technology in this industry are: More versatility to applications with more diversity if

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we compare the dimensions and the kind of material, the thermal effect over the simple is lower, the process quality is very high, very high velocity of production, easy to integrate into robotic systems. In the Others (4%) sector are included the laser surface treatments (Lisiecki 2012).

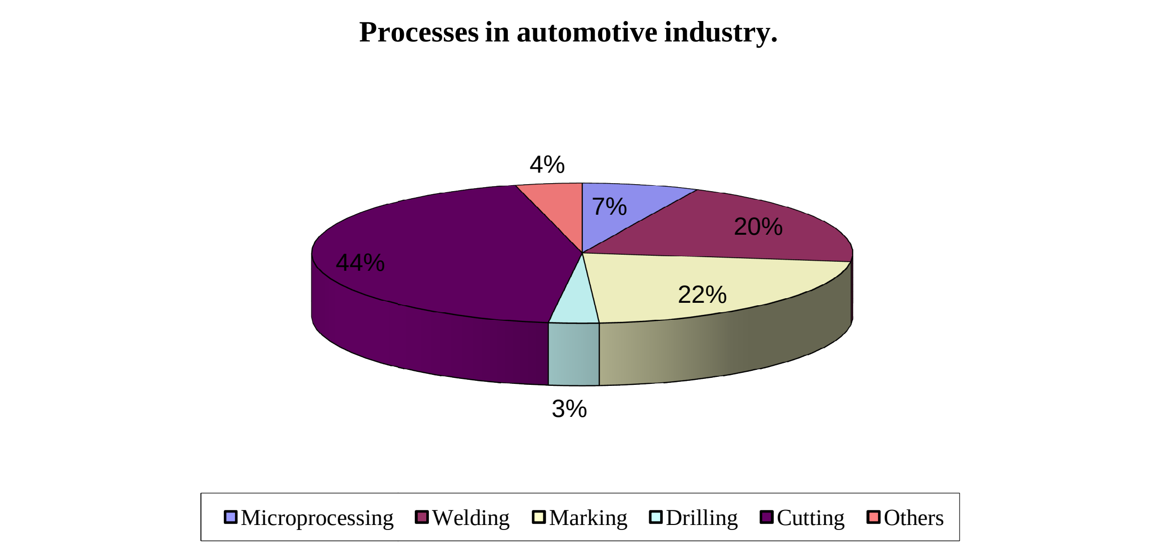

Fig. 1 Sector distribution in the processing of materials by laser meanings

The investigations about surfacing-alloys reveal that the surface treatments and the surface coatings are very good in order to protect the dies against the thermal fatigue, and increase the life of the die too. In fact, the surface coatings increase the resistance to abrasion because it provides higher hardness, toughness and corrosion resistance (Steen 2010).
One of this treatments could be laser surface treatment, which allows modify the properties of the surface of the material without modifying the core of it. These kinds of treatments make a very low grain and homogenous microstructure at the surface with a very short HAZ (Heat Affected Zone), providing a higher solid solubility by the alloying elements. The resulting surface has very good mechanical properties because the steel is melting and cooling in a very short period of time (10^4 – 10^5 times faster than conventional moulding), giving rise to a composition, distribution of the alloying elements and microstructural changes (Dobrzanski *at al.* 2015).

Employment of the laser surface treatment is justified both from the economical point of view and because the laser treatment, in many cases, ensures obtaining better mechanical properties of the processed surfaces, e.g., teeth of gear wheels or cutting tools edges, which could not be attained using the conventional surface treatment methods. The laser heat treatment includes operations which are conducted using the laser beam as the source of energy needed for heating the surface layer of the processed material, to change its structure for obtaining the relevant mechanical, physical, or chemical properties, improving service life of the processed element (Tański 2014).

The number of research centres in the world specialising in materials engineering in which the HPDL high power diode lasers are used grows steadily. Until recently, the widespread use of lasers for materials processing has been hindered by the size, complexity and high investment cost of the laser systems. The wavelength of the emitted radiation allows high metallic absorption, which when coupled with favourable spatial and temporal beam profiles allows the HPDL to achieve a high efficiency power density delivered to the surface layer of the heat treated materials is lower for the HPDL lasers compared to the monomode distribution characteristic for other laser types, and the energy is distributed uniformly on the rectangular