BENEFITS AND PROPERTIES OF TOOLS PROCESSED BY LASER BEAM

Němeček Stanislav

RAPTECH s.r.o., U Vodárny 473, 330 08 Zruč-Senec, Czech Republic,

Corresponding author: nemecek@raptech.cz

Laser hardening brings a great increase in part life and it is an industry-proven process, typically used for hardening of moulds, gears, shafts etc. It was mainly the recent advancement of diode lasers that turned it into a competitive process. The contribution describes the nature of residual stresses, the influence on hardness, tribological lifetime and fatigue properties of such parts. Investigations have to be performed in order to gain a comprehensive knowledge about effects on microstructure, hardness, surface properties of treated materials. This contribution contains results of a partial studies of laser hardening and cladding in industrial practice at RAPTECH company.

INTRODUCTION

Laser hardening and cladding offers short processing times and appreciable cost savings, as well as capabilities to accommodate almost any geometry, and control the depths and widths of the treated surfaces. In addition, laser processsed surfaces exhibit additional beneficial properties when compared to conventionally hardened surfaces. These include differences in tribological, fatigue, and corrosion behavior, specifically an improved wear life, fatigue and corrosion resistance.

Sheet forming dies for automotive industry may serve as a good example in this context. The car body consists of about 300 components, which represent a demand for about 750 pairs of press dies (progressive dies, punching and trimming dies). Car manufacturers launch about 120 new car models every year. Based on that number, the cost estimate for die making is 12 billion euro every year. Laser hardening of rounded and shearing edges may double the number of parts formed.

Differences in surface hardening technologies

In ***flame hardening***, the depth of heating is given by the relative speed of the flame movement across the surface. The efficiency of heat transfer to the material is poor and the surrounding surfaces become heated as well. As a result, the dwell time required for austenitizing increases, the grains in the material coarsen, and their boundaries may become burnt. The surface also develops a layer of oxides. In this process, the uniformity and control of temperature are limited and inaccurate. In induction hardening, the heat generated depends on electric resistance and current. The depth of heating is given by the frequency of the power source. The lower the frequency, the shallower is the hardening depth. Even with high-frequency induction heating, however, heating takes several seconds.

In **flame hardening**, as well as in **induction hardening**, the heating stage must be followed by sufficiently rapid cooling (using a water spray or polymer solution). There is an ever-present risk that steam and a vapor blanket may form during cooling, which would retard the heat removal rate and prevent the surface from hardening. Similar to the heat-affected zone in weld joints, there is a deep transition zone beneath the hardened layer. This is the zone in which the elevated temperature, though insufficient for hardening, has caused some changes in the matrix of the parent metal. Unfortunately, these changes are typically for the worse.

In ***laser treatment***, the austenitizing temperature must be achieved in the surface, as with the other techniques. However, thanks to rapid heating rates of thousands of degrees per second, the resulting transitional heat-affected zone is very thin.

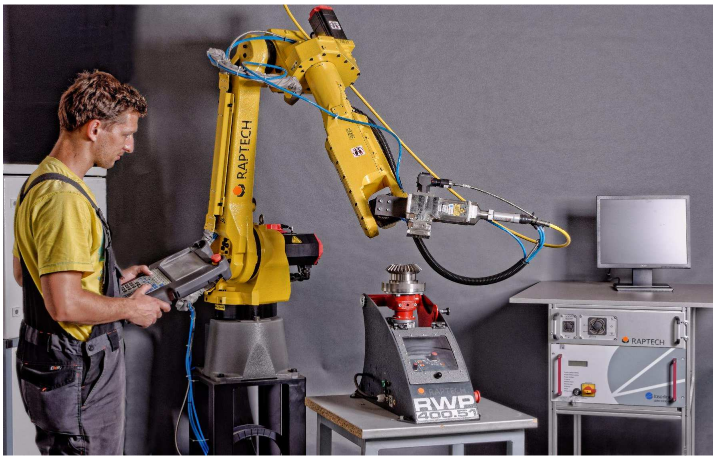
The maximum laser hardened depth is approximately 2 mm, depending on the heat conductivity of the material. The hardening depth can be controlled by the speed of the beam movement and by the temperature. To improve control, the process is typically monitored using a pyrometer linked to the laser source and operated by robot. By regulating the power input, this control loop can maintain a fixed surface temperature, thus providing uniform hardness and preventing local melting.

In the heating step, austenitizing temperature, that is, a temperature above Ac3, must be achieved in the surface layer of steel. Rapid heating with a laser beam is one of the factors which minimize the distortion of the part heated. As the material around the laser spot remains cold, it does not expand, and the distortion does not occur. Another difference from the other surface hardening techniques lies in the heat removal mechanism which is based on self-quenching. It involves rates of several thousand °C/sec. There is no need for cooling the surface using a liquid supplied from outside because the interior of the part remains cold and absorbs the heat by conduction at a sufficient rate (i.e., cooling by convection). One can therefore assume that phase transformation begins from within the part and the surface is the last to cool down.

Laser beam hardening is much more favorable to the material in terms of crack susceptibility than other techniques. The steep thermal gradient from quenching causes severe (tensile) stresses which lead to surface crack initiation. In laser hardening, however, the cooling process begins by heat removal to the cold interior of the workpiece. The temperatures thus equalize gradually from within the part. This minimizes the resulting stresses and eliminates cracking.

Laser cladding is increasingly being used to repair molds and dies. As with hardening, the method is non-invasive and minimally affects the structure around the weld. It even allows you to create 3D structures, similar to additive manufacturing. Molds with a size of centimeter to a few meters and a weight of tens of tons can be repaired. The service life of tools repaired in this way is even longer than with original tools produced by machining and heat treatment, probably due to the fine-grained homogeneous microstructure.

Continuous wave laser sources are preferred for laser hardening applications. The most widely used systems rely on diode or fiber lasers. Surfaces of experimental specimens were laser treated using the facilities of the RAPTECH company, 3kW high power diode laser from LaserLine GmBH with a dual-channel pyrometer for temperature measurement. The optical head is installed on FANUC robot, see figure bellow.



ACKNOWLEDGMENT

This contribution presents results of the project Additec TH03020130, supported by Technological Agency of Czech Republic.

REFERENCES

1. Fiedler L., Monitoring of Wear and Dynamic Impact Loading of Laser Surface Hardened Steels. Bachelor thesis, University of West Bohemia, 2012.