RENOVATION OF TOOLS WITH LASER CLADDING: OFF - AXIS POWDER INJECTION

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Abstract

This article represents in complex form the results of surface layer creation by using laser beam. It contains results of research for surface layers creation by laser beam. It describes methods and results of technological, material research as well as study of clad structure created by laser beam. This article includes cladding with powder and wire filler material with their direct feeding to the cladding process. The possibility of clad exploitation is analyzed for the various industrial applications such as clad upon sharp edges used in the tools production and renovation for the engineering.

Key words

renovation, laser cladding, tool steel, filler materials – powder

Introduction

There are lots of technologies that are used for cladding of new material surface or surface worn by renovation. Laser beam cladding is nowadays used in broad range as a part of manufacturing technology and as a means to extend the life of machines, devices and tools. Laser cladding is characterised as an application of filler material onto the surface of basic material. Applied filler material may be in a form of wire, tape or powder. Laser cladding uses laser heat source (radiance) that enables application of thin layer of required material onto the current base. The applied material can be fed onto the basic material by several methods, e.g. direct feeding of powder coaxial with the laser beam axis or sidelong angle-wise or by wire feeding.

The characteristic features of this process are:

- precise, automated deposition of a layer of material with a thickness varying between 0.1 millimeters and several centimeters,
- metallurgical bonding of the cladding material with the base material,
- helps reduce processing time,
- low heat input into the substrate,
- a wide selection of homologous and non-homologous powder materials,
- the ability to process virtually any type of metal alloy.

Laser cladding is a deposition welding process in which a layer of powder is deposited on the substrate material, and these materials are fused by metallurgical bonding through the action of a laser beam.

In off-axis powder injection the nozzle is positioned lateral to the laser beam. The position is determined by the angle between nozzle and work piece (α) and the distance between nozzle tip and work piece (*l*) as shown in Fig.1.

Powder feeding nozzle consists of two holes. Powder floats through the central hole with the help of carrier gas, most frequently Ar. Shielding gas floats through the end hole. It sets bounds to the stream of powder. He, Ar, N are used as shielding gases. Since the powder stream diverges when leaving the nozzle *l* should be as small as possible to achieve a high powder efficiency (= weight of clad track per unit length versus powder amount fed per unit length). Typical values of *l* range from 8 to 12 mm.

Since the nozzle is positioned close to the melt pool it is exposed to laser beam reflections. Therefore the nozzle should be water-cooled to ensure long-term operation without any damage.

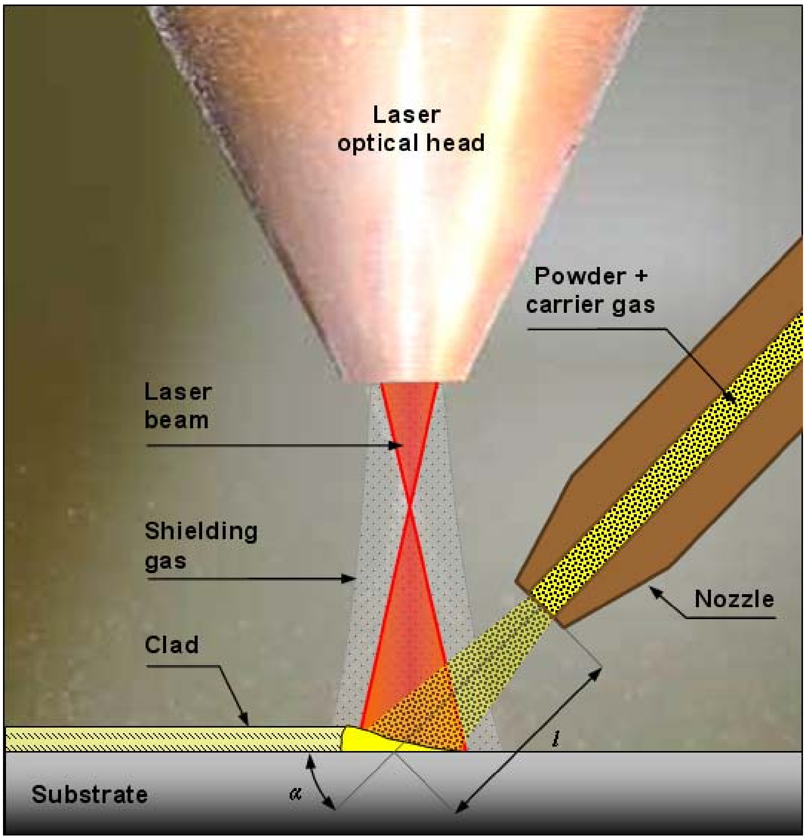

Fig. 1. *Principle of laser beam cladding: off - axis powder injection*

Experiment

As a basic material for laser beam cladding was used tool steel type 90MnCrV8. It is carbon steel, low carbon steel. It is used for tool production concerning tools for cold cutting and mechanical working. Welding property of this steel is quite difficult. Steel plates made for cladding of filler material were used in the experiment. In the Table 1 is chemical composition of steel type 90MnCrV8.

CHEMICAL COMPOSITION OF STEEL 90MnCrV8 *(19 312)* Table 1

C	*Mn*	*Si*	*V*	*Cr*	*Ni*
0,75-0,85	1,8-2,15	0,15-0,35	0,1-0,2	max.0,25	max.0,35

For cladding was used filler material in the powder form (Table 2). Filler material – powder Höganes 1660-12 is metal powder on base Ni. The reached hardness of this powder is 60 HRC. This filler material is used to creating of anticorrosive layers. Ni powders with main additives, boron and chrome, are used most often.

CHEMICAL COMPOSITION OF HÖGANÄS 1660 -12 POWDER Table 2

C	*B*	*Si*	*Cr*	*Fe*	*Ni*
0,6	2,8	3,7	14,3	3,5	Bal.

CO_2 laser device Feranti Photonics, type AF8, with performance 8 000 W, and wavelength 10,6 µm was used for cladding (Fig.2). Defocused laser beam was used and it was vertically directed towards the worked surface. Welding material was fed into the place of interaction with the beam through the slant feeding spout in an angle of 30 degrees.

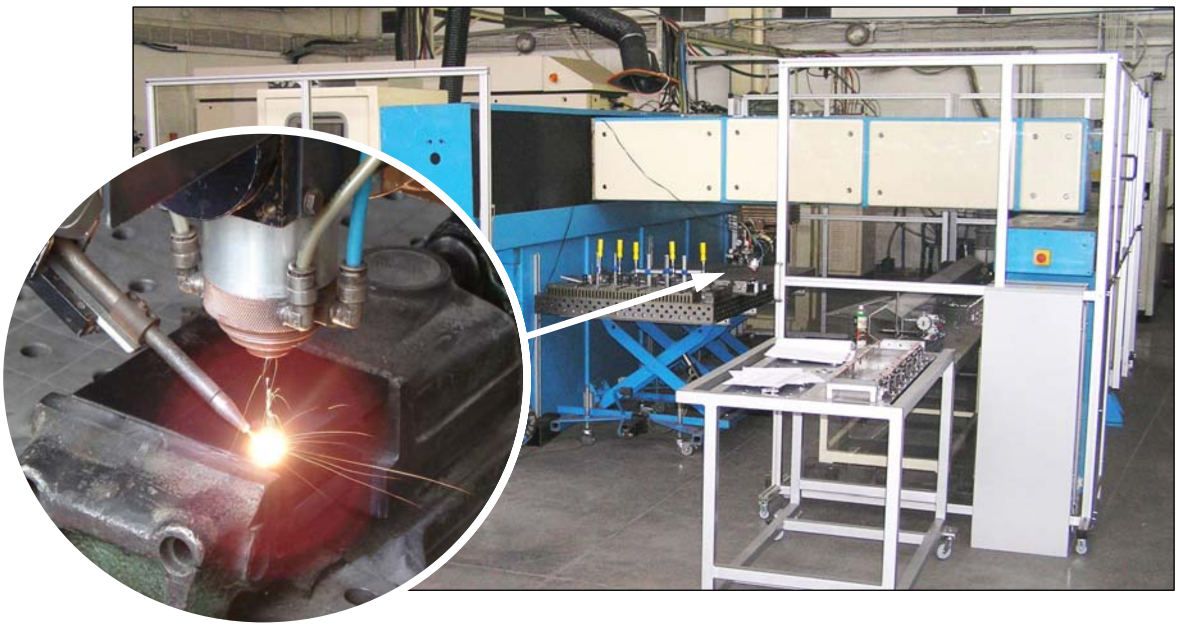

Fig. 2. *Laser device used for laser cladding*

Parameters of cladding are given in Tab.3.

PARAMETERS OF CLADDING Table 3

Parameters			**Filler material**
			Höganäs 1660-12
Output		*[kW]*	4
Speed of cladding		*[mm/s]*	5
Flow rate of	*shielding gas*	*[l/min]*	15
	carrier gas	*[l/min]*	9
Inclination angle of nozzle		*[°]*	30
Defocusing		*[mm]*	27

Attained results

Clad, made by the powder Höganäs 1660-12, was evaluated following its main mechanical, metallurgical and qualitative properties. The experiment was evaluated in terms of the surface forming, macrostructure, microstructure and hardness.

On the Fig.3, we can see the surface forming of the clad. Clad presented the surface forming with minimal undulation both at longitudinal and cross directions. Clad surface was roughened, this was caused by welding of redundant powder particles to clad surface. Clad was remelted enough and metallurgically connected with the substrate. It did not feature any greater disintegrity like welding defects, poruses or cracks.

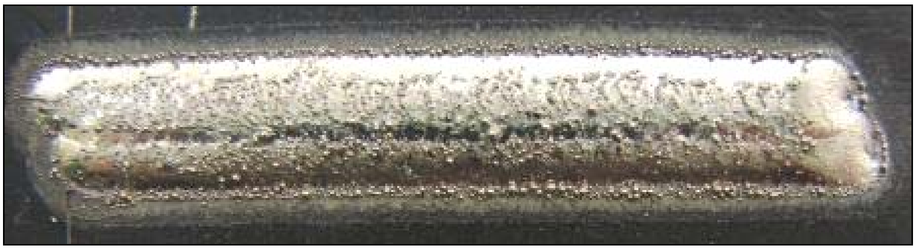

Fig. 3. *Surface formation of clad*

Fig. 4. illustrates the macrostructure of the clad. Cladding layers are thin, homogeneous and smooth, several tenths of millimetres thick. Cladding layers are uniform throughout whole cross-section and individual cladding beads are perfectly covered and remelted reciprocally without any welding defects between the individual cladding beads as well as between the clad and the base material. Dilution zone between the layer and the base material is sharp, without any area mixing, contiguous, relatively plain and without any integrity defects. These facts point to the perfect metallurgic joint between the weld and the substrate. Further, we can observe the clearly recognizable heat affected zone which is homogenous throughout whole cross-section. Clads are integral and without any existence of cladding defects, cracks or poruses.

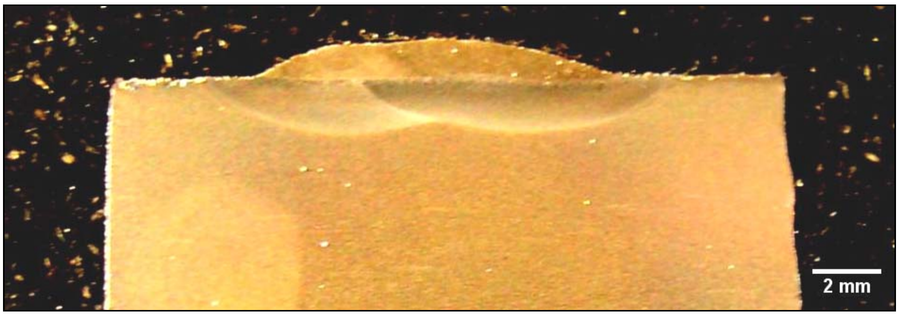

Fig. 4. *Macrostructure of clad*

In the Fig.5, there is a microstructure of the clad made out by the powder Höganäs 1660-12. The clad microstructure (Fig.5a) is formed by dendrites and eutecticum. These are characterized by a very delicate and inexpressive pattern. Eutecticum, which is secreted in the interdendritic environment, is of lamellar character. Picture *a* shows that dendrites and eutecticum ratio is identical.

Dilution zone between the clad and the heat affected zone (Fig.5b) is without any area mixing, contiguous, and relatively plain, without any integrity defects. These facts point to the perfect metallurgic joint of the clad and the substrate. Martensitic structure occurs in the heat affected zone.

In the Fig.5c, we can see the transition from the heat affected zone to the base material where the refined grain and the base material structure are formed from a ferrite and carbides mixture.

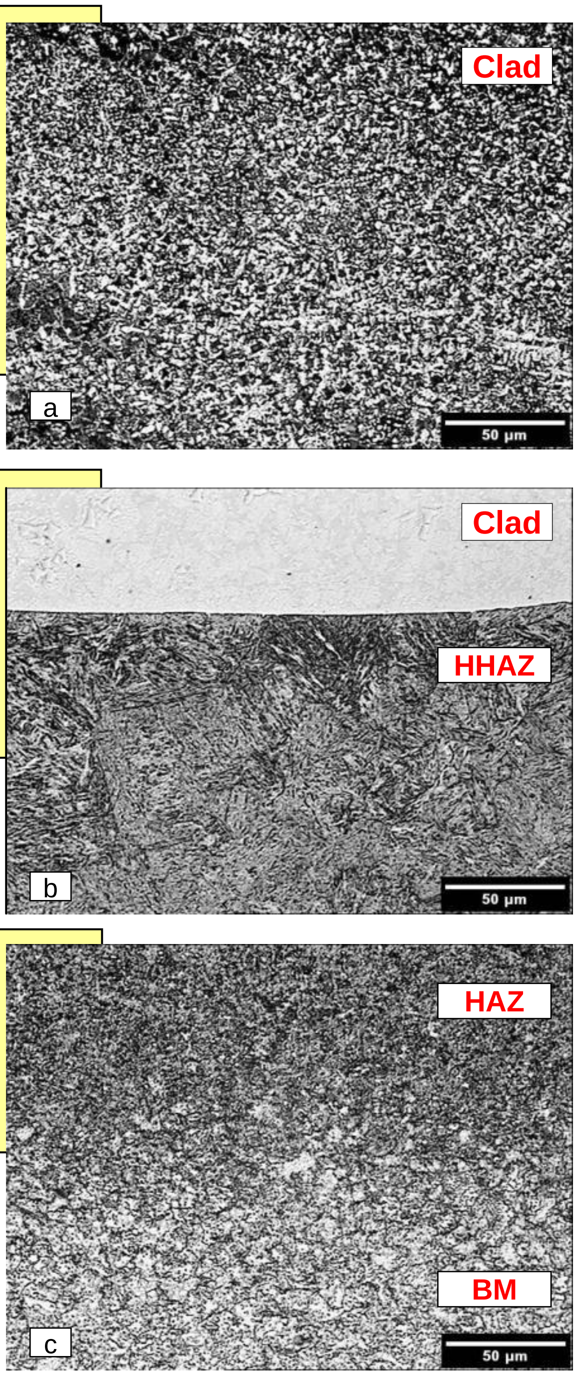

Fig .5. *Microstructure of clad*

Measured and computed data were processed as average. Particular figures of individual indenters hardness in single areas were transferred into the graph depending on microhardness $HV_{0,1}$ and the distance of individual indenters in the sample measured in millimetres.

On the graph (Fig.6), hardness figures are measured and processed for the purposes of the sample made by laser cladding with using the powder Höganäs 1660-12. Clad reached high levels of hardness, 687 $HV_{0,1}$ at average throughout whole cross-section. Hardness figures started to fall after achieving the melting limit and the transition to the heat affected zone. In the heat affected zone, the hardness figures rose again only after the transition to the base material where they continuously fell again to the hardness figures corresponding with the figures of the base material.

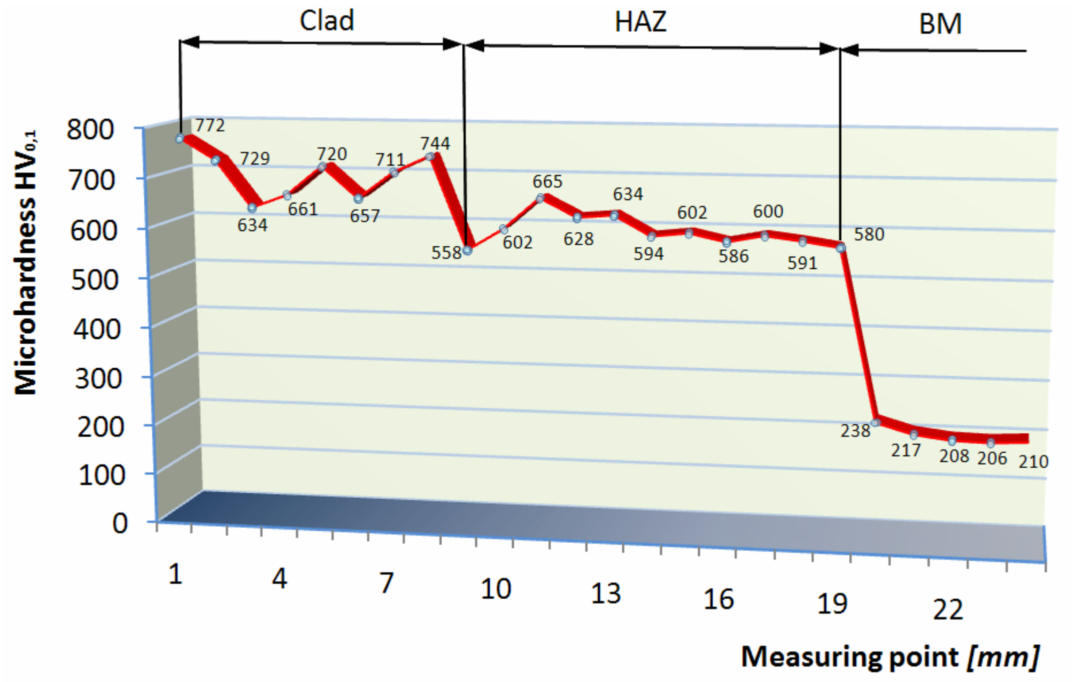

Fig. 6. Course of microhardness

Conclusion

Laser cladding is today progressive method of precise cladding of tools and moulds, with aim to obtain resistance against wear and specific characteristic of surface coatings of filler, in the process is lifetime extend.

Conventional methods use welding to retrieve these damaged components however, these methods are usually destructive due to the highly distributed temperature over the area of repair. This thermal destruction causes a low mechanical quality, crack, porosity and very short life of the component. Laser cladding can provide a permanent structural repair and renovation of tools that are generally considered unweldable by conventional methods. The success of the laser cladding technology in this area is due to the small heat zone, rapid solidification, increased cleanness, lower dilution, and increased controllability over the depth of heat-affected zone. On the ground of done experiments we can say that laser beam presents a general-purpose tool for metalworking not only by welding and separation, but at present especially by creating surface layers of specific properties. It is possible to achieve quality weld overlays of required utility properties while having optimized cladding parameters so the solved technologies can be fully utilized in practice.

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