Hard, Wear Resistant Metal Surfaces for Industrial Applications through Laser Powder Deposition

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Abstract

Laser Powder Deposition (LPD) is a technology capable of modifying a metallic structure by adding the appropriate material to perform a desired function. LPD offers a unique fabrication technique that allows the use of soft (tough) materials as base structures. Through LPD a hard material can be applied to the base material with little thermal input (minimal dilution and heat-affected-zone {HAZ}), thus providing the function of a heat treatment or other surface modifications. These surface modifications have been evaluated through standard wear testing (ASTM G-65), surface hardness (Rc), micro-hardness (vickers), and optical microscopy.

Keywords : hard metals, laser, cladding, wear resistance, tungsten carbide, cermets

1. Introduction

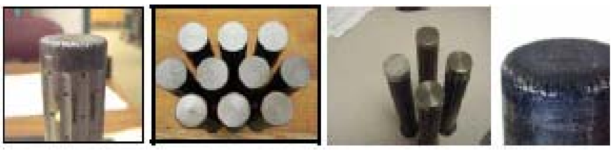
Manufacturing industries that form metal and glass can benefit from tools and dies that have better wear characteristics, thermal properties, and reduced chemical reactivity with the product being formed. Most tools and dies are made from H13 or some other grade tool steel. These materials are relatively inexpensive, but exhibit numerous failure modes including heat checking, soldering, fatigue, chipping, cracking, loss of hardness, and corrosion. As the tools deteriorate, problems including poor mold release and surface imperfections arise that result in part rejection and reduced process efficiency including increased energy consumption. Using higher performing materials could mitigate these problems, but fabricating tools from these materials would significantly increase their cost. In this investigation, the advantages of using some of these higher performing materials is being sought by cladding them onto the commonly used tool surfaces by using laser powder deposition (LPD).

LPD offers a convenient means of producing a compliant transition from conventional tool steel (in this case H-13) to a higher performing material (selected based on the application). LPD is a flexible and rapid manufacturing technique that directly deposits metal powder into a molten metal pool produced by laser interaction with the underlying metal surface thereby forming a clad or laminate layer on the metal surface [1]. The advantages of LPD over other manufacturing techniques for tool modification include: the minimal heat affected zone; high solidification rate resulting fine grain size; minimal segregation; minimal second phase coarsening; high density coating; and minimal mixing of the cladding with the base material (dilution). Other advantages include near-net shape, good surface durability and finish, efficient material use, and versatile part manufacturing or repair [2-5].

The paramount issue that arises in placing surface layers of high performance metals onto tool steel (H-13) is the nature of the bond with the tool steel and thermal stresses [2] at the interface. Since the desired surfacing materials might not always produce the best metallurgical interface and therefore not produce compatible mechanical properties with the H-13 tool steel, the working surfaces of these tool steels were laser deposited with a variety of metals to determine compatibility. Since different applications have varying and different material requirements, a variety of materials were selected for use in this study. Initial investigations were performed by LPD cladding more conventional alloys (nickel and stainless steels alloys) onto the end of H-13 bars. More recent, tools were clad with higher performing materials and delivered for industrial testing in actual manufacturing operations (i.e., hot die forging).

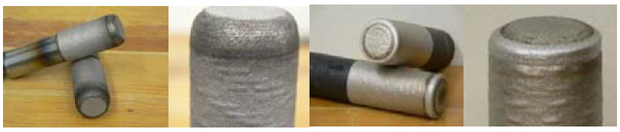
2. LPD Cladding Industrial Tooling

The LPD cladding experiments were conducted with Ni-based, Co-based and Fe-based super alloys on H13 bars and actual industrial tools and dies. Inconel®(625 and 718) [6], Stellite® (6 and 21) [7-8], DM21®, CCW+®, AeroMet100, NiTung60® and Co-WC were selected for their high-temperature wear and corrosion resistance properties [6-8]. These alloys produced a compliant metallurgical interface with H-13 tools. Also observed was that H13 tools and specimens exhibited little softening after the LPD cladding operation. The materials, Inconel®, and Stellite®, were deposited onto H13 to determine the deposition characteristics or capability of LPD, including hardness profiles, microstructures, and deposition quality. Anvils (Figure 1) and extrusion mandrels (Figure 2) were LPD clad with CCW+®, DM21®, and NiTung60® and then inserted into actual industrial operations. The typical LPD processing parameters used during the cladding operations were laser power of 1000 to 100 watts, linear speed of 14 mm/s, layer thickness of 0.5 mm and spacing width of 0.75 mm..



(a) (b) (c) (d)

Fig. 1. Photograph of H13 hot die forging anvils (a) after use (~6000 cycles) and (b) LPD clad, (c) clad and finished machined and (d) NiTung60 clad anvil after ~10,000 cycles.



(a) (b)

Fig. 2. Extrusion mandrel tools LPD clad with a) NiTung-60 and b) CCW-plus.

3. Summary

Many commercial powder metal alloys can be deposited successfully on H-13 with little dilution, good metallurgical interface, minimal porosity and little thermal softening of the substrate. LPD of the alloys CCW+® and NiTung60® on H-13 in hot die forging have produce a three times improvement in tool life. A path for producing high temperature refractory metal surfaces on H-13 tooling through the use of LPD layering seems feasible.

4. Acknowledgements

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5. References

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