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APPLICATION OF A LOW HEAT INPUT DEPOSITION PROCESS FOR REFURBISHMENT OF WORN PM FORMING DIES USING Fe-Ni BASED FILLER METAL

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Abstract
Refurbishment of worn Dies is an interesting research area which also has high economic benefit. Material which is used in PM dies for compacting powders are high carbon steel which have very low weldabilitis. Due to the high hardness, high carbon content and martensitic microstructure, these Dies are very sensitive to the thermal shock produced from fusion welding. For successfully refurbishing the worn Dies, Fine spark deposition was used for deposition of a new layer on the cold work 1.2436 steel. Different heat inputs were used for deposition of nickel based material and finally microstructure and HAZ were studied. Results show the HAZ area is very narrow, free from cracks and HAZ microstructure is similar to the base metal. GTAW welding using same filler metal induced many cracks in HAZ of weld which is detrimental to the refurbished Die performance. Results show increasing heat input in Fine spark deposition can results in crack formation in HAZ even if the weld pool does not occurred in base metal. However these cracks are much smaller than those occurred in GTAW.
Keywords: Powder metallurgy, Fine spark deposition, Die, 1.2436 steel.

INTRODUCTION

AISI D6 or DIN 1.2436 is a 12% chromium alloy cold work tool steel which is used as die and punch in blanking, piercing and cold forming processes. This steel is widely used for powder shaping Dies manufacturing in powder metallurgy industry. Tool service life is limited by plastic deformations, wear and rupture due to the presence of high stresses and cracks. [1,2].

The as-cast microstructure is composed of ferrite, carbides especially Cr_7C_3, pearlite, and bainite with a hardness of 240 HV. Hardness after annealing at 800-840°C and slow furnace cooling will be approximately 225 brinell. Annealed microstructure consists of large amount of Cr_7C_3 carbides in an austenitic matrix. Hardening of this steel results in high hardness. Microstructure of double tempered sample consists of tempered martensite and fine distribution of chromium carbide particles [3].

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Because of high hardenability and large amount of carbide particles, this tool steel has very low weldability. The weldability of steels with more than 0.2% carbon is usually considered to be poor. Hence, tool steels with 0.3–2.5% carbon are difficult to weld and many steel suppliers will actually recommend against welding. Depend on different situations, welding with arc welding processes required high preheating temperature near 200-250 C and sophisticated post weld heat treatment, which makes welding process very difficult [4].

One of the major drawback of arc welding processes e.g. GTAW is high volume of heat input and formation of weld pool which induces high heat affected zone area (HAZ). These areas are prone to severe cracking after welding if proper preheat and post weld heat treatment cannot be carried out.

Previous studies on welding precipitated nickel based super alloy using low heat input processes e.g laser welding and fine spark deposition showed promising results on crack free welding of these alloys. Beside low heat input fusion welding processes like pulsed laser welding, Fine spark deposition (FSD) is another low heat input process which makes it ideal as a coating and build up technology in many applications. Fine spark deposition has many applications in rebuilding and coating conductive materials. Because of its very low heat input, it is ideal for rebuilding metals which are susceptible to HAZ cracking [5,6].

In this process, very small droplets of molten metal are detached from rotating electrode, then transfer to the substrate and impact the substrate. This phenomenon induces such inherent defects like lack of fusion (LOF) and porosity in deposition. The researchers have not achieved great success for complete elimination of such defects in FSD overlay.

In a recent study by the author it was shown that IN738LC can be built up by Fine spark deposition (FSD) process and then subjected to pulsed laser fusion processing to improve the integrity of the FSD deposited layer [6]. It is found that the FSD material has more resistance to liquation and solidification cracking than the cast base metal. In the present study, FSD was used as a buildup technique for deposition high Ni-Cr steel based alloy on the 1.2436 tool steel for refurbishment of steel Dies used in powder metal pressing.

EXPERIMENTAL MATERIALS AND METHODS

The material used for this research was quench and tempered 1.2436 tool steel with chemical composition has shown in table 1. The filler metal which is used in fine spark deposition was a round cylindrical rod with 4 mm diameter with chemical composition shown in Table 1.

Tab.1. Chemical Composition Wt%.

Composition	C	Mn	Si	Cr	W	Ni
1.2436	2	0.2	0.2	11.5	0.7	-
FSD filler	0.11	1.67	0.68	15.2	-	35
GTAW filler	0.2	0.6	0.2	2	-	-

Heat treatment of steel was done in following manner:

- Annealing in 970 C
- Hardening 940 C, Quenching in oil
- Tempering in 450 C for 2 hours

Fine spark deposition was performed on a 2 mm diameter quench and tempered cast billets. FSD deposition was performed using a hand held gun with a co-axis shield gas facility. Initially a number of tests were performed to establish a suitable FSD process window with respect to the appearance of the deposit for example surface roughness and spatter. For the experiments that are reported here, electrode rotation speed was 2500 rpm and electrical parameters were voltage of 40 volt, frequency of 110 Hz and duty cycle of 40 %. During FSD process argon shielding gas was fed to the surface with a flow rate of 15 liters/min.

For comparison of results, Micro GTAW using P20 filler wire was carried out with current if 30 A and pulsed frequency of 5 Hz. Composition of GTAW filler wire can be seen in Table 1.

A number of samples were taken for metallographic characterization of the as deposited fine spark buildup layer of steel. Some samples are studied for micro hardness test. Vickers micro hardness test was done using 200 g load and 15 s dwell time.

RESULTS AND DISCUSSION

The Figure 1 shows the microstructure of GTAW weld on high chromium steel. Microstructure of base metal consists of large amount of fine white chromium carbide particles embedded in tempered martensitic matrix.

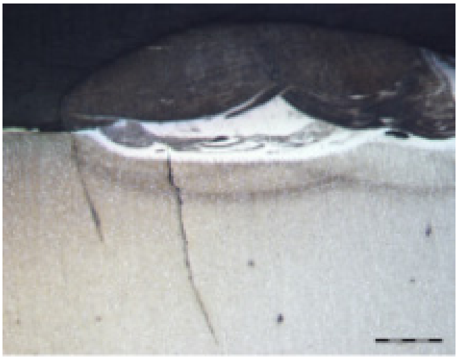

Fig.1. cracks in HAZ of 1.2436 steel weldment in GTAW process.

As it is clear, 2 large cracks are initiated from HAZ and propagate to the weld zone and base metal. These cracks show the welding impossible without preheat and post weld heat treatment.

The Figure 2 shows different areas in GTAW weldments in higher magnification. The thickness of HAZ beneath weld is about 200 μm. There is not considerable different between HAZ microstructure and base metal. This is because of very fast cooling rate in micro GTAW and low heat input in this process in comparison with GTAW process.

The Figure 3 shows the FSD microstructure and base metal. Form micrograph one can see there is not HAZ indication in the weldment and interface of rebuilding area has metallurgical bonding to the base metal. Although some crack like indication in upper part of coating can be detected, the entire coating has good fusion to the base metal.

There is no crack in base metal of FSD process and makes it ideal for rebuilding the worn areas of steel dies. Higher magnification of coating can be seen in Fig.4.

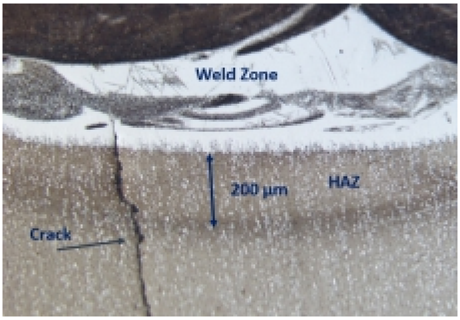

Fig.2. Different areas in GTAW weldments.

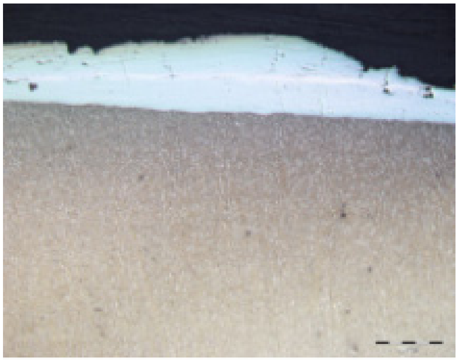

Fig.3. The FSD coating on the steel 1.2436.

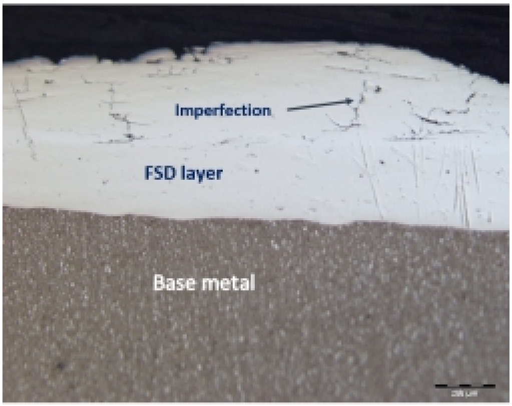

Fig.4. FSD layer which has some imperfection.

The FSD layer has some imperfection which are like cracks. However, these imperfection were detected also in previous studies [4,5].

Micro hardness results are shown in Table 2. In the GTAW sample, high hardness in HAZ and base metal along high tensile stress which is exerted on HAZ by shrinkage of weld metal during solidification can cause severe cracking in HAZ.

Tab.2. Microhardness results.

Avg. Hardness	Hardness 3	Hardness 2	Hardness 1	Hardness HVN
298	347	299	248	FSD layer
407	465	396	362	GTAW

Average hardness of base metal is about 550 HVN. HAZ hardness in GTAW has highest hardness e.g. 644 HVN. Because the weld metal has lower hardness than HAZ and base metal the crack blinded in weld metal. The crack formation is very feasible in High hardness HAZ and then it cannot resist cracking due to the high hardness and brittle microstructure.

Although hardness of FSD layer is lower than GTAW weld, hardness of FSD layer is acceptable. However, the hardness is much lower than base metal. The low heat input in FSD process makes the welding feasible without preheating the sample. Because the deposition forms by depositing large numbers of tiny droplets of filler metal, the heat input per every single droplet is very small.

Figures 5 and 6 show an area of worn Punch dies and subsequent repair area by FSD process. Service work shows sound performance of repaired area under actual service condition.

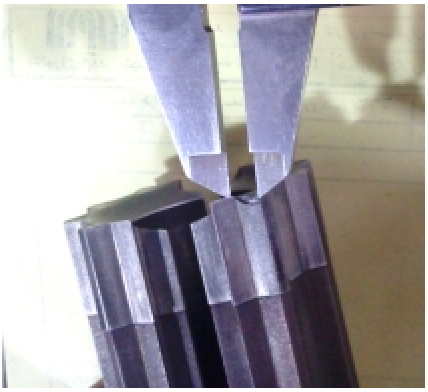

Fig.5. Worn area on the edge of steel 1.2436 die.

Fig.6. Repaired area before machining.

CONCLUSION

Weld deposition of steel 1.2436 using two different method show the effect of heat input on sound, crack free buildup of worn area. This work can be concluded as follows:

- The FSD process is used for deposition of high nickel chromium filler metal on 1.2436 steel without HAZ cracking.
- Micro GTAW process using steel filler wire results in HAZ cracking. High hardness of base metal and high amount of weld shrinkage can be the problem of arc welding of this alloy without preheat and post weld heat treatment.
- Service performance of refurbishment area shows acceptable weld overlay by FSD process.
- Low heat input, low tensile stress and very narrow HAZ have synergetic effect on crack free repair welding of high chromium steel using FSD welding without preheat and post weld heat treatment.

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