MECHANICAL PROPERTIES OF STELLITE-6 COATED AISI 316L STAINLESS STEEL

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Resume

Present paper describes the mechanical properties of Stellite-6 coated AISI 316L stainless steel. Specimens were coated using Detonation Gun thermal spray process, with different coating thicknesses of Stellite-6 ranging from 50 μm to 150 μm. Afterwards their properties like tensile strength, impact strength and micro hardness were evaluated on the basis of the results obtained from the experimentation. For comparison of substrate and coated material, graphs were plotted. The coated specimens exhibited superior impact strength and microhardness than that of the bare specimens, whereas the tensile strength of coated specimens decreased marginally with the increase in coating thickness.

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1. Introduction

In a wide variety of applications, mechanical components have to operate under severe conditions, such as high load, speed or temperature and hostile chemical environment. Thus, their surface modification is necessary in order to protect them against various types of degradation. Thermal spraying has emerged as an important tool of increasingly sophisticated surface engineering technology. The different properties of the coating provide corrosion resistance, wear resistance, better thermal or electrical conductivity etc. [1]. AISI 316L austenitic stainless steel is widely used in corrosive environments as it has high corrosion resistance. However, its wear, cavitation and erosion resistances are poor due to low hardness (220 HV), which restricts its use in many industrial applications as reported by Viswanathan et al. [2]. Austenitic stainless steel exhibits a sticking behaviour during wear test, which is a distinctive feature of ductile materials that are capable of absorbing much larger quantities of energy before failure as found by Dalmau et al. [3].

Coating a material with another material is done to obtain a combination of properties that combine the properties of the base material with other necessary properties that give corrosion resistance, wear resistance, better thermal or electrical conductivity as reported by Molleda et al. [4].

Stellite-6 is the most widely used cobalt based alloy exhibiting excellent resistance to many forms of mechanical & chemical degradation. Its applications include valve seats & gates, pump shafts, bearings and erosion shields. The exceptional wear resistance of Stellite-6 is mainly due to the unique and inherent characteristics of the hard carbide phase dispersed in Co-Cr alloy matrix as found by Prasad Rao et al. [5].

This paper deals with influence of Stellite-6 coating on AISI 316L stainless steel and on mechanical properties viz. tensile strength, impact strength and microhardness.

2. Experimental Material & Procedure

Stellite-6 alloy in powder form was used as coating material, the nominal composition of which is shown in Table 1.

The substrate material used was AISI 316L stainless steel. AISI 316 L Stainless Steel is extra low carbon version of 316 steel alloys. The low carbon content in AISI 316 L Stainless Steel prevents the formation of carbide on the surface when material comes in contact of heat. This can be used for bearings which operate in corrosive environments such as running inside liquids. But this steel has slightly lower mechanical properties. This steel fails mainly due to wear and elevated temperatures.

The chemical composition of substrate material is given in Table 2.

Before coating, the material was machined and different specimens for tensile, impact and micro hardness tests were prepared.

2.1 Fabrication of microhardness test specimens

For microhardness test, specimens of Dia. 20 mm x 20 mm length were prepared by cylindrical turning on lathe machine. Both flat sides of the specimens were ground on a surface grinder. Fig. 1 depicts the specimens for micro hardness test.

Fig. 1. Specimens for Micro hardness test.

2.2 Fabrication of Charpy impact test specimens

The specimens for Charpy impact test were prepared on a milling machine and dimensions kept according to specifications of standard ASTM A370. Firstly the samples were roughly cut and then were ground on a surface grinder to make the sides truly perpendicular. Three specimens for each coating with dimensions of 10x10x55 mm were prepared so as to maintain repeatability of test results. The notch with depth of 2 mm was made in the centre of specimens using a wire cut machine. The included notch angle was kept 45˚. Fig. 2 depicts the impact test specimens.

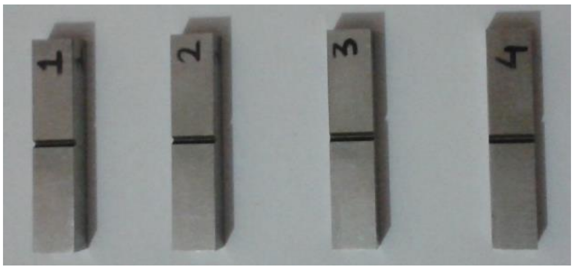


Fig. 2. Impact Test Specimens.

2.3Fabrication of tensile test specimens

The raw material was machined on lathe machine and tensile test specimens were prepared according to standard ASTM E8. The gauge length was ground to 50 μm. The gauge length diameter was kept 12.5 mm for bare specimen. For specimens which were to be coated, the gauge length diameters were kept 12.4 mm, 12.3 mm and 12.2 mm for coating thickness 50 μm, 100 μm and 150 μm respectively. Three specimens for each coating were prepared to maintain repeatability of results. Fig. 3 shows the machined specimens (prior to coating) for tensile test.

Fig. 3. Tensile Test Specimens.

Table1

The chemical composition of Stellite-6.

Element	Cr	W	C	Ni	Fe	Si	Mn	Mo	Co
wt. %	28.60	4.90	1.30	0.65	0.79	1.25	1.13	<0.10	Bal.

Table 2

Chemical composition of AISI 316 L

Element	C	Si	Mn	P	S	Ni	Cr	Mo	Fe
wt. %	0.02	0.40	1.32	0.026	0.03	10.27	16.57	2.01	Bal.

Table 3

Technical Specification of Awaaz Detonation Gun.

Working Gases	Oxygen, Acetylene, Nitrogen and Air
Consumption of Powder per Shot	0.02-0.05g/ shot
Water Consumption Rate	15-25 litres/minute
Firing Rate	1-10 Hz
Coating Thickness per Shot	5-25 µm
System Control	Manual/ Semi auto
Dimensions (L X B x H) mm	1200 x 500 x 1500
Sound Pressure Level	150 dB

Table 4

Process parameters for Stellite-6 coating by D- gun thermal spray process.

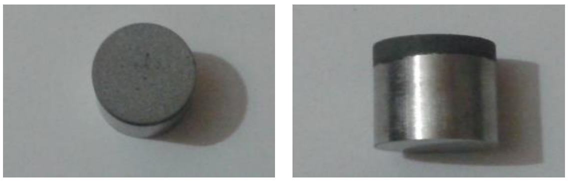
Parameter	Value
Oxygen Flow Rate	3120 SLPH (Standard Litres Per Hour)
Pressure	0.2 MPa
Acetylene Flow Rate	2400 SLPH (Standard Litres Per Hour)
Pressure	0.14 MPa
Nitrogen Flow Rate	1040 SLPH (Standard Litres Per Hour)
Pressure	0.4 MPa
Spray Angle	90˚
Spray Distance	150 mm
Power	450 VA

2.4 Coating of specimens

For coating process the equipment used was "Awaaz Detonation Gun" available at M/s SVX Powder M Surface Engineering Pvt. Ltd., Greater Noida (India).

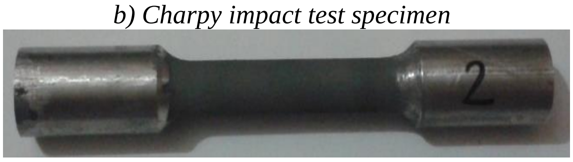
The technical specifications of the detonation gun are given in Table 3.

The process parameters for thermal spray Stellite-6 coating by detonation gun are given in Table 4. The specimens to be coated were firstly sand blasted using alumina powder (Al_2O_3) to make the surface suitable for coating deposition. Fig. 4 shows different coated specimens.



a) Micro Vickers hardness test specimen

b) Charpy impact test specimen



c) Tensile test specimen.

Fig. 4. Different coated Specimens.

2.5 Testing of specimens

Micro Hardness test: The bare and coated specimens were tested on micro Vickers hardness tester available at Research and Development Centre for Bicycles and Sewing Machines, Ludhiana.

Charpy impact test: The bare and coated specimens for Charpy impact test were tested on Charpy impact test machine available at Research and Development Centre for Bicycles and Sewing Machines, Focal Point, Ludhiana. The impact testing was done using ASTM A370 standard. Fig. 5 shows the specimens after Charpy impact test.

a) Bare AISI 316L specimen

b) Specimen with 50μm Stellite 6 coating

c) Specimen with 100μm Stellite 6 coating

d) Specimen with 150μm Stellite 6 coating

Fig. 5. Specimens after Charpy impact test.

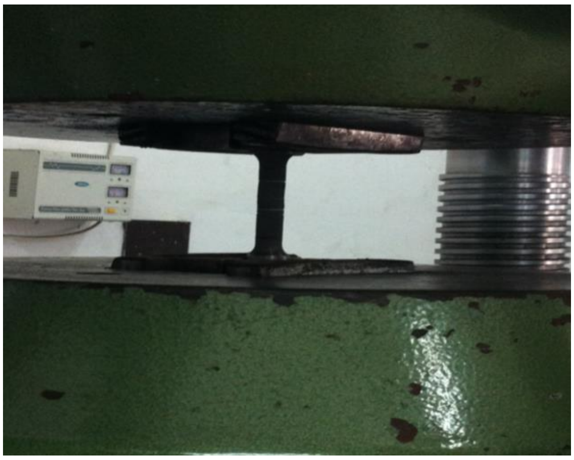
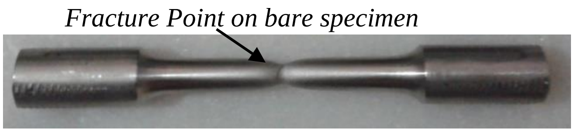


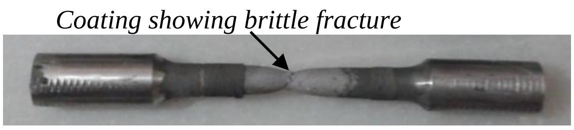
Fig. 6. Tensile test being performed on UTM.
(full colour version available online)

Tensile Test: The bare and coated specimens for tensile test were tested on FIE make Universal Tensile Testing machine (UTE-100) of 100 ton capacity, available at CITCO-IDFC Testing Laboratory, Chandigarh. The tensile testing was done using ASTM E8/E8M standard. The gauge length was kept 60 mm and gauge points were marked by using dot punch. The dumbbell shaped specimens were tightened in the jaws of the UTM as depicted in Fig. 6.

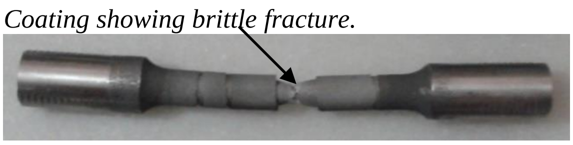
The load was applied gradually and readings were taken. Fig. 7 shows the specimens after tensile test.



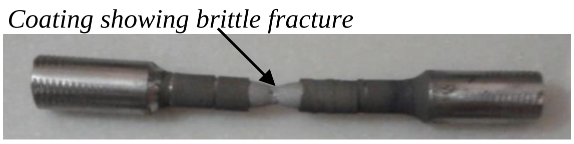
a) Bare AISI 316L specimen



b) Specimen with 50μm Stellite 6 coating



c) Specimen with 100μm Stellite 6 coating



d) Specimen with 150μm Stellite 6 coating

Fig. 7. Specimens after tensile test.

3. Results and discussion

3.1 Micro hardness test

A drastic difference was found in the microhardness of the specimens. The average hardness of specimen with150 μm thick coating of Stellite-6 at 653 $HV_{0.5}$ was significantly higher than that of the substrate at average value of 249 $HV_{0.5}$. The microhardness profile is shown in Fig. 8.

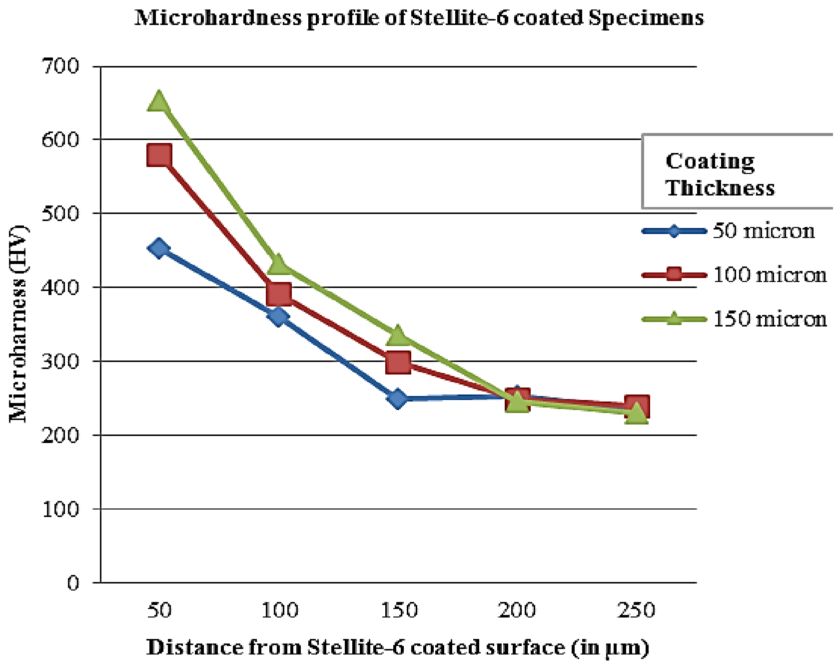


Fig. 8. Microhardness profile across coated and substrate region.
(full colour version available online)

The microhardness of the specimen with 150 µm Stellite-6 coating increased by more than 200 % as compared to the substrate region of AISI 316L. It was inferred that the increase is not only due to presence of chromium carbide particles in micron, but due to formation of tiny particles within the coating as found by Apay and Gulenc [6].

3.2 Charpy impact test

The energy consumed by the bare specimens was lower than that of the coated specimens. The bare specimens consumed 156 kJ of energy whereas the specimens with 150 µm Stellite 6 coating absorbed 216 kJ of energy. Therefore distinct behaviour was observed. The bare specimens showed less impact strength and the coated specimens showed better impact strength. The crack was made to propagate first through the Stellite-6 coated section followed by substrate. Similar investigations have been carried out by Ganesh et al. [7].The impact strength went on increasing with the increase in coating thickness. Fig. 9 shows the variation in impact strength with respect to coating thickness.

3.3 Tensile test

The results of tensile test revealed that the bare AISI 316L specimens showed ductile failure. Necking took place in the gauge section and the specimen failed at a high value of UTS. However the specimens with Stellite-6 coating showed different behaviour. The coating on the specimens showed a brittle fracture and coating got detached from substrate thereby exposing the bare stainless steel beneath. This was followed by ductile failure of the substrate. The tensile strength went on decreasing with increase in coating thickness. The specimen of bare AISI 316L had the maximum tensile strength and the one with 150 µm had the lowest tensile strength. This may be due to the effect of heat during the surface treatment which may have resulted in microstructural changes. But the decrease is only marginal. The specimens with coating thickness of 150 µm had an average tensile strength of 0.681 $kN.mm^{-2}$ whereas the bare specimens of AISI had an average tensile strength of 0.726 $kN.mm^{-2}$. Therefore the decrease in tensile strength is only about 7 % which is negligible. Fig. 10 shows the tensile behaviour of bare and coated specimens.

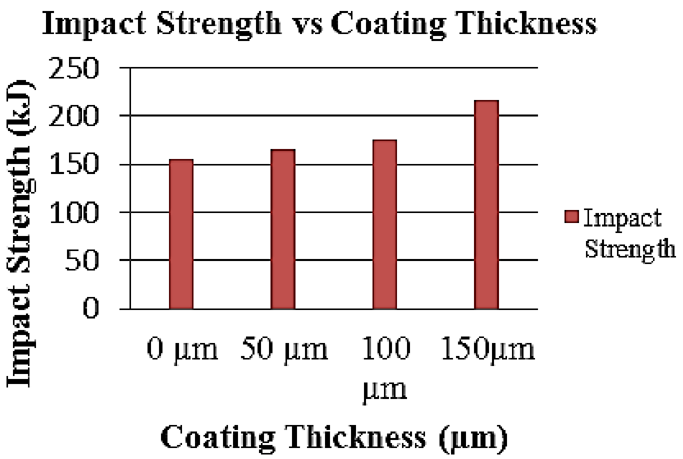


Fig. 9. Graph showing relationship between impact strength and coating thickness.
(full colour version available online)

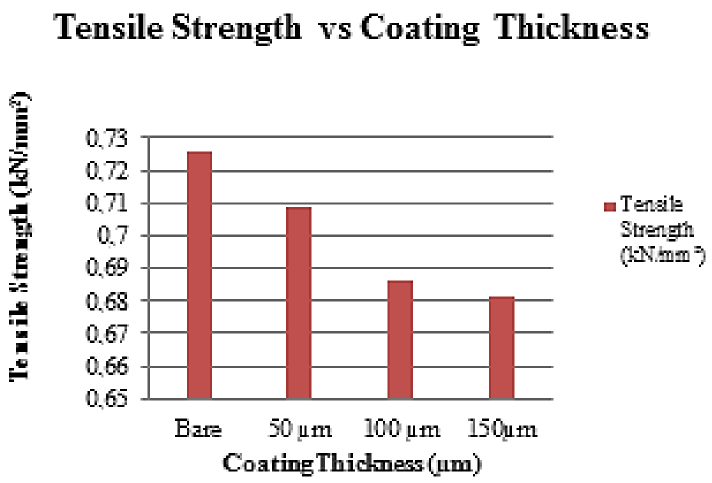


Fig. 10. Graph showing relationship between tensile strength and coating thickness.
(full colour version available online)

4. Conclusions

In the light of the results obtained during the course of present investigation, it is inferred that:

• The Stellite-6 coating, on AISI 316 L, done by D-gun process resulted in great increase in micro hardness which can be attributed to Co-Cr matrix formed in the coated section.

• The impact strength also improved as the thickness of Stellite-6 coating went on increasing. This is due to crack propagation through the coating section first and then going through the stainless steel substrate region.

• The increase in thickness of Stellite-6 coating resulted in marginal decrease in tensile strength. Detachment of the coating material occurred during tensile test which exposed the ductile substrate material. Therefore application of an interlayer or bond coat was suggested.

•The decrease in tensile strength which is only about 7% can be neglected in the comparison to drastic increments in microhardness and impact strength which increased about 200% and 40% respectively.

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