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## CHARACTERIZATION OF STAINLESS STEEL 316L COATED BY THERMAL SPRAY COATING

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**Abstract**— an experimental investigation was carried out to find the characteristic of coated stainless steel 316L, coating was done by D-gun method. Surface properties corrosion is check out of both coated base metals and uncoated base metals. Two specimens of coating were prepared with coating thickness of 150 microns (single layer) and 300 microns (multilayer). Pitting corrosion test was performed to analysis the corrosion properties of base metal and coated metals, corrosion test was conducted for 96 hours and solution used was stagnant seawater composition and temperature of solution was at a temperature of 42<sup>o</sup>C. Characterization of Inconel 718 and stainless steel 316L was done by using XRD. Result obtained from corrosion test showed that weight loss of base metal SS 316L was 0.0002 gram which 50% more than the weight loss in multilayer coated specimens that 0.0001 gram.

**Keywords**— CORROSIVE WEAR, XRD, D-GUN SPRAY.

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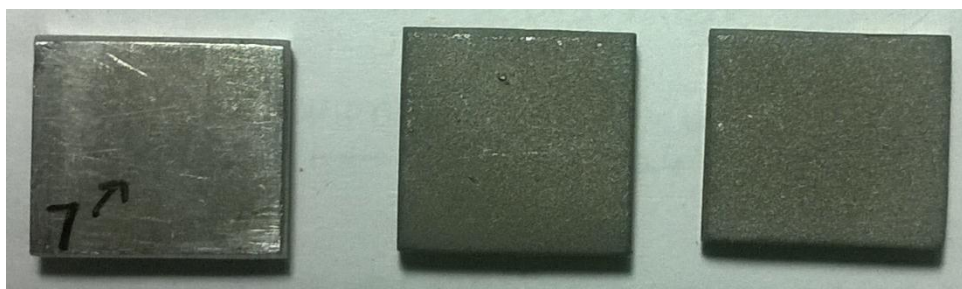
### I. INTRODUCTION

Thermal spray processes are now widely used to spray coatings against, wear and corrosion but also against heat (thermal barrier coating) and for functional purposes [6]. The choice of the deposition process depends strongly on the expected coating properties for the application and coating deposition cost. Coating properties are determined by the coating material, the form in which it is provided, and by the set of parameters used to operate the deposition process [9]. Thermal spray coatings are generally characterized by a lamellar structure and the real contact between the splats and the substrate or the previously deposited layers determine to a large extent the coating properties, such as thermal conductivity, Young's modulus, etc. [3]. The real contact area ranges generally between 20 to 60 % of the coating surface parallel to the substrate. It increases with impact velocities of particles provided that the latter are not either too much superheated or below their melting temperature. That is why roughly the density of coatings increases from flame, wire arc, plasma, HVOF or HVAF and finally D-gun spraying and self-fluxing alloys flame sprayed and then re-fused. Also thermal spray coatings contain some defects as pores, often globular, formed during their generation, un-molten or partially melted particles that create the worst defects, exploded particles, and cracks formed during residual stress relaxation [9]. The cracks appear as micro-cracks within splats and macro-cracks running through layered splats especially at their interfaces and tending to initiate inter-connected porosities [13]. Moreover, when the spraying process is operated in air, oxidation of hot or fully melted particles can occur in flight as well as that of splats and successive passes during coating formation [9]. Thus, depending on the spray conditions and materials sprayed, the coatings are more or less porous and for certain applications must be sealed by appropriate means

## II. EXPERIMENTATION

### 2.1 Corrosion test

No standard corrosion test is used to check the corrosion resistance properties of specimens. Customized test condition is created according to the requirements, after preparation of the specimens for corrosion test polish the specimens with emery paper and after polishing the specimen's initial weight of the specimens is taken than after that specimens were dipped in stagnant seawater solution for 96 hours and temperature of exposure zone is maintained at 42°C plus minus 2°C. After 96 hour specimens is taken out from the solution and final weight is measured.

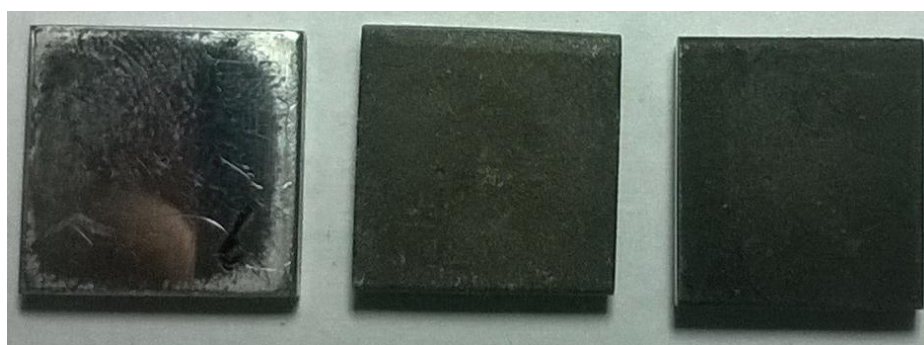


**Fig1.** Specimens before corrosion test

Different in initial and final weight is calculated and with the help of formula corrosion rate is find out of each specimens. The test was performed at Spectro Analytical lab, Delhi.

Name	Weight (mg/l)
Chloride	18980
Bromide	65
Sulphate	2649
Bicarbonate	140
Floride	1
Boric acid	26
Magnesium	1272
Calcium	400
Strontium	13
Potassium	380
Sodium	10556
Total	34482mg/l

**Table 1.** Composition of stagnant seawater



**Fig. 2** Specimens after corrosion test.

### 2.2 X Ray Diffraction (XRD)

XRD is a technique designed to provide more in details information about crystalline compounds, identification and quantification of crystalline phase. It can also be used to find the proportion of different minerals or many other substances that are present in the mixture. By using this method, the atoms size, length and chemical nature can be determined for various materials.

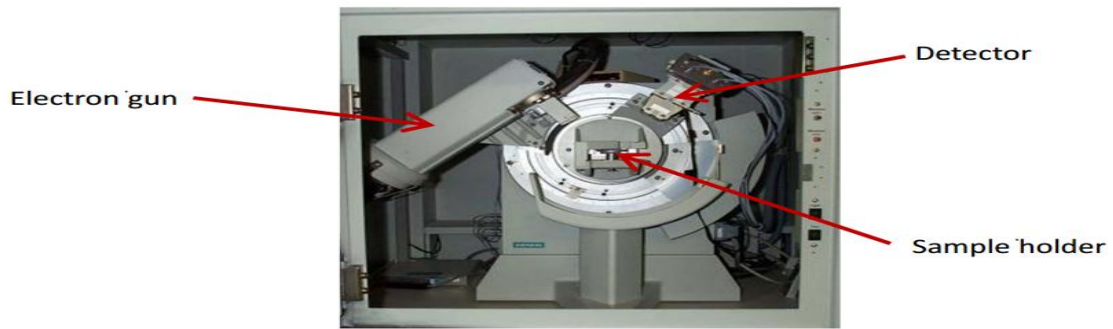


Fig 3 show the XRD machine

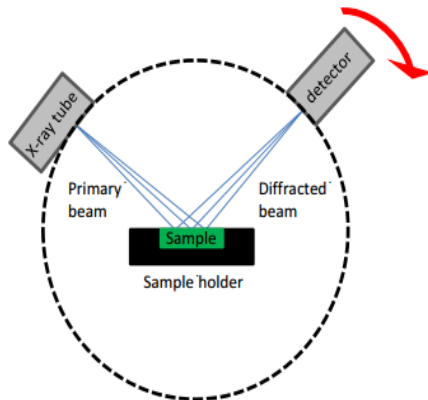


Fig.4 Classic reflection geometry.

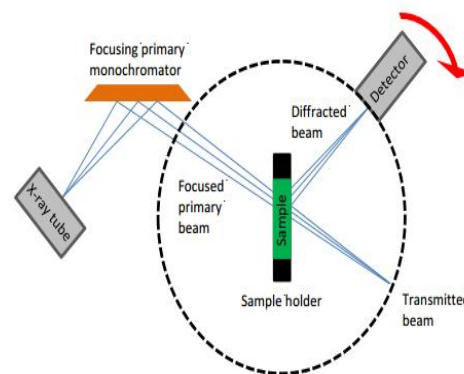


Fig. 5 Classic transmission geometry.

Two principal method for X-ray generation:

- First- Fire a beam of electron at metal surface. Ionization of inner shell electron result in formation of electron hole. Relaxation of electrons from upper shell, the energy difference  $\Delta E$  ( $10^{10}\text{m}$ ) escapes in form of X-ray of specific wave length. Commonly used metals are Cu and Mo. Very inefficient method most energy dissipated as heat thus require permanent cooling.
- Second- Accelerate electron in a particle accelerator, Electron accelerated at relativistic velocities in circular orbits. As the velocity reach the speed of light they emits electromagnetic radiation in the X-ray region.

### Application of XRD

Phase composition determination, characterization of doped cell structure of electro ceramics, measurements of hard coating structure and composition, characterization of hydroxyl-apatite coating on medical implant materials.

### Corrosion test

The objective of performing corrosion test is to observe the corrosion resistance properties of samples in stagnant seawater.

Time	Temperature	Composition of solution
96 Hours	40°C plus minus 2°C	Stagnant seawater

Table 2. Parameters that are kept constant in corrosion test

Test procedure:

Samples are polished, after polishing take the initial weight of each specimens and dip the samples in stagnant seawater solution for 96 hours. Keep the temperature of solution above ambient temperature of seawater i.e. temperature maintained in this test is 40° C plus minus 2° C.

Sample Name	Initial wt. after polishing	Final wt. after 96 hours	Weight loss (gm)
Stainless steel, AISI 316L	8.5229	8.5227	0.0002

Table 3. Observation table recorded for corrosion test of stainless steel AISI 316L.

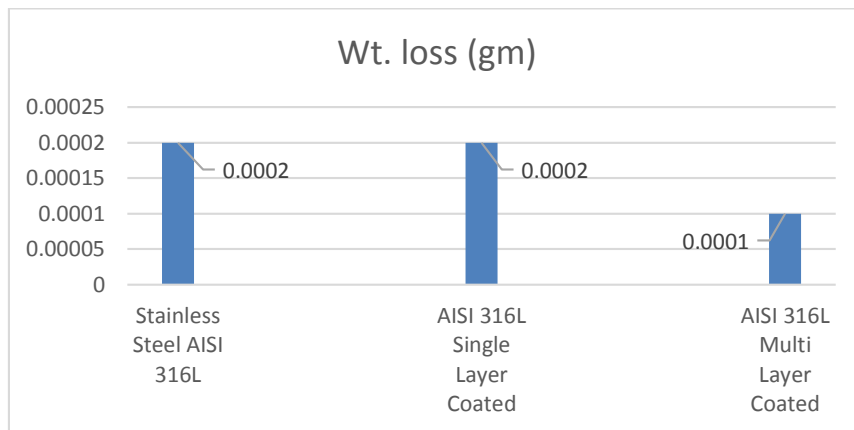
Sample Name	Initial wt. after polishing	Final wt. after 96 hours	Weight loss (gm)
AISI 316L, single layer coated	8.4750	8.4748	0.0002

**Table 4. Observation table recorded for corrosion test of stainless steel AISI 316L single layer coated**

Sample Name	Initial wt. after polishing	Final wt. after 96 hours	Weight loss (gm)
AISI 316L, multilayer coated	7.6215	7.6214	0.0001

**Table 5. Observation table recorded for corrosion test of stainless steel AISI 316L multilayer coated.**

Values obtained from the corrosion resistance test for all the three specimens i.e. stainless steel, single layer coated with Inconel, and multilayer coated with Inconel are lead to conclusion that weight loss is greater in stainless steel and single layer coated as compared to multilayer coated stainless steel.



**Fig. 6 Wt. loss in Specimens**

Above graph showed the weight loss of all three specimens in gram. It is shown in graph that the wear in multilayer coated surface is 50% less when compare to stainless steel and single layer coated stainless steel. This will lead to conclusion corrosion resistance properties of stainless steel AISI 316L increased 50% by using Inconel 718 as coating materials. Reasons for increased in corrosion resistance properties of coated stainless steel AISI 316L. Specific alloying composition of Inconel 718 give strong resistance to corrosion up to temperature of 1000°C.

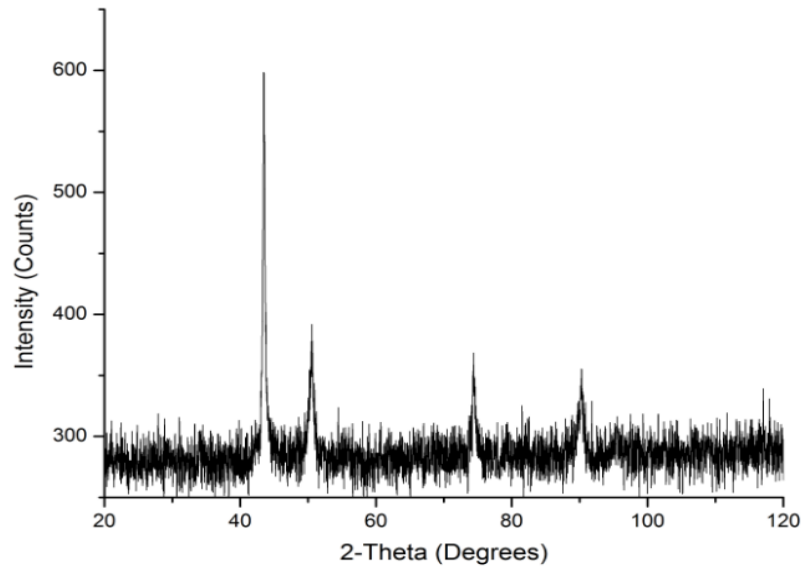
Percent of nickel in Inconel 718 is 50% to 55% where as in stainless steel only 10% to 14% nickel found, this large amount of present of nickel help in combating chloride-ion stress-corrosion and protect the specimens from corrosion in many inorganic and organic oxidizing compound, in large range of alkalinity and acidity.

Percent of Chromium is also more in Inconel 718 as compared to stainless steel AISI 316L which provide Inconel 718 an ability to withstand attack from sulphur compound and oxidizing medium.

Present of Molybdenum help to improve resistance in pitting corrosion.

**X-Ray Diffraction**

In this paper X-ray diffraction of two sample was done, first uncoated SS AISI 316L and coated SS AISI 316L with nickel alloy Inconel 718, coating was done by detonation gun method. Figure7 showed the XRD image of stainless steel AISI 316L.

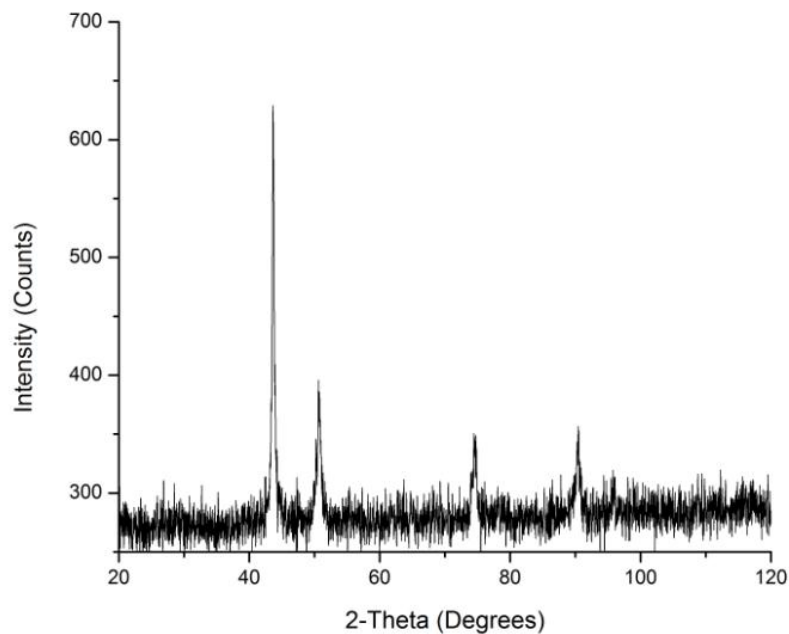


**Figure 7 XRD image of AISI 316L**

In figure 7 the peak corresponding of graph is belonged to nickel and chromium because these two components are the major constituents of stainless steel AISI 316L.

Figure 8 showed the XRD result of stainless steel AISI 316L coated with nickel alloy Inconel 718 by using detonation gun method.

Inconel 718 contain Nickel (Ni) and Chromium (Cr) as major phase, figure 8 so the X-ray diffraction pattern of thermal sprayed coated Inconel 718 on stainless steel AISI 316L. As it is observed from the graph that peak corresponding to the present of nickel as major phase.



**Figure 8. XRD result of coated stainless steel with Inconel 718**

Graphs of uncoated stainless steel and coated stainless steel are somewhat similar because of chemical composition of stainless steel AISI 316L and coating powder used i.e. Inconel 718. Both Inconel 718 and stainless steel AISI 316L have higher percentage of nickel and chromium chemical in their respective chemical composition. Thus the face formed in coated and uncoated stainless steel are similar but not same because Inconel 718 have 50% to 55% nickel and chromium 17% to 21% whereas in stainless steel AISI 316L in only 10% to 14% nickel and 16% to 18% chromium.

## CONCLUSION

- Corrosion resistance properties of stainless steel AISI 316L was increased by coating it with Inconel 718 using detonation gun method. By seeing the result of weight loss corrosion test which was conducted for 96 hours in stagnant seawater composition it

was observed that corrosion resistance properties of multilayer coated specimen of AISI 316L is actually doubled than single layer coated AISI 316L specimen and stainless steel AISI 316L.

- Total weight loss after 96 hours for stainless steel AISI 316L was 0.0002 gram for single layer coating after 96 hours' weight loss was 0.0002 gram in multilayer coated specimens after 96 hours was 0.0001 gram which half as compared to single layer coated AISI 316L and stainless steel 316L.
- Thus it was concluded that corrosion resistance properties of stainless steel AISI 316L is actually double by applying coating of Inconel 718 using detonation gun coating method.
- XRD test was also conducted to know the different phase generated in uncoated AISI 316L and coated AISI 316L. XRD results of uncoated AISI 316L and coated AISI 316L are similar because coating materials Inconel 718 and base materials AISI 316L have nickel and chromium is in maximum percentage in their chemical composition.

### FUTURE SCOPE

In present research work coating was done by using Detonation gun method, base metal used was AISI 316L and coating material used was Inconel 718. For future work in stead of Detonation gun thermal spray process another thermal spray process will be select like HVOF thermal spray method. Base material can also be change from AISI 316L to AISI 304 and perform different test to check the effect of coating on properties of base metals.

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