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Wear characterisation of thermal spray coatings on Stainless Steel 316 L

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Abstract: Thermal spray coating process is a surface modification technique in which a coating material like cermet's, metallic, ceramic and some other materials in form powder are fed into a torch or a gun, the powder inserted into torch will be melted by high temperature developed by a torch. Coating thickness can achieve by applying multiple layers of melted coated material. This paper aims at the study of mechanical characterisation of thermal spray single layer and multi-layer coatings. Coatings on SS 316L is followed by the wear test.It has been found that the wear rate of base metal i.e. SS 316L is more than a single layer and multilayer coatings of Ni-30Cr powder (. The multilayers have shown the maximum resistance to the wear rate.

Keywords: Wear, Single layer, Multi-layer, Wear rate.

I.INTRODUCTION

The family of stainless steel has several branches, which are derived in different ways e.g. by their metallurgical phase present in the microstructures. Which may be Austenitic, Martensitic ferrite or a duplex phase consist of austenite and ferrite. Stainless steel consists of various group and each one having different grade classify according to their chemical constituents [13]. The stainless steel having Fe and Cr 12 to 18 consider as ferritic steel such type of steel doesn't consist Ni.Ferritic steel consists of small amount of non-heat treatable carbon but shows excellent corrosion resistance to and oxidation as compared to martensitic. Martensitic stainless steel consists of carbon0.19 to 1.1% and Cr 11 to 17% [15]. The heat treatment can be done on such materials and their corrosion resistance properties are not too good as compare to other materials having the same amount of Cr and other alloy composition. Duplex stainless steel consists of copper, iron, nickel (4-7%), chromium (18-26%), and molybdenum (0-4%). It showed the microstructure of both austenitic and ferritic thus provide the properties of corrosion resistance and have greater strength [11]. Austenitic stainless steel consists of Fe, Cr 15% to 25% and Ni 5 % to 11 properties can be improved further by adding molybdenum added as per requirement. Its exhibits superior corrosion resistance properties as compared to Ferritic and Martensitic, Example of austenitic stainless steel is AISI 316L. Although stainless steel is having better as compare to corrosion resistance than any other carbon or alloy steel, in some circumstance, it can corrode the material of the application [9].

II.EXPERIMENTAL ANALYSIS

2.1 Specimens preparation
Standard shape and size of specimens are required for carrying out the different tests. It took a resource like time, labour and machine to prepare the specimens according to some fixed standards.

Each specimen had to go through various machining process to come into standard shape and size. All process for each test is discussed below in complete details.

2.2 Specimens preparation for wear test
PIN ON DISC technique is used to check the wears of specimens and preparation of specimens is done according to the ASTM G99 standard. For pin on disc test, cylindrical specimens of diameter 3, 4, 6, 8, 10, 12 mm is required and length of specimens can be between 30 to 50 mm. Any diameters from them is selected and length between 30 to 50 mm to make specimens. It is not easy to take out cylindrical pin directly from base metals sheet of dimension length 150 mm breadth 150 mm and thickness 12 mm, therefore

first specimen of dimension of 50 mm length, 12 mm breadth and 12 mm thickness is cut out from the original sheet of base metals. After that hold the cutting specimens on lath machine and by using turning operation start removing the materials of the specimens at slow rpm, square slab specimens now start taking cylindrical shape and once the diameter 10 mm is remained of cylinder stops the machine take out the specimens from the lath machine. By using same steps three more specimens were prepared. Figure 3.1 and 3.2 show the preparation of specimens on lath machine and figure 3.3 the final shape of specimens i.e. cylinder.

Fig. 2.1 Specimens into lath chuck **Fig. 2.2 Turning operation on specimens**

Fig. 2.3 Final shape of specimens for wear test

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight Loss. (gm)	Cumulative wt. Loss(gm)
1	30 N	5	17.1980	17.1971	0.0009	0.0009
		5	17.1971	17.1967	0.0004	0.0013
		10	17.1967	17.1955	0.0012	0.0025
		10	17.1955	17.1941	0.0014	0.0039
		20	17.1941	17.1924	0.0017	0.0056
		40	17.1924	17.1911	0.0013	0.0069

Table 3.2 Wear test data at 30N load.

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight Loss. (gm)	Cumulative wt. Loss(gm)
2	40N	5	17.3111	17.3100	0.0011	0.0011
		5	17.3100	17.3087	0.0013	0.0024
		10	17.3087	17.3059	0.0014	0.0038
		10	17.3059	17.3036	0.0028	0.0066

Table 3.3 Wear test data collected at 40N load

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight loss. (gm)	Cumulative wt. Loss(gm)
3	50 N	5	17.2310	17.2295	0.0015	0.0015
		5	17.2295	17.2281	0.0014	0.0029
		10	17.2281	17.2251	0.0030	0.0059
		10	17.2251	17.2218	0.0033	0.0092
		20	17.2218	17.2174	0.0044	0.0136
		40	17.2174	17.2109	0.0065	0.0201

Table 3.4 Wear test data collected at 50N load.

Table 3.2, 3.3, and 3.4 showed the data collected from wear test of stainless steel AIS 316L at loads of 30N, 40N, and 50N.

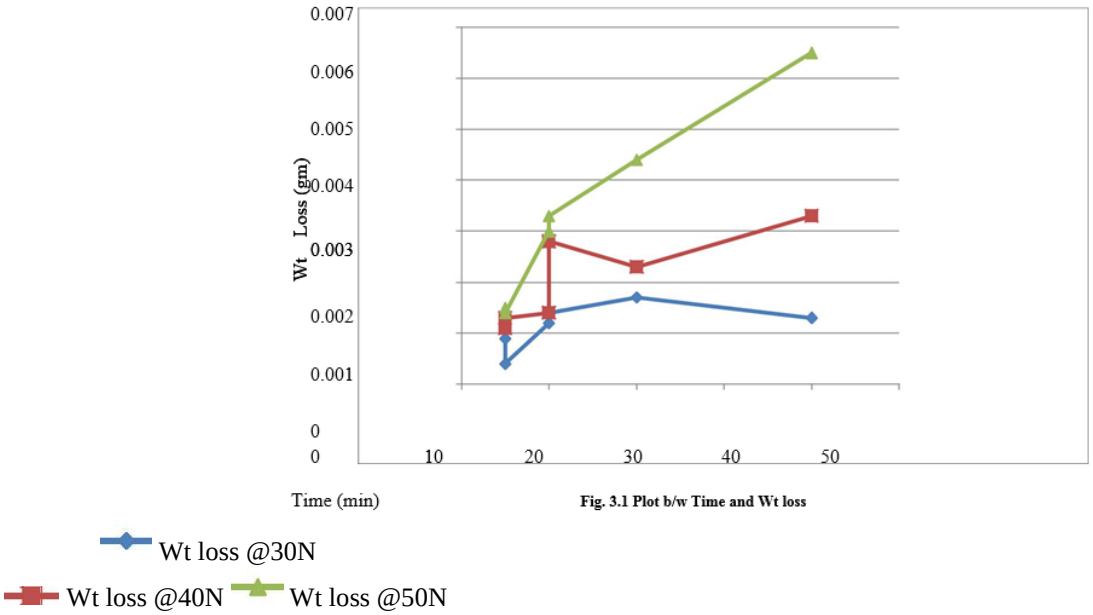

Fig. 3.1 Plot b/w Time and Wt loss

Table 3.5 Show the wear test result of the single layer coated AISI 316L with Ni-30Cr powder at 30N load.

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight loss. (gm)	Cumulative wt. Loss(gm)
		5	17.1260	17.1260	0.0000	0.0000
		5	17.1260	17.1259	0.0001	0.0001
1	30 N	10	17.1259	17.1258	0.0001	0.0002
		10	17.1258	17.1256	0.0020	0.0004
		20	17.1256	17.1254	0.0002	0.0006
		40	17.1254	17.1252	0.0002	0.0008

Table 3.6 wear test result of stainless steel AISI 316L coated with Ni-30Cr powder at 40N load.

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight loss. (gm)	Cumulative wt. Loss(gm)
2	40 N	5	17.1216	17.1213	0.0003	0.0003
		5	17.1213	17.1211	0.0002	0.0005
		10	17.1211	17.1209	0.0002	0.0007
		10	17.1209	17.1207	0.0002	0.0009
		20	17.1207	17.1204	0.0003	0.0012
		40	17.1204	17.1202	0.0002	0.0014

Table 3.7 show the wear test result of stainless steel AISI 316L coated with Ni-30Cr powder at 50N load.

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight loss. (gm)	Cumulative wt. Loss(gm)
3	50 N	5	17.2189	17.2187	0.0002	0.0002
		5	17.2187	17.2186	0.0001	0.0003
		10	17.2186	17.2184	0.0002	0.0005
		10	17.2184	17.2184	0.0000	0.0005
		20	17.2184	17.2179	0.0005	0.0010
		40	17.2179	17.2173	0.0006	0.0016

Time (min)

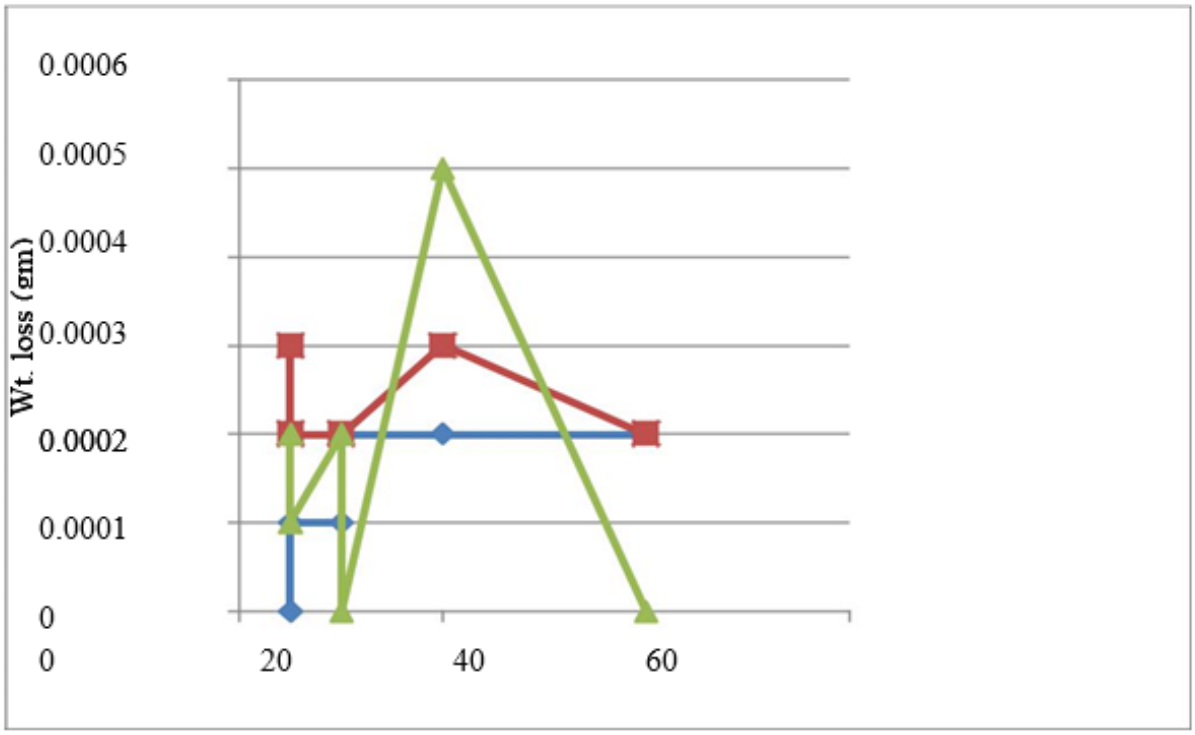

Fig.3.2 Plot b/w Time and wt loss

Wt loss @30N
Wt loss @40N
Wt loss @50N

Table 4.8 show the result of wear test of AISI 316L double layer coated with Ni-30Cr powder at load of 30N.

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight loss. (gm)	Cumulative wt. Loss(gm)
1	30 N	5	17.1256	17.1256	0.0000	0.0000
		5	17.1260	17.1256	0.0000	0.0000
		10	17.1259	17.1255	0.0001	0.0001
		10	17.1258	17.1255	0.0000	0.0001
		20	17.1256	17.1255	0.0000	0.0001
		40	17.1254	17.1254	0.0001	0.0002

Table 3.9 show the result of wear test of AISI 316L double layer coated with Ni-30Cr powder at a load of 40N.

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight loss. (gm)	Cumulative wt. Loss(gm)
2	40 N	5	17.1213	17.1213	0.0000	0.0000
		5	17.1213	17.1211	0.0002	0.0002
		10	17.1211	17.1209	0.0002	0.0004
		10	17.1209	17.1207	0.0002	0.0006
		20	17.1207	17.1204	0.0003	0.0009
		40	17.1204	17.1202	0.0002	0.0011

Table 3.10 show the result of wear test of AISI 316L double layer coated with Inconel 718 at a load of 50N.

Sample No	Load	Time (min)	Initial wt. (gm)	Final wt. (gm)	Weight Loss. (gm)	Cumulative wt. Loss(gm)
3	50 N	5	17.2187	17.2187	0.0000	0.0000
		5	17.2187	17.2186	0.0001	0.0001
		10	17.2186	17.2184	0.0002	0.0003
		10	17.2184	17.2184	0.0000	0.0003
		20	17.2184	17.2179	0.0005	0.0008
		40	17.2179	17.2174	0.0005	0.0013

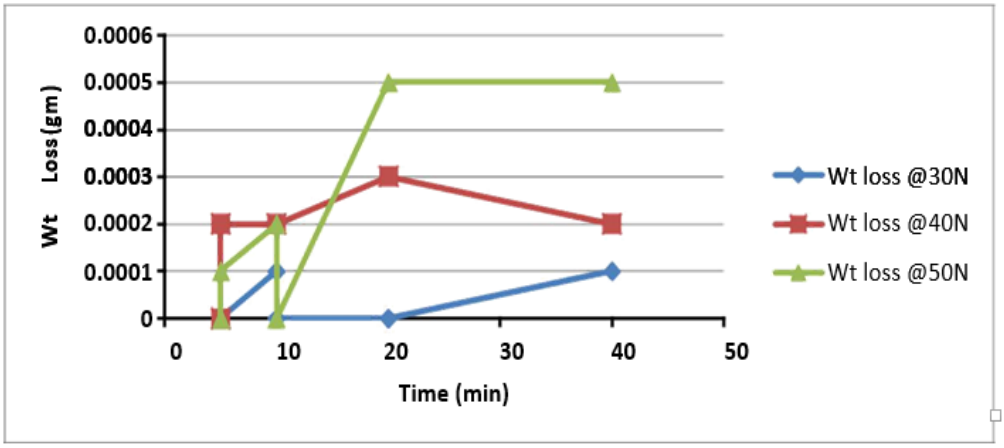

Fig.4.3 Plot b/w Time and Cumulative wt loss

Comparing weight loss of stainless steel, single layer coated stainless steel and multilayer coated stainless steel at 30 N load are shown in the following graph.

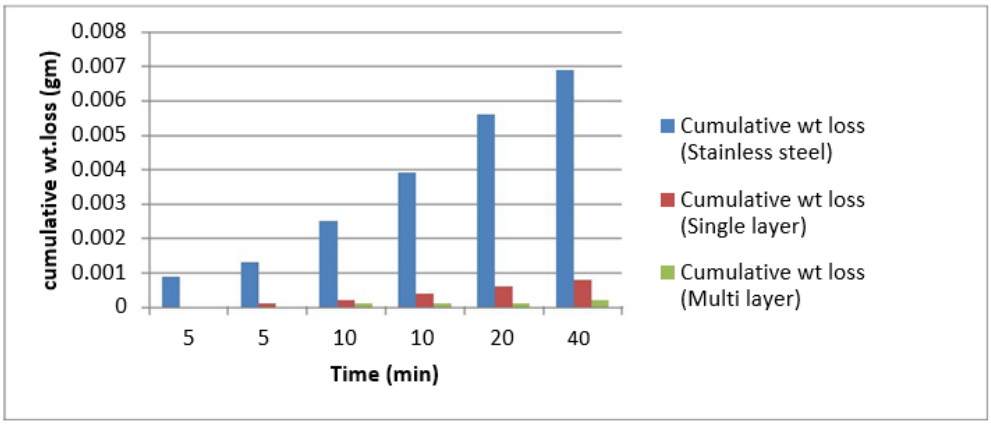

Fig.3.4 Plot b/w Time and Cumulative wt.loss

Comparing weight loss of stainless steel, single layer coated stainless steel and multilayer coated stainless steel at 40 N load are shown in the following graph.

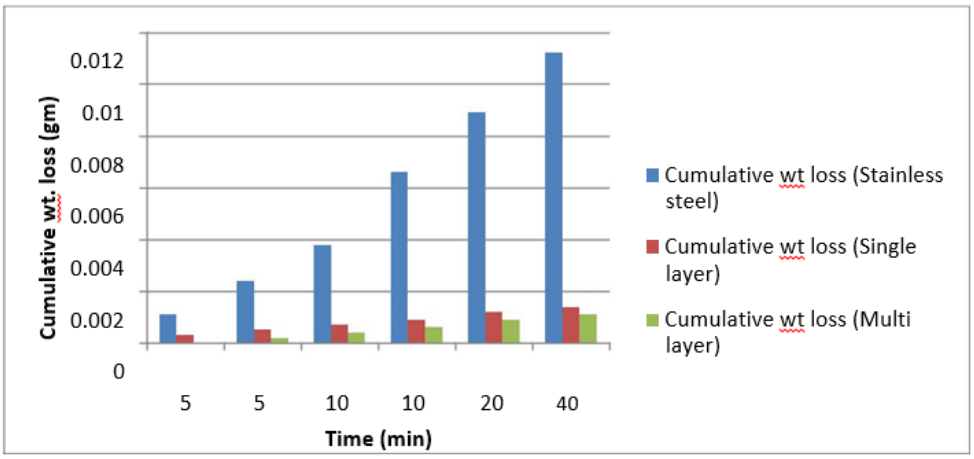

Fig.3.5 Plot bw Time and Cumulative loss

Comparing weight loss of stainless steel, single layer coated stainless steel and multilayer coated stainless steel at 50 N load are shown in following graph.

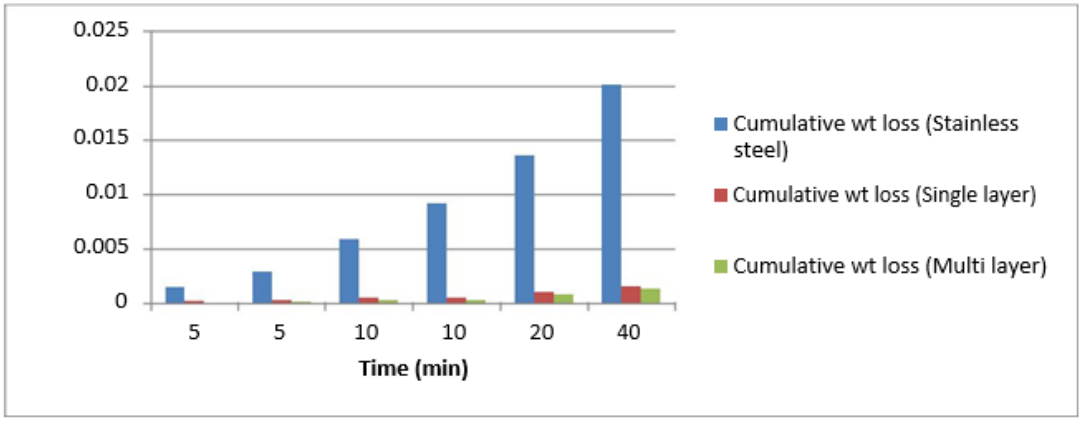

Fig.3.6 Plot b/w Time and Cumulative wt. Loss

Mean weight loss of all the three specimens stainless steel, single layer coated stainless steel and multilayer coated stainless steel at different loads 30N, 40N, and 50N are shown below in graph form.

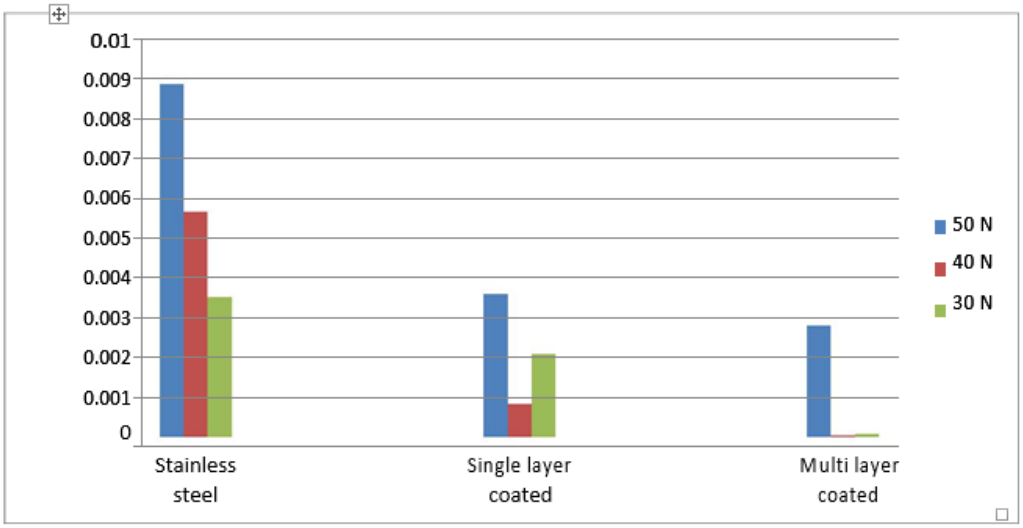

Fig. 3.7 Plot b/w specimen and Cumulative Wt loss

By seeing all the result of wear test and by validating the result with the graph, the conclusion is drawn that wear resistance properties of stainless steel increase by coating surface. Load and time play important role in Pin on disc wear test, as load increases wear increases. It is observed from above data as time of test increase, wear rate also increased.

All the experiments are conducted for 90 minutes in six cycles of 5, 5, 10, 10, 20 and 40min. Total weight loss of stainless steel at 30N is 0.0069 gram, at a 40N load total weight loss increase to 0.0112 gram and at 50N load it further increases to 0.0201 gram. When stainless steel AISI 316L is coated with Inconel 718, weight loss at 30N load is 0.0008 gram and at 40N load weight loss is 0.0014 gram and at 50N load weight loss noted is 0.0016 gram. Weight loss of stainless steel AISI 316L multilayer coated at 30N load is 0.0002 gram at 40N load weight loss noted is 0.0011 gram and at 50N load weight loss noted is 0.0013 gram.Reasons for the increase in wear resistance properties of coated stainless steel AISI 316L.From the result, it was concluded that wear rate depends on various parameters such as the hardness of elements, coating thickness, porosity, surface roughness, and microstructure.

CONCLUSION

In this study, an attempt was made to improve the corrosion and wear properties of SS 316L coated with nickel based alloy the result obtained from the test were compared with SS 316L on the basis of the result obtained some conclusion are made given below.

- Total weight loss in wear test of stainless steel AISI 316L conducted for 90 minutes divided into six cycles of 5, 5, 10, 10, 20 and 40min at lode of 30N was 0.0069 gram, at lode of 40N was 0.0112 gram and at lode of 50N was 0.0201 gram it showed that wear rate increased with increased in load applied.
- Total weight loss in wear test of single layer coated stainless steel AISI 316L with ***Ni-30Cr powder*** by using detonation gun method, conducted for 90 minutes divided into six cycles of 5, 5, 10, 10, 20 and 40min at load of 30N was 0.0008 gram, at lode

of 40N was 0.0014 gram and at lode of 50N was 0.0016 gram it showed that wear rate increased with increased in load applied but wear rate of single layer coated AISI 316L decreased as compared to uncoated stainless steel AISI 316L.

- Total weight loss in wear test of multilayer coated stainless steel AISI 316L with ***Ni-30Cr powder*** by using detonation gun method, conducted for 90 minutes divided into six cycles of 5, 5, 10, 10, 20 and 40min at load of 30N was 0.0002 gram, at lode of 40N was 0.0011 gram and at lode of 50N was 0.0013 gram it showed that wear rate increased with increased in load applied but wear rate decreased as compared to uncoated stainless steel AISI 316L and single layer coated stainless steel AISI 316L.
- Thus from above three-point it was concluded that wear resistance properties of stainless steel AISI 316L were much improved by coating it with ***Ni-30Cr powder*** by using Detonation gun method. Wear rate was improved because the ***Ni-30Cr powder*** is harder materials than stainless steel 316L and hardness of ***Ni-30Cr powder*** increases with increases in temperature.

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