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Corrosion Behaviour of Sintered Austenitic Stainless Steel Composites

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***Abstract*— This study examines the corrosion behaviour of sintered powder metallurgy (P/M) austenitic stainless steel composites with carbide and oxide like TiC and Al2 O3 as reinforcements. The carbide and oxide were added in proportion of 4wt. % to 6wt. %. The powders were compacted into a disc of 20mm diameter and 2mm thick at 10 tonnes load. The compacts obtained were sintered in Nitrogen atmosphere at 1250˚c for 20 minutes. The sintered compacts were subjected to micro hardness, pin on disc wear testing and corrosion rate study by Tafel extrapolation method. The study revealed that the sintered specimens from TiC reinforced stainless steel powders have better micro hardness value than the other composite with Al2O3 and Y2O3 reinforced composite. Potentio dynamic polarization measurements indicated that addition of TiC in the matrix improves the corrosion resistance of sintered austenitic stainless steel in 3.5% NaCl**

I. INTRODUCTION

Sintered stainless steels have a wide range of applications, mainly in the automotive industry (such as ABS rings or temperature control valves). However, they present lower properties than their wrought counter- parts in terms of strength, corrosion and wear resistance. The main reason for this lower performance is the presence of porosity, and the problems arising when these steels are sintered in industrial atmospheres [1]. In order to achieve the best performance, stainless steels produced by powder metallurgy (PM) must be sintered in inert atmospheres at high temperatures. Their properties can be improved with different additions, with the aim of improving the final density of the steel and enhancing the mechanical and corrosion behaviour [2]. When the goal is to improve the wear resistance, oxide ceramic particles [3, 4] are used on account of their hardness. The main problem related to these particulate metal matrix composites (MMCs) is their poor corrosion behaviour as compared with their unreinforced matrix due to the low interaction between matrix and reinforcement.

This study, therefore, investigates the effect of addition of TiC, Al2 O3 and Y2O3 on the mechanical and corrosion behaviour of P/M austenitic 304 Stainless steel.

II. EXPERIMENTAL PROCEDURE

The chemical composition of 304 stainless steel powder used in the present work is shown in the below table

Table 1: Composition of stainless steel powder

ELEMENTS	Wt. (%)
Carbon	0.08
Manganese	2.00
Phosphorus	0.045
Sulphur	0.030
Silicon	1.00
Chromium	18
Nickel	10
Nitrogen	0.19
Iron	Balance

The reinforcement powders were TiC, Al_2 O_3 and Y_2O_3, particle size of the given powders has been measured using the particle size analyzer. After that, particle size has been reduced using the planetary ball mill.

The 304 austenitic stainless steel powder was mixed with required proportion of TiC, Al_2O_3 and Y_2O_3 (4, 5 and 6 Wt. %) with a planetary ball mill. The mixed powders were uniaxially compacted at 10 tonnes in a universal testing machine(model UTN/E40).To minimize the friction,compaction was carried out using zinc stearate as a die wall lubricant.The green compacts were sintered using Tubular furnace.The compacts were sintered at 1250˚C for 20 minutes in Nitrogen atmosphere.The microhardness of the stainless steel composites were measured using Vickers micro hardness testing machine with a load of 0.1kgf.The average of five replicated values were recorded.

Composite's composition and morphologies were analyzed using Scanning Electron Microscope (SEM Model JSM-6380 LA from JEOL, Japan) and the percentage of TiC, Al_2 O_3 and Y_2O_3 in the deposits was analyzed by the EDAX analyzer.

Corrosion studies of composites are made by electrochemical methods (Tafel extrapolation method) using Potentiostat/Galvanostat in a three electrode configuration cell and the reference electrode was an Ag/AgCl/KCl electrode, sample was used as working electrode and platinum as the counter electrode. The 3.5 % NaCl solution was used as corrosion medium.

III. RESULTS AND DISCUSSIONS

The particle size of the stainless steel powder in the as received condition is found about 1200 nm and after the reduction by ball milling for 16Hrs it was observed about

600 nm. The particle size of the reinforcements TiC, Al_2O_3 and Y_2O_3 was 700 nm (0.7 micron)

Micro hardness

Micro hardness of three different type of stainless steel composites were evaluated and tabulated in table 2 and shown in fig 1

Table 2: Micro hardness values of sintered austenitic stainless steel composites

Reinforcement	Wt% of Reinforcement	Vickers Microhardness (HV0.1)
TiC	4%	170
TiC	5%	189
TiC	6%	196
Al_2O_3	4%	155
Al_2O_3	5%	164
Al_2O_3	6%	175
Y_2O_3	4%	158
Y_2O_3	5%	166
Y_2O_3	6%	177

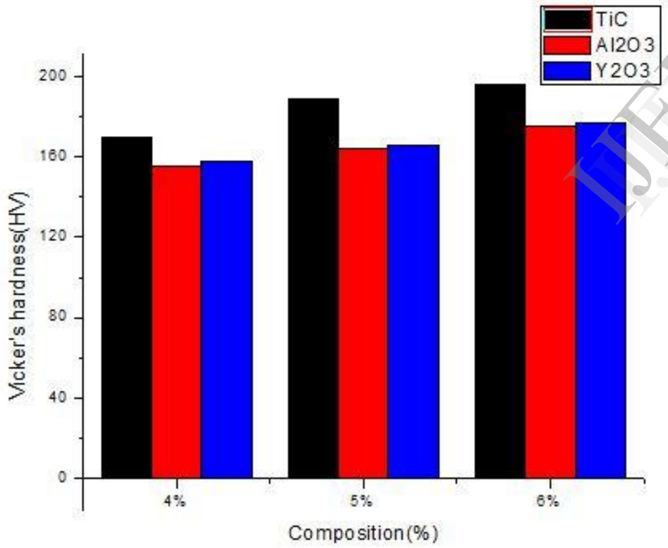

Fig 1: Variation of Vickers hardness

Fig 1 shows the variation of Vickers Hardness as the percentage of reinforcements is increased. Microhardness is found to increase with the addition of reinforcements. It was observed that maximum hardness was found for the addition of 6 wt% TiC in the stainless steel matrix

Micro structural analyses

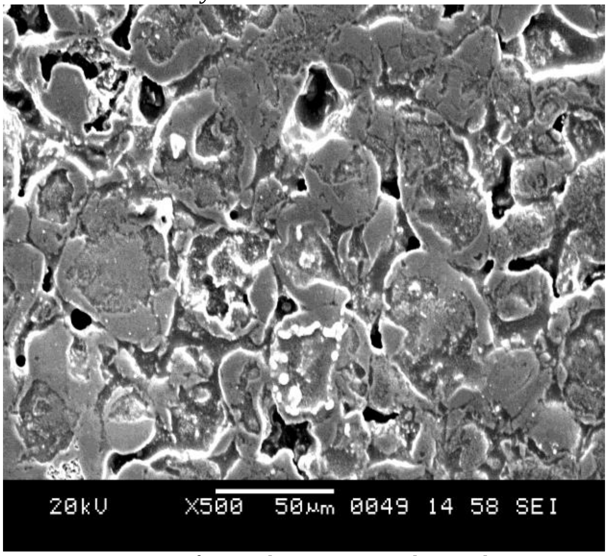

Fig 2: SEM image of sintered 4wt% TiC stainless steel composite

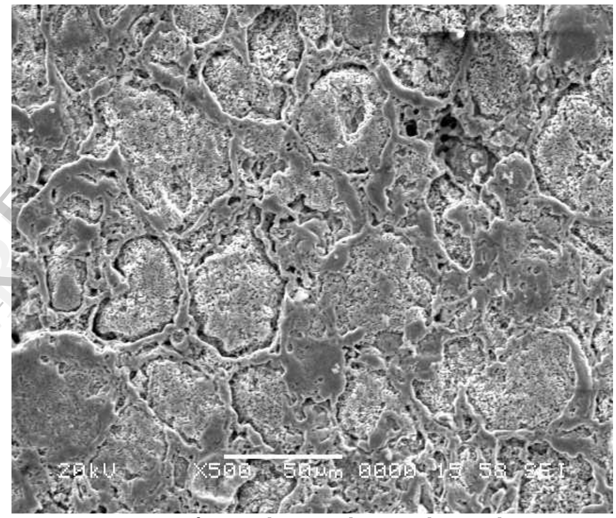

Fig 3: SEM image of sintered 4wt% Al_2O_3 stainless steel composite

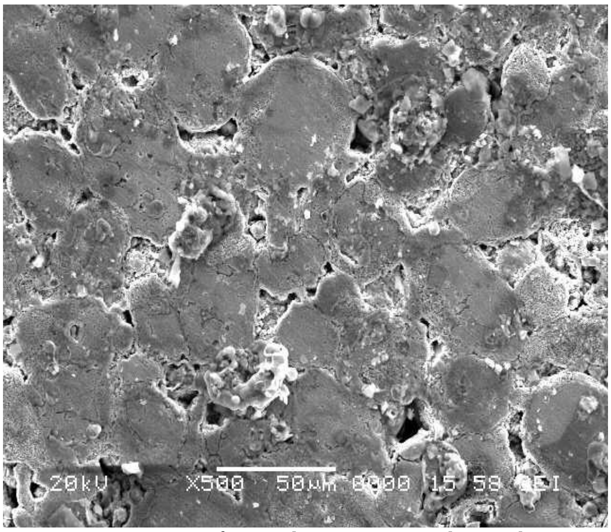

Fig 4: SEM image of sintered 4wt% Y_2O_3 stainless steel composite

Fig 2 to Fig 4 depicted the microstructures of stainless steel composites of 4wt% TiC, Al_2O_3 and Y_2O_3 respectively. The micrographs reveal the loose particle bonding between the stainless steel and reinforcement. The reinforcement powders were randomly distributed in the stainless steel matrix. Sintered microstructure reveals large and irregular pores which is predominantly along the grain boundaries shown in Fig 3 and Fig 4

A bigger size pores have been observed for 4 wt% TiC-stainless steel composite (as shown in fig 2). Sintered 4 wt % Al_2O_3 stainless steel composite which is containing finer pores along the grain boundary is shown in fig 3 where as mixed pores are observed in 4 wt% Y_2O_3 as shown in fig 4

Corrosion studies

Table 2: Corrosion parameters for austenitic stainless steel -TiC composite in 3.5 wt % NaCl solution

Sl. No.	Sample	E_{corr} (V)	I_{corr} (mA)	Corrosion rate (mills/year)
1	4% TiC	- 0.53	0.396	49.55
2	5% TiC	- 0.35	0.095	11.89
3	6% TiC	- 0.12	0.0092	1.163

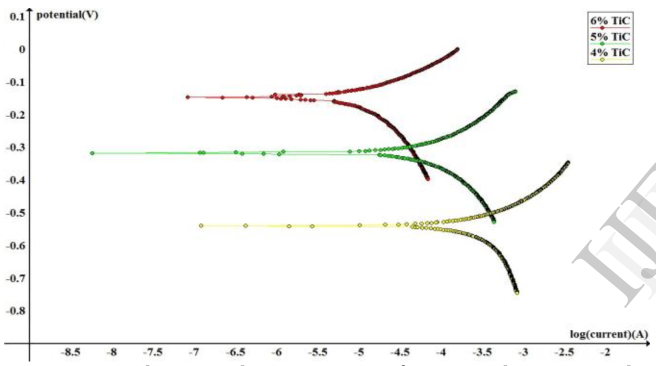

Fig 5. Potentio-dynamic polarization curves of 4%,5% and 6% TiC stainless steel composite

Table 3: Corrosion parameters for austenitic stainless steel -Al_2O_3 composite in 3.5 wt % NaCl solution

SI. No.	Sample	E_{corr} (V)	I_{corr} (mA)	Corrosion rate (mills/year)
1	4% Al_2O_3	- 0.24	0.0108	1.351
2	5% Al_2O_3	- 0.41	0.0997	1.246
3	6% Al_2O_3	- 0.37	0.0177	22.1

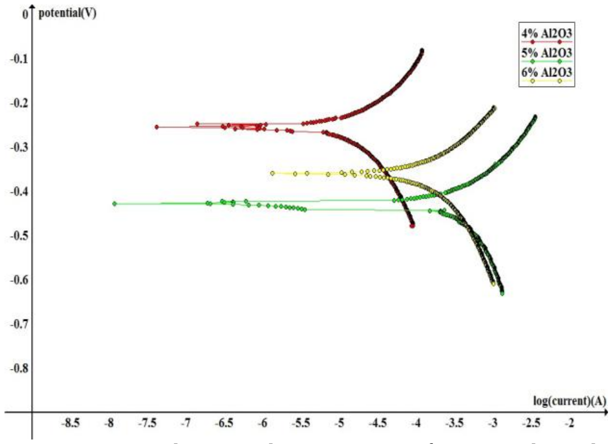

Fig 6. Potentio-dynamic polarization curves of 4%,5% and 6% Al_2O_3 stainless steel composite

Table 4: Corrosion parameters for austenitic stainless steel -Y_2O_3 composite in 3.5 wt % NaCl solution

SI. No.	Sample	E_{corr} (V)	I_{corr} (Amp)	Corrosion rate (mills/year)
1	4% Y_2O_3	- 0.11	0.128	16.12
2	5% Y_2O_3	- 0.30	0.041	5.139
3	6% Y_2O_3	- 0.39	0.0595	7.44

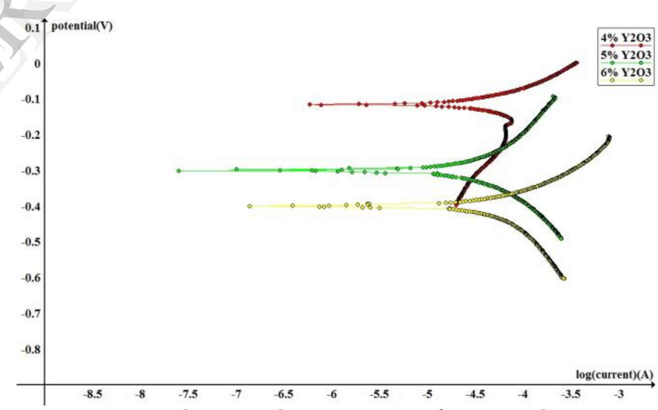

Fig 7. Potentio-dynamic polarization curves of 4%,5% and 6% Y_2O_3 stainless steel composite

The effect of different reinforcements on corrosion are compared at the same composition .Addition of 6% TiC gives the better corrosion rate among all the reinforcements and composition EDAX analyses were done after polarization test. A very small amount of Ti was detected.It could be due to the conversion of TiC to oxide. When the matrix is reinforced with TiC the effective area of stainless steel exposed to the corrosion media decreases

During processing, the interaction between the particle and the matrix decide the atomic registry in the interface. This in turn affects the corrosion resistance. The addition of TiC to the stainless steel matrix improves the corrosion resistance. Corrosion rate has been reducing as the amount of TiC addition increased and 6wt% TiC gives the best corrosion resistance among all. It could be due to the formation of

oxide from TiC and the deposition at the grain boundary.
The addition of 4wt% Y_2O_3 and 5wt% Y_2O_3 improves the corrosion resistance but further addition of 6wt% gives higher corrosion rate. The addition of 4wt% Al_2O_3 and 5wt% Al_2O_3 gives a trivial change in corrosion resistance where as 6wt% Al_2O_3 gives high corrosion rate.

IV. CONCLUSIONS

The sintered microstructure showed large and irregular pores along the grain boundary area. Microhardness of the composites was found to increase with the increase in reinforcement percentage of TiC, Al_2O_3 and Y_2O_3 .Corrosion rate decreases as the amount of TiC increases from to 4wt% to 6wt% in the stainless steel matrix. Lower corrosion rate was observed at 6 wt% TiC stainless steel composite. Addition of 4wt% and 5wt% Al_2O_3 and Y_2O_3 shows a trivial change in the corrosion rate. Corrosion rate increases on the further addition of 6wt% Al_2O_3 and Y_2O_3. Lower weight loss was observed in the addition of TiC among Al_2O_3, Y_2O_3 and TiC

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