# Wear Resistance Properties of Tungsten Carbide/Stainless Steel Composite Materials Prepared by Pulsed Current Sintering

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**Abstract**

*Austenitic stainless steel has been used as a corrosion resistance material. However, austenitic stainless steel has poor wear resistance property due to its low hardness. In this investigation, we apply powder composite process to obtain hard layer of Stainless steel. The composite material was fabricated from planetary ball milled SUS316L stainless steel powder and WC powder and then sintered by Pulsed Current Sintering (PCS) method. We also added TiC powder as a hard particle in WC layer. Evaluations of wear properties were performed by pin-on-disk wear testing machine, and a remarkable improvement in wear resistance property was obtained.*

**Keywords : wear resistance property, microstructure, Composite, PCS, pin on disk**

## 1. Introduction

Austenitic stainless steel (SUS) has the highest corrosion resistance among stainless steels. In addition, austenitic stainless steel has well weld ability and well machine ability. Therefore, austenitic stainless steel has been widely used as a corrosion resistance material. However, its poor wear resistance property restricts it from being used as wear resistance parts and in an abrasive circumstance. In general, the only technique that can be used to obtain a hard surface on austenitic stainless steel is by hard phase plating (wet plating, PVD, CVD) or hard phase spraying. Through, these techniques, the thickness of the hard phase can be slightly increased. Furthermore, these hard phase elements do not diffuse into a stainless steel matrix and the hard phase peels off under heavy wear condition. In order to overcome these severe conditions, a tough hard phase that can endure high load pressure, corrosive circumstances and other wear condition need to be developed. Tungsten carbide (WC) alloys have been widely used as wear resistance materials because of their high strength, high hardness, and other excellent properties. We adopted a pulsed current sintering (PCS) method to make a composite layer [1]. PCS process has some advantages on fabrication composite, FGM, and advanced materials [2].

## 2. Experimental and Results

We used WC-50 (Japan New Metals Co. Ltd. 4.67μm) powder as a base hard metal matrix and SUS316L (Kobe Steel, Ltd. 10.58μm) powder as a stainless steel matrix. As a hard particle dispersion material, we added 30wt% of TiC powders into WC powders. TiC has some attractive properties such as strength, hardness, thermal stability and erosion resistance [3]. For composite layers, we prepared two kinds of layers: one consisting of 20% hard phase (WC or WC+TiC) and the other consisting of 40wt% hard phase. The sintering properties of both types of composite layers were pre-examined and were found to be well sintered with SUS316L matrix [1]. All mixed powders were planetary ball milled for 10.8ks in acetone using WC ball and WC pot. The mixed powders were sintered by PCS machine. (SPS Syntex Inc. SPS-3.20MK-4) We used larger cylindrical graphite mold (inner diameter ϕ50mm) in order to make large disk for pin on disk wear test. We filled up the graphite die with 100g of matrix SUS316L and 35g of hard composite phase. We assumed that the size of the sintered specimen size was a ϕ50mm × 8.5mm thickness and a thickness of the hard phase was 2mm. PCS sintering was performed in vacuum atmosphere (<10Pa), at 20MPa pressure and at 1323K for 600s.

Wear properties were evaluated by a pin on disk wear testing machine. The specimen disks were fine grinded as surface roughness would be about Rz=0.5 μm. We used 5.0mm SKH51 (HRC65) for testing pin material. The sliding speed was 9.42 m/min., a pin load pressure was 100N, and no lubrication was used. The wear limit of the test is defined as a maximum wear depth of 3mm and a

**Table 1. Composite layer contents and result of Hardness test**

| Specimens (Composite contents) | Symbol | Hardness (HRA) |
|---|---|---|
| 80%SUS-20%WC | 8-2 | 79.10 |
| 60%SUS-40%WC | 6-4 | 81.37 |
| 80%SUS-20%(70WC-30TiC) | 8-2/TiC | 81.43 |
| 60%SUS-40%(70WC-30TiC) | 6-4/TiC | 83.77 |
| SUS316L | SUS | 62.90 |

maximum friction coefficient of 0.7. Wear resistance properties were evaluated by weight loss rate.

Composite layer alloy contents and results of hardness test are summarized in Table 1. By adding WC, the hardness value increased compared to that of the SUS matrix, and by adding TiC hard particle, the hardness value also increased. 40% content of WC layer is harder than 20% content of WC layer. The results of pin on disk wear test are shown in Fig.1. It can be seen from this figure that there is obvious improvement of wear property by composite layer. 60%SUS-40%(70WC-30TiC) (6-4/TiC) composite layer produced the best result for wear property. On the other hand, the ratio of weight loss rates of pin to hard composite layers were higher than to SUS316L except 8-2/TiC, since the hardness of composite layer is higher than SUS316L and affected to pin wear. This also shows that the addition of TiC hard particle influences the weight loss rate of the pin. TiC hard particle may improved lubrication circumstance as it act self-lubrication, then weight loss rate of pin to TiC added layer was fewer than that to WC single layer. Microstructure observations were carried out. The thickness of the hard composite layer of 60wt%SUS/40wt%(70WC-30TiC) is about 2mm. No pores and defects were observed at composite layer and Interface area. Composition and connection were performed properly. EPMA analysis was performed to investigate element diffusion at the interface and uniformity of composite layer. The elements of hard composite layer (W and C) do not appear to diffuse well into matrix layer. However, Stainless matrix elements (Fe and Cr) had no segregation between interface layers. Stainless matrix elements existed around W, C and Ti and acted as a binder metal of WC-TiC hard phase composite. There is quite significant dispersion of WC hard phase and TiC hard particle is very well.

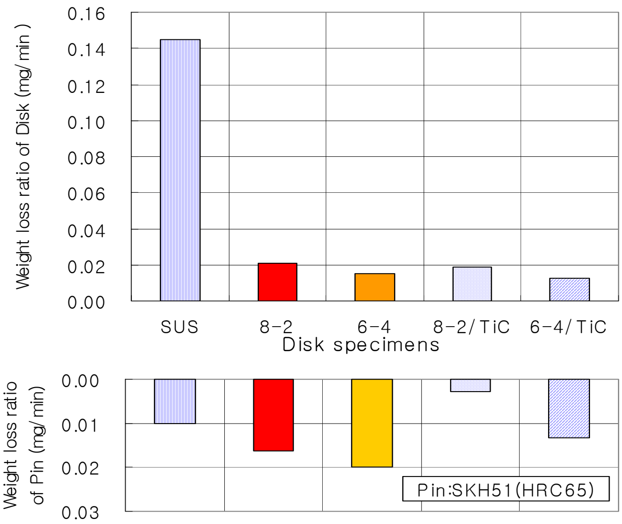


**Fig. 1. Results of pin on disk wear test**

## 3. Summary

To improve the wear properties of austenitic stainless steel, a technique of composition by PCS method was applied. To this end, we developed SUS/WC (/TiC) composite material. The summary of the research is as follows:

1) Hardness of the composite materials was relatively harder than that of SUS316L matrix.

2) Wear resistance property was significantly improved by the composite layer. TiC addition contributed to the improvement of the opponent (pin) weight loss.

3) Microstructure of hard composite layer and the interface have no defects. Stainless matrix acted as a binder metal of hard composite phase. WC and TiC in hard phase disperse uniformly.

## 4. References


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