ENHANCEMENT OF WEAR RESISTANCE OF RASP PARTS USED IN THE PAPER INDUSTRY

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Abstract

The aim of this study is to improve wear resistance of the rasp parts which used in paper industry drying step by using thermal spraying coating techniques. Improving the wear resistance of coated rasp used in the paper industry with the development of a large part of the production process is automated, wasting paper will reduce, wear blasting damaging the paper will be blocked and frequent blasting replaced with production processes in line continuity will be provided. The main purpose of thermal spraying method is to produce wear resistant surfaces. Easy applicability, very low possibility of metallurgical changes and low distortion of coated parts due to low heat transfer to the substrate and salvation of worn parts are some of the practical advantages of this process. Plasma spray coating and powder flame spraying (spray powder fusing) techniques were used prevent wear of the steel substrates. The commercial feedstock powders in the mass fractions 75 % Cr_2O_3 (Metco 106)-25 %TiO_2 (Metco 102) and Colmonoy 705 (Nickel-Base Hard Surfacing Alloy) powders were used as a coating powder. ASTM G65 Wear Test was used for evaluating abrasion resistance of the coatings.

Keywords: Wear, Cr_2O_3-TiO_2, Colmonoy 705, plasma spray coating

1. INTRODUCTION

Thermally sprayed hardmetal coatings are used in many industrial applications for wear protection under very different service conditions, including high temperatures and aggressive media. These composite coatings consist of hard phase particles (typically carbides) dispersed in a metal matrix. Thermal spraying offers two distinct advantages over weld surfacing. First, it can be applied to non-weldable coating materials, such as ceramics, and secondly it can be applied to coatings to materials unsuited to weld surfacing because of composition or susceptibility to distortion. Generally, there is little or no distortion, dilution or metallurgical impact on the substrate. Total coating thickness can be 0.0025-10 mm depending on the stress limitations of the material being sprayed. The state-of-the-art deposition techniques are plasma spraying and powder flame spraying [1-4].

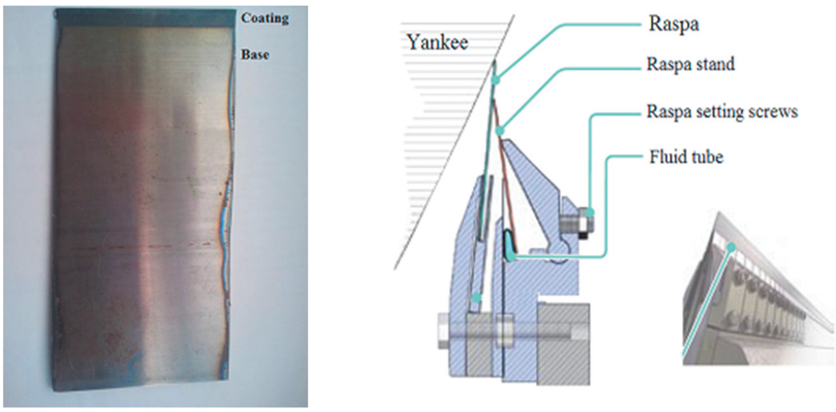
In plasma spraying, a coated layer is formed on a substrate surface by spraying melted powders into a substrate at a high speed using a high-temperature plasma heat source. the plasma spraying is an economical and effective method applied to various machine parts to reduce the surface degradation. Plasma-sprayed ceramic coatings have been widely used for structural applications in order to improve resistances to wear, corrosion, oxidization, erosion, and heat [5].

Cr_2O_3 has a wide range of applications such as green pigments, coating materials for thermal protection and wear resistance as well as refractory applications due to the high melting temperature (about 2435 °C). Plasma-sprayed Cr_2O_3 coatings are widely used as wear resistant coatings in applications such as drilling components and moving parts in textile machines. The wear resistance of the Cr_2O_3 coating is based on the good mechanical properties of the coating, in combination with high hardness and low friction coefficient. Plasma-sprayed Cr_2O_3 is also widely used as paper press rolls. The surface of the plasma-sprayed Cr_2O_3 coating is laser-engraved so that the surface contains a large number of fine dimples. These coatings are also state-of-the-art coatings on paper machine center press rolls, having surface areas of several tens of square meters. The surface properties of these rolls may control the maximum speed of the whole paper machine. The surface properties of common oxide materials have been intensively studied during the past decades. The problem is that the plasma-spraying process itself may radically influence the composition and oxidation state of the material, and this alters the surface properties of the material [6,7].

Titania (TiO_2) is an important additive element for these coatings. It is basically used for providing less porous coating structure as compared to monolithic powder coatings as reported earlier. Further TiO_2 addition results in the improvement of fracture toughness and wear resistance of the plasma sprayed oxide based ceramic coating. When it is used together with coarser Cr_2O_3, titania binds the grains of Cr_2O_3 together to provide better properties as suggested earlier. Several authors have investigated the wear performance of Cr_2O_3 coatings but the literature is scarce for Cr_2O_3-3%TiO_2 (C3T) coatings [6].

The flame spray process utilizes combustible gas as a heat source to melt the coating material. Flame spray guns are available to spray materials in rod, wire or powder form. An acetylene flame having a temperature of 3300 °C is used, in which ceramic material is fed. Colmonoy 705 A self-fluxing type, hard surfacing alloy powder having tungsten carbide particles densely dispersed in matrix of a nickel base alloy containing chromium carbides and it has excellent resistance against metal-to-metal wear, abrasion, oxidation at high temperature and corrosion. Suitable for spray fuse coating on a variety of steels and monel, inconel, cast iron etc. These coating materials often contain WC and CrC particles as per needs to improve the abrasive wear resistance. High fraction of WC particles increases hardness whereas cobalt and chromium matrix provides desired toughness. Hardness of Co base coating depends on microstructural parameters such as fraction of soft matrix and type and fraction of carbide particles, size and shape of carbide particles etc. [8].

The dry sand/rubber heel abrasion test involves the abrading of a standard test specimen with a grit of controlled size and composition. The abrasive is introduced between the test specimen and a rotating 1018heel with a chlorobutyl rubber tire or rim of a specified hardness. This test specimen is pressed against the rotating 1018heel at a specified force by means of a lever arm while a controlled flow of grit abrades the test surface. The rotation of the 1018heel is such that its contact face moves in the direction of the sand flow. Note that the pivot axis of the lever arm lies within a plane which is approximately tangent to the rubber 1018heel surface, and normal to the horizontal diameter along which the load is applied. The test duration and force applied by the lever arm is varied as noted in Procedure A through E. Specimens are weighed before and after the test and the loss in mass recorded. It is necessary to convert the mass loss to 1018heel1018 loss in cubic millimeters, due to the wide differences in the density of materials. Abrasion is reported as 1018heel1018 loss per specified procedure [4].



(a) (b)

Fig. 1 Macro image (a) and the service life (b) of the rasp part [9]

The present paper deals with the wear resistance of the plasma-sprayed Cr_2O_3-TiO_2 and the powder flame sprayed Colmonoy 705 (Ni-Cr-B-WC powders) coatings that increased the service life of the rasp (as seen in **Fig. 1**) used in the paper industry.

2. EXPERIMENTAL PROCEDURE

2.1. Materials

DIN Ck 75 steel (AISI 1075) was used as a substrate and its chemical compositions are shown in **Table 1**. The commercial feedstock powders in the mass fractions 75 % Cr_2O_3 (Metco 106)-25 %TiO_2 (Metco 102) and Colmonoy 705 (Nickel-Base Hard Surfacing Alloy) powders were used as a coating powder. The chemical compositions of the materials used are shown in **Table 2**.

Table 1 Chemical composition (wt.%) of the substrate

Elements	Fe	C	Si	Mn	P	S	Cr
	98	0.739	0.203	0.705	0.0146	0.0025	0.206
	Ni	Mo	Al	Co	Cu	Sn	others
	0.0287	0.0082	0.0046	0.0021	0.0413	0.0126	0.032

Table 2 Coating powders and properties

Coating Powders	Powder size (μm)	Melting Temp. (°C)	Density(gr/cm^3)	Hardness(Hv)
Metco 106 (Cr_2O_3)	11-90	2435	5.21	~1700
Metco 102 (TiO_2)	11-45	1843	4.23	~800
Colmonoy 705 (Ni-Cr-B-WC)	15-63	1024	13.38	690 - 820

2.2. Coating Process

Cr_2O_3-25 wt% TiO_2 powder was sprayed using a Sulzer Metco F4 plasma gun with a 6-mm nozzle, controlled by a Sulzer Metco MULTICOAT system (80 kW). AISI 1075 steel was used as the substrate. The samples were not preheated. The spray parameters are given in **Table 3**.

Table 3 Selected plasma spray coating parameters

Robot motion rate (mm/s)	200
Substrate	AISI 1075
D.C. Current (A)	500
D.C. Volts (V)	70
Primary-gas flow rate (Ar, L/min)	45
Secondary-gas flow rate (H_2, L/min)	8
Carrier-gas flow rate (Ar, L/min)	2.5
Spray distance (mm)	100

2.3. Wear tests

The abrasive wear resistance of the various coatings was evaluated in three-body abrasive wear condition using a dry sand rubber heel abrasion test rig based on ASTM G65 according to C procedure. **Fig. 2** shows the schematic diagram of the dry sand rubber 1019heel apparatus, as taken from this ASTM standard. While this standard proposes to use 200-300 μm size Ottawa silica sand as the abrasive [10].

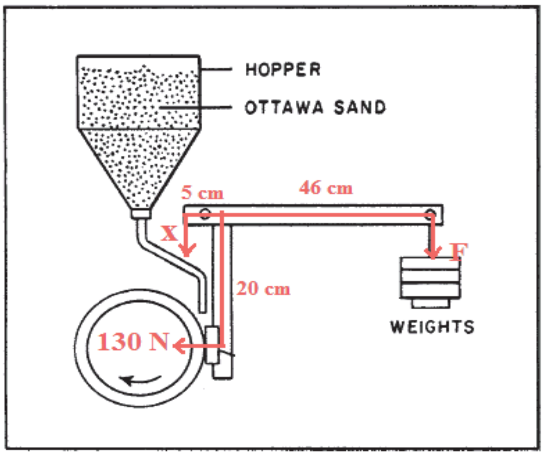


Fig. 2 Schematic diagram of dry sand rubber heel abrasion test apparatus (ASTM G65) *[11]*

2.4. Coating characterization

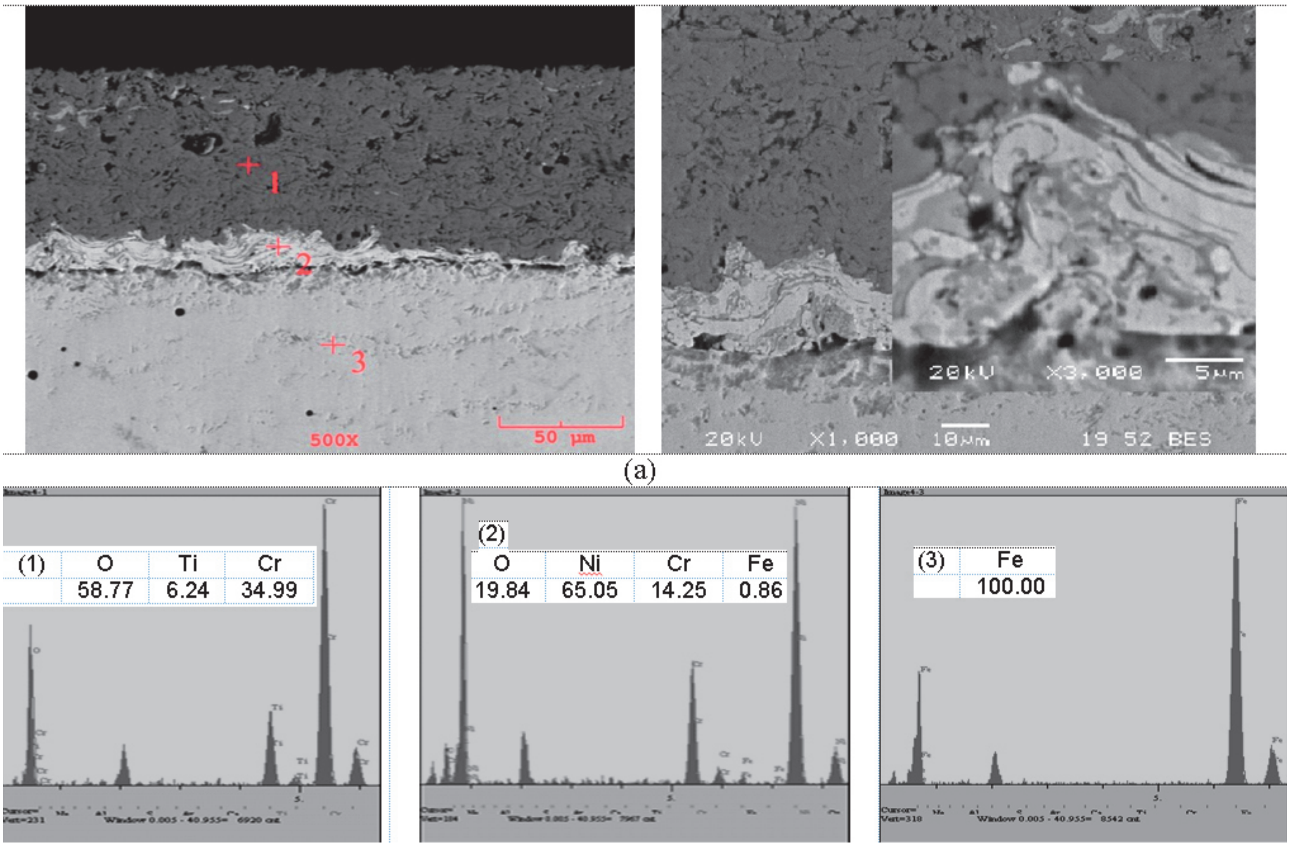
A scanning electron microscope (SEM) (JEOL JSM-6060LV) equipped with an energy dispersive X-ray spectrometer (EDS) was used to examine the microstructures and chemical compositions of the coatings. The micro hardness values of the specimens were taken from the cross-sections of the polished samples at the load of 300 g and after a loading time of 15 s using LEICA VMHT MOT micro hardness equipment.

3. RESULTS AND DISCUSSION

3.1. Microstructural characterization of the coating

Fig. 3 shows SEM micrographs of used coating rasp part cross-section and EDS analysis of coating layer, bond layer and substrate material. As a result of EDS analysis the coating layer Cr_2O_3+TiO_2 based, bond coat FeNiCr based are identified. It is well known that the structure and the phase of each splat depend on the cooling and solidification rates experienced during solidification. The cooling rate, in turn, depends on material properties including the melting point, density and specific heat and on the thermal contact between the splat and previously deposited layer.

At the coating microstructure coded as number 1, light colored areas have chrome oxide essential (the material whose atom number is higher has been seen shiner); it can be said that the atom number of dark areas have bigger Ni elements compared to others when the detailed micro structure of bunch sheet enlarged 3000x the code number 2 FeNiCr essential. In this study performed as improving the physical life of worn coated rasp; one of the techniques to be applied is plasma spray coating and the other is powder spray fusing which can lead us to get more economical coating and it is strongly preferred.



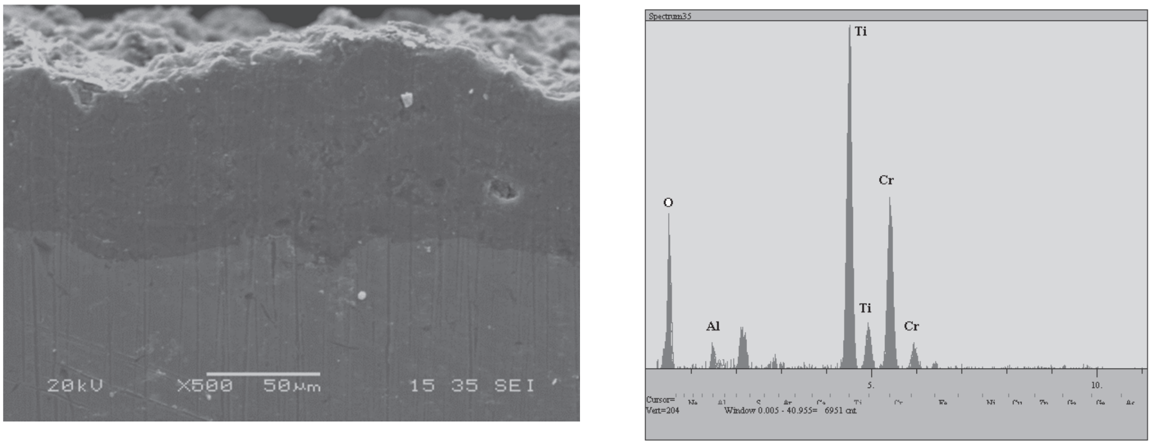
b c d

Fig. 3 a) SEM micrographs of used coated rasp part interface b) coating layer, c) bond layer and d) substrate material EDS analysis

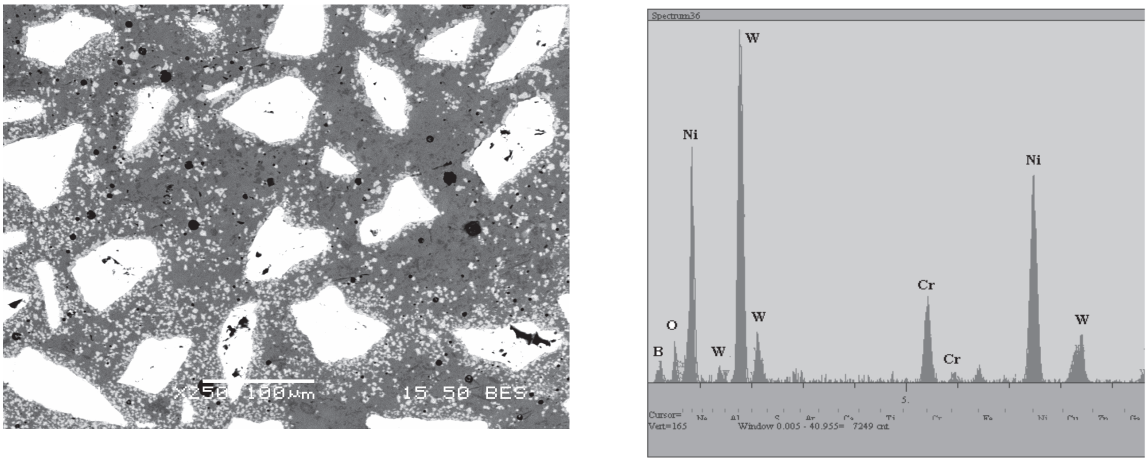
The SEM-EDS analysis of the coatings samples used by the plasma spray coating (75 % Cr_2O_3 + 25 % TiO_2 powder) and the powder spray fusing (Colmonoy 705 alloy powder) techniques are seen in **Fig. 4**. In the image of SEM belonging to Cr_2O_3-TiO_2 essential coating performed plasma spray coating, coating thickness is homogeneous and it can be stated that it can exhibit typical lamellar coating structure and it approximate, has 90 µm coating thickness. It has been seen that there is homogeneous distribution in the WC powder particles which have different particle size distance in the coating sheet performed by powder spray fusing technique using Colmonoy 705 coating powder. In the EDS analysis, WC, Ni, Cr peaks which is found in the coating powder composition but B peak has not been detected.

3.2. Wear Test (ASTM G65 Procedure C) Results

ASTM G65 Procedure C wear test have been applied to both plasma sprayed Cr_2O_3-TiO_2 ceramic and powder spray fusing Colmonoy 705 coatings. Colmonoy 705 is higher abrasion resistance of coatings and also the using coating system (powder spray fusing) is cheaper than plasma spray coating. It is known that drilling knives and scrapers, which are necessary in the resistance of highly wear coating performed with Colmonoy 705 Ni-Cr-B-WC essential have been able to be used in the fields of ceramic industry which needs wear resistance.



(a)



(b)

Fig. 4 SEM images and EDS analysis of a) plasma spray, b) powder spray fusing coating layer

The microhardness values of the specimens were taken from the cross-sections of the polished samples at the load of 300 g and after a loading time of 15 s. The hardness values of all samples determined by taking 5 measurements from three different areas. Vickers hardness on cross-section of coatings was observed to increase with the increase in Cr_2O_3 mixing ratio. The presence of Cr_2O_3 commonly improves the hardness of the Cr_2O_3-TiO_2 coatings and the presence of WC commonly improves the hardness of the Colmonoy coatings.

In **Table 4** shows average abrasive wear loss and hardness values of the coatings. Abrasive wear resistance of flame sprayed coatings was seen to be dependent on the chemical composition and characteristics of coating materials and coating condition. The large spread in the coating hardness of thermal sprayed coating is a function of the non-homogenous coating microstructure. Low porosity in the coating is fundamental requirement to achieving good abrasion resistance of coatings. The coating hardness is strongly influenced by the binder mean free path of carbides [10,12].

The microhardness values are also in direct correlation with the coating microstructure. A relatively higher value of the microhardness is a representative phenomenon of presence of adequate lamellar structure with high cohesion strength between the layers and high adhesion strength on the coating/substrate interface [13]. Addition of carbide particles increased hardness as expected and it is primarily attributed to increased fraction of hard WC carbide particles. Moreover, higher hardness would effectively be reducing the depth of indentation by coarse abrasives [12].

Table 4 Abrasive wear loss and hardness values of the coatings

Coatings	Abrasion loss (mg)	Average volume loss (mm^3)	Hardness(Hv)
Colmonoy 705	35.3	2.6382	1020
75%Cr_2O_3 -25% TiO_2	88.1	17.8891	1004

CONCLUSIONS

It has been determined that the hardness value of coatings performed with the plasma spray coating technique has the similar hardness value as to the powder spray fusing technique. But, the abrasion loss values taken from the ASTM G65 test, are better in Colmonoy based coatings. According to the service life of the rasp part, it is suggested that the material coated with Colmonoy 705 has higher abrasion resistance of coatings and also the using coating system (powder spray fusing) is cheaper than plasma spray coating.

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