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Feasibility Study of Friction Surfaced Coatings over Non-Ferrous Substrates

Mohammed Shariq*[a], Madhulika Srivastava*[a], Rupam Tripathi[a], Somnath Chattopadhyaya[a], Amit Rai Dixit[a]

[a]*Department of Mechanical Engineering, Indian School of Mines, Dhanbad, India (826004)*

Abstract

The present work examines the feasibility of getting friction surfaced coatings on different combinations of consumable rods and non-ferrous substrates. Aluminium (AA1050A), Copper, Stainless Steel (AISI 304), Mild Steel were used as substrates and commercially pure Copper and Stainless Steel (AISI 304) were used as consumable rods. Friction surfacing was carried out using these consumable rods and substrate combinations with a conventional universal milling machine FNU2213. The investigation revealed that certain combinations metallurgically bonded coating is formed quickly over the substrate while with certain other combinations, this coating is formed with the assistance of a start-up plate. However, for a certain combination of parameters, no coating is formed whatsoever. The formation of coating is influenced by the coefficient of friction as well as material properties, such as, thermal conductivity and stability at high temperature.

Keywords: Friction Surfacing ; Feasibility analysis ; Ferrous and non ferrous alloys.

1. Introduction

Friction surfacing (FS) is a solid state process used for ferrous and non-ferrous coatings by means of plastic deformation of the metal-based consumable rod over a substrate [1]. It has emerged as an important technology in the area of solid-based material processing as it can be used for localized modification and micro-structural control of surface layers of ferrous and non-ferrous processed alloys for specific property enhancement. [2]

Nomenclature

FS	Friction Surfacing
MS	Mild Steel
SS	Stainless Steel
CP	Commercially Pure Copper
RPM	Rotation per minute
HV	Hardness Value
IR	Infrared

* Corresponding author. Tel.:+386 30 316 087.
*E-mail address:*mohdshariq.03@hotmail.com

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In this process, a consumable rotating tool in the form of a rod is rotated against a substrate under an applied axial load. The initial frictional heat generation due to rubbing makes the tip of the rod softer resulting in a viscoplastic layer. This viscoplastic layer gets coated over the substrate surface due to conduction of heat [3]. The deposited layer has refined microstructures due to recrystallization and shows excellent metallurgical adhesion and mechanical bonding at interface of the deposited layer and the substrate [4]. This interface is free from defects, such as, holes, pores, inclusions, etc., which are common in fusion-based techniques [5]. Chandrashekharan et al. [6] investigated the feasibility of coating ferrous and non-ferrous materials such as, Al and Ti rods on MS and SS substrates as well as MS and Inconel on Al substrates. It was found that Ti cannot be deposited on MS due to a high degree of plasticity under the attained temperature. Nevertheless, it is possible to get a coating by carrying out initial treatment of Ti. Rao et al. [6] conducted a feasibility study of various combinations of non-ferrous substrates, such as, Al alloy (AA 6063), CP Cu, Ti rods over CP Cu, Mg (ZM21), Inconel 800 and Ti Alloy (Ti-6Al-4V). Process parameter selection as a function of material properties is a key factor in ensuring successful coatings. CP Copper and CP Ti cannot be deposited on any substrate material while AA 6063 Al alloy can be successfully deposited only on CP Al substrate. Fukukusa (1996) analyzed the material flow during the FS process using the tracer technique. Hollow AISI 403 rod was inserted into the AISI 304 solid rod, thereby making it a composite assembly. The study helped in understanding the Al alloy coating formation on the substrates [7]. Due to a narrow band of parameters, it is difficult to ensure successful coatings under different loads and temperatures in non-ferrous alloys. As far as this area of study is concerned, so far, there have not been enough investigations on the coating mechanism, relationships between different process parameters and the feasibility issue. Therefore, an attempt is being made to study the feasibility of coating formation by using SS (AISI 304) on Al (AA 1050), SS (AISI 304) on CP Cu and CP Cu on CP Cu. Thermo-graphic analysis has been done to study the influence of temperature profiles on different stages of the coating mechanism.

2. Experimental Procedure

2.1 Material

In this experiment, compositions of the materials used are shown in Table. 1. The substrate plates with dimension of 150mm × 100mm × 10mm were first cleaned with acetone and then clamped. To clamp the substrate plate on the table, universal serrated block and serrated clamp were used. The surface of different substrate plates was cleaned with the help of a surface grinder to get an even surface for coating.

Table 1. Composition of the materials used.

Element	C%	Mn%	S%	Si%	P%	Ni%	Cr%
MS	0.16-0.18	0.70-0.90	-	0.4	0.04	-	-
SS (AISI 304)	0.08	2.00	0.03	1.0	0.04	8-10.5	18-20

Element	Si%	Fe%	Cu%	Mn%	Mg%	Zn%	Ti%	Cr%
AA1050A	0.4 – 0.8	0.70	0.15-0.40	0.15	0.8-1.2	0.25	0.15	0.04-0.35
CP Cu	-	-	99.9	-	-	-	-	-

2.2 Experimental Setup

In the present work, friction surfacing was carried out on ‘Conventional Universal Milling Machine FNU2213’ with a combination of process parameters as shown in Table 2. Following were the specifications of this milling machine: Overall dimensions - 1070×230 mm, Clamping Area- 900 × 230 mm, Milling Spindle Speed Range- 45-2000 rpm, and Spindle Feed Range-16-630 mm/min. The substrate plate was held with the help of fixtures, such as, serrated block and serrated strap clamp as shown in Fig. 1.

2.3 Thermography

The thermal images were taken with the help of CHAUVIN ARNOX C.A. 1888 camera. These cameras are ideal for preventive or predictive maintenance techniques in engineering field. The 3.5-inch screen device has the following specifications: Thermal sensitivity: 0.08°C, Detector: 384*288, Frequency: 50 Hz, Spatial resolution: 1.3 mrad, Spectral band: 7.5 to 14 mm, Temperatures: –20°C to +1500°C, plus ‘High temperature’ option, Mix Vision mode for viewing the IR image, the real image and the overlay of the IR on the real image, Analysis functions: 1 to 4 movable cursors, 3.5-inch screen, Leak proofing: IP 54, Battery life: 3h minimum, Interfaces: Video output