# SURFACE MODIFICATIONS THROUGH PLASMA ENHANCED SHIELDED METAL ARC WELDING PROCESS (PESMAW)

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## ABSTRACT

Low alloyed steels are widely employed in the agricultural, transport and metal processing industries and are often treated to improve surface wear resistant properties. In this study, the surface of plain carbon steel is melted using a metal arc heat source and the surfaces are simultaneously alloyed using a metallic powder and nitrogen gas. This process is novel in that the nitrogen gas carries metallic powder through the electrode and into the plasma created between the tip of the electrode and substrate surface. The changes in wear characteristics of the modified surfaces are monitored using a pin-on-plate wear testing machine and micro-indentation hardness measurements as a function of depth from the surface. Preliminary results indicate a significant increase in wear resistance for surfaces alloyed with nitrogen and chromium powder compared to the untreated surfaces. These changes in wear properties are explained through changes in micro structural features within the solidified surface.

***KEY WORDS :*** Surfacing, Surface melting, Wear resistance, Tribology of steels, Surface alloying, Hardness, Plain carbon steels, Plasma Enhanced Shielded Metal Arc Welding.

## INTRODUCTION

A multitude of processes are being used to modify the wear resistant behaviour of low-alloyed steels for use in applications in the agricultural, transport and metal processing industries. In general, the surfaces of a component can be modified extrinsically by depositing hard coatings using vapour phase coating, plasma spraying or hard facing methods to name just a few [1,2]. However, surfaces modified intrinsically by melting are produced by a limited number of techniques and include surface melting and alloying using laser, electron beam glazing techniques and tungsten arc processes [3,4,5]. In this study, the Plasma Enhanced Shielded Metal Arc welding (PESMAW) [6] which is a modified version of conventional Shielded metal arc welding process (SMAW) is used to modify surfaces by simultaneously melting and alloying with a metallic powder. The process uses a hollow, mild steel electrode, which not only creates an arc between the electrode tip, but nitrogen gas is used to feed metallic powder directly into the plasma created within the arc. The changes in the properties of the modified surfaces were monitored using metallurgical techniques, micro-indentation hardness measurements as a function of depth through the surface. The wear behaviour of the surfaces was monitored using a pin-on-plate wear testing equipment.

## PLASMA ENHANCED SHIELDED METAL ARC WELDING (PESMAW) PROCESS*

It is an arc welding process developed by The Indian Institute of Technology, Delhi (IITD) in which welding, deep penetration welding, surfacing, cutting and piercing is done by feeding suitable gases (argon, helium, carbon dioxide or a combination of these gases, oxygen), powders (metallic, ceramic or a combination of alloying elements) or a combination of both gases and powders through the orifice of the covered electrode [7,8]. The flow diagram of PESMAW process is shown in Figure-1.

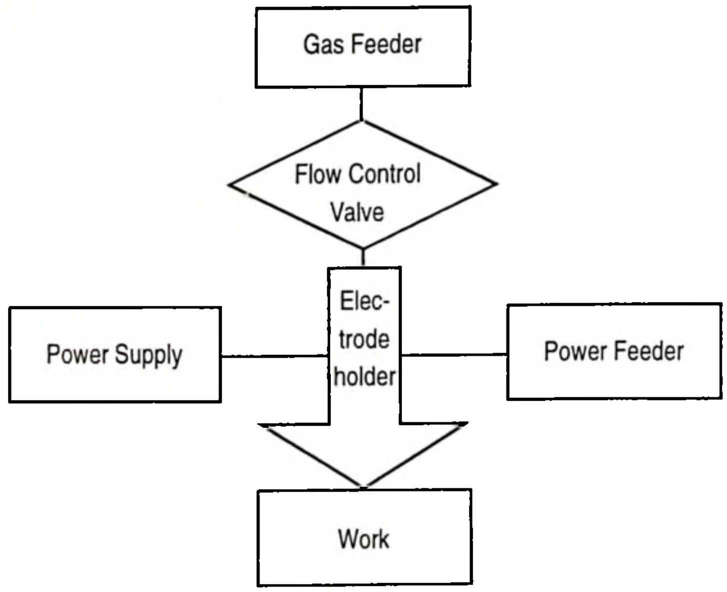


**Fig. 1 :** Flow Diagram for PESMAW Process

### Principle of operation

In PESMAW process, welding begins when an electric arc is struck between the tip of the electrode and the work. The arc action is shown in the Figure –2.The intense heat of the arc melts the tip of the electrode and the surface of the work beneath the arc. Tiny globules of molten metal rapidly form on the tip of the electrode, get accelerated due to the centerline velocity of the plasma gas supplied through the electrode. The extra heat liberated from the chemical reaction of the plasma gas then transfer through the arc stream into the molten weld pool.

In this manner, filler metal is deposited as the electrode is progressively consumed. The arc is moved over the work at an appropriate arc length and travel speed, melting and fusing a portion of the base metal and adding filler metal as the arc progresses.

## 3. EXPERIMENTAL PROCEDURE

### Materials

Plain carbon steel was used as the substrate surface in this study. The steel samples were cut into rectangular plates with a dimension of 50 x 30 x 10 mm. The surfaces of the samples were cleaned using 600 grit abrasive before surface melting. A hollow, general purpose, rutile coated mild steel electrode with an internal diameter of 2 mm and 363-mm length was used to melt a surface track (10 mm wide) onto the substrate surface.

**Table 1 :**
**Welding conditions used during the experimental program**

| S. No. | Parameters | Values |
|---|---|---|
| 1 | Current (Amperes) | 124 |
| 2 | Voltage (Volts) | 20 |
| 3 | Travel Speed (mm/sec) | 1.0-1.5 |
| 4 | Heat input (kJ/mm) | 2.4 |

### Welding Procedure

All welds were deposited manually bead-on-plate by a skilled welder using an AC welding power source. All surface tracks were produced using a current of 124 A. Surfaces were modified using pure nitrogen gas flowing through the electrode and onto the molten surface. The process was repeated using a holder, which allowed the flow of chromium powder into the nitrogen gas and this mixture, was fed into the arc

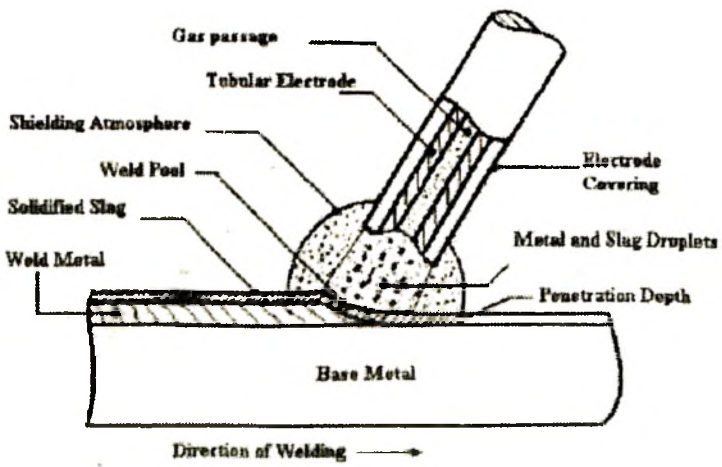


**Fig. 2 :** Process Details

and the molten surface. The welding conditions used in the experimental procedure are shown in Table-1.These conditions were chosen based on trial and error basis in accordance with the current range suggested for the external diameter of the wire. An approximate nominal linear heat input of 2.4 kJ/mm was kept constant during the experimental procedure.

**Metallographic Analysis**

Metallographic sections were prepared from the solidified tracks and etched for light microscopy using 5% nital solution. Micro-hardness profiles as a function of depth through the surface tracks were obtained using a Leitz micro-hardness indentor with a load of 2N. The wear resistant behaviour of the untreated surface was compared with the modified surfaces using a reciprocating pin-on-plate wear-testing machine. Dry wear tests were performed using a load of 1 kg and a diamond pin moving against the modified surfaces. The change in wear rate was monitored quantitatively by recording wear groove depth as a function of sliding distance.

**Fig. 3a :** Micrograph showing microstructure of the solidified track produced using Nitrogen gas x 500

**Fig. 3b :** Micrograph showing microstructure from a surface track produced using chromium powder and Nitrogen gas x 500

**RESULTS AND DISCUSSION.**

**Weld metal microstructure**

Plain carbon mild steel normally consists of hypo-eutectoid ferrite with colonies of pearlite. However, the micrographs in Figure-3 (a) and (b) show that the re-solidified surface microstructure has changed significantly.

The results show that in general, surfaces melted under a flow of pure nitrogen gas or when a mixture of nitrogen and chromium powder was used produced tracks free from micro-cracks although some porosity and silicate internal inclusions. The microstructure of the solidified tracks produced under a nitrogen gas shows a ferrite matrix dispersed with retained austenite (light, angular grains) and dark, rugged needles of carbides. The formation of bainite can be expected due to the rapid cooling affect of the gas. A similar structure was produced for surfaces alloyed with chromium powder in a flow of nitrogen gas. However, a finer microstructure was obtained showing a greater concentration of needle-like carbides. These carbides will most probably be chromium carbides and can be expected to increase the wear resistance properties of the surface. Further definitive analysis is necessary in order to establish these microstructural developments.

**Weld metal Hardness**

A comparison of micro-hardness profiles for the treated surfaces shown in the Figure-4 indicates that the hardness values are uniform with depth for surfaces melted under nitrogen and the nitrogen and powder mixture. However a higher hardness value of ~270 VHN for surfaces melted under the nitrogen and powder mixture is achieved. The hardness profile increases suddenly at the fusion boundary between the melt track and heat affected zone due to a change in the grain size of the steel. The differences in hardness correspond directly to the increase in wear resistance observed in Figure-5 for the modified surfaces over the untreated steel.

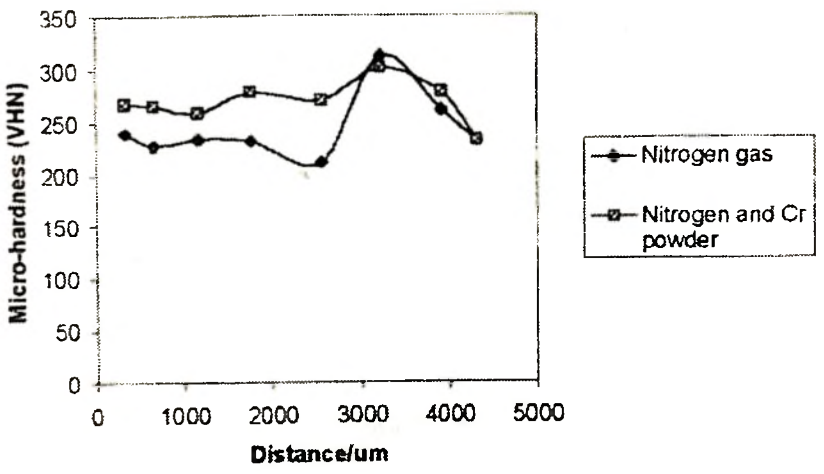


**Fig. 4 :** Micro-hardness profiles as a function of depth through modified steel surface

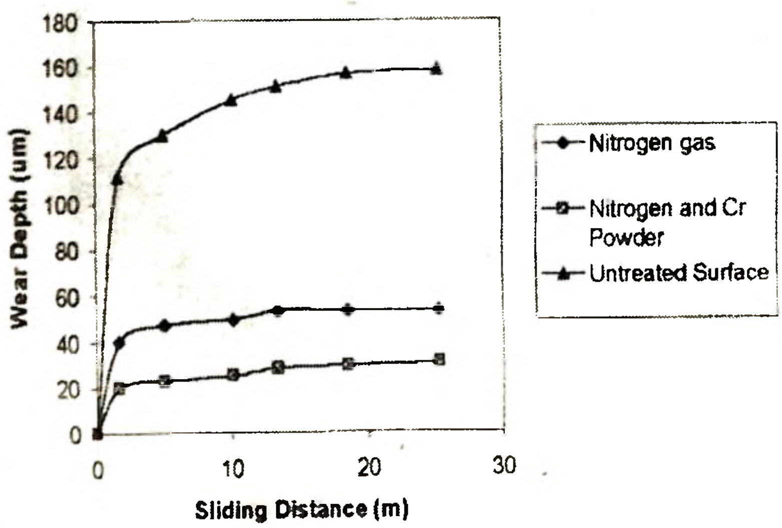


**Fig. 5 :** Comparisons in wear groove depth as a function of sliding distance for untreated and treated surfaces.

This change in wear behaviour is significant and can be attributed directly to a change in phase within the solidified surfaces. The formation of hard compounds, such as chromium carbides within the surface tracks produced using chromium powder gives the best wear resistant properties. However, further work is necessary to define the change in wear mechanisms between the two types of modified surfaces.

## CONCLUSIONS

The preliminary results from this study are as follows:

1. The Plasma Enhanced Shielded Metal Arc welding (PESMAW) can be used as a cost effective process for increasing the wear resistant properties of steel surfaces.

2. In this work, the best wear resistance was achieved using a mixture of nitrogen gas and chromium powder.

3. This investigation gives hope to attain any desired surface chemistry by changing the powder composition and feeding rate with same electrode coating, which furthers the flexibility and versatility of the PESMAW process manifold and thereby reduces initial inventory.

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