Atmospheric plasma spraying of industrial waste to enhance the erosion property of metal

Ajit Behera* and Biswajit Swain
Department of Metallurgical & Materials Engineering
National Institute of Technology, Rourkela-769008, Odisha, India

*Corresponding Author, email id: ajit.behera88@gmail.com

Abstract

Our investigation is to utilize the industrial waste as a erosion resistance material using plasma spray technology. Utilization of such kind of industrial waste as coating material minimizes the cost of plasma spray coating deposition. We are taking fly-ash composite powder that is to be deposited on mild steel and copper substrates by atmospheric plasma spraying. We are varying the plasma gun operating power levels ranging from 11 to 21 kW during plasma spraying. Different morphology with different kind of splat characterized have been done using SEM. Coating porosity is measured by image analysis technique. The phase developed due to high temperature plasma are analysed by the XRD pattern. Coating interface adhesion strength is evaluated using coating pull out method, confirming to ASTM C-633 standard. The erosion resistance have been analysed by using Air Jet erosion test Reg (As per ASTM G76) with silica erodent typically 150-250 µm in size. Multiple tests were performed at increasing the time duration from 60 sec to 180 sec with increasing pressure (from 1 bar to 2.5 bar) and angle (60° & 90°). The analysis of these coating concluded that with low cost, these are excellent candidates for providing protection against abrasive wear and resistant to erosion.

***Keyword**: Plasma Spray, Erosion resistance, fly ash, Mild steel, copper.*

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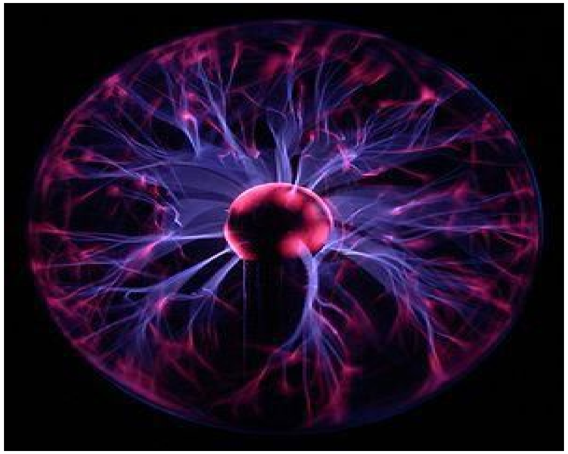
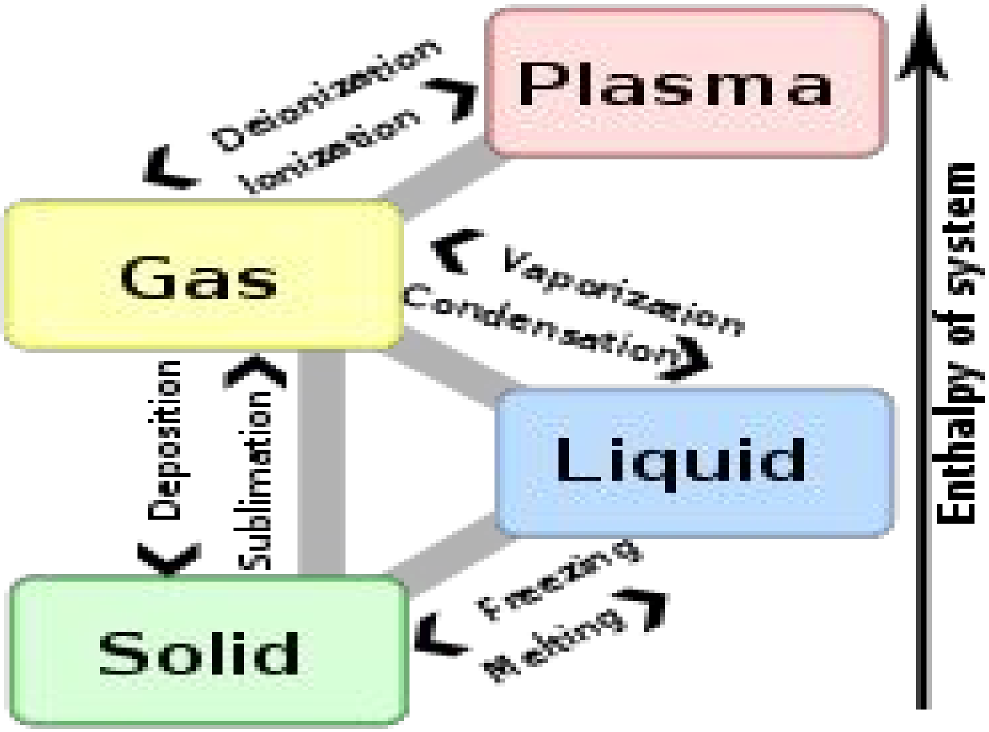
Presentation Outlines

- Background
- Objective
- Experimental Methods
- Results
- Conclusions
- References

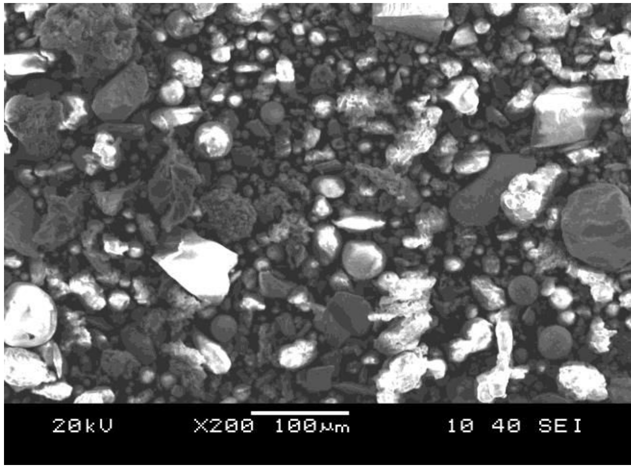
Background



- Plasma is the fourth state of matter.



- Plasma spray technology➔ thermal spraying
- Fly ash as a ceramic material



Objective

The objective of the present investigation is as follows:

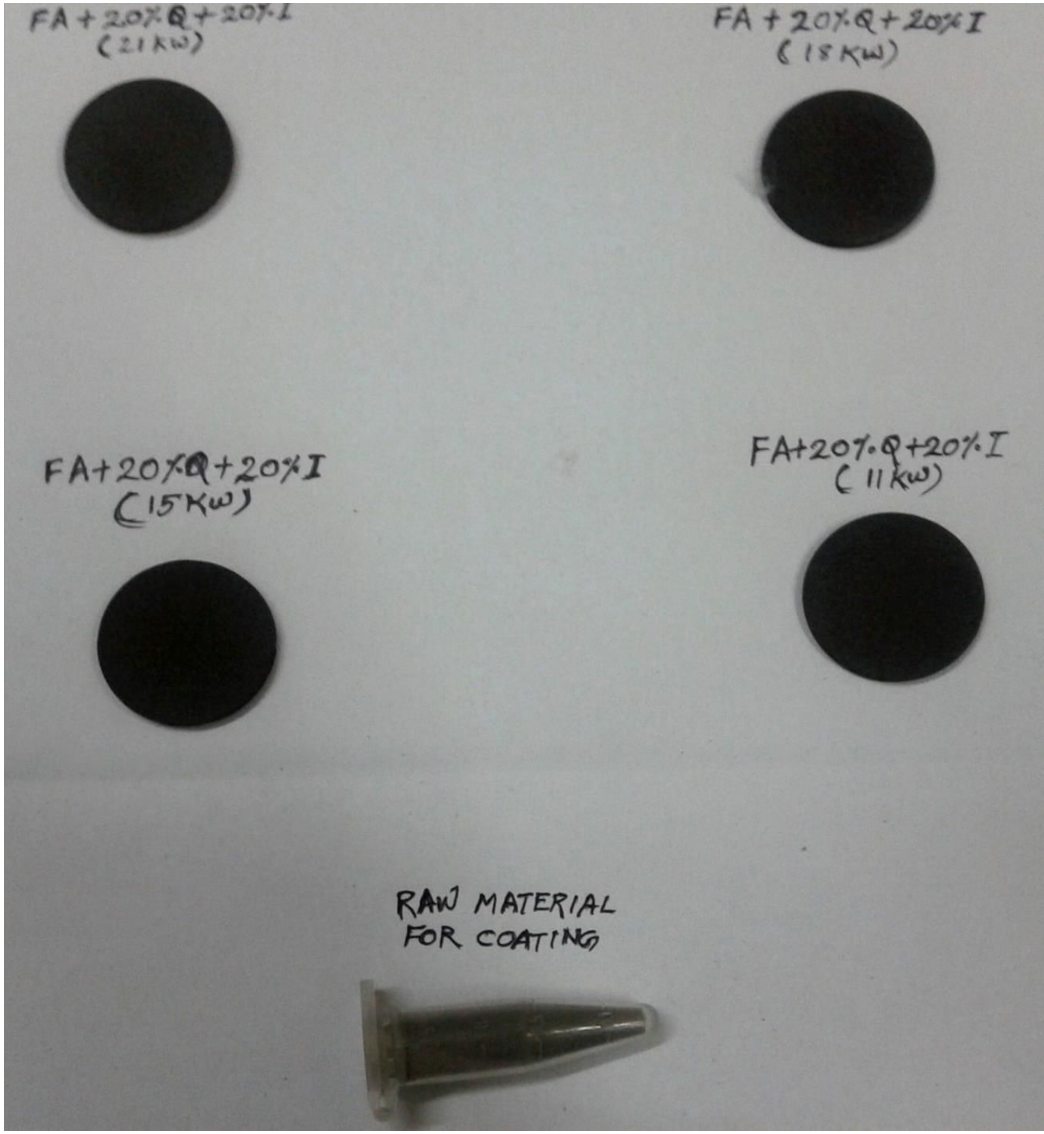
- ✓ To develop plasma sprayed coatings from fly ash+quartz+illmenite on metal substrates and to find out deposition efficiency, adhesion strength, surface roughness, thickness and wear properties etc.
- ✓ To find out the sustainability of the coatings against wear with solid particle erosion test.

Experimental method

- Fly-ash, quartz, illmenite mixture in 60:20:20 weight ratio was taken → mechanically milled in a planetary ball mill for 3 hrs for homogenization of mixture
- Plasma spraying of this mixture carried out on Mild steel and copper(dimensions 1 inch dia. and 3 mm thickness).
- Specimens →grit blasted and cleaned by acetone
- The plasma gun power was varied from 11 to 21 kW by controlling the gas flow rate and arc current.

Top View of Prepared Samples

Operating parameters	values
Plasma arc current(amp)	260-500
Arc voltage (volt)	40-44
Torch input power(kW)	11,15,18,21
Plasma gas(argon) flow rate(IPM)	28
Secondary gas(N2) flow rate(IPM)	3
Carrier gas(Ar) flow rate(IPM)	12
Powder feed rate (gm/min)	15
Torch to base distance(TBD)(mm)	100



Results

Surface Morphology

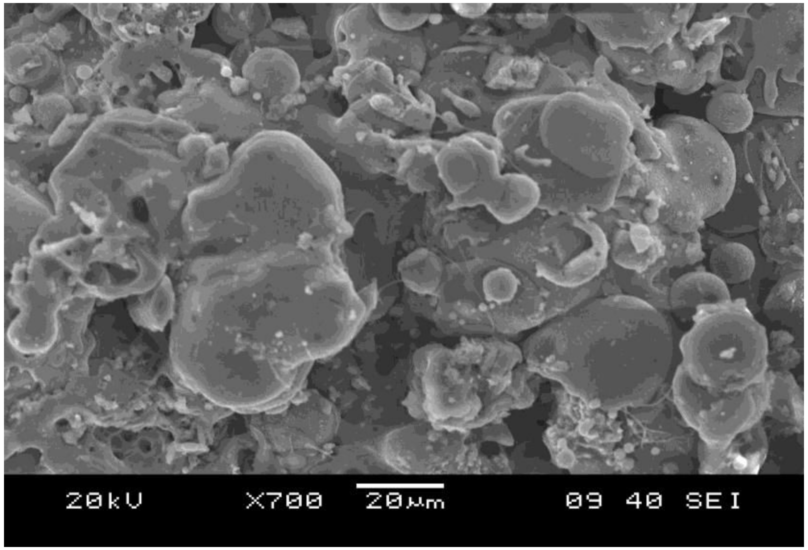


Fig.1: Mild Steel substrate at 11KW

- Molten/semi-moltel particle agglomerated to form splats.
- More amount of cavitation observed.
- Inadequate flow of molten particles

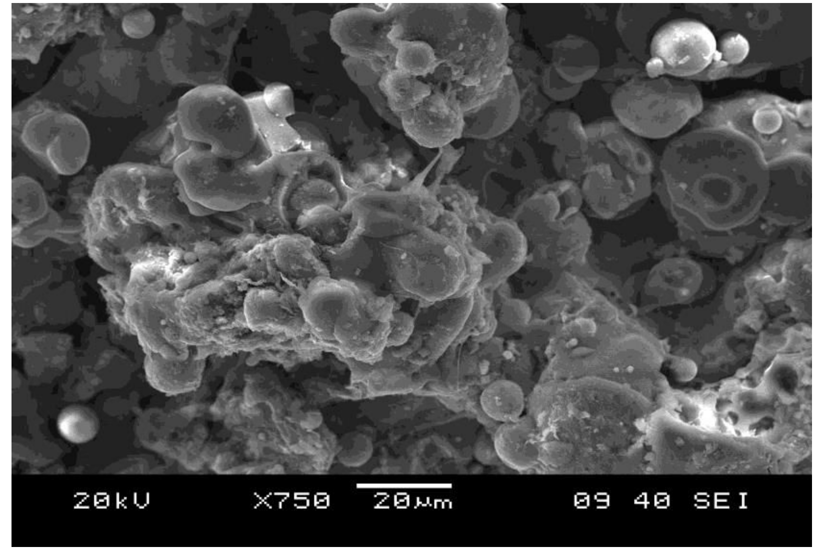


Fig.2: Mild Steel substrate at 15KW

- Some spheroidal splats are found.
- Cavitation found in inter-granular boundaries.
- Little more adherance found

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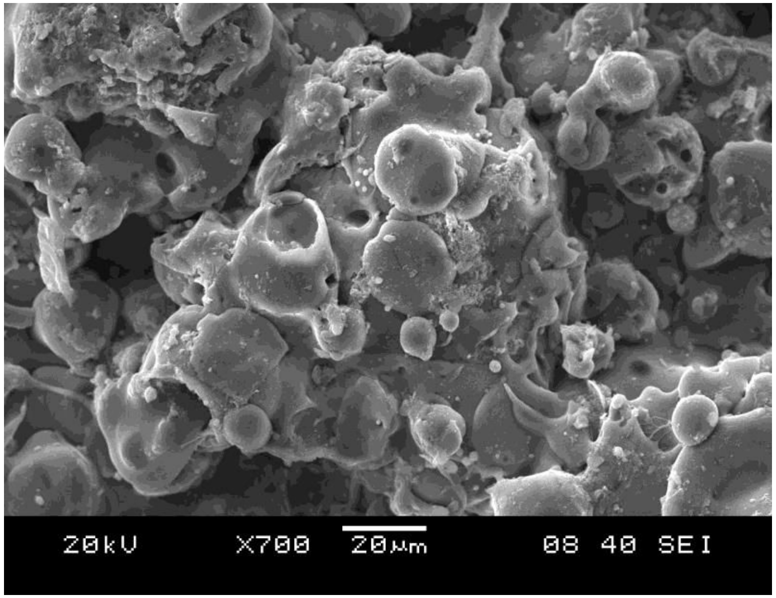

Fig.3: Mild Steel substrate at 18KW

- Splats formed due to increase in power level.
- Lesser cavitation found than previous.
- Uniform distribution as increases power level

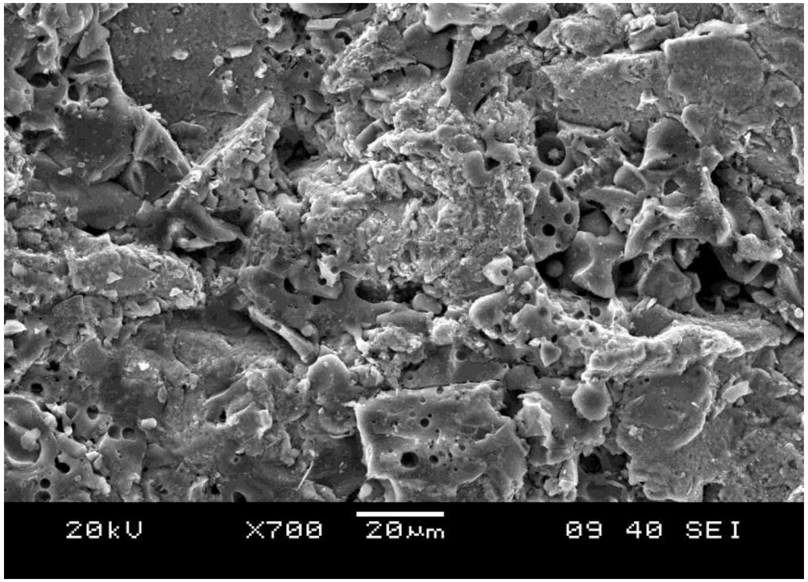

Fig.4: Mild Steel substrate at 21KW

- Particle gets more thermal energy.
- Agglomerate to form splats or flatten region.
- More Uniform distribution.

Interface Morphology

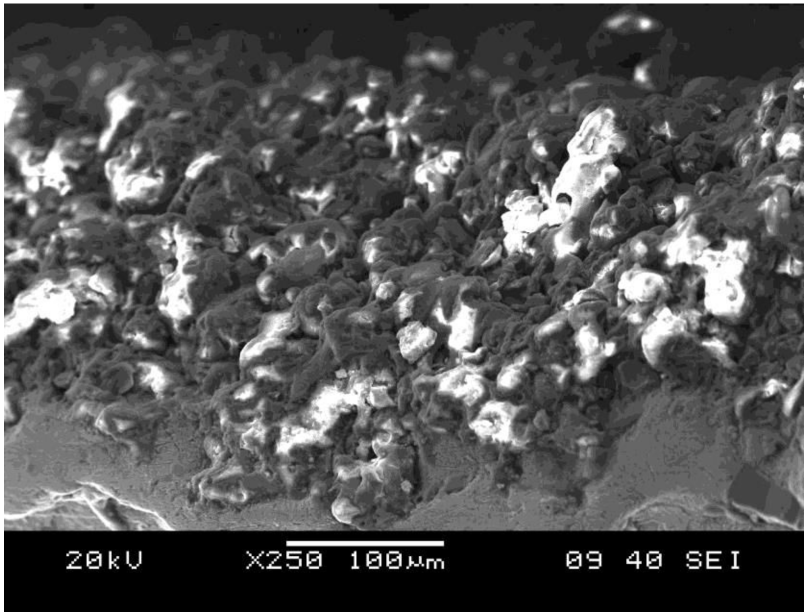

Fig.5: Mild Steel substrate at 11KW

•The coating deposited shows some amount of cavitations at the interface between the lamellas.
•Poor mechanical bonding of the coating onto the substrate observed at some places.
•Minimum adhesion strength.

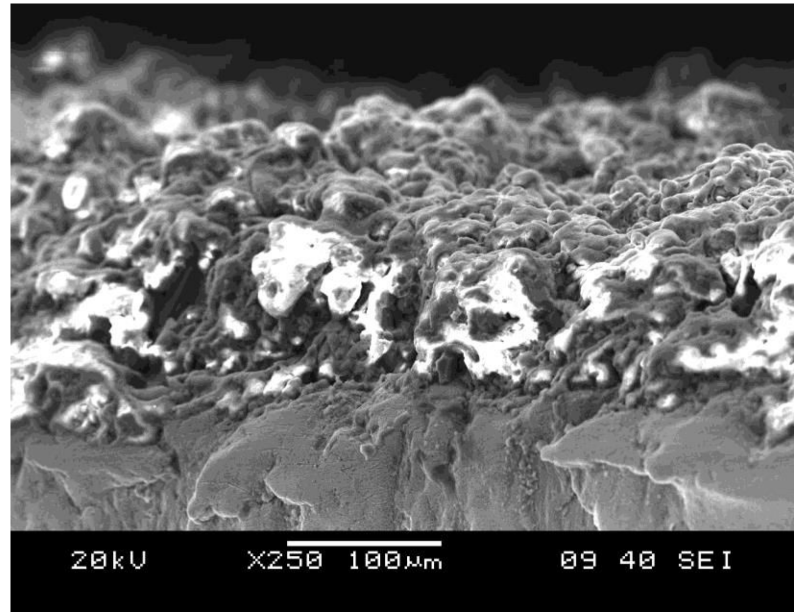

Fig.6: Mild Steel substrate at 15KW

•Improved mechanical bonding.
• Splats layers are globular, larger in dimension and equi-axed type.
• Less amount of cavitations are observed.
•Some spheroidal particles are also observed

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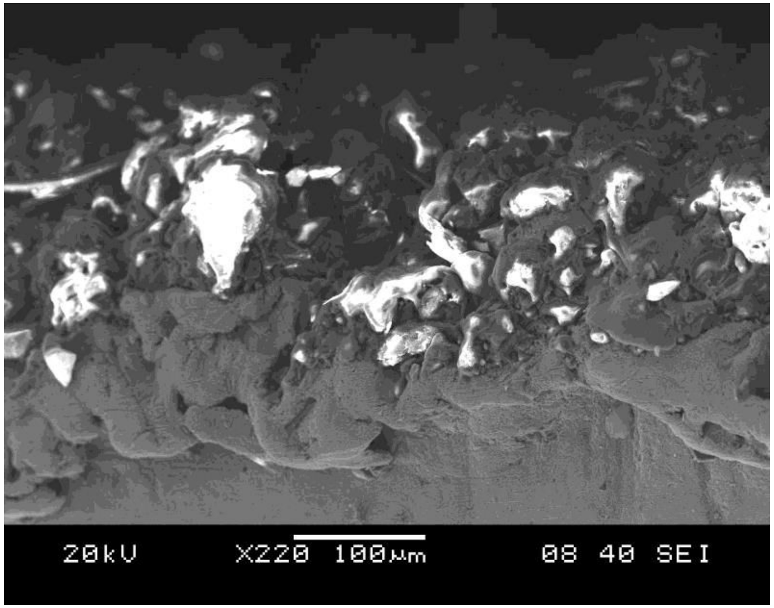


Fig.7: Mild Steel substrate at 18KW

- Good interface bonding .
- Porosity decreased .

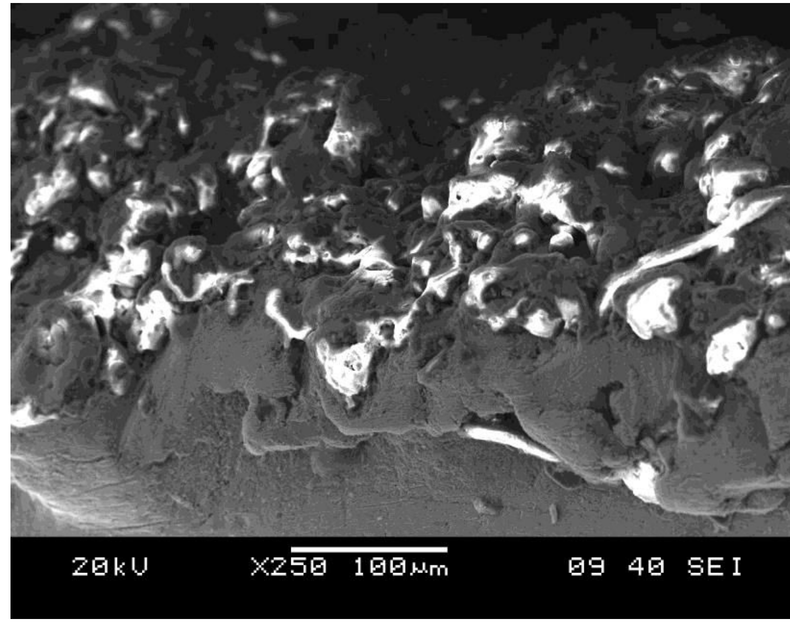


Fig.8: Mild Steel substrate at 21KW

•Particles of smaller dimensions by high energy form a uniform bonding at interface.
•Metallurgical bonding occurred at the interface.

X-Ray Analysis

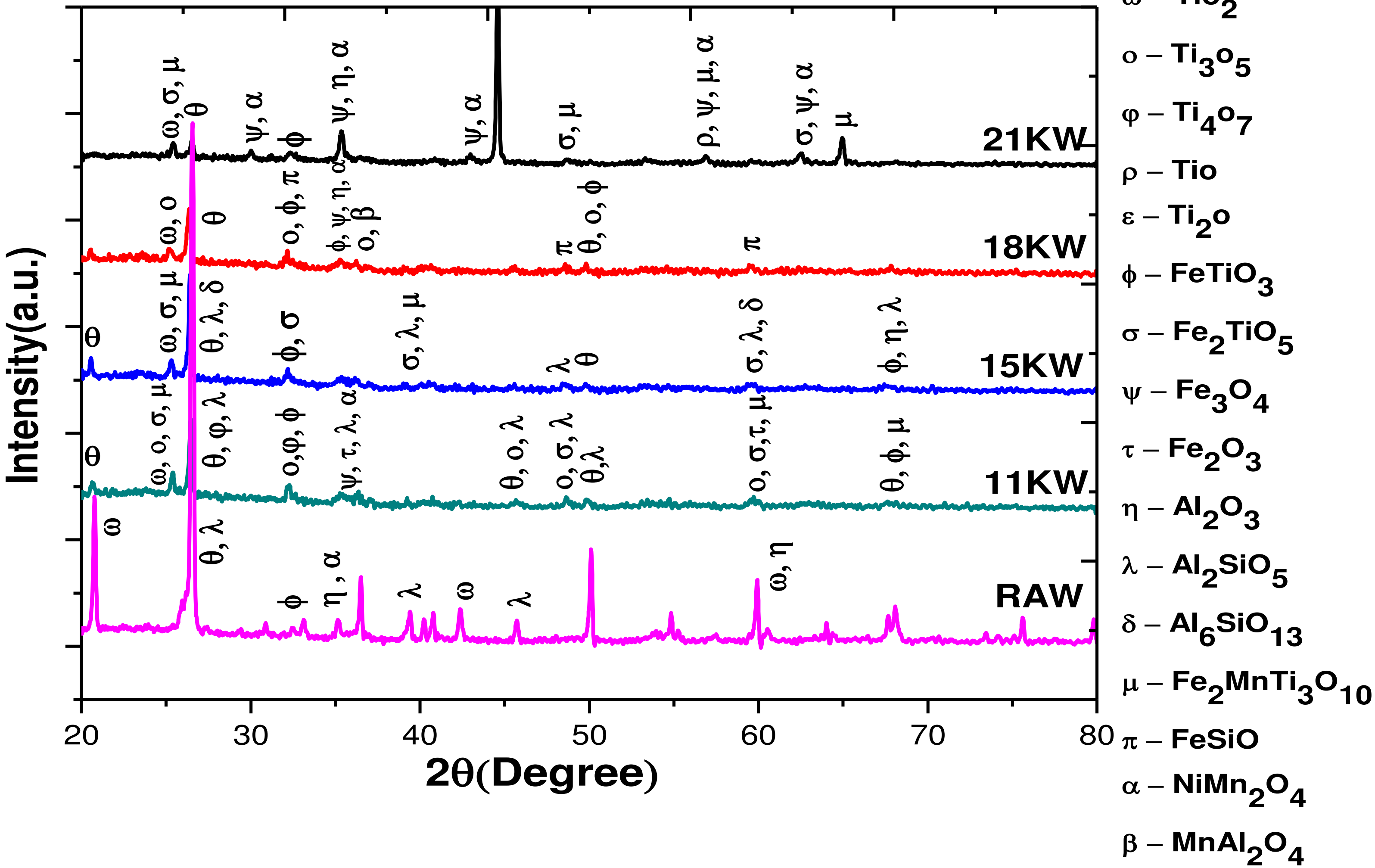


Fig.9: Phase Analysis of different sample & raw material

Coating Adhesion Strength vs Gun Power

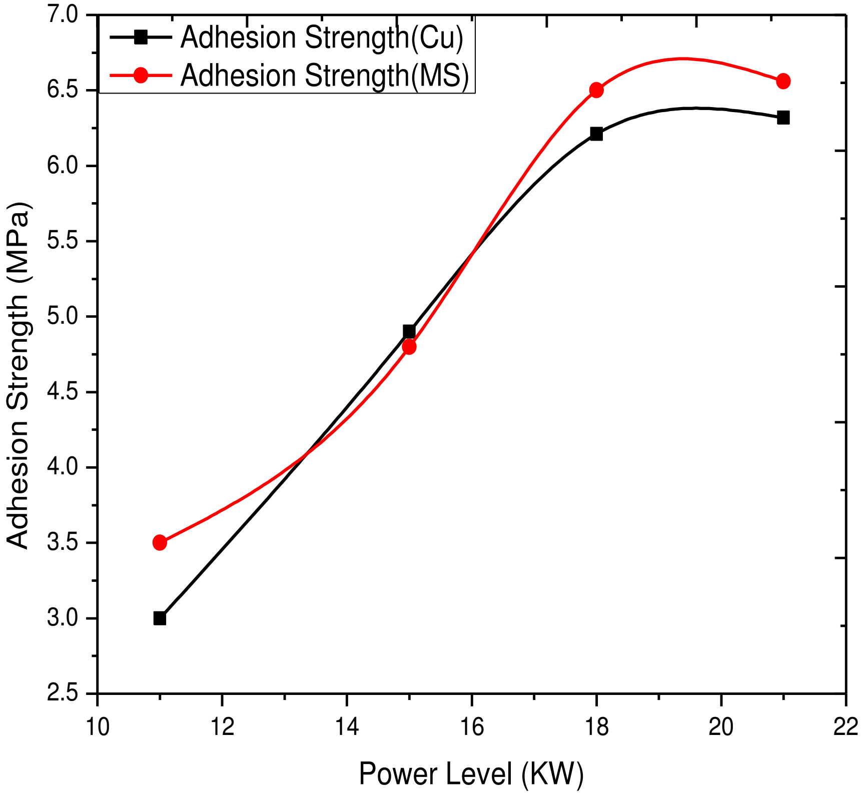


Fig.10: Comparison of adhesion strength of mild steel and copper with respect to gun power.

- It is found that, with increase in operating power level there is an increase in adhesion strength up to a certain level of operating power of the torch.
- It is found that for different type of substrate, the magnitude of adhesion strength differs. For Mild Steel the strength has varied from 3.5MPa to 6.56MPa, the maximum of 6.56MPa at 21kW power level. For Copper substrate this value ranges from 3.00MPa to 6.32MPa.

Coating Deposition Efficiency vs Gun Power

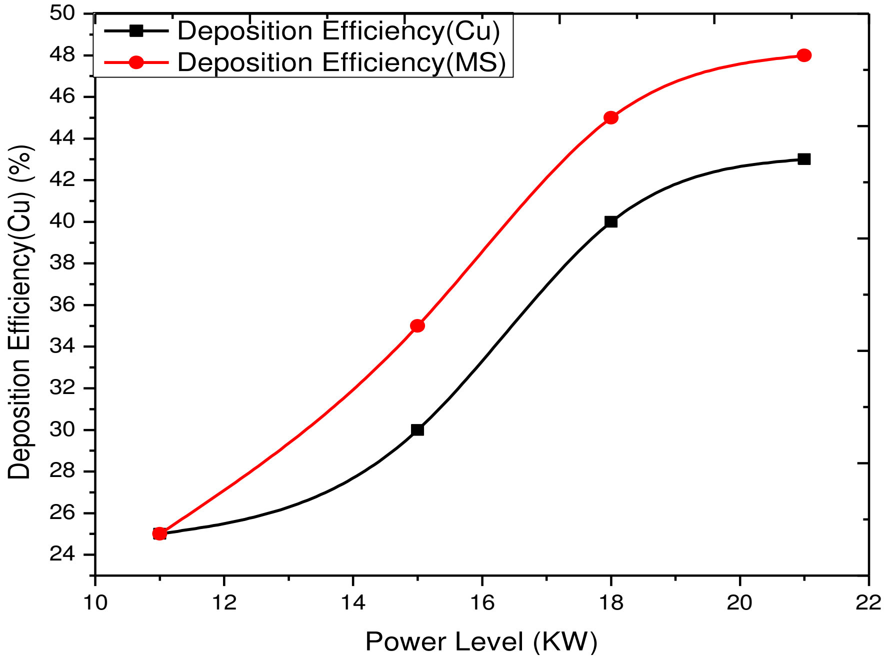


Fig.11: Variation of deposition efficiency of fly-ash+quartz+illmenite coatings at different gun power.

•At lower power level, the plasma jet temperature is not high enough to melt the entire feed powder that enters the plasma jet.

•As the power level is increased, plasma temperature and enthalpy increases, thus melting a larger fraction of the feed powder. The spray efficiency therefore increases with increase in input power to the plasma torch.

•However, beyond a certain power level of the torch, temperature of the plasma becomes high enough leading to vaporization/dissociation of the feedstock and leads to formation of inter-layer voids

Adhesion Strength Vs. Coating Thickness

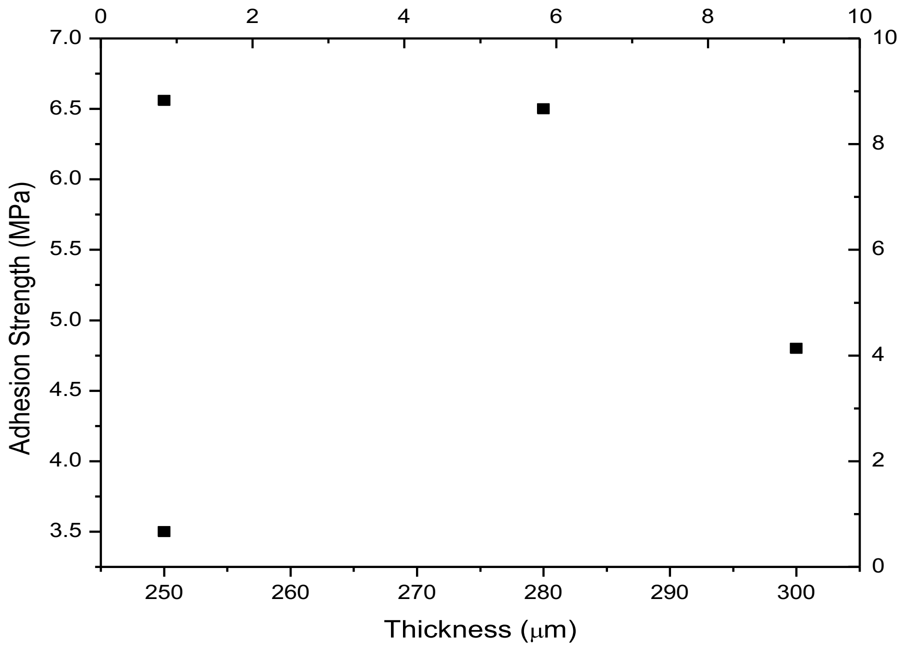


Fig. 12: Variation of Adhesion Strength with Coating Thickness.

- Adhesion strength increases up to a certain coating thickness and further increase in thickness adhesive strength decreases.
- Higher residual stress occure in thick coatings.
- The bond to the substrate reduces with the increasing thickness.
- In Mild Steel the highest adhesion strength 6.56MPa is observed at 250 μm thicknesses and it decreases to 4.8MPa at 300 μm thickness.

Hardness Vs. Power level

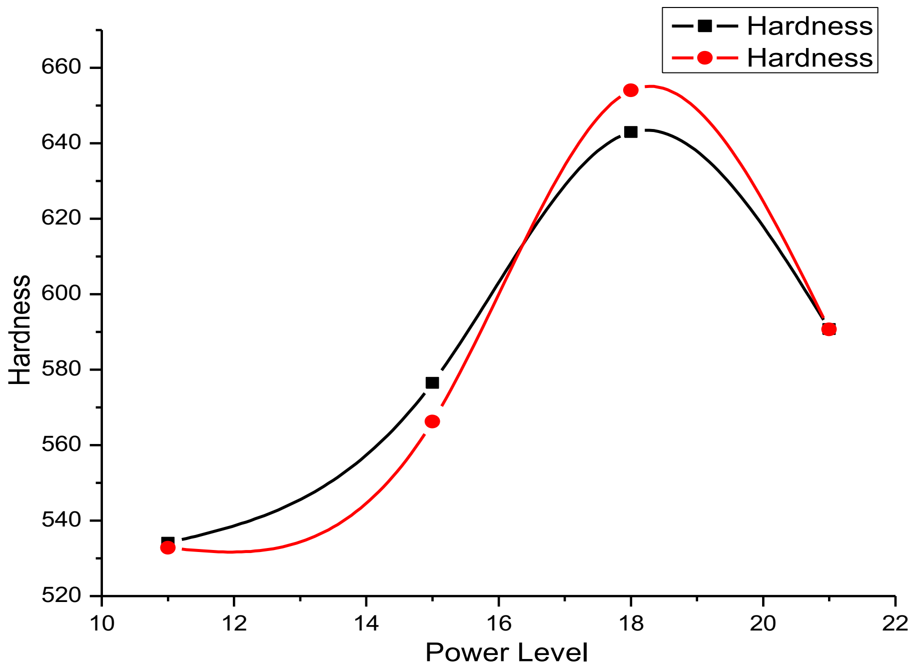


Fig.13: Variation of coating hardness of fly ash+quartz+illmenite coatings at different power levels.

- it is observed that there is an increase in coating hardness with the increase in plasma power level. This may be due to the formation/transformation of compounds viz. silica and alumina etc. to their allotropic forms and their compositional variations during spray deposition with the increase in input power to the plasma torch.

Coating porosity vs. Gun power

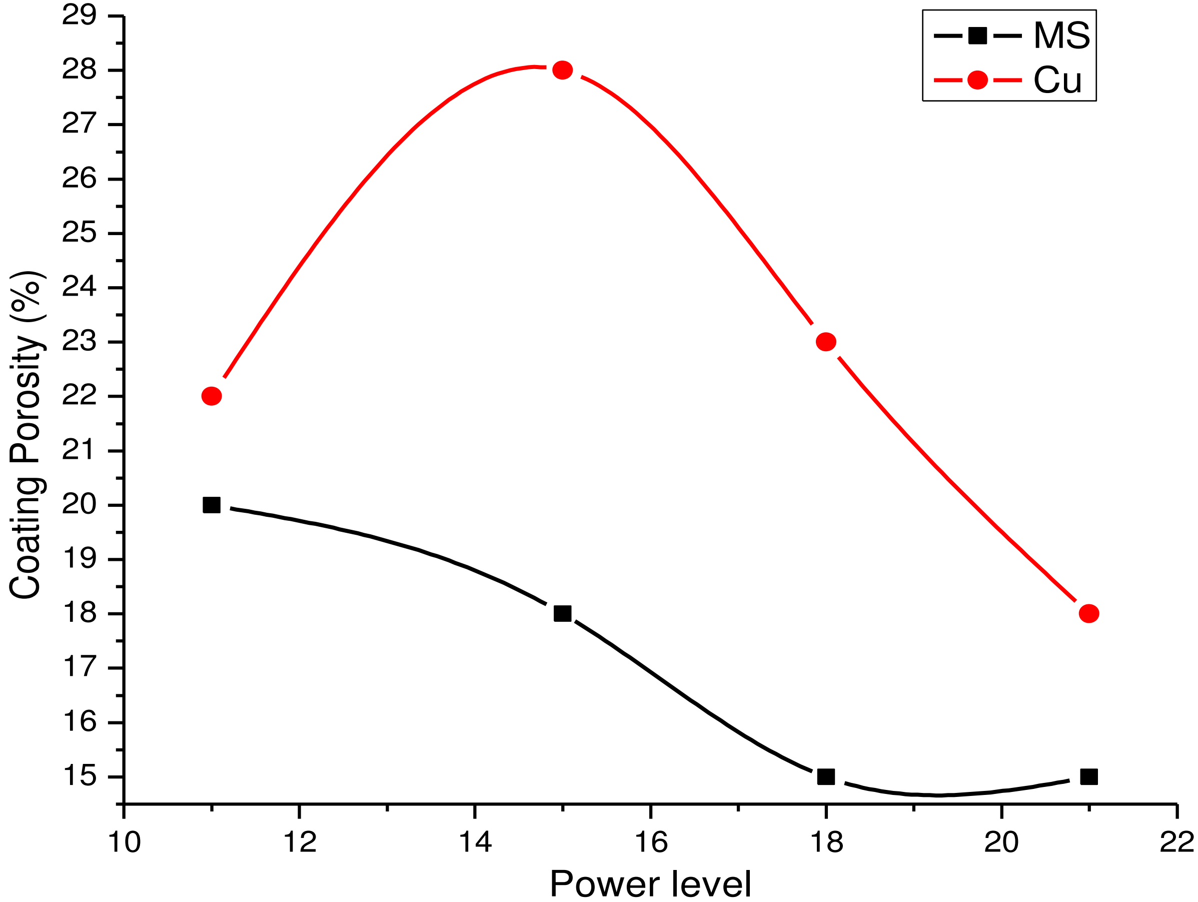


Fig.14: Variation of coating porosity of fly ash+quartz+illmenite coating with torch power.

- The pore interconnectivity in the structure, influencing the cohesion of the deposit .
- With decrease in coating porosity, adhesion strength increases.
- In Copper coating porosity decreases from 28% to 18% with increase in adhesion strength from 4.9MPa to 6.32MPa.

Microstructural Investigation of Erodants and Eroded Surfaces

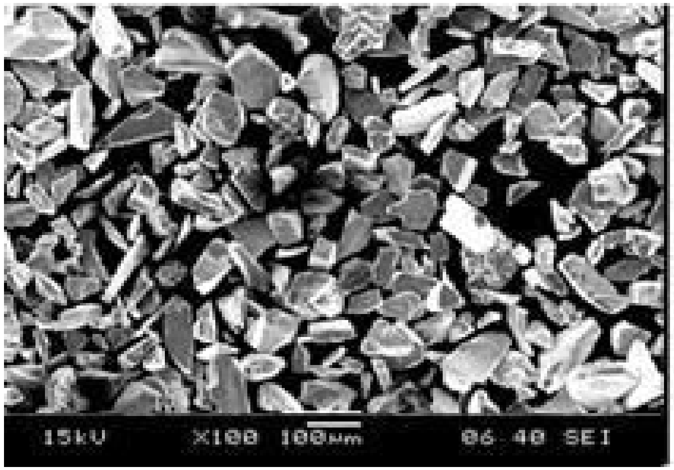
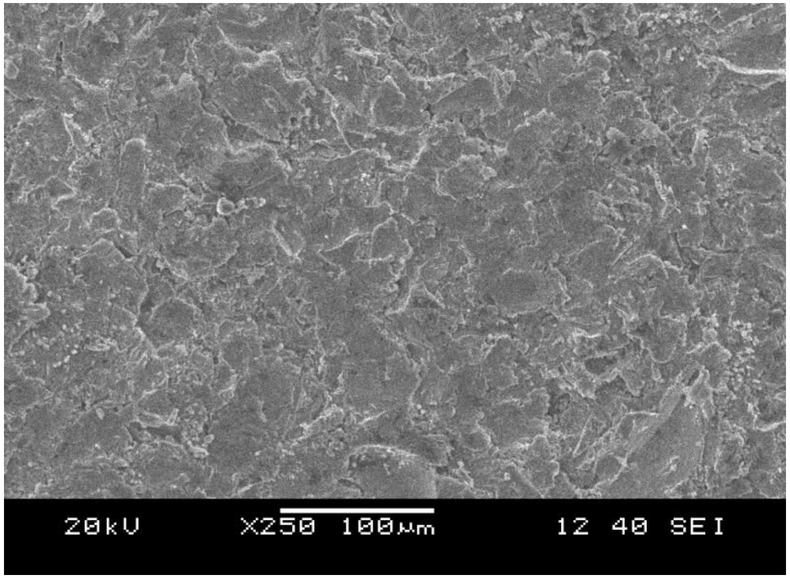
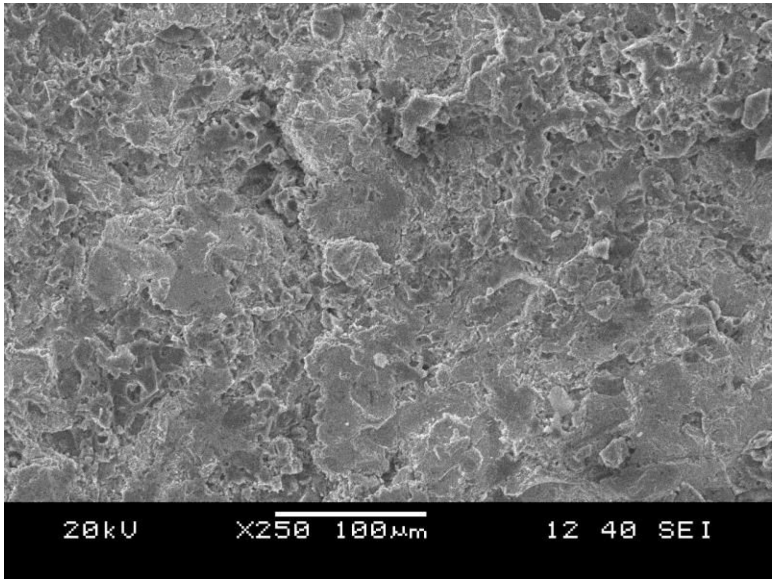


Fig. 16: Morphology of Erodant



(a)



(b)

Fig. 17: SEM micrographs of eroded surfaces of coatings deposited at 18 kW at angle of impact **(a)** 60° and **(b)** 90° using SiC as the erodent.

Erosion Wear Behavior of Coatings

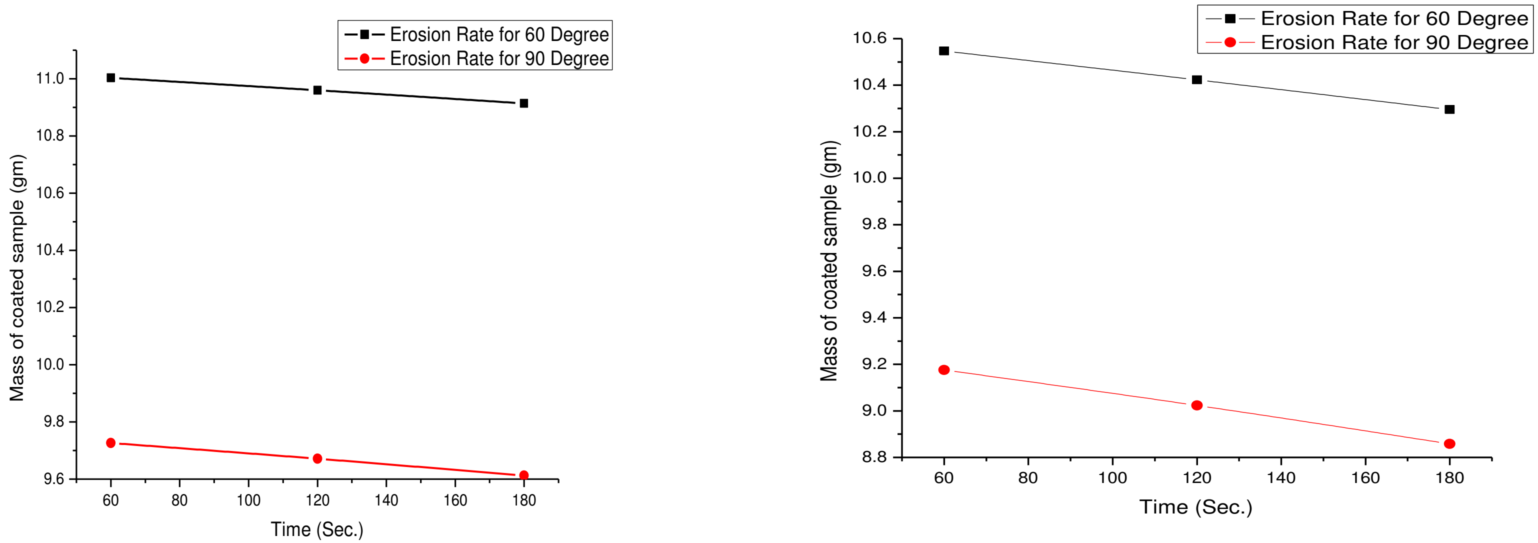


Fig. 18: cumulative mass loss of coating vs time for 18kW coating substrate at erodent impact pressure of (a) 1 bar, (b) 2 bar.

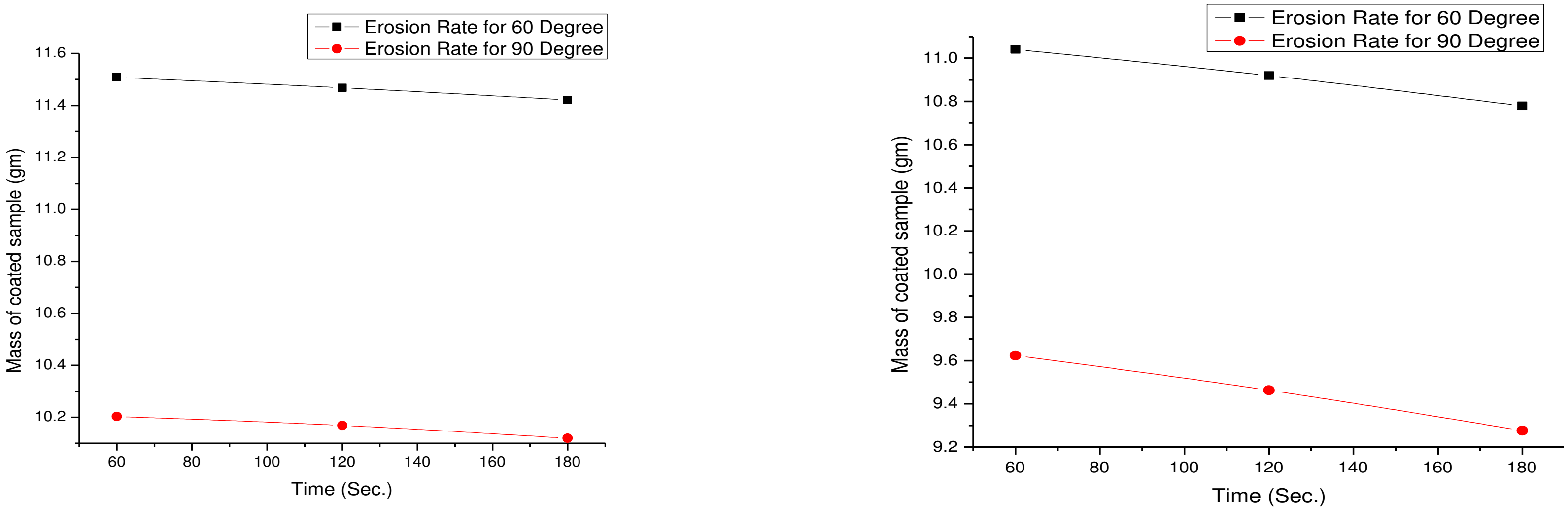


Fig. 19: Cumulative mass loss of coating vs time for 21kW coating substrate at erodent impact pressure of (a) 1 bar, (b) 2 bar.

Conclusions

- Operating gun power of the plasma torch influences the coating adhesion strength, deposition efficiency, coating hardness and coating morphology to a great extent.
- Factors such as erodent size, impact angle of the erodent, velocity of impact and standoff distance and hardness etc. affect the coating erosion wear rate.
- Maximum erosion of the coatings took place at an impact angle of 90^0.
- The coating sustains erosion by solid particle impingement substantially and therefore fly ash+quartz+illmenite can be considered as a potential coating material suitable for various tribological applications.

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Thank You