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COMPARATIVESTUDY OFHARD FACING OF AISI 1020 STEEL BY THREE DIFFERENT WELDING PROCESSES

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G.R.C. Pradeep [α], Dr. A. Ramesh [σ] & Dr. B. Durga Prasad [ρ]

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I. Introduction

Hardfacing or Hardsurfacing, is the application of build-up of deposits of specialized alloys by means of welding process to resist wear and tear by abrasion, corrosion, high temperature, or impact. Such deposition can be done on the surface, or edge, or merely at the point of a part where it is subjected to wear [Pradeep *et al.,* (2010)]. Welding is a key technology to fulfil these requirements and to apply hardfacing alloys [Kirchgaßner *et al.,* (2008)]. These welding deposits can help to reclaim the components by extending their service life [Agustín *et al.,* (2010)]. A hard-faced part is like a laminate, with the base material contributing for strength and economy, and the hard-facing material contributing for the specific wearing conditions to which the part will be subjected in service. Hard facing may be applied to new parts during, or to worn parts to restore a worn-down surface. Hard-facing extends the lifetime of machinery equipment efficiently by increasing the service life of its parts,.

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[Kirchgaßner *et al.,* (2008)]. In order to avoid costly downtimes and to reduce the cost of expensive spare parts, the core components that are exposed to heavy wear, require efficient surface protection measures [Kirchga ßner *et al.,* (2008)]. Weld hard facing has been adopted in many industries like Mining, Steel, Petro-chemical, Cement, Power, Food and Sugar cane [Kirchga ßner *et al.,* (2008)]. In recent years, these processes have been developed rapidly and are now applied in numerous industries, such as nuclear and steam power plants, chemical and fertilizer plants, agriculture machines and pressure vessels, railways, and even in aerospace components [Richard LL (1990)]. Hard facing is mainly done to improve the surface properties of the base metal [Gourd LM (1998)].

II. Hard Facing Processes Used

A number of welding processes can be used to hardface the components. The various factors that control the selection of the most suitable welding process for a given job are: Size and shape of component, Base metal composition, Nature of work to which the component to be Hard-faced is subjected to, Accessibility of weld equipment, Function of the component, Number of same or similar items to be hard-faced and cost of replacement of the part, State of repair of worn components, etc [Pradeep *et al.,* (2010)]. The following processes are compared in the present study:

- Hardfacing by Gas welding - Deposition by Oxy-Acetylene Gas welding [Buchely *et al.,* (2005)].
- Hardfacing by Arc welding - Shielded Metal Arc Welding [Amado *et al.,* (2008)].
- Hardfacing by combination of Arc and Gas - Tungsten Inert Gas Welding [Kashani *et al.,* (2007)].

III. Base Material and Weld Consumable used in Hard Facing

Almost 85% of the metal produced and used in most applications comprises of Steel. The Low-Carbon Steels and Low-Alloy Steels used in the industry for making different components for different applications include the AISI series C-1008 to C-1020, 2315, 2515, and 2517 [Wang *et al.,* (2008)]. These steels generally have, 0.10 to 0.25% Carbon, 0.25 to 1.5% manganese, up to 0.4% (maximum) phosphorous, and 0.5%

(maximum) sulfur. These steels can be easily welded with any of the welding processes. The other low-alloy high-strength steels of the AISI designation system include low-manganese steels, low nickel-chromium steels, low-to-medium nickel steels, nickel-chromium-molybdenum steels, chromium-molybdenum steels, molybdenum steels etc. [Wang *et al.,* (2008)]. These alloys are included in AISI series 2315, 2515, and 2517. They contain 0.12-0.30% Carbon, 0.40-0.60% manganese, 0.20-0.45% silicon and 3.25-5.25% nickel. In the present study AISI 1020 steel has been used for experimentation. In order to facilitate easy assessment of the effect of different welding processes on the wear of hard-faced components, same material has been used as base material and deposit material.

IV. Sample Preparation and Testing

The material used for the sample preparation is AISI 1020 steel. The chemical composition, physical and mechanical properties of the material are given in Tables 1 & 2:

Element	C	Mn	P	S	Fe
Composition (%)	0.18-0.23	0.30-0.60	0.04 (Max)	0.05 (Max)	Balance

Table 1: Chemical Composition of AISI 1020 Steel by Wt %

Property	Elastic Modulus (GPa)	Density (x 10^3 Kg/m^3)	Poisson's Ratio	Hardness (HB)	Tensile Strength (MPa)
Value	190-210	7.7-8.03	0.27-0.30	111	394.7

Table 2 : Physical and Mechanical Properties of AISI 1020 Steel

ASTM standards were used to prepare the test samples. 10 mm diameter round rods of AISI 1020 are taken and cut in to cylinders of required lengths as per ASTM standards. Finishing of samples is done by removing the burr and thorough cleaning of oil and dirt. AISI 1020 material is deposited on the flat face of each sample using three different welding processes- Gas welding, Arc welding and TIG welding (with Argon as Inert Gas). Turning is done with fine cuts to get smooth cylindrical finish and also maintain the required size as per ASTM standards. As the POD testing requires perfect contact, the ends of the samples are rubbed on a sand belt machine by holding the sample in drilling machine so that the test surface is perfectly flat. The Weld deposit height is maintained at least 5 mm in the total sample length as shown in figure 1. Computerized Pin on Disc Wear testing Machine with the sample as test material and High Carbon EN31 steel (HRC 60) as counter-surface equipped with LVDT and digital display system was used to record the wear height loss.

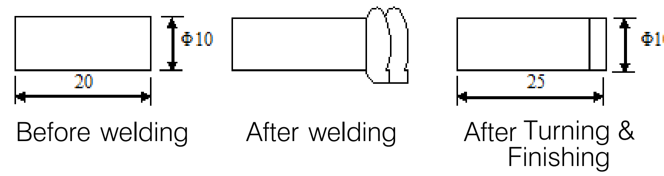

Figure 1 : Steps in Sample Preparation

V. Results and Discussion

In order to find out the wear characteristics at different sliding distances and different loads, four types of samples namely, plain Sample without welding, Gas welded sample, Arc welded sample and TIG welded sample, are tested on the POD machine. The load was varied from 9.81N to 49.05 N in steps of 9.81 N and three Sliding Velocities of 0.9426 m/s, 1.256 m/s, 1.571 m/s were chosen for the test. Each sample was tested for different sliding distances ranging from 282.78 m to 2827.8 m in steps of 94.26 m. The average of 8 readings is considered for calculation of parameters like Wear Volume, Wear Factor and Frictional Coefficient. These values are plotted on the graphs for analysis. The figures 2, 3, 4 show some sample graphs obtained for a particular sliding velocity and load.

a) Effect on Wear Volume

From the results it was observed (figure 2) that TIG welding sample was showing better the values of Wear Volume at Sliding Velocity of 0.9426m/s, compared to remaining three samples i.e, plain sample without welding, Gas welded sample and Arc welded sample. It was also observed that the values of these three samples are very close. Further it was also observed that at higher Sliding Velocities (above 1.256 m/s) the Wear Volume values of TIG welding sample were better than Gas Welding Sample and Arc Welding Sample even though all the values of these samples are closer to each other. May be the narrow heat affected zone of higher hardness than the base material in TIG welding might have offered resistance to wear and resulted in enhanced wear properties at lower sliding velocities compared to Gas Welding and Arc welding. However at higher sliding velocities of 1.571 m/s, the Wear Volume values of Gas welded samples and Arc welded samples were better compared to TIG welded samples. This may be due to broader heat affected zone of higher hardness in Gas welding and Arc welding which might have offered resistance to wear resulting in enhanced wear properties at higher sliding velocities. At higher velocities, the narrow heat affected zone of higher hardness in TIG welding might have reduced the resistance to wear, as the heat generation is higher, which in turn makes the metal to peel out in the form of chips. It was also observed that at higher sliding velocities of 1.571 m/s, Gas welding samples were showing slightly better Wear Volume values compared to Arc welding up to sliding distances of 1500 m at still higher sliding distances higher than 1500 m, the Arc welded samples were showing better Wear Volume values compared to Gas welded samples

b) Effect on Wear Factor

From the results it was observed (figure 3) that at Sliding Velocity of 0.9426m/s, the values of the Wear Factor for TIG welding sample were better than Gas welded sample and Arc welded sample. Also at higher Sliding Velocities (above 1.256 m/s) TIG welding sample was showing better wear factor values compared to the values of Gas welding sample and Arc welding sample even though all these values were observed to be very close. Further at higher sliding velocities of 1.571 m/s, Gas welding samples were showing slightly better values of wear factor compared to Arc welding up to sliding distances of 1500 m. At still higher sliding distances higher than 1500 m, the Arc welded samples were showing better Wear Factor values compared to Gas welded samples.

c) Effect on Friction Coefficient

From the results it was observed (figure 4) that at Sliding Velocity of 0.9426m/s, the values of the Friction Coefficient for TIG welding sample were better than Gas welded sample and Arc welded sample. However the Friction Coefficient values of Gas welded samples and Arc welded samples were enhanced compared to TIG Welding samples at higher sliding velocities of above 1.256 m/s. Also it was observed that at higher sliding velocities of 1.571 m/s, Gas welding samples were showing slightly higher values of Friction coefficient compared to Arc welding up to sliding distances of 1500 m. At still higher sliding distances higher than 1500 m, the Arc welded samples were showing higher Friction coefficient values compared to Gas welded samples.

d) SEM Micro Photographs

Scanning Electron Microscopy, which is one of the conventional characterization techniques, was employed to study the nature of the wear surface of the welded samples. Micro photographs at 50x, 200x, 400x magnifications were taken. Few sample photographs are shown in figure 5 and 6.

It can be clearly observed from figures 5 and 6 that at Sliding Velocities (above 1.256 m/s) the Gas welding Sample and Arc welding sample show deeper plough marks and TIG welding sample show small chips and particles, showing that TIG welding sample has better wear properties compared to Gas welding sample and Arc welding sample. However at higher sliding velocities of 1.571 m/s, TIG welding samples show deeper plough marks with delimitation compared to Gas welded samples and Arc welded samples. Hence the wear properties of Gas welded samples and Arc welded samples at higher sliding velocities of 1.571 m/s were seen enhanced compared to TIG welding samples. Hence the SEM microphotographs also support the discussion in the previous sections.

e) Result Agreement with earlier researchers

The results obtained are in close agreement with the earlier researchers who have compared different welding processes using AHP (Analytic Hierarchy Process Model) based on quantitative and qualitative factors, [Balasubramanian *et al.,*(2009)]. In their research it has been concluded that, based on both quantitative and qualitative factors, an integrated process measure (PM) for TIG welding was 0.2150 among the different processes to hard face carbon steels. The values of integrated process measure for other processes are lesser than TIG welding except PTAW. Conventional weld hard facing is done by Oxy-fuel welding, gas tungsten arc welding (GTAW/TIG), gas metal arc welding (GMAW/MIG), shielded metal arc welding (SMAW), and flux cored arc welding (FCAW) processes. Percentage dilution plays a major role in determining the properties of a hard-faced surface [Gourd LM (1998)]. Dilution is defined as the percentage of base metal in the weld metal deposit. If the percentage of dilution is high, then the percentage of base metal in the weld metal deposit will be high and vice versa. At a higher percentage of dilution level, the surface properties are not enhanced to the expected level because of the presence of a higher amount of base metal. On the other hand, at a lower percentage of dilution level, the surface properties are much better compared to the base metal because of a low percentage of base metal in the deposited weld metal. Hence, the welding process which produces a low percentage of dilution is generally preferred for hard facing applications [Marimuthu *et al.,* (2003)]. The dilution factors for various processes are given below [Product Reference Manual – AFROX – Section -12]:

Welding Process	Dilution Factors
Oxy-Acetylene Gas Welding	0 - 5 % Dilution
TIG Welding	5 - 15 % Dilution
Shielded Metal Arc Welding	20 - 45 % Dilution
Flux Cored Wire Arc Welding	20 - 45 % Dilution
Submerged Arc	25 - 50 % Dilution

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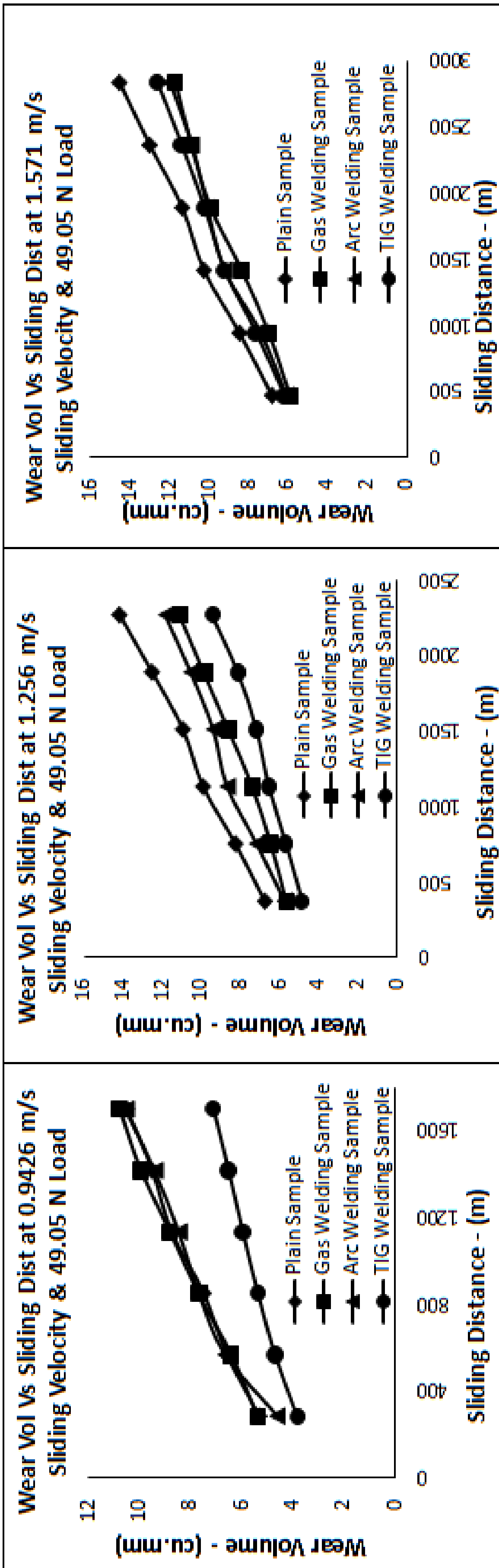


Fig. 2 : Effect of Welding process on Wear Volume at various sliding distances and loading conditions

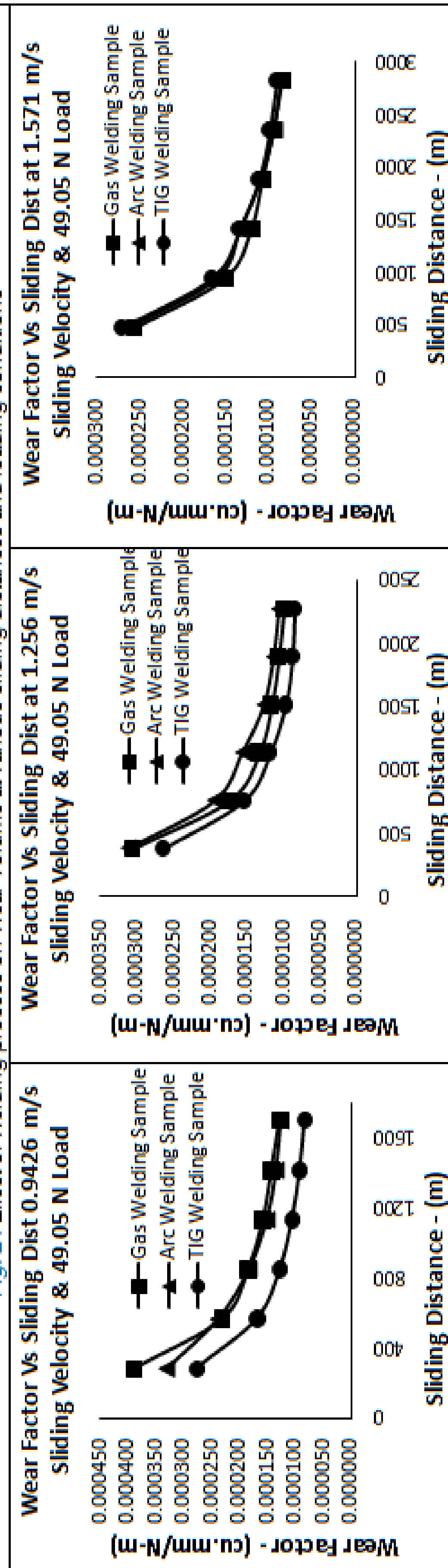


Fig. 3 : Effect of Welding process on Wear Factor at various sliding distances and loading conditions

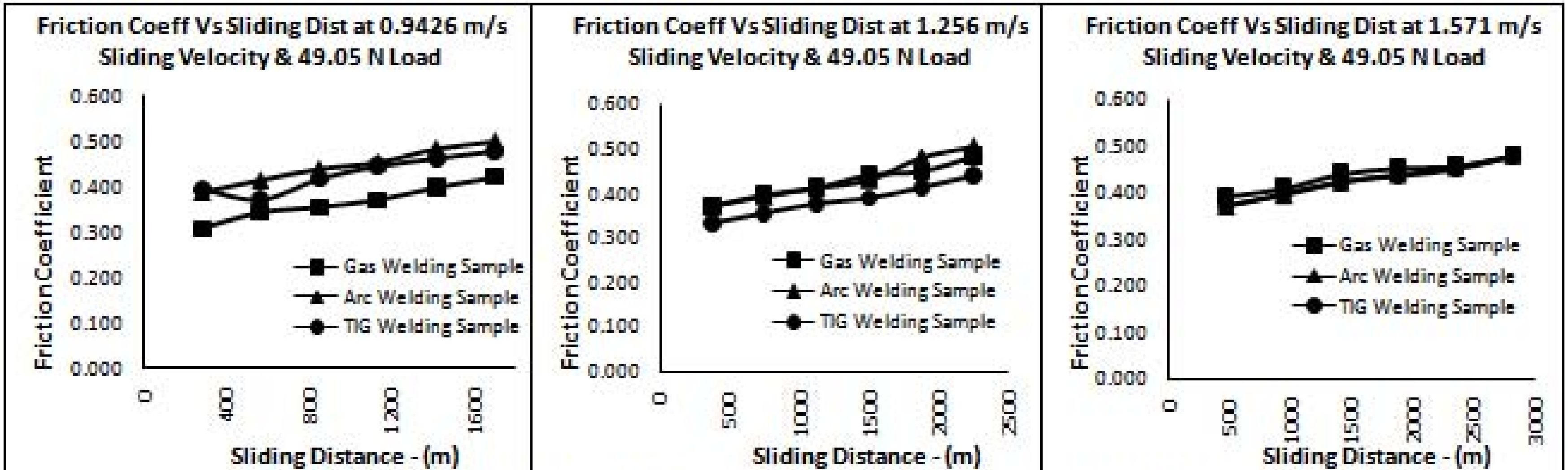
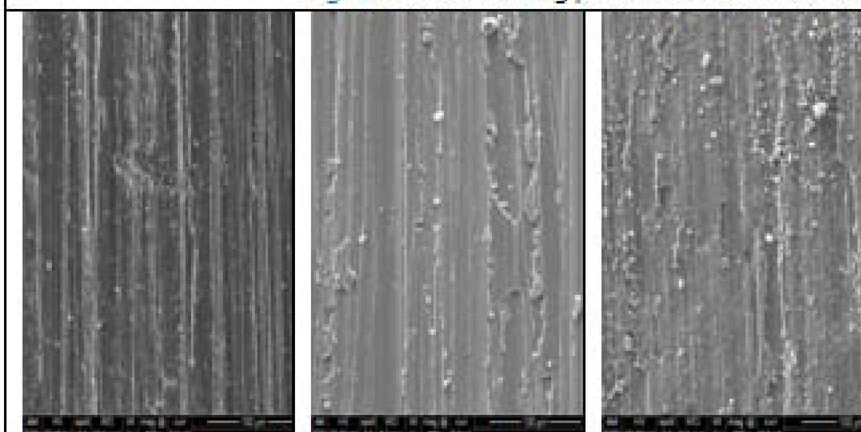
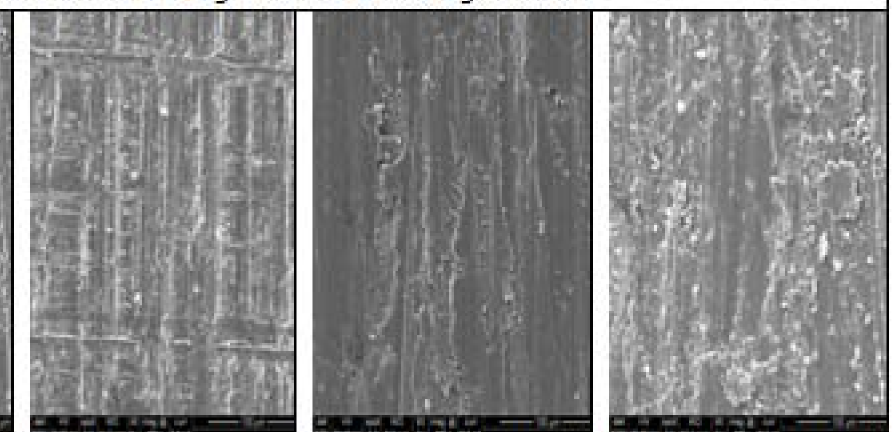


Fig. 4 : Effect of Welding process on Friction Coefficient at various sliding distances and loading conditions



Gas Weld Sample at 1.256 m/s Sliding Velocity, Load 49.05 N	Arc Weld Sample at 1.256 m/s Sliding Velocity, Load 49.05 N	TIG Weld Sample at 1.256 m/s Sliding Velocity, Load 49.05 N

Fig. 5 : SEM Micro Photographs at 400x Magnification



Gas Weld Sample at 1.571 m/s Sliding Velocity, Load 49.05 N	Arc Weld Sample at 1.571 m/s Sliding Velocity, Load 49.05 N	TIG Weld Sample at 1.571 m/s Sliding Velocity, Load 49.05 N

Fig. 6 : SEM Micro Photographs at 400x Magnification

VI. Conclusions

1. TIG welding samples were showing better wear properties until a sliding velocity of 1.256 m/s with various sliding distances and loads, compared to Gas welding samples and Arc welding samples.
2. Gas Welding samples and Arc Welding samples yielded better wear properties at higher sliding velocities above 1.571 m/s with various sliding distances and various loads compared to TIG Welded Samples.
3. Arc Welding samples were showing better wear properties than Gas welding samples at higher sliding velocities above 1.571 m/s and at higher sliding distances higher than 1500 m.

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