KAUNAS UNIVERSITY OF TECHNOLOGY
MECHANICAL ENGINEERING AND DESIGN FACULTY

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Investigation of Hardfacings Prepared by Various Arc Welding Technique

Master's Degree Final Project

Supervisor
Assoc. prof. dr. **Antanas Čiuplys**

KAUNAS, 2017

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Industrial Engineering and Management (621H77003)

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Industrial Engineering and Management 621H77003

(Title and code of study programme)

"Investigation of Hardfacings Prepared by Various Arc Welding Technique"

DECLARATION OF ACADEMIC INTEGRITY

13 JUNE 2017

Kaunas

I confirm that the final project of mine, **Ravi Shankar Gorli**, on the subject "Investigation of hardfacing Prepared by various arc welding technique." is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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Ravi Shankar Gorli. Kietųjų dangų suformuotų įvairiais lankinio suvirinimo būdais tyrimas. *Magistro* baigiamasis projektas / vadovas doc. dr. Antanas Čiuplys; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

Mokslo kryptis ir sritis: Technologijos mokslai, gamybos inžinerija.

Reikšminiai žodžiai: *kietosios dangos, elektrolankinis apvirinimas, atsparumo dilimui bandymai, mikroskopinė analizė.*

Kaunas, 2017. 51 p.

SANTRAUKA

Įrenginių dalių gyvavimo laikas labai priklauso nuo susidėvėjimo, o nusidėvėjusios dalys sugenda. Dilimas būna įvairių rūšių: abrazyvinis dilimas, adhezinis dilimas, erozija ir kt. Kietosios dangos sustiprina pasipriešinimą dilimui. Tai pasiekiama naudojant tvirtesnes sudedamąsias medžiagas nei esamas gaminio paviršiaus, kuriam atliekama procedūra. Atsparumas dilimui priklauso nuo tokių elementų kaip naudojamos medžiagos dangų formavimui, suformuojamų junginių savybių, kietinamųjų priemonių, temperatūros įtakos. Šiame darbe pateikiami dviem būdais – elektrolankiniu apvirinimu bei plazmos srautu suformuotų kietųjų dangų tyrimai. Atlikti kietumo matavimo, abrazyvinio dilimo testai bei suformuotų kietųjų dangų mikrostruktūrų tyrimai. Darbo pabaigoje pateiktos išvados ir rekomendacijos.

Ravi Shankar Gorli. Investigation of hardfacing prepared by various arc welding technique. *Master's* Final Project / supervisor Assoc. prof. dr. Antanas Čiuplys; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Research field and area: Technological Sciences, Production Engineering.

Keywords*: Hard facings, submerged arc welding, plasma transfer welding, abrasion wear test, microscopic examination*

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SUMMARY

Life component of machine parts relies on upon the wear and machine parts intended break because of impact brought on by wear. Wear has ordinary modes, for example, scraped spot, abrasion, erosion, effect and consumption. Hardfacing is a resistance to wear, it is a utilization of development of structures of uncommon compounds on the surfaces. The wear resistance relies on upon the variables like hardfacing composites, materials composition, solidifying specialists, temperature, erodent and scraped area particles. The present work reports on the wear resistance identification and weight loss of the samples prepared by Submerged arc welding and plasma transferred arc welding. And this process is under the abrasion testing and finally microscopic examination and display the results out.

Keywords- *Hard facings, submerged arc welding, plasma transfer welding, abrasion test, microscopic examination.*

KAUNAS UN IVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:
Head of Production engineering Department

(*Signature, date*)

Kazimieras Juzėnas
(*Name, Surname*)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Investigation of Hardfacings Prepared by Various Arc Welding Technique.

Approved by the Dean Order No.V25-11-8, 21 April 2017

2. Aim of the project

To compare hardfacings produced using two different hardfacing technologies

3. Structure of the project

1.Introduction of the hardfacing and its purposes in an industry.
2.Preparing of samples using submerged and plasma transfer arc welding.
3.Calculating their weight loss and wear resistance using abrasion tests.
4.Calculating the hardness of the samples.
5.Comparing the microscopic images and finding out the best technique.

4. Requirements and conditions

No requirements and conditions.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 May 31st.

Student Ravi Shankar Gorli
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor Assoc_prof.Antanas Čiuplys
(*Position, Name, Surname*) (*Signature, date*)

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Introduction

Hardfacing (otherwise called hard surfacing) is the use of a hard, wear-safe metal or metal alloy to the surface of a milder metal by a welding procedure. As opposed to make the whole part from a costly alloy, it is more conservative to make it from customary steel and cover the wear surface zone with a layer of weld metal prepared to do withstanding the conditions it will be subjected to [1].

The normal welding procedures might be used for hardfacing. The most appropriate welding handle decision depends on the hard surface material you are applying.

This process is mainly included in a grouping such as [2].

- ➢ Cladding
- ➢ Buttering
- ➢ Build up

Cladding

This process is mainly used for the improvement of the heat resistance and the corrosion of the deposited surfactants.

Buildup

In this process, the main target is to achieve the desired shape after working with the hardfacing.

Buttering

This is mainly deals with the welded parts and the compatibility for the subsequent completion of the weld.

Types of base metals than can hardfaced.

Carbon and low-compound steels with carbon substance of under 1 percent can be hardfaced. Medium carbon and low-compound steels are extremely normal since they give higher quality than mild steels and better abrasive spot resistance. High carbon alloys may require an exceptional support layer.

The accompanying base metals can be hardfaced:

- ➢ Stainless steels
- ➢ Manganese steels
- ➢ Carbon and compound steels
- ➢ Cast irons
- ➢ Nickel-base combinations

- Copper-base combinations

Carbon and low-combination steels are firmly attractive and can easily recognized from the previous manganese steel which is non-attractive. There are some low-combination and higher carbon steels that are utilized for assembling hardware and extra parts, particularly gear that requires higher quality and abrasive resistance. They are not effectively separated, but rather ought to be recognized keeping in mind the end goal to decide legitimate preheat and post heat temperature. As the alloy content expands, the requirement for preheat and post heat turns out to be more basic.

For example, steel produced using 4130 for the most part requires a preheat of 400ºF(200ºC). Steel utilized for rails is normally higher carbon and requires a base preheat of 600ºF to 700ºF (315ºC to 370ºC). Manganese steel does not require preheat. Actually, steps ought to be taken to keep the base metal warmth beneath 500ºF (260ºC).

Review for the material hardness

Hardness is a complete property of the material performance and efficiency. Therefore, Hardness is very crucial in an engineering product because on this hardness there are lot of parameters which depends directly on hardness. Resistance to wear and some other parameters.

These hardness tests are very based on experimental and observational part because they are completely empirical. And the chief value is an inspection device and it can be easily identified the differences in the hardness and quality.

So, based on the material characteristics and the nature of the materials and requirements the hardness differs. There are lot of tests based on different terms. The most commonly used hardness testing methods are Brinell, Rockwell, and files test etc. The brinell and Rockwell tests are completely based on the indentation tests and while coming to the File tests they are based on rebound height of a diamond tipped metallic hammer.

And comparing to the results obtained from the each and every hardness tests we can easily identify that there is not any relation found even mathematically.

For example, [3] if we are finding any relation between the Brinell and Rockwell we can see like

Brinell testing result = 350 Brinell

Rockwell testing = C-38.

Finally, this hardness makes the material resistant towards Penetration and Indentation and scratching.

Hard facing applications

In hardfacing applications, a layer of surfacing metal is connected to lessen wear by expanding the resistance of a metal surface to abraded spot, impact erosion, bothering, or cavitation. Similarly, as with cladding, the quality of hardfacing is not considered in the outline of the segment.

Notwithstanding the qualities of the surfacing material and base metal, other critical contemplations while picking hardfacing applications are:

- Geometry of the part to be surfaced well.
- Cost of the material and work.
- Techniques to avoid cracks in the surfacing or application-produced cracks.
- Distortion from thermal stresses of welding.
- Quality of the store.

Hard facing purposes

The reasons for hardfacing are to:

- combat wear,
- increase the life of the part,
- Decrease the expenses of down time
- To control the cost of replaced parts.

It is more efficient to hardface another part or worn part instead of buying another piece. On the off chance that parts are completely worn from their unique measurements or shape, they ought to first be developed with an appropriate material before hardfacing. Sometimes the hardfacing material might be utilized for development also.

Make sure not to develop a section with metal that is too delicate. On the off chance that the part is hard-faced with a hard, weak material, the delicate metal underneath may have melted under effect. This could bring about splitting and spalling of the hard surface layer.

The main aim involved in this is to compare the hardfacings produced using two different hardfacing technologies. And calculating the hardness tests from the specimens and finding out the wear resistance and average weight losses among the samples and comparing them.

1. Hard facing processes

This hardfacing is applied using a wide variety of techniques by the usage of different composition of materials.

- ➢ These metals can be either wires or powder or granules.
- ➢ We can use different processes like arc welding, oxy-acetylene welding and heat treatment such as thermal spraying.
- ➢ Generally, the arc welding is mainly used to avoid excess heat.

Most used hardfacing processes are [4]

1. Gas metal arc welding.
2. Flux cored arc welding.
3. Metal cored arc welding.
4. Submerged arc welding.
5. Shielded metal arc welding.
6. Gas tungsten arc welding.
7. Thermal spray surfacing.

Table 1 Hard facing process mode of applications

Hardfacing process	*Mode of applications*
Gas metal arc welding.	semi-automatic
Flux cored arc welding.	Manual
Metal cored arc welding.	Automatic
Submerged arc welding.	Automatic
Shielded metal arc welding.	Automatic
Gas tungsten arc welding.	Automatic
Thermal spray surfacing.	Automatic

1.1. Gas metal arc welding

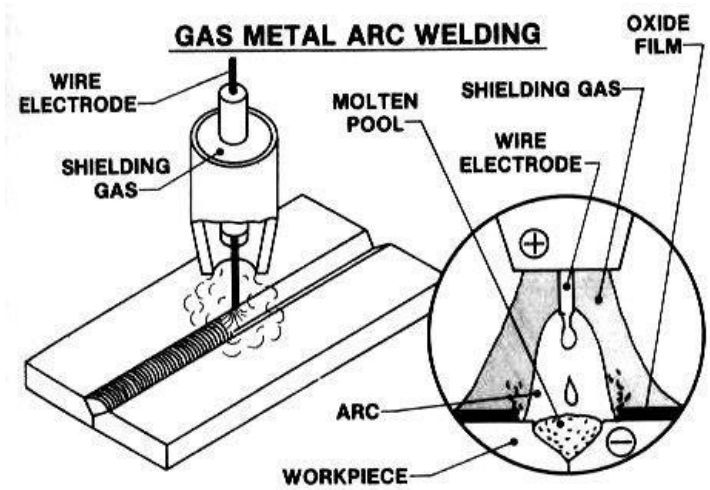


Figure 1 Gas metal arc welding [5]

Gas Metal Arc Welding (GMAW), by definition, is an
circular segment welding process which delivers the combination of metals came by heating up them by a circular segment between a persistently fed filler metal electrode and the work.
The handle utilizes to protect from an externally provided gas to secure the liquidity weld pool. The application of GMAW for the most part requires DC+ (switch) extremity to the cathode.
In non-standard working, GMAW is traditionally known as MIG (Metal Inert Gas) welding and it is less generally known as MAG (Metal Active Gas) welding [6].
In either case, the GMAW procedure fits weld an extensive variety of both strong carbon steel and tubular metal-cored anodes. The combination of material range for GMAW incorporates: carbon steel, stainless steel, aluminum, magnesium, copper, nickel, silicon bronze and tubular metal-cored surfacing combinations.
The GMAW procedure fits self-loader, mechanical automization and hard welding applications.
Advantages

1. More capable to join large varieties of thickness and materials.
2. Components available for the equipment is not so expensive.
3. The weld density if hydrogen is very less.
4. The heat input is very less.

5. In this case, it is very easy to clean up the surface because the weld shatter is very less comparatively less.

6. Very low welding fume.

Disadvantages

1. It is kindly restricted to use over hard thickness materials.

1.2. Submerged arc welding

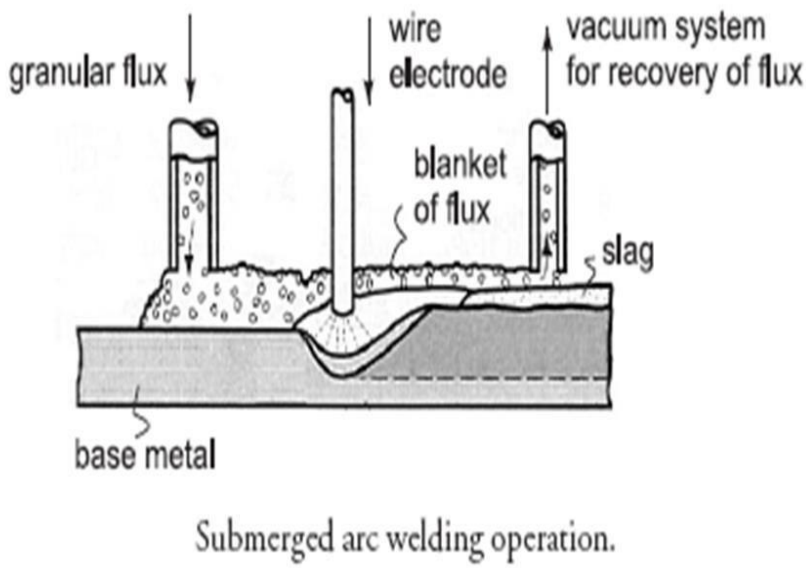


Figure 2 Submerged arc welding

Submerged circular segment welding, with its generally profound infiltration attributes and defensive flux cover, puts more warmth into the workpiece than the other bend welding forms. As-a-result of this weakening, the full properties of the surfacing metal are not accomplished until at least two layers are kept.

An extensive variety of cathode sorts permits the decision of either DC or AC. In some, applications the SAW anode can be in a snaked strip, which is frequently utilized for consumption safe surfacing applications. Two points of interest of utilizing SAW for hardfacing is that there is no splash and no introduction to bright radiation from the submerged curve.

Figure 3 shows the development and hardfacing of an idler wheel from a bulldozer tractor. The well-used wheel has been expelled from the machine, and it is being developed and hardfaced utilizing SAW. In the wake of welding has been finished, the wheel is machined with the goal that it can be reinstalled on the machine and utilized once more [7].

Advantages

- It, usually generates high velocity including concentration.
- Whole throughout the welding process the weld flames are completely zero.
- Smooth surface obtained in this process.
- Under 12mm thickness there is no need of edge preparation.
- Complete corrosion resistant.

Dis advantages

- Operator himself can't examine or judge the process because of light beam devices.
- Cast iron and some more elements can't work over this process.

Applications

- working on boilers and railway construction.
- Improvements in the machine parts.

1.3. Shielded metal arc welding.

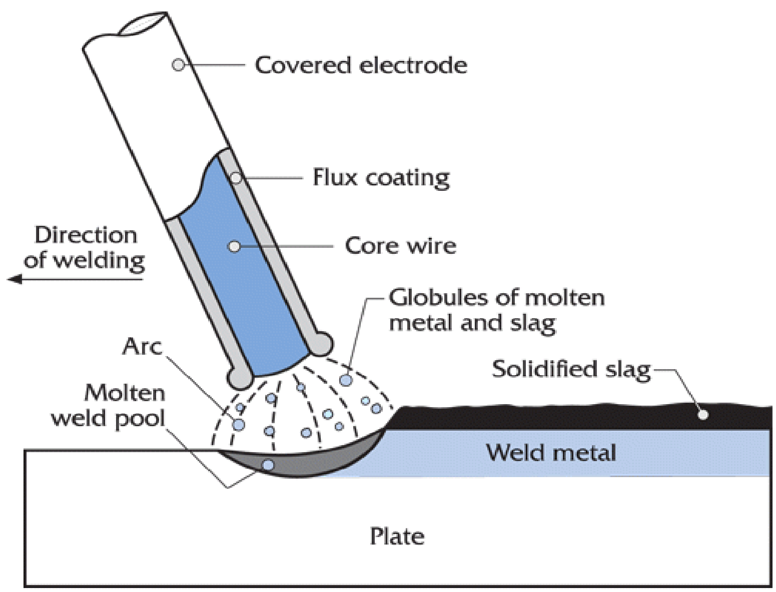


Figure 3 Shielded metal arc welding *[8]*

The most used traditional method is shielded arc welding process. In this process, the electrode which is going to be used in this is flux covered electrodes and it lies between 9 to 18 inches by length and the breadth lies between 1.6 to 8.0 mm.

The weld probing is very less when compared to GMAW for galvanized steel but the opening for some welds are improved a lot compared to uncoated steel finishing. When the angle of electrode is 70 to 30 degrees than gradually the weld speed is also reduced so that we can achieve our normal weld depth.

Equipment used

- Cables for welding.
- Ac or dc adaptor.
- Holders for electrode.
- Clamps
- Hammers, brushes etc.

Advantages

- Quite inexpensive.
- Usage of wide variety of materials.
- Applicable for outdoor materials.

Dis advantages

- This process carried out in a very slow compared to many other processes.
- The arc is not at all clear in this process.

Applications

- Submerged arc welding is generally used for long welds.
- However, because of high fluidity of the weld pool, the welding is mostly carried out on butt joints in the flat and straight position and the fillet joints in both the flat and horizontal-vertical positions.
- For rotational joints, the workpiece is rotated under a fixed standard welding head with welding taking place in the flat position. And the passes of the welding also completely depend on the thickness of the object or the material which is selected.
- There is virtually no restriction on the material thickness, provided a suitable joint preparation is adopted.

1.4. Gas tungsten arc welding

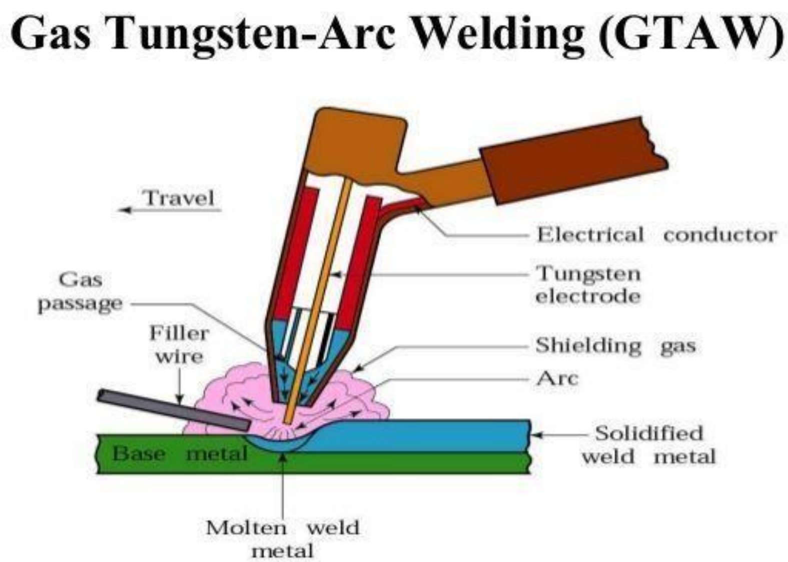


Figure 4 Gas tungsten arc welding [9]

In this case of welding technique, it is mostly used for small metals. The electrodes may be stainless steel or some other alloys such as manganese. This welding holds for a long time because it is completely for thin and small materials.

This process uses two hands in the working machine because one is to hold the work piece and another is move the flame from one end to another end. And this shows that the person should have a great experience between the work piece and equipment [10].

The electric spark is completely generated, by high frequency tesla coil. This is allowed to reach the spark and it reaches to arc to start the work. The separation ranges from 1.5 to 3.0 mm. And this process goes on continuously until the work piece is firmly welded.

Advantages

- No corrosion
- Weld is completely strong.
- The operator can have a keen inspection during the process.
- This is completely suitable for high quality weld materials.
- Highly suitable for either ferrous nor non-ferrous materials.

Figure 5 Gas tungsten welding example

Dis advantages

- The process is bit expensive compared to many other.
- Probability of contamination is high due to welds.

Applications

- This type of welding is generally used for light and low strength metals like the automobiles from space and some of the hollow parts [11].
- Additionally, Gas tungsten arc welding are used to make welds for aluminum parts. The working area will be at the pipes, tubes etc.
- The main advantage of this process is it won't allow the metal to get in contact directly like others.
- In fact, some alloys like aluminum and chromium can loss their properties by electric arcs but in gas tungsten arc welding it is quite different.

1.5. Thermal spray surfacing

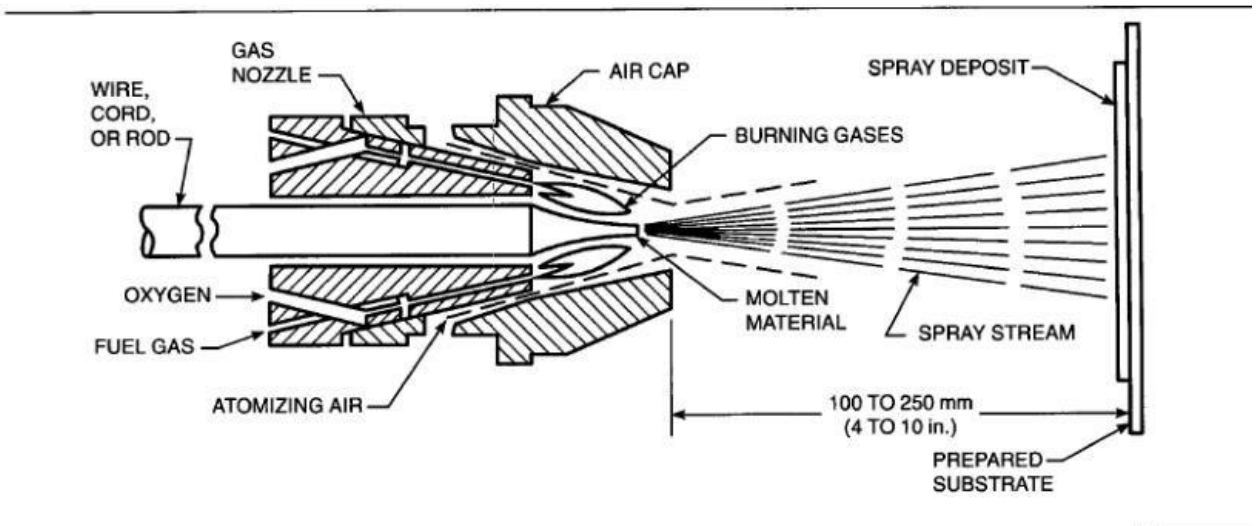


Figure 6 Thermal spraying [12]

Thermal spraying is a procedure that warms a metallic or non-metallic material to an almost liquid state and after that pushes it onto a surface to be surfaced.

They are further classified into few types [13]

- ➢ Conventional spray process.
- ➢ Electric arc spray process.
- ➢ Plasma spray process.
- ➢ Oxy fuel spray process.

wire spray material is liquid in an exceedingly gaseous oxygen-fuel flame. The fuel gases are often alkyne, propane or atomic number 1. The wire is fed concentrically into the flame, wherever it's liquid and atomized by the addition of compressed gas that also directs the liquid material towards the work surface.

In the conventional spraying process, the wire spraying and powder spraying acts on the same basic principle. Only difference is the electrode changes.

In the powder spraying process the electrode which they are using is a powder material because not every material supports the conventional wire processes.

1.5.1. Plasma spray process

The Plasma Spray Process is fundamentally the spraying of liquid or relaxed material onto a surface to give a covering. Material as powder is infused into a high temperature plasma fire, where it is quickly warmed and quickened to a high speed. The hot material effects on the substrate surface and quickly cools framing a covering. This plasma arcs prepared accurately known as a "chilly process" (with respect to the substrate material being covered) as the substrate temperature can be kept low and handling staying away from harm, metallurgical changes and twisting to the substrate material.

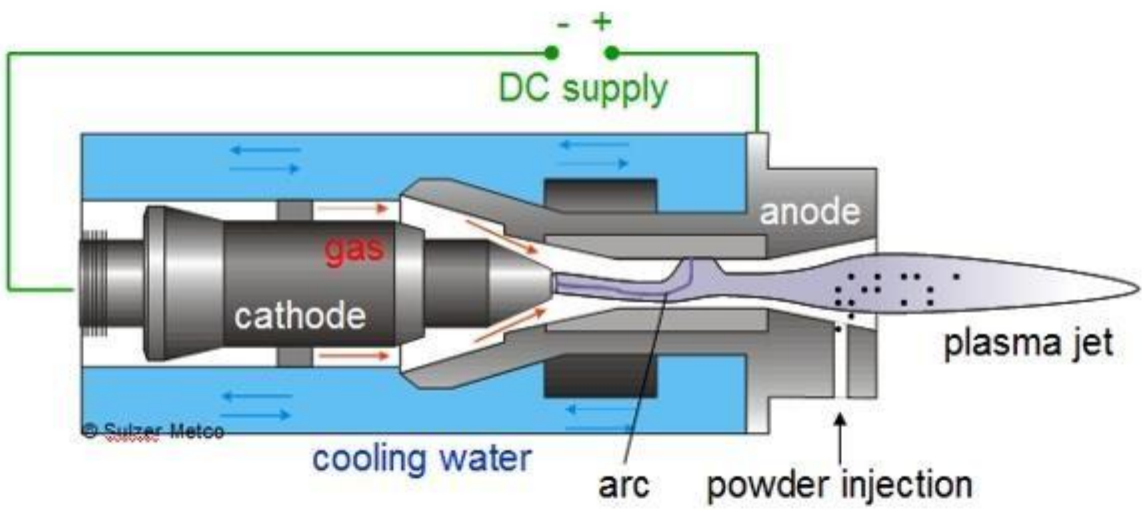


Figure 7 plasma spraying process

The plasma spraying injector contains a copper anode and tungsten cathode, both of which are water cooled. Plasma gas (argon, nitrogen, hydrogen, helium) streams around the cathode and through the anode which is molded as a tightening spout. The plasma is started by a high voltage release which causes confined ionization and a conductive way for a DC circular segment to frame amongst cathode and anode. The resistance warming from the bend causes the gas to achieve outrageous temperatures, separate and ionize to shape a plasma. The plasma leaves the anode spout as a free or nonpartisan plasma fire (plasma which does not convey electric current) which is unique to the Plasma Transferred Arc covering process where the curve stretches out to the surface to be covered. At the point when the plasma is settled prepared for spraying the electric circular segment stretches out down the spout, rather than shorting out to the closest edge of the anode spout. This extending of the bend is because of a heated squeeze impact. Chilly gas around the surface of the water-cooled anode spout being electrically non-conductive chokes the plasma bend, raising its temperature and speed. Powder is bolstered into the plasma fire most regularly by means of an outer powder port mounted close to the anode spout exit. The powder is so quickly warmed and quickened that splash separations can be in the request of 25 to 150 mm [14].

Practically there are two types of plasma arc welding process.

1.Transferred process

In this process, the working electrode i.e tungsten Is connected to negative terminal and the work substrate is connected to the positive terminal. And an electric gas is maintained always in between them in a flow process in a plasma state.

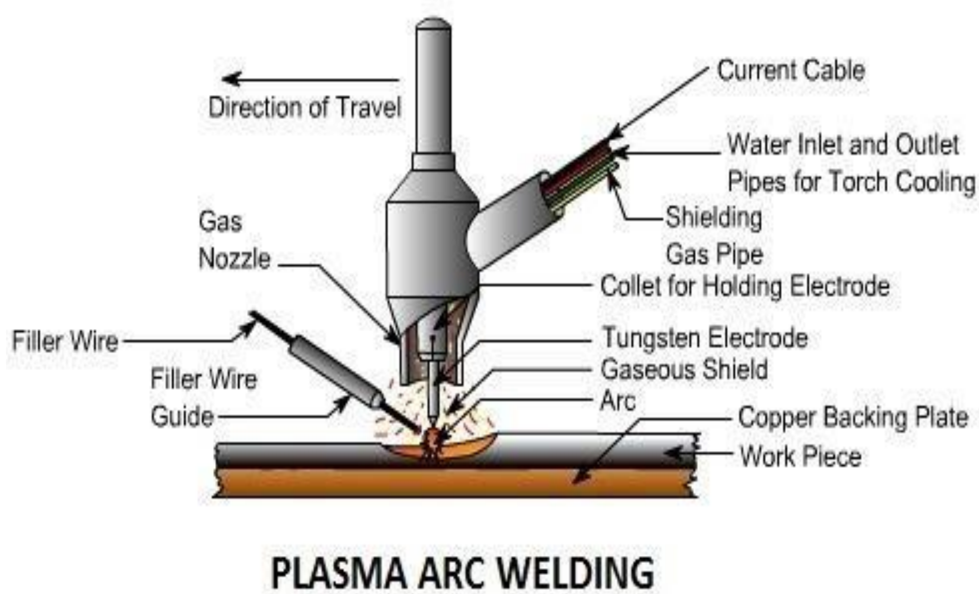


Figure 8 plasma arc welding [15]

1.5.2. Non-transferred type.

In this case of process the power transmission is generated directly to the electrode and the nozzle. The main advantage of this process is the heat is generated only inside the process rather outside is completely normal. Thermal efficiency is very low in this process.

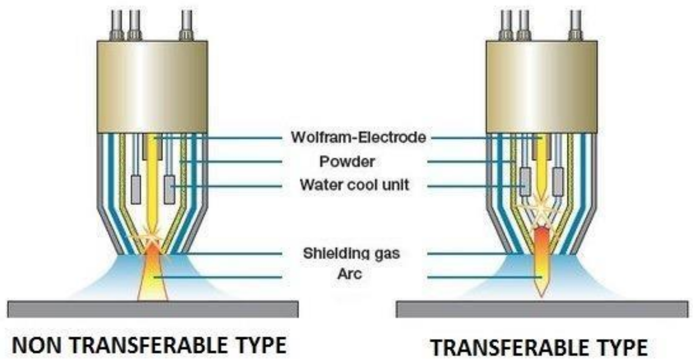


Figure 9 Transferable and Non transferable

The base metals used in this process are stainless steel, copper alloys and other carbon and aluminum alloys.

Dis advantages

- Cost's high when compared to the other processes.
- The process is too complex.

Advantages

- Efficient to the workers who are operating the equipment.
- High standards of coating.
- A wide variety of materials can be sprayed using this technique.
- Even broader powder materials can also be used.

Applications

- Completely, used in aerospace.
- Used for high melting materials.
- Mostly, alloys made of titanium are used.

2. Methodology

In this case of description, it totally functions and works according the experiment and these are described in detailed version below.

2.1. Sample preparation

At first according to the experiment the required workpiece which is made up of the dimensions is obtained by the machining process. Now the work piece is not clear to the surface because of the preparation in the different materials.

Now the material is completely oxidized in-order to remove the dust surface and other unwanted materials on the surface layer. Now, the oxidization is completely done by the grinding machine with the minimum rotation of the grinding wheel. We must make sure about the removal of the dust surface so that the deposited surface layer will be very clear and obtain the efficient sample.

Here, is the relation among three samples.

- B1
- B2
- F1

No.	Powder composition, vol.%	Method
B1	50 WC-Co [2], 50 LCW[3]	SAW
B2	25 WC-Co [2] + 25 FeCrSiB[1] + 50 LCW[3]	SAW
F1	50 WC-Co [2] + 50 FeCrSiB[1]	PTAW

[1] Iron-based self-fluxing alloy 6 AB from Höganäs AB: Cr 13.7 %, Si 2.7 %, B 3.4 %, Ni C 2.1 %, bal. Fe;

[2] Disintegrator milled recycled WC-Co powder; fraction size 1.6 – 2.0 mm;

[3] LCW – low carbon wire (C < 0.1%, Si < 0.03%, Mn 0.35-0.6%, Cr < 0.15%, Ni < 0.3%)

Table 2 powder composition for samples

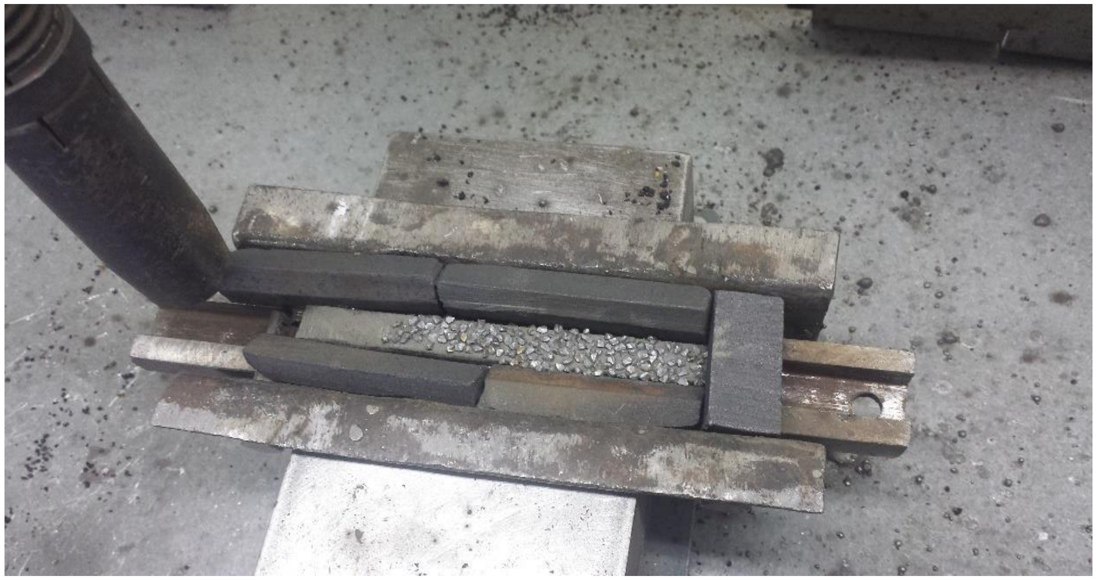


Figure 10 sample preparation of B1

2.2. Preparation of B1 using submerged arc welding

From the above figure {9} it can conclude the work process carried out in a sequential order through the experiment.

As discussed in the preparation we can see that the oxidized sample is placed on the holder of the welding machine. As we placed on the holder we should be very careful about the slipping and moving of the sample in a precise manner. In order to avoid such slipping we have to place a graphite rod and place it perpendicularly at the complete four sides in a complete way.

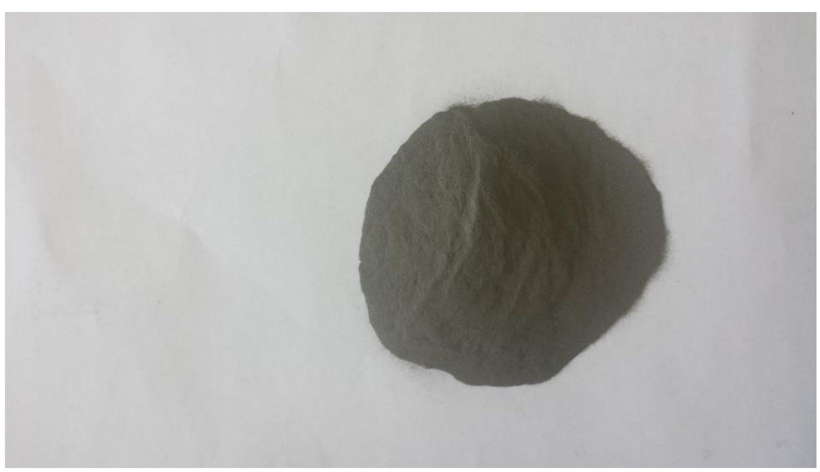


Figure 11 Self fluxing powder

Figure 12 Hard material

After completing the setup, we should fill the complete sample surface with the hard metal and we should keep the arc exactly to the center of the workpiece. once if this is completed we need to turn on the process and the copper starts melting on the surface and the desired layer is completely framed over the sample. The temperature at the point of contact will be around 1400degrees.

2.3. Preparation of B2 using submerged arc welding

In this sample B2 the composition is a mixture of Self fluxing material + hard metal powder (25 WC-Co [2] + 25 FeCrSiB[1] + 50 LCW). As, discussed in the preparation we can see that the oxidized sample is placed on the holder of the welding machine. As we placed on the holder we should be very careful about the slipping and moving of the sample in a precise manner. To avoid such slipping we have to place a graphite rod and place it perpendicularly at the complete four sides in a complete manner.

After completing the setup, it should be filled the complete sample surface with the hard metal and self-fluxing materials. And In the same manner as preparation of sample B1 we should place the graphite around the composition of hard and self-fluxing. So, that the graphite prevents the scattering of the layer out of the work piece. After that the arc is kept exactly to the center of the workpiece and done with the two passive moments in the arc.

Figure 13 Mixture of both Hard and self-fluxing powder

Once if this is completed we need to turn on the process and the steel starts melting on the surface and the desired layer is completely framed over the sample. The temperature at the point of contact will be around 1400degrees.

Figure 14 Submerged arc welding equipment

From Fig 13 the torch which is quite perpendicular to the sample moves on sample and helps in the complete process in a specific interval. And when it starts generating the arc the materials start melting on the sample and starts depositing on the surface layer of the sample which is made up of steel C235.

Figure 15 Sample output after welding

2.3. Preparation of F1 using Plasma arc transferred welding

During PTAW self-fluxing alloy bond layer was welded first, with the deposition rate of 50 mm^3/s and current of 65A. Then hardmetal layer with thickness of 2 mm was deposited on that layer freely. Final step was welding third layer of self-fluxing alloy with deposition rate of 40 mm^3/s and current of 55A.

The hardfacing process was performed in a single pass using SAW and standard flux AMS1 (LST EN 10204:2004) to shield and prevent the welding area. Low carbon single electrode wire with diameter of 1.2 mm (C < 0.1 %; Si < 0.03 %, Mn 0.35 – 0.6 %, Cr < 0.15 %, Ni < 0.3%) was feeded at the 25.2 m/h rate into the welding zone under correctly chosen process parameters: welding current 180 – 200 A, voltage 22 – 24 V, travel steel – 14.4 m/h. SAW was carried out with an automatic welding device – torch MIG/MAG EN 500 78). As substrate material for production of composite Hardfacings cheap structural steel S235 (C 0.17 %, Mn 0.55.65 %, S≤ 0.05 %, P ≤ 0.04%) provided as 10 × 10 mm bars was used. The hardfacing was accomplished on 10 × 100 mm samples with hardmetal powder mixture (~ 2 mm) spread on the surface of substrate under the flux.

Figure 16 Plasma transfered arc welding machine

The PTAW welded Hardfacings contained ~50 vol% of matrix (FeCrSiB) and ~50 vol% reinforcement (recycled disintegrator milled WC-Co).

The matrix powder was dried before welding, the hardmetal powder was used as it comes from disintegrator milling (some parts of it has been cleaned with acetone or alcohol, but it has to be dry before welding).

Before wear test and hardness measurements the PTAW hardfacing is grinded (with a grinding wheel) so that it would have a smooth surface. After grinding the thickness is around 2 mm.

2.4. Hardness test for specimen

Hardness completely deals with the material characteristics and properties of the material.

It is stated as the obtaining to surface of smoothening, and it is controlled by measuring the changeless profundity of the depth. Basically, when utilizing a constant force (load)* and a given indenter, the littler the space, the harder the material. In this hardness values got by measuring the depth of the sample by utilizing one of more than 12 diverse test strategies.

There are lot of testing methods for measuring the hardness and equipment for the respected functioning of the samples or products. And they vary according to different composition and material properties. And here are some of the properties to some of the materials.

- Size of the samples
- Thickness
- Rotational/cylindrical samples
- Scales
- Gage R/R

Size of the samples

In the case, of taking small parts we should be in very precise sate so that they should not worn out during the testing. And the applied force should be limited according the part thickness and we should make sure about the inside and outside edges too. And if we are talking about the larger parts while testing we should be very careful about some parameters like slipping and fixture movements.

Thickness

The thickness of our sample should be in minimum by ten times of the depth And, there are few recommendations for the normal tests.

Rotational samples

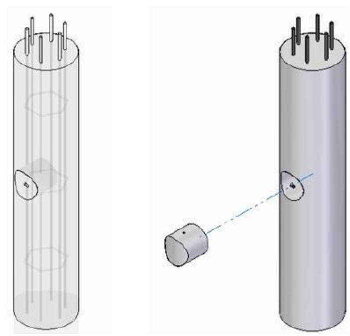


Figure 17 Rotational samples

Slight modifications are much needed for the cylindrical parts in the experiment. Especially, for the small parts and small diameters due to the difference between the radial flow and axial flow And, we have to make sure about the sample diameter and indents diameter.

2.5. Rockwell hardness testing

The Rockwell hardness testing Is otherwise called ASTM E-18 and this is most utilized strategy in finding out the hardness test. The Rockwell test is generally less requesting to perform, and more exact than various sorts of hardness testing methodologies. The Rockwell test procedure is used on all metals, with exemption of in condition where the test metal structure or surface conditions would introduce too much assortments; where the spaces would be excessively immense for the application; or where the example size or tests doesn't permit the usage.

.

Figure 18 Rockwell hardness testing

The Rockwell strategy measures the changeless profundity of depth delivered by a load on an indenter. Initial, a preparatory test constrains generally alluded to as preload or minor load is connected to an example utilizing a diamond indenter. This heap speaks to the zero or reference position that gets through the surface to decrease the impacts of surface wrap up. After the preload, an extra load, call the real load, is connected to achieve the aggregate required test stack. This drive is held for a foreordained measure of time to take into account versatile recuperation. This significant load is then discharged and the last position is measured against the position gotten from the preload, the space profundity fluctuation between the preload value and real value.

Preliminary test loads (preloads) range from 3 kgf (used in the "Superficial" Rockwell scale) to 10 kgf (used in the "Regular" Rockwell scale) to 200 kgs (used as a macro scale and not part of ASTM E-18; see ASTM E-1842). Total test forces range from 15kgf to 150 kgf (superficial and regular) to 500 to 3000 kgf (macro-hardness).

Test Method Illustration [16].

A = Depth reached by indenter after application of preload (minor load)

B = Position of indenter during major load

C = Final position reached by indenter after elastic recovery of sample material

D = Distance measurement taken representing difference between preload and major load position

An assortment of indenters might be utilized: conical diamond with a round tip for harder metals to ball indenters ranges with a breadth range running from 1/16" to ½" for milder materials.

While choosing a Rockwell scale, a general guide is to choose the scale that indicates the biggest load and the littlest indenter conceivable without exceeding characterized operation conditions and representing conditions that may impact the test outcome. These conditions incorporate test examples that are underneath the base thickness for the profundity of space; a test impression that falls excessively near the edge of the example or another impression; or testing on round and hollow examples. Also, the test pivot ought to be around 2-degress of exact measurement; there ought to be no redirection of the test or analyzer amid the stacking application from conditions, for example, soil under the test example or on the lifting screw. It is imperative to keep the surface complete clean and decarburization from heat treatment should be evacuated.

Sheet metal can be too thin and too delicate for testing on a specific Rockwell scale For, this situation, a rolled sheet iron can be utilized to give a predictable impact of the outcome. Another unique case in testing chilly moved sheet metal is that work solidifying can make a slope of hardness through the example so any test is measuring the normal of the hardness over the profundity of space impact. For this situation, any Rockwell test result will be liable to question, there is frequently a past filled with testing utilizing a specific scale on a specific material that operators are utilized to and ready to practically translate.

2.6. Tampering process for steel

Tampering is a procedure of Heat treating, which is utilized to expand the durability of iron-based alloys. Treating is generally performed in the wake of solidifying, to diminish a portion of the abundance hardness, and is finished by warming the metal to some temperature underneath the basic point for a specific period, then enabling it to cool in still air. The correct temperature decides the measure of hardness evacuated, and relies on upon both the particular properties of the combination and on the coveted properties in the completed item.

Highly concentrated Heat can treat steel to give it distinctive properties of hardness and delicate quality. This relies on upon the measure of carbon in the steel (just high carbon steel can be solidified and tempered).

CARBON CONTENT OF COMMON STEELS: Mild steel: 0.4% carbon, Medium carbon steel approximately 0.8% carbon, High Carbon Steel approximately 1.2% carbon (this steel is also known as Tool Steel and includes Silver Steel and Gauge Plate).

Mild steel and medium carbon steel don't have enough carbon to change their crystalline structure and therefore can't be solidified and tempered. Medium carbon steel may turn out to be somewhat harder even though it can't be solidified to the point where it can't be documented or cut with a hacksaw (the exemplary trial of whether steel has been solidified).

On the off chance that steel is warmed until it gleams red and is extinguished in clean water promptly, it turns out to be hard additionally fragile. This implies it is probably going to lose its properties and break or snap if we applied more pressure. Then again, if the intensely hot steel is permitted to cool gradually, the subsequent steel may have less demand for the transformations underwent record as it will be generally smoother. Because the industrial heat treatment is little complex compared to many others.

2.7. Polishing machine

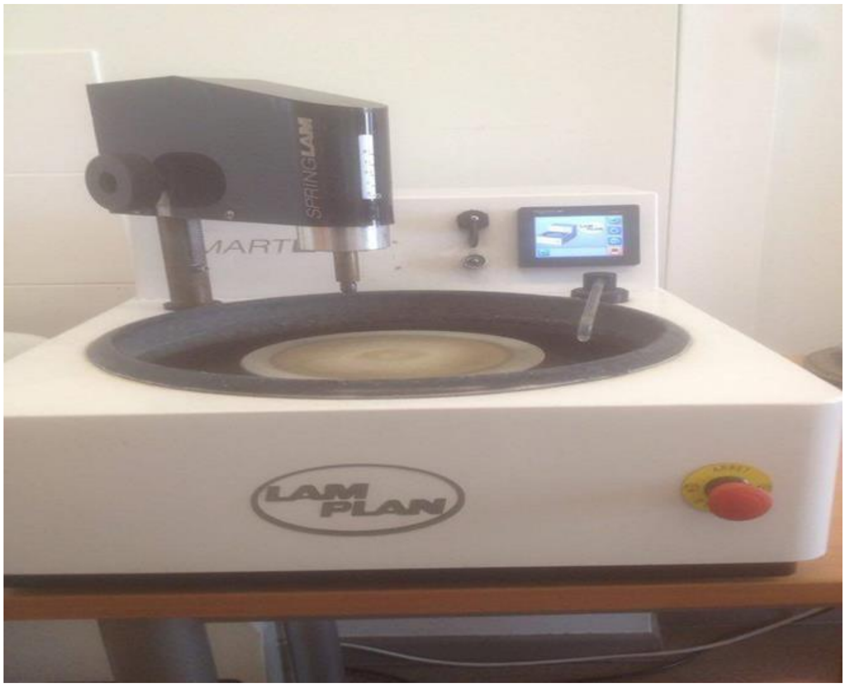


Figure 19 Polishing machine

Technical parameters

Table 3. Technical parameters

Capacity	250 to 300mm
Body	Steel coated with epoxy
Head speed	Two directions of rotatio 10 to 150rpm
Available supply of wat	Removable valve with f control
Cumulative	1.1 kw
Voltage	230-50hz
Dimensions	550mm,650mm,580m
Mass	80kg

Polishing plays a vital role in production of a metallographic sample, thus choosing the best solution for your needs in polishing machine is very important.

All useful operations are disentangled to help you accomplish your objectives in an advanced way. Regardless of whether you work in metallography research or generation control, we have a polisher which lives up to your desires. Each model meets particular reacts to integral needs, every development is an impression of our field involvement.

The SMARTLAM®2.0 is a minimized, single-plate cleaning machine that gives you an extensive variety of potential outcomes both in manual and self-loader cleaning.

Affordable and simple to-utilize, the SMARTLAM®2.0 is totally controlled by a shading touch screen outfitted with an instinctive interface. The interior memory can store 9 programs that can be sent out by means of the USB port.

The energy of the bidirectional revolution, variable-speed, steady torque engine and the likelihood to utilize plates with a measurement from 200 to 300 mm are restrictive resources that will enable you to confront up to all circumstances experienced in metallographic investigate cleaning.

Before working on the polishing machine, we should be make sure about the samples and ready or not. Once if they are done we need to select the polishing paper according the roughness of the material and their removal.

We should attach the polishing paper to the rotation wheel so that the attached samples to the head portion of the machine keeps on turning perpendicularly to the paper with the help of the shaft attached to the head portion.

As per the above lines the whole setup is completed and now we have to make sure about the water flow over the rotatory object In, order to act as an agent to control the frictional forces.

In this machine, the stopping and rotation is completely automatic feed, and the speed of rotation and clock wise and anti-clock wise directions.

2.8. Metallographic -microscope

Figure 20 Microscope

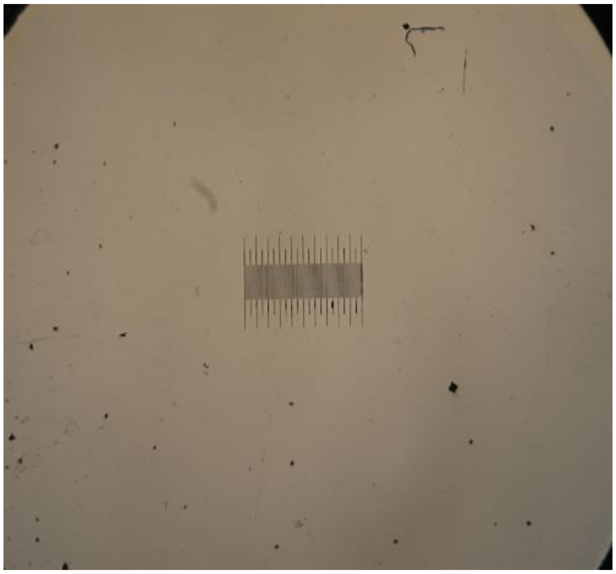
The main aim behind this microscope is to capture the images of the experimental samples in a human visible form. This is prepared to do progressively and higher magnifications and has a more prominent settling power than a light magnifying instrument, enabling it to see significantly smaller or minute objects in better detail. They are vast, costly bits of gear, exceptionally outlined room and requiring prepared work force to work them.

In this experiment, the microscope plays a vital role. After finishing the preparation of the samples, they are polished completely without any dust-particles.

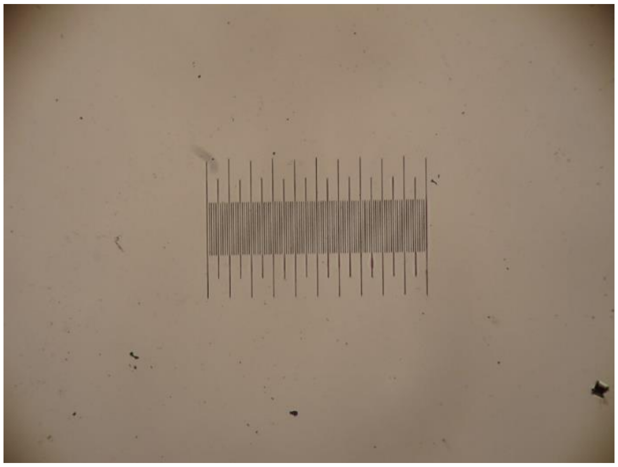
The final sample is kept under careful observation like it is zoomed completely until the maximum point and the final image is captured.

The main advantage of this device is we can easily identify the cracks and any unwanted particles on the base surface and on the metal surface.

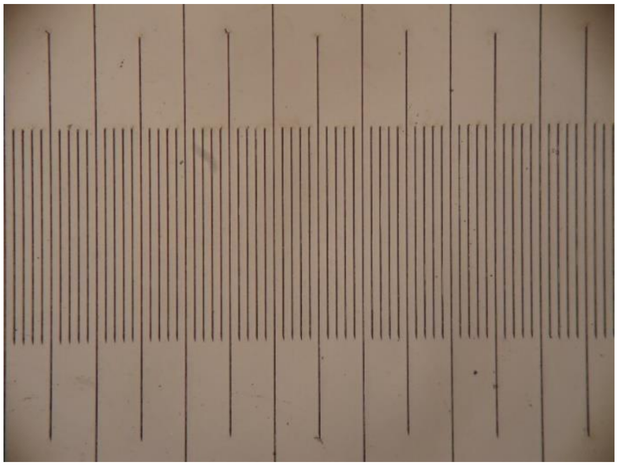
And the measurement of the scales for the microscopic examination are mentioned completely in the below figures.



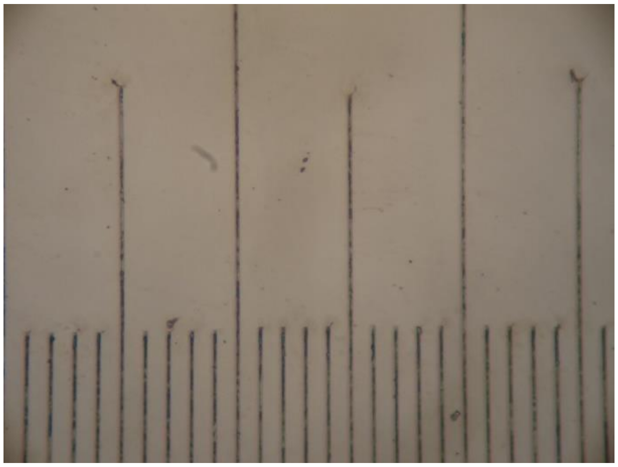
Microscopic 1 Scale 2.5x



Microscopic 2 scale 5x



Microscopic 3 scale 20x



Microscopic 4 Scale 50x

In this magnification, of different images the scale varies according to the required view obtained from the sample. And the scales of this magnification are as follows,

2.5x = 1mm

5x =500µm

20x =200µm

50x =100µm

These scales are measurement for the microscopic examination of the required samples and to find out the resistance of the samples in precise.

And these scales are measured according the scales from the above images and distance between that each single point and declared in µ meters.

And based on these measurements and scales the quality of the samples and cracks and pores are easily identified. And these samples are prepared by some arc welding techniques.

2.9. Electronic scale

Figure 21 Electronic scale

This is the laboratory purpose simple weight machine which is completely used to measure the weights of the samples in the experiment.

This machine is quite sensitive when compared to the other weighing machines. When the samples are ready to find out the values of their weights they have to clean with the spirit so that other dust particles won't play any role while measuring the device.

Working details.

1. The machine is completely used in a gentle manner because of any disturbances they may show impact on the work samples.
2. Once if the weights are placed in the weighing pans than the weight machine knob is turned on.
3. After checking everything we have to make sure about the values which they are going to measure and if necessary we have to add some supporting weights in-order to overcome the unnecessary errors.
4. There will be a display on the top which shows the results in precise to the weights.
5. And there will be an equity line which shows the exact weight of the sample. And In additional to this there will be an add-on to that weight in grams to get the desired output from the electronic scale.
6. The maximum precise measurement obtained from this scale is up to 0.0001 grams.

3.Experimental details

As, we discussed in the above methodology part about the composition of the samples

- B1 (Hard material)
- B2 (hard material + flux material)
- F1

At, first before going to the experiment we should be clear regarding the dust and other particles to be precise in weight.in this experiment the initial weights of the samples are very important in order to find out the weight losses.

3.1. Comparison of samples B1&B2

In the initial moment, the samples are cleared out with the 100% spirit in order to remove the unwanted specimens on the respected samples. And the complete weights are carried out in the electronic scale from figure (22). And the track periods are maintained well from each interval regularly.

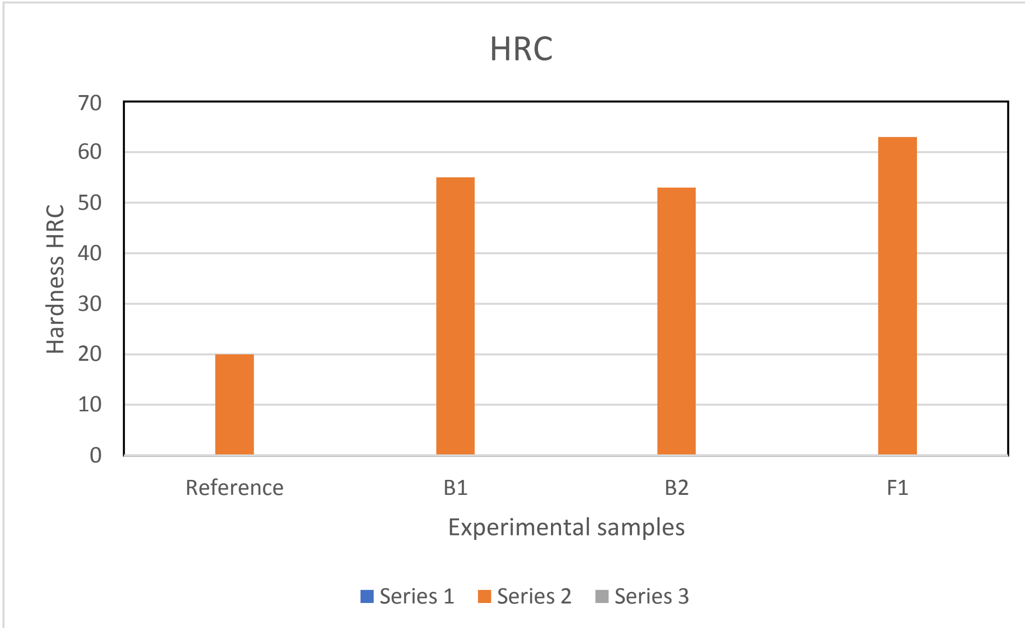
So that the minimum or maximum losses are recorded and it will be easy for performing the abrasive tests for wear. And here is the table for the specimens which are composed of different materials according to their hardness and Hardfacings.

Reference sample	Sample B1	Sample B2	Sample F1
20HRC	55HRC	53HRC	63HRC

Table 4 Hard facing composition

From the above table [4] we can see the hardness composition and their values mentioned in the table. And these samples are completely headed to the experiment and based on their results they are carried out to the wear tests and etc and finally carried out through the metallographic microscopic.

And after following the complete road path they were exhibited out with graphs and results.



Graph 1 Hardness composition

From the above table, we can see that the composition of the hardness varied by different techniques and the respected surface is tampered at 600℃ and the Rockwell's test are done at the universal load of 750ccd with the load of 1440N with the help of diamond intender.

3.2. Abrasive wear testing method

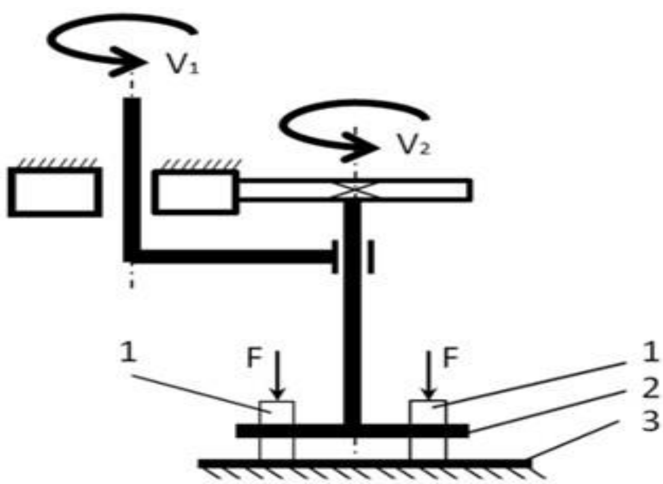


Figure 22 Scheme of abrasive emery wear test: 1 – wear samples; 2 – holder; 3 – emery substrate

In this critical mechanical process, the samples are attached to the holder of the machine which has a clock wise rotation about 240meters radius. And the equipment is suspended with a weight at the holder in order to suspend some weight on the samples. And these samples are rotated perpendicularly against the emery substrate of paper in the dimension of a square.

Calculation for the distance in the machining process.

Rotation of the handle = 63 rps / min or 1.05 rps / sec.

The diameter of the first holder D1 = 50MM

The diameter of the second one D2 = 78MM

The distance from the center to the center =60mm

The distance from the sample =49mm

As, per the above dimensions of the abrasive emery wear test machine we can conclude the final distance and the rotational distance as follows.

And it is stated as 240meters.

<u>Wear samples</u>

These samples are nothing other than the composed hardfacings B1&B2&F1.

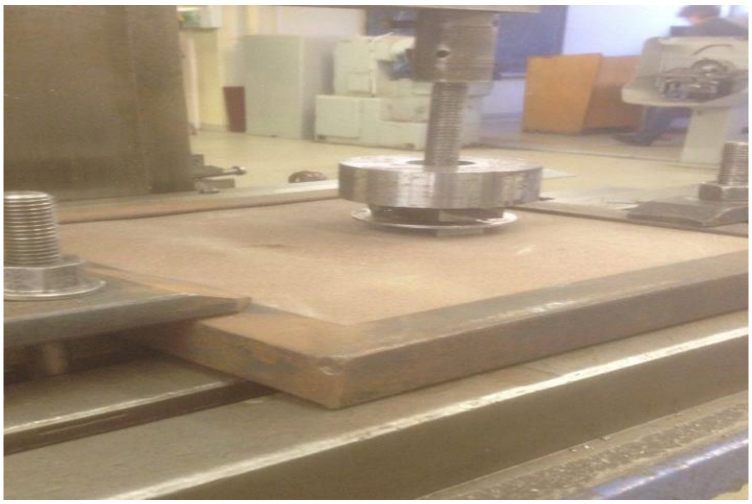


Figure 23 emery substrate

Figure 24 Abrasive wear machine

Holder

In this equipment. the holder plays a vital role and it completely hold the samples when it was rotating in a respected direction and the time and schedules are declared as per according to the specimen required. And there will be two holders with a suspended weight on them. This weight helps the samples to reduce the weight when they are rotating.

Emery substrate

Emery substrate is used as a friction agent in this experiment. The suspended samples are layed perpendicularly on the emery paper and starts rotating. Due the friction of the sample and the paper the samples starts losing their weights in a particular time intervals.

The above three parameters are the main structures involved in the experimental part and the keen observations from them gives the desired output.

Now the samples were performed under abrasive wear test and the values are recorded and the samples are first removed with spirit and calculated for every 10 minutes and change the samples in each position and recorded as follows.

B1 (12.58685g)		**B2 (12.59400g)**	
Mass in grams	◊	Mass in grams	◊
12.58705	0.048	**12.53415**	0.01705
12.53905	0.002	**12.55120**	0.03615
12.33770	0.0629	**12.51505**	0.0312
12.27480	0.0100	**12.48385**	0.002
12.27490	0.03415	**12.48405**	0.03795
12.24075	0.03753	**12.44610**	0.0114
12.20325	0.0166	**12.43470**	0.0111
12.18665	0.03305	**12.42360**	0.0127
12.15360	0.01515	**12.41090**	0.0129
12.13845	0.03317	**12.39800**	0.01185
12.10528		**12.38615**	

Table 5 Weight loss in B1 & B2

Weight loss for the samples B1 and B2

From the above table the samples are recorded for every 10minutes and changed in specific intervals with respective to the emery paper.

And the final output is completely recorded and calculated as follows.

Distance recorded is **240Meters**

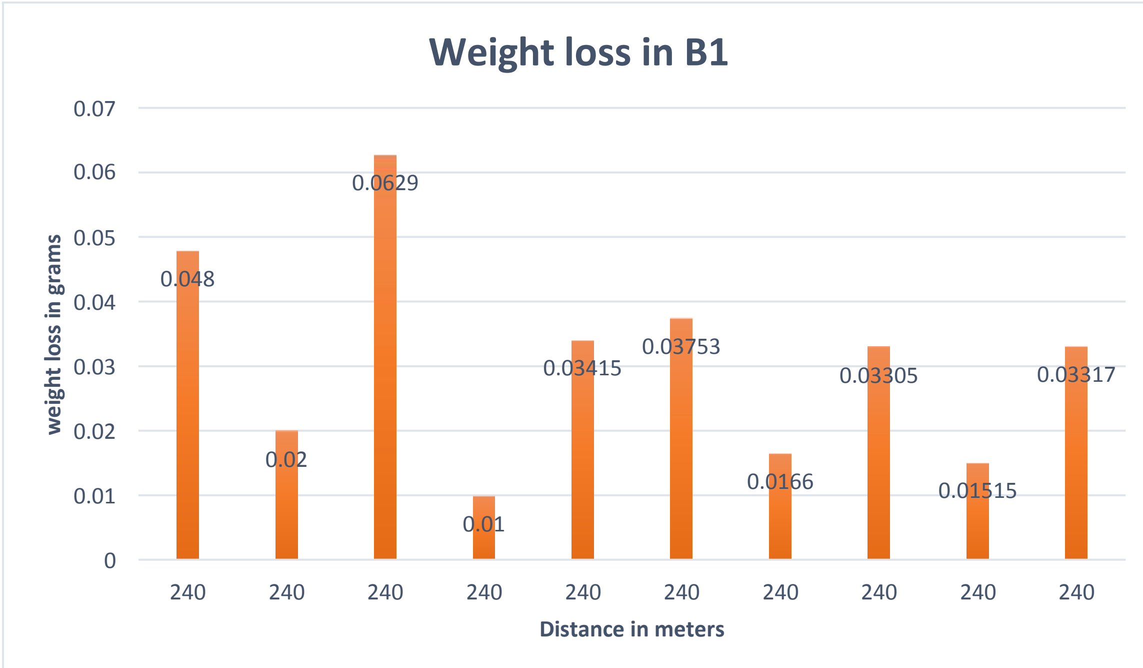
Time recorded is **10minutes**

◊ = W2 – W1

W2= weight of the sample in the first rotation.

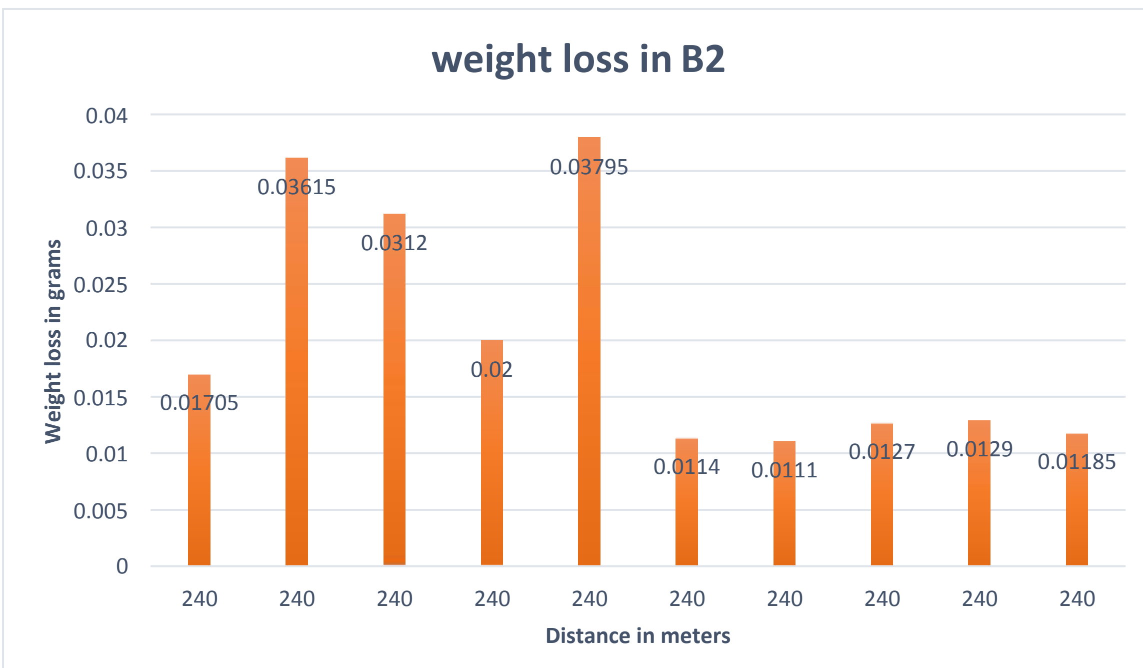
W1= weight of the sample initially.

◊ = difference of the weight loss periodically.



Graph 2 weight loss in B1

Weight loss of B1



Graph 3 Weight loss in B2

From the above graph, we can illustrate that after the abrasive wear test the weight loss of the sample B1 which is made up of submerged arc welding is gradually loosing weight. And talking about the wear resistance it also going down.

The main reason behind this unusual weight loss in the sample is due to the investment of the hardfacing on the material. And due to the uneven transformations, the suspended materials are not deposited or settled well and they have their own desired shape and stops reducing weight suddenly. And in some cases, due to the width of the hard metal it may takes very less period to- loose, their weight and it suddenly it drops off their original weight.

Due to sudden weight reduction in the sample hardfaced material there will unusual changes.

Now the same procedure is repeated for another samples F1 which is prepared under the plasma transferred arc welding and the other one is normal sample which is completely used as reference sample. This is completely different technique compared to B1 and B2 because they are prepared from the submerged arc welding.

The same experiment is again recorded and done according the abrasive wear test method and in the holder the samples recorded as F1 and reference sample

F1 sample	◊	**Reference sample**	◊
12.65920	0.0006	**12.91960**	0.0778
12.65860	0.0020	**12.84180**	0.1042
12.65660	0.0017	**12.73760**	0.02395
12.65490	0.0012	**12.71365**	0.00595
12.65370	0.0021	**12.64465**	0.069
12.65160	0.00405	**12.57340**	0.07125
12.64755	0.0025	**12.57380**	0.11085
12.64750		**12.46295**	

Table 6 Weight loss in F1 and reference sample

F1 Sample and reference sample

And the final output is completely recorded and calculated as follows.

Distance recorded is **240Meters**

Time recorded is **10minutes**

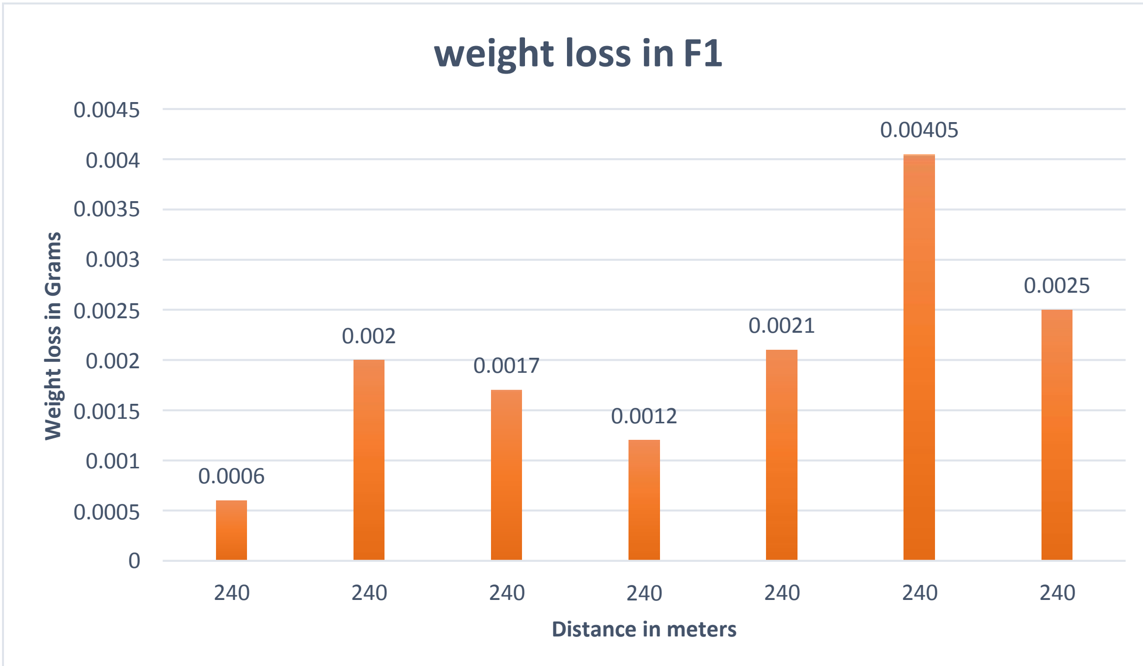
◊ = W2 – W1

W2= weight of the sample in the first rotation.

W1= weight of the sample initially.

◊ = difference of the weight loss periodically.

Weight loss for Sample F1



Graph 4 Weight loss in F1

Based on the above two tables the final calculations are stated In, the single work sheet and based on the three different weight losses and the table as follows below

Overall weight loss and tendency

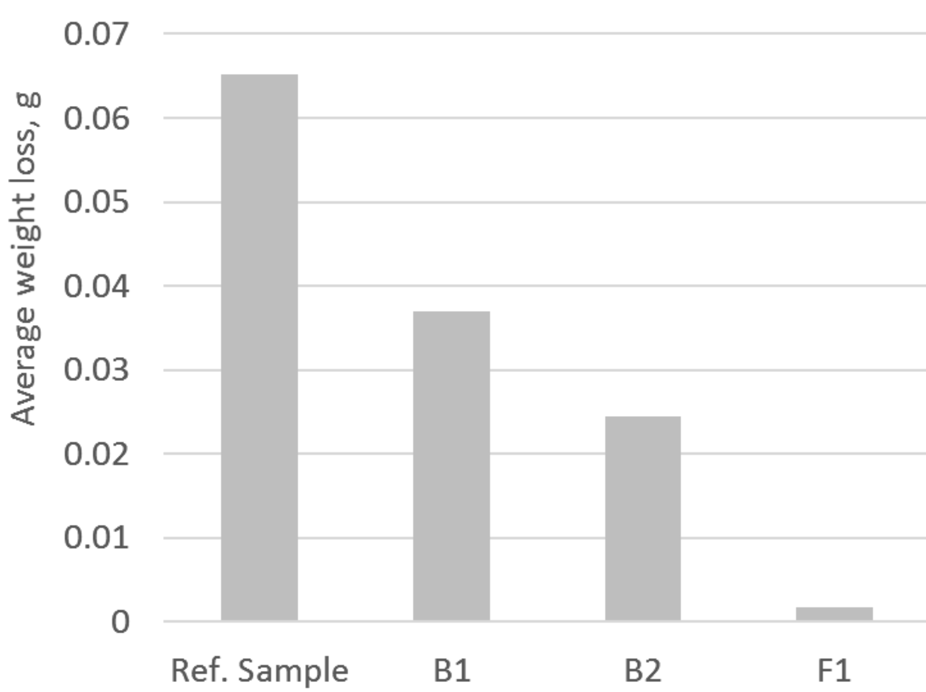
Distance in Meters	Reference sample	Sample B1	Sample B2	Sample F1
240	0.077	0.04800	0.04285	0.00060
480	0.1669	0.1009	0.07900	0.0026
720	0.20585	0.1538	0.1102	0.0043

960	0.30791	0.18795	0.13505	0.0055
1200	0.3792	0.22545	0.14815	0.0076
1440	0.4408	0.24205	0.15950	0.01165
1680	0.48965	0.25875	0.17065	0.01215

Table 7Average weight loss for every 10minutes at a 240meters.

Graph regarding average weight loss for a periodic level

Based on the above values obtained from the experimental part the graphs are included.



Graph 5 Average weight loss in a periodic level

After preparation of Hardfacings by SAW and PTAW technique, the hardness measuring of surface layer were accomplished. The results of hardness of all samples, including reference sample is shown in Table. It can be observed that adding self-fluxing alloy in hardfacing (Sample B2) did not have significant influence of hardness. The highest hardness was achieved in sample F1 which was prepared by PTAW technique.

Comparing wear resistance tests with the harness tests, some changes can be observed in sample B1 and B2. Weight loss of sample B1 after 1680 m of sliding length made up 0.25875 g, while for sample B2 just 0.17065 g. Declining tendency of weight loss for samples prepared by SAW, high hardness leads to high wear resistance of hardfacing prepared by PTAW technique.

3.3. Tendency graphs

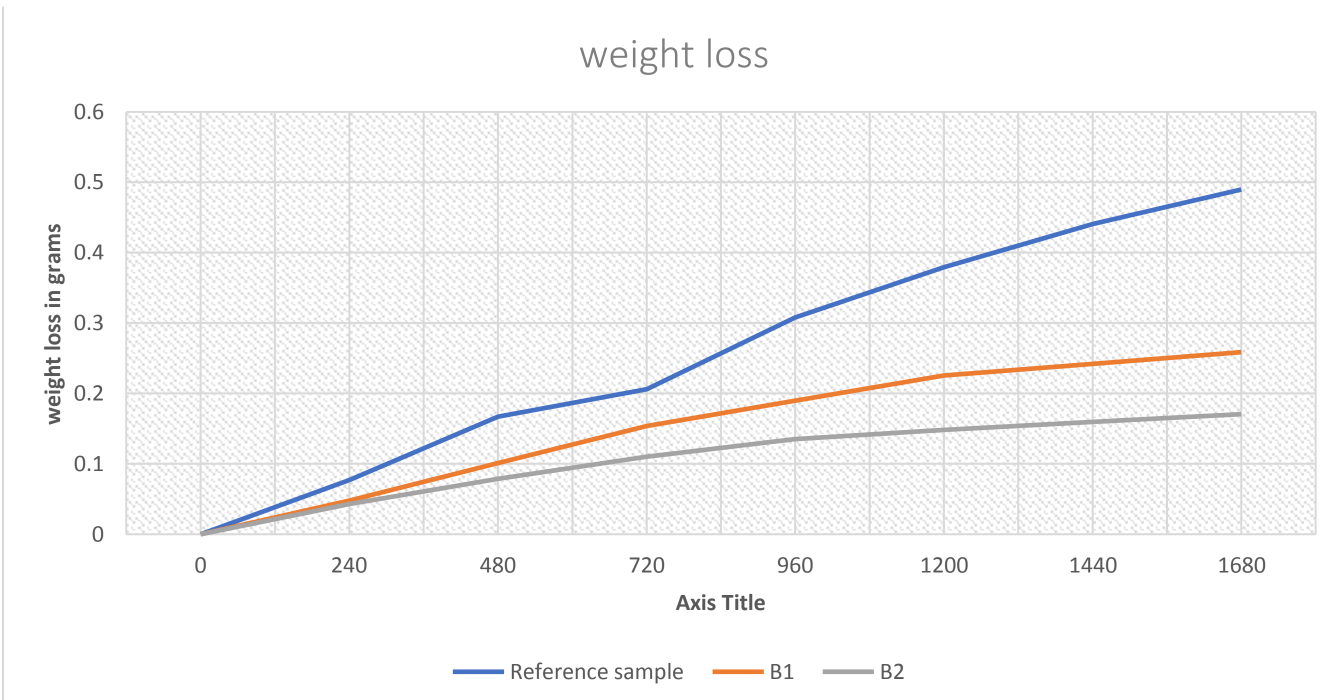
Tendency graph for Samples B1,B2,F1

Graph 6 Weight tendency for B1,B2,F1

From, the above graph the three samples which are compared and derived according to their tendency levels and others. In this variation, we can easily identify the graphs B1 and B2 which are made up of composition Hard materials and self-fluxing materials. And this process is done completely under submerged arc welding. And the deposited hard metals differ from process to process and according to that the samples starts losing their weight in a respective time intervals at 240meters.

When compared to sample F1 which is made up of plasma transfer arc welding we can see that the weight loss and tendency curve is straight and linear.

Now the values are compared against B1 and B2 and Reference sample.



Graph 7 Average tendency for B1,B2,Reference sample

In the above tendency graph the comparison between Reference sample and B1& B2 are shown. Here, the reference sample which is made up of steel (c235) and that material is not subjected to any other hardfacings either submerged arc welding nor plasma transfer arc welding. And from the graph we can see that the weight loss is almost all in 360degrees curve. At the distance of 240meters the curve started to raise and all of a sudden it started becoming linear near 960meters and started following the straight line.

But at certain distance until 720meters the sample started losing weight normally as like samples prepared from different welding technique like B1 and B2.

So, from that actual distance the weight loss in the sample is completely reduced and at certain position it stopped losing the weight of the sample.

1. While comparing the samples B1 and B2 and F1 we can see that the curve goes linear until 1440meters and suddenly gives a raise and it is showing some weight loss at that level.

2. In the comparison of sample B1, B2 and F1 the samples started losing their weight at 240meters with 0.04800grams from B1 and 0.4285grams from B2 and from the sample F1 it is 0.0060grams and from the reference sample starts at 0.077.

3. And the graph was stated completely the average weight loss. In regular intervals at distance of every 240meters.

4. From the Graph 7 if we have a look at graph from B1 we can see a small fluctuation of the graph in the sample B1 at 480meters. All of a sudden, the weight of the sample starts reducing and increasing suddenly.

5. And the samples B1 and B2 which are composed of the hard metals and self-fluxing materials are subjected with the submerged arc welding started losing the weight in a regular interval. And the variation of curves states it completely.

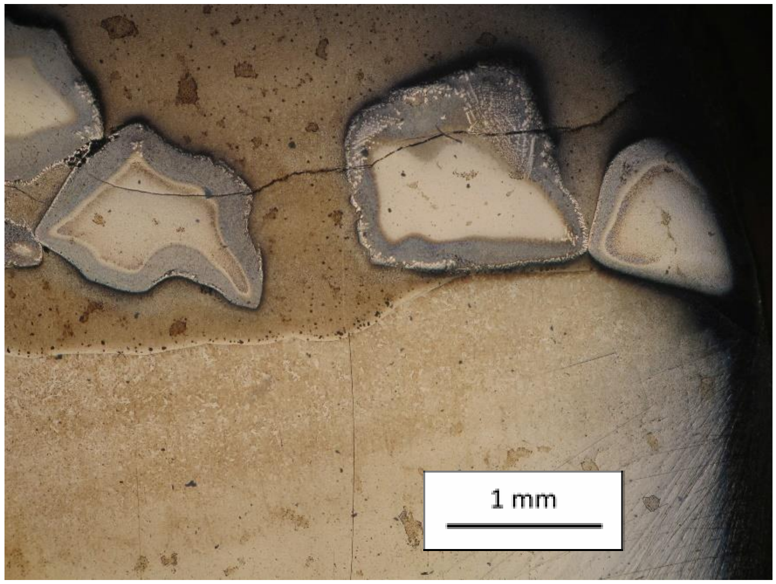
6. In the second graph as mentioned the reference sample is in a linear state and goes parallel to the distance.

7. Based on the both the graphs7 and 8 the sample which are made up of plasma transfer arc welding i.e. F1 and Reference sample have a linear state and raises parallelly towards the distance axis. And the weight loss is also very less compared to the other samples.

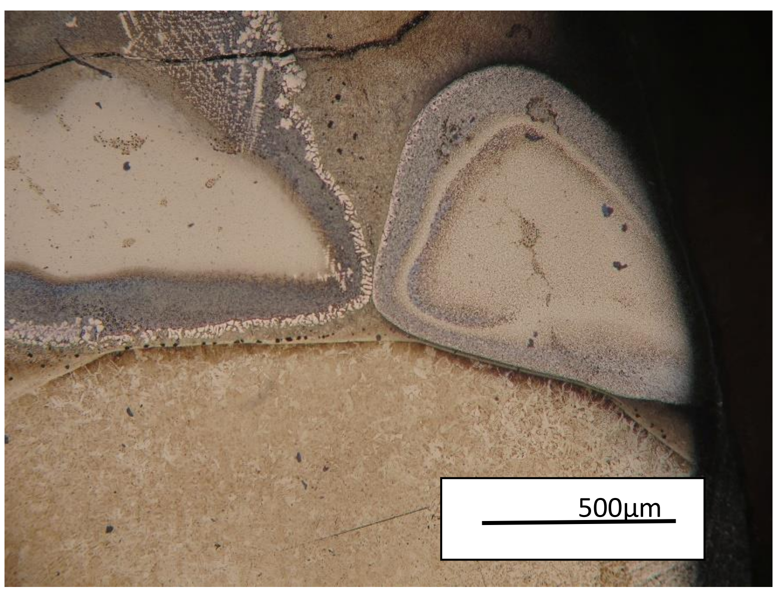
4. Microscopic examination

Microscopic examination can be explained as displaying the information in the form of pictorial view of the respected samples. And based on these structures we can conclude whether the sample is efficient or else need to do some other heat treatment techniques to reform it in to efficient position. From that images, we can see the clear view of the samples until 50X. From the images, the observation of the pores and cracks are clear.

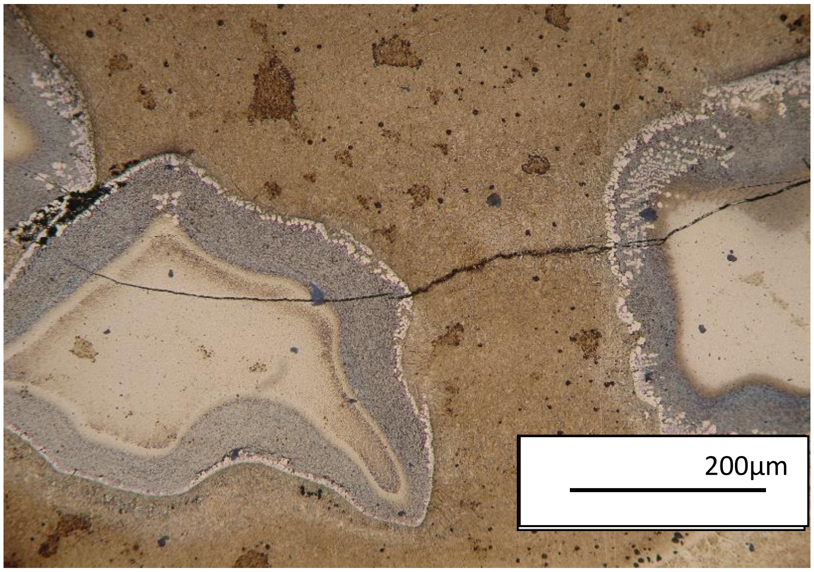
4.1. Microscopic view of sample B1



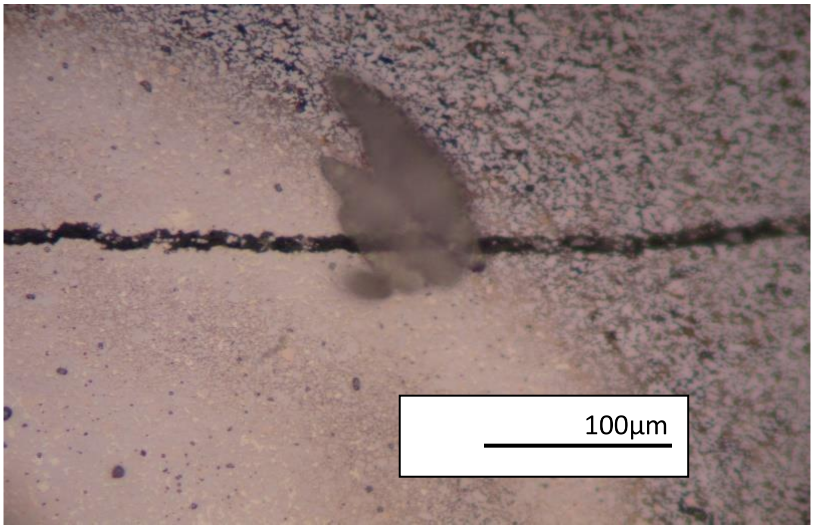
Microscopic 5 Scale 2.5x Sample B1



Microscopic 6 Scale 5x Sample B1



Microscopic 7 Scale 20X Sample B1

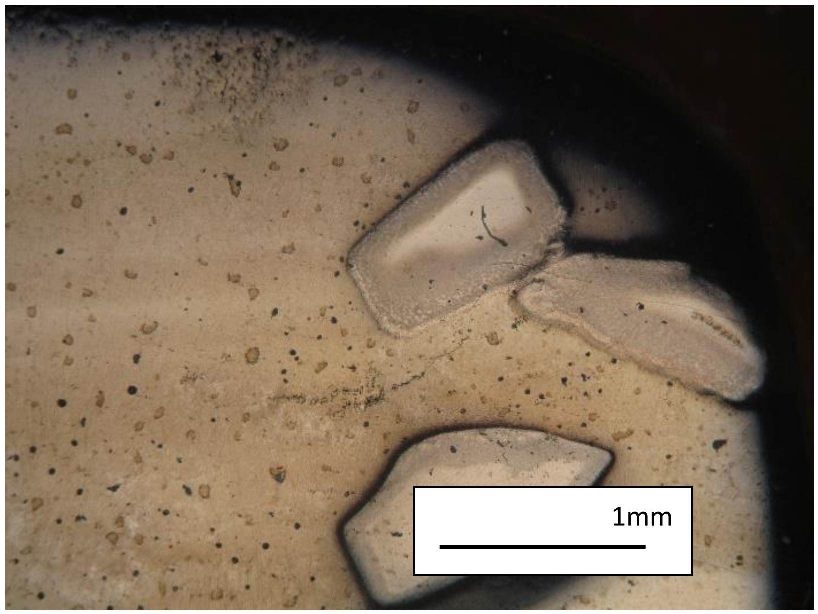


Microscopic 8 Scale 50X Sample B1

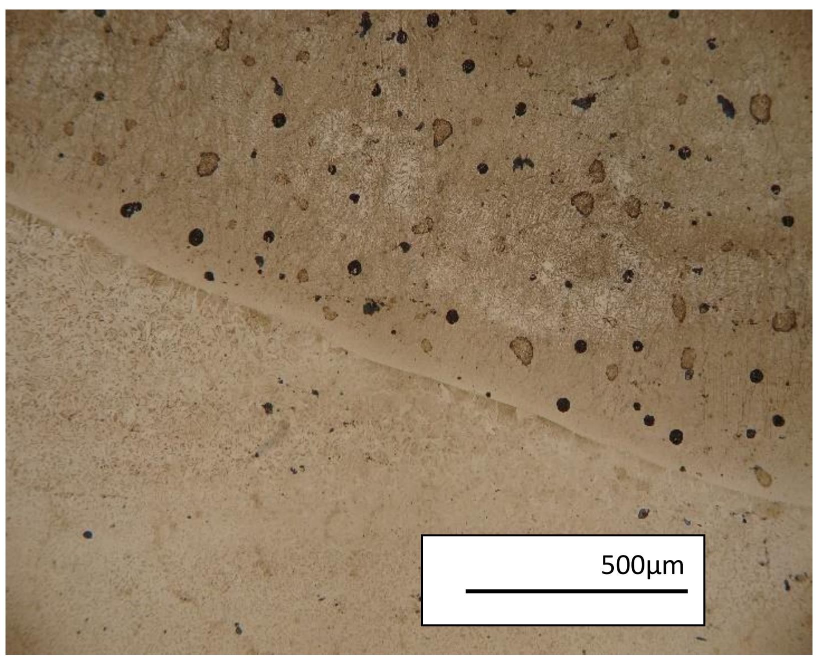
The above microscopic images are from the sample B1 which are subjected with the submerged arc welding. In this experiment after polishing the samples well in the polishing machine they are obtained in a desired position.

Now, the deposition of metals is done and started looking up for the images. And even they have different scales of looking up for an image and here below as follows. 2.5X,5X,20X and 50X.And they are completely in µmeters. From the images at first, we can see that deposited metal parts are not deposited or settled well on the base metal and started giving up with the cracks as shown in the above microscopic images. But in the image 50X we can see the difference of the base layer with the hard layer.

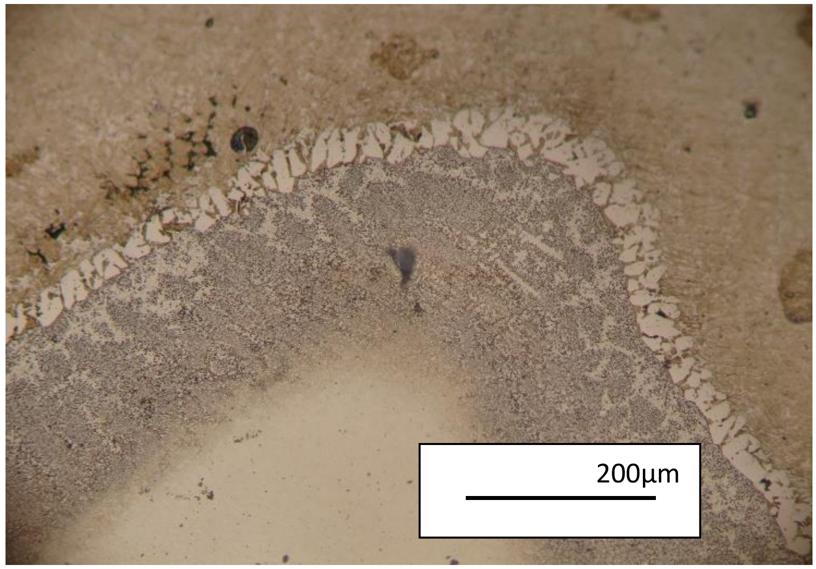
4.2. Microscopic view of sample B2



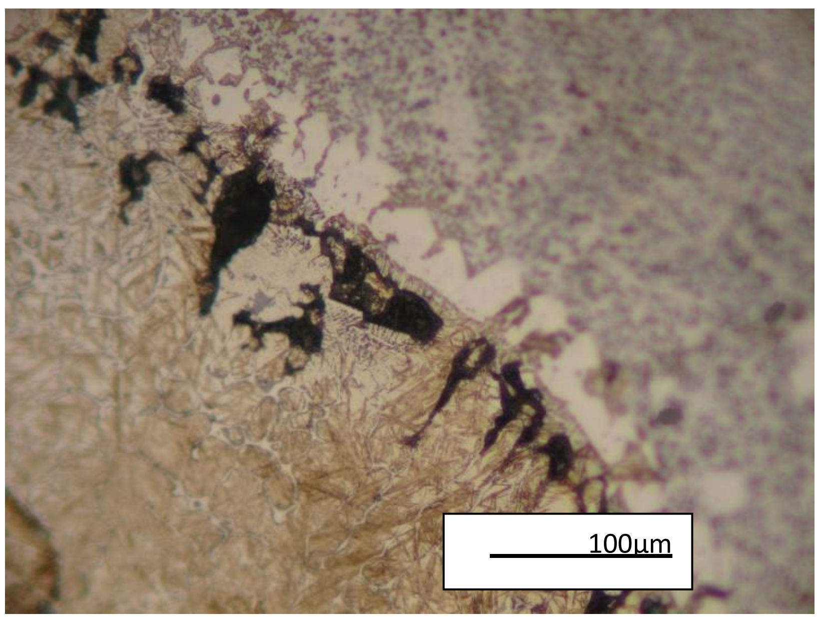
Microscopic 9 Scale 2.5X Sample B2



Microscopic 10 Scale 5X Sample B2



Microscopic 11 Scale 20X Sample B2

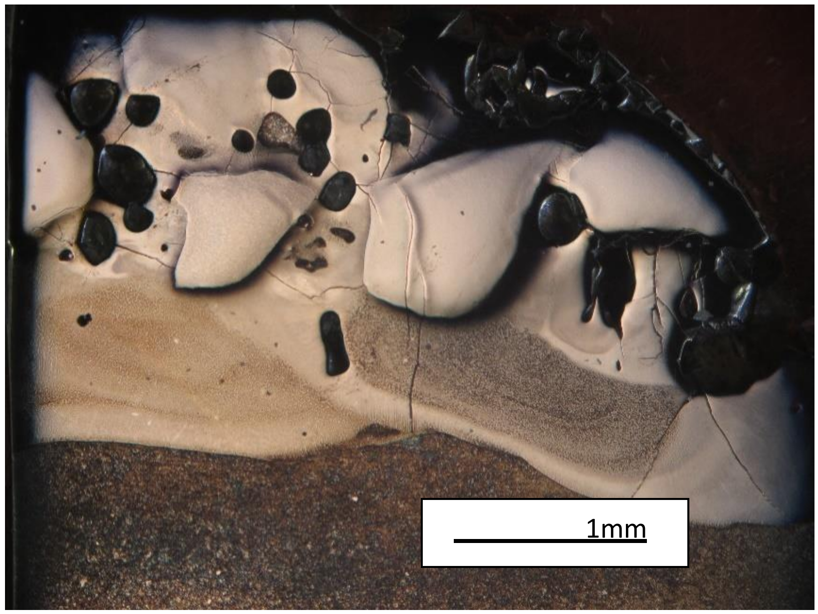


Microscopic 12 Scale 50X Sample B2

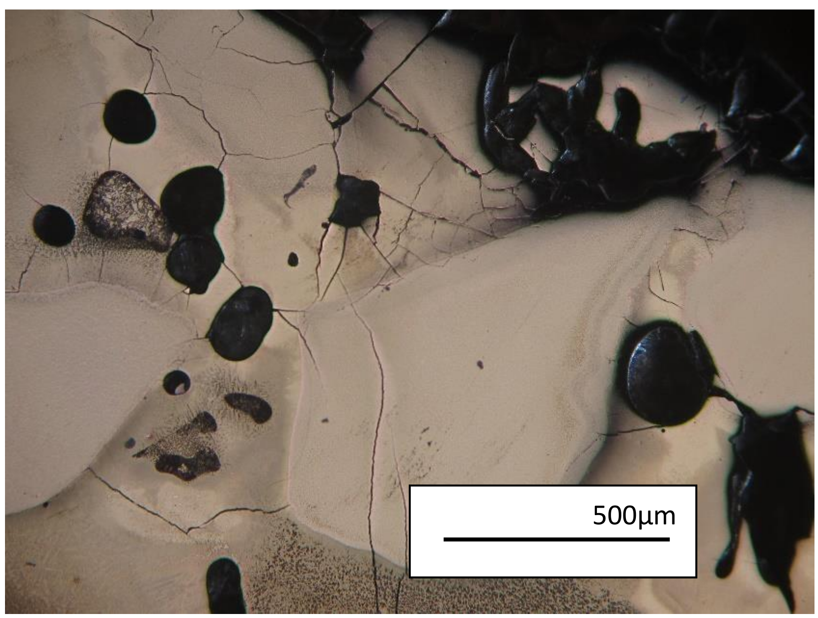
The above microscopic images are from the sample B1 which are subjected with the submerged arc welding. In this experiment after polishing the samples well in the polishing machine they are obtained in a desired position.

Now the main composition in the sample B2 is quite different when compared to the sample B1 because in this it is prepared by using the Hard material and self-fluxing materials. And coming to the images due to the mixture and unsettled particle in the metal surface we can see the pores on the layer and this pores completely effects on the resistance of the sample or work piece.

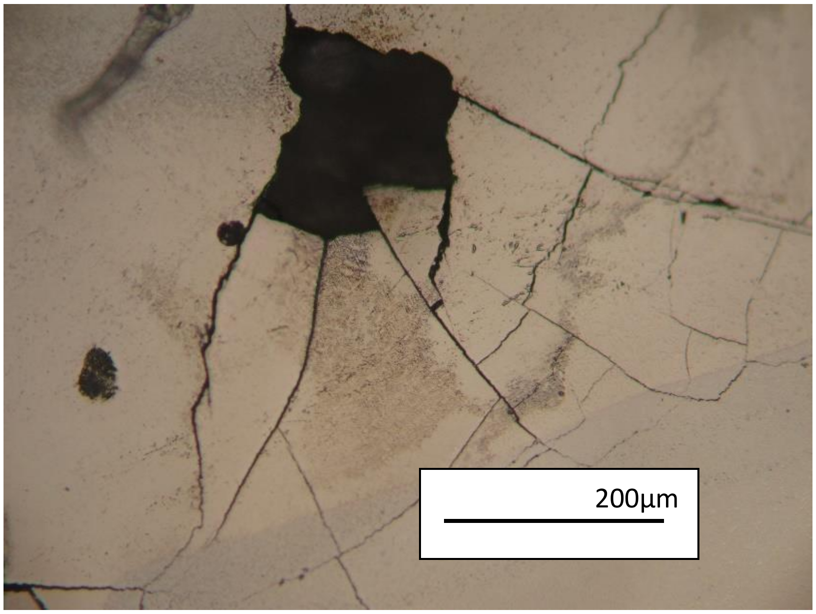
4.3. Microscopic view of sample F1



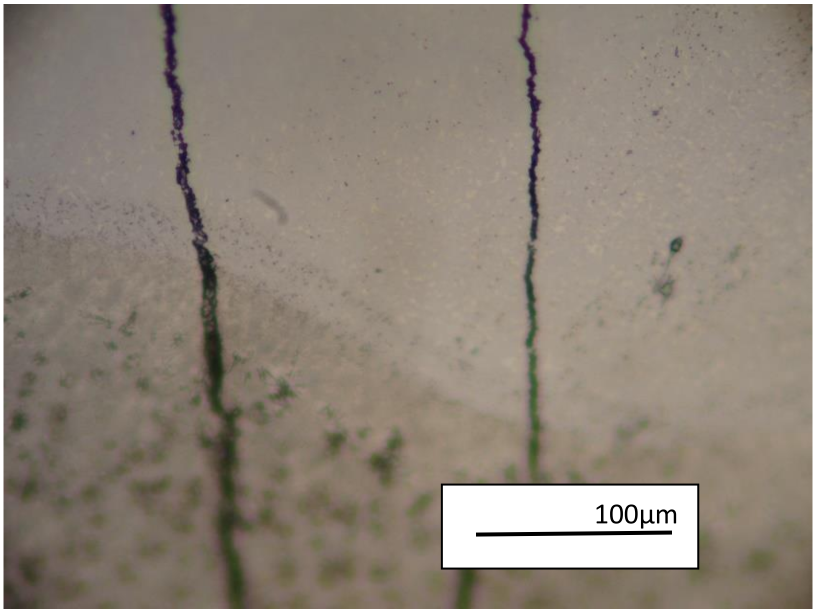
Microscopic 13 Scale 2.5X Sample F1



Microscopic 14 Scale 5X Sample F1



Microscopic 15 Scale 20X Sample F1



Microscopic 16 Scale 50X Sample F1

From, the above figure we can see the deposition of the flux and hard materials. This technique is Plasma transfer arc welding and it is completely different when compared to the submerged arc welding. In this the deposited elements are completely formed as a hard layer and looks like dark solid particles and they have the highest wear resistance compared to the samples B1 & B2. At some point of magnification, we can easily identify the complete cracks in the image at 20x.

5. Conclusion

1. Hardfacing helps in improving or repairing the worn parts especially in industries.
2. Hardness and wear resistance tests showed, that sample F1(50 WC-Co [2] + 50 FeCrSiB[1]), has obtained 63HRC and the sample B1(50 WC-Co [2], 50 LCW[3]) has obtained 55HRC and the sample B2(25 WC-Co [2] + 25 FeCrSiB[1] + 50 LCW[3]) has obtained 53HRC. The hardness of the sample F1 is completely high.
3. The sample F1 hardness is completely high due the composition of Hard materials and self-fluxing materials. And this process is done by using plasma transfer arc welding.
4. The rest of the samples are prepared using submerged arc welding.
5. The average weight loss the F1 has 0.001 g and the sample B1&B2 has 0.02 g and 0.01 g. Even the sample F1 have lowest average weight loss.
6. Sample B1 has a higher hardness comparing with the sample B2, but wear resistance was much lower.
7. From micro-structures the images from the sample B1 see that there, lot of unsettled particles deposited on the base layer. And even the other sample also the same technique but the compositions are different.
8. Comparing the microstructures of all samples it can be observed that sample F1 is composed of lot of pores and cracks on the surface, but it doesn't have significant influence on wear resistance.
9. Finally, the sample F1 has the wear resistance 10 times higher than the other samples.

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Appendix

Jaunųjų mokslininkų konferencija

pažymėjimas

PRAMONĖS inžinerija

2017

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Ravi Shankar Gorli

Jaunųjų mokslininkų konferencijoje „Pramonės inžinerija 2017" pristatė stendinį pranešimą ir konferencijos pranešimų leidiniui pateikė straipsnį

„Investigation of hardfacings prepared by submerged arc welding technique"

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organizatoriai

ktu 1922 mechanikos inžinerijos ir dizaino fakultetas

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