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OPTIOMIZATION OF PROCESS PARAMETERS AND STUDY OF WEAR DURING HARD FACING OF MILD STEEL USING TAGUCHI METHOD

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ABSTRACT

Hard facing is an important tool in tribology in which a layer of wear resistant material deposited over base metal or substrate to improve surface characteristics. There are numerous processes and consumables available in the market to improve the surface characteristics of components. This technique has potential to deposit hard-faced layer on substrate. The properties usually sought are greater resistance to wear from abrasion, impact, adhesion (metal-to-metal), heat, corrosion or any combination of these factors. Hard facing is applied only to specific areas of metal parts that are exposed to wear. There is often no need to protect the entire surface of a component from wear. Hard facing can be applied selectively and in different thickness to suit the exact requirements of a piece of equipment, thereby proving a most economical way of combating wear

Shielded metal arc welding is most commonly used process for hard facing due to its easy availability and versatility of operation. Low carbon steel is selected for the present work as substrate material due to its low cost, easy availability and variety of applications. In the present work a detailed study was done to study the effect of different level of current and different layer of hard facing electrode on mild steel, deposited by SMAW.

Minitab software was used to determine the no. experiments to be performed with different factors at different levels. A total of Eight experiments were performed according to the combinations given by the software. test were carried out on the above samples like wear test, bead geometry to record the observations. Optimization of the parameters was done with Taguchi Method and wear rate among the eight sample in study. It was observed that with an increase in number of layer there is the wear resistance is also improved.

KEYWORDS: Hard facing, Wear, SMAW

INTRODUCTION

Welding plays an important role in the development of our society and mankind as a whole. One of the indexes used for measuring the prosperity of a country is the per capita steel consumption. Higher the production of steel, the greater is the role of welding. Welding is a process of permanent joining of two materials through localized coalescence resulting from a suitable combination of temperature, pressure and metallurgical conditions. Depending upon the combination of temperature and pressure from a high temperature with low pressure to a high pressure with low temperature, a wide range of welding processes has been developed. While there are many methods for joining metals, welding is one of the most convenient and rapid methods available. It is a principal means of fabricating and repairing metal parts. The term welding refers to the process of joining metals by heating them to their melting temperature and causing the molten metal to flow together. These range from simple steel brackets to nuclear reactors. Welding, like any skilled trade, is broad in scope and one cannot become a welder simply by reading a book. One need practice and experience as well as patience, however much can be gained through study. Historically the welding was developed in the ancient times and can be traced during the Bronze Age when the lap joints were made by heating and hammering the two metal pieces. During excavation, parts and tools have been found, which were welded by pressure welding during the time as back as 1000 B.C. The earliest known form of welding, called forge welding, dates back to the year 2000 B.C. Forge welding is a primitive process of joining metals by heating and hammering until the metals are fused (mixed) together. Although forge

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welding still exists, it is mainly limited to the blacksmith trade. Some of the most recently welding technologies include: Friction welding, which uses rotational speed and upset pressure to provide friction heat, was developed in the Soviet Union. It is a specialized process and has applications only where a sufficient volume of similar parts is to be welded because of the initial expense for equipment and tooling. This process is called inertia welding. Laser welding is one of the newest processes.

HARD FACING

Hard facing is a process of depositing a layer of material over base metal or substrate either to improve surface characteristics like corrosion resistance, wear resistance etc. or to get required size of dimension. If a hard wear resistant material is deposited over a soft, ductile material to improve the wear resistance then the process is called hard facing. When the layer of material deposited for corrosion resistance the process is known as cladding. Sometime worn out parts are built up to required size so that they can be put back into service. Hard facing is one of the most useful and economical ways to improve the performance of components submitted to severe wear condition. Hard facing is commonly employed method to improve surface properties of agriculture tools, components for mining operation, soil preparation equipment's and other. An alloy is homogeneously deposited into the surface of a soft material (usually low or medium carbon steels) by welding with the purpose of increase hardness and wear resistance without significant loss in ductility and toughness of the substrate. A wide variety of hard facing alloys is commercially available for protection against wear. Deposits with a microstructure composed by disperse carbides in austenite matrix are extensively used for abrasion application and are typically classified according to the expected hardness. Durability and longevity of any material is priceless for any nation especially developing countries like India. All types of industrial set ups irrespective of whether being in manufacturing or service sector had off late drawn their reputation from the durability and reliability of their products. Degradation of material by wear and corrosion cost a very high loss whether it is of reputation or economic loss to all the countries. Although considerable attention has already been paid by the researchers to develop modern techniques and methods to arrest and control the problems resulting from wear and corrosion, still there is a need for further research to reduce the losses incurred because of them.

It is estimated that more that 30% of wear and corrosion related cost can be reduced by developing and using better techniques of controlling wear and corrosion. These wear and corrosion related problems can be minimized mainly by two methods.

1. By using high cost wear and corrosion and corrosion resistant alloys better than the existing low cost ones.
2. By improving the wear and corrosion resistance of the existing metals and alloys by applying certain modifications to the surface

Wear

It is the removal of material from a solid surface as a result of sliding action. It constitutes the main reason why the artifacts of society (automobiles, washing machines, tape recorders, cameras, and clothing) become useless and have to be replaced. Different persons and agencies have defined wear in different ways but all, at the end, mean the same. Few definitions are given below:-

- "Damage or loss of quality by usage" - Dictionary definition and general concept of the wear.
- The removal of material from the solid surface as a result of a mechanical action" – Mr. Ernest Rabinowicz.
- "Removal of material from surface in relative motion by mechanical and/or chemical process" - Mr. D. Tabor.
- "The progressive loss of the substance from the operating surface of a body, occurring as a result of a relative motion of surfaces" - OECD Scientific Committee.
- "The destruction of material, produced as a result of repeated disturbances of friction bonds" - Mr. Kragelski.

Factors Affecting Wear

The main factors affecting wear are:

1. Design
2. Applied load
3. Contact area and degree of movement
4. Lubrication
5. Environment
6. Material properties (surface finish, hardness and steel microstructure).

Different Types of Wear

The wear can be categorized into different types based on the sources/causes of wear mentioned earlier. The

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wear, encountered in industrial situations, can broadly be divided into following types and a rough share of each type of wear as a percentage of all the wears taken together, is against each type as shown in causes like vibration, cavitations' and environmental attack etc.

Table 1.1 Types of Wear

Types of wear	Abrasive wears	Adhesive wear	Erosive wear	Corrosive wear	Fretting wear	Others
Percentage	50%	15%	8%	5%	8%	14%

The action of one material sliding over another with surface interaction and welding (adhesion) at localized contact. [2] As we know, strong adhesive force sets up when the atoms from two materials come into intimate contact. During sliding, a small patch of the surfaces comes into intimate contact with a small patch of other surface and if this bond is strong, this contact is broken. This breakage is usually not of the interface of the two patches; however it takes place from within one of the materials depending upon the bond strength. This is known as adhesive wear.

Abrasive wear

Abrasive wear occurs when a hard rough surface slides against a soft surface, digs into it and plows a series of grooves. The materials, originally in the grooves, normally come out in the form of loose fragments. This is known as two bodies wear. Abrasive wear also occurs when hard abrasive particles are introduced between two sliding surfaces and these particles abrade either or both materials. The mechanism is that an abrasive particle adheres temporarily to one of the sliding surfaces or, else, gets embedded in it and plows out grooves in the other surface. This form of abrasive wear is known as three bodies wear. Two body wear does not occur much when the hard sliding surfaces are smooth. Similarly three-body wear does not normally occur when the particles, introduced in between the sliding surfaces are small, or they are softer than sliding materials.

Corrosive wear

Corrosive wear occurs as a result of chemical reaction on a wearing surface. The most common form of corrosion is due to a reaction between the metal and oxygen (oxidation); however, other chemicals may also contribute. Corrosion products, usually oxide, have shear strengths different from those of the wearing surface metals from which they are formed. The oxides tend to flake away, resulting in the pitting of wearing surfaces to reduce frictional effects. Corrosive pitting is especially detrimental to these bearings. Corrosive wear occurs in situations in which the environment surrounding a sliding surface is corrosive and interacts chemically with the sliding surface. As such, this wear is also known as "chemical wear". Corrosive wear differs from corrosion as, in corrosion, no sliding of surfaces takes place and formation of reaction films on the surface tends to slow down the process with increase of thickness of layer and may avoid further corrosion after some critical thickness; but it becomes corrosive wear when sliding of the surfaces occurs and continues as, in that case, the sliding action continuously wears out the films of reaction from the surface and fresh corrosive attack continuous.

Erosive wear

Erosive wear is caused by particles that impinge on a component surface or edge and remove material from that surface due to momentum effects. This type of wear is especially noticed in components with high velocity flows such as servo and proportional valves. Particles repeatedly striking the surface may also cause denting and eventual fatigue of the surface. It is the damage produced by sharp particles impinging on an object. For example particles in water erode the rocks over which a river flows or the erosion of both, rope and stone pulley when the rope continuously slides over the pulley.

EXPERIMENTATION

This chapter is about the experimental procedure and other related aspects of the present study. The chapter deals with the methodology adopted to achieve the goals or objectives for the present work which includes the hard facing of mild steel using hard facing electrode and analysis of result with Taguchi methodology. After finalization of process parameters and levels, the complete set of eight trials has been prepared as per orthogonal array selected from the Minitab software

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Base Plate & Electrode Used

According to the AISI standard the grade of Low carbon Mild steel 1020 is used having dimensions 150x50 x10 (mm3).The chemical compositions are shown in table 3.1

Table 3.1 Chemical composition of base plate

C	Si	Mn	P	S	Fe
0.20	0.19	0.52	0.03	0.033	Rest

The electrode used for experimentation is DUROBUILD-A and DUROBUILD-C. It is an all position electrode for structural work. Medium penetration for lower dilution levels with least spatter. Versatile electrode used for variety of application of welding. Almost all general purpose welding is done by shielded metal arc welding using coated electrode. The coating electrodes consist of core wire with a covering of coating material.

Table 3.2- Chemical composition of electrodes

C	Si	Mn	cr	Fe
0.18	0.42	0.76	2.00	Rest

DUROBUILD-A composition

C	Si	Mn	cr	Mo	V	Fe
0.50	0.70	0.70	7.00	0.80	0.50	Rest

DUROBUILD-C composition

Conducting Trials Runs

Trail runs were conducted on the base plate according to different parameters selected randomly from the orthogonal array. It is also worth mentioning that the welding conditions such as electrode type, electrode size, electrode to work angle, baking and hence moisture content conditions, welding positions and welding speed etc. were kept constant to the maximum possibility. In the trial runs it was observed changing the electrode changes the wear rate . Also same variation was encountered with changing the number of welding layers. Number of specimens were prepared and examined visually and then selective specimens were selected for further investigations based upon the visual examination wear test examinations were conducted over selected specimens.

Conducting Actual Runs

Beads on mild steel plates have been deposited as per orthogonal array using hard facing electrode with dimensions of4mm×450mm. and 5mm×450mm. DCEN polarity was used to minimize the dilution which otherwise will decrease the hardness. Experiments were conducted according to orthogonal array with different combinations of selected parameters.

Base Metal Preparation

Low carbon mild steel was used as a base metal. The surfaces to be joined must be clean to obtain good

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fusion between the filler metal and the base metal. This means that they must be free of relatively thick oxide, moisture, greases, oils, paints or any other substance.

Testing
Following tests were conducted on the samples obtained after experiment

Wear Test
Wear test was done on pin on disc apparatus at MMU MULLANA. Prior to wear testing, pins with dimensions of 8mm dia. and 30 mm length were prepared with CNC Wire Cut available at CITCO Chandigarh.

CNC wire cut machine

Table 3.3 Wear test data

Applied load	5kg
Speed	500 rpm
Disk diameter	80 mm.
Time	10 minutes
Specimen size	30 mm (length)*8 mm (diameter)

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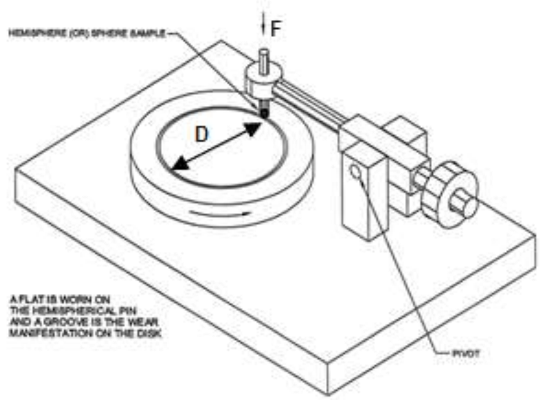

Fig. 3.4 Schematics wear testing machine

Pin on Disk Apparatus

As outlined by ASTM G99-03, pin-on-disk testing consists of a rotating disk in contact with a fixed pin with a spherical top. For the pin-on-disk wear test, two specimens are required. One a pin with radius tip is positioned perpendicular to the other, usually a flat circular disk. A ball rigidly held, is often used as the pin specimen. The test machine specimen causes either the disk specimen or pin specimen to revolve about disk center. A schematic is shown below.

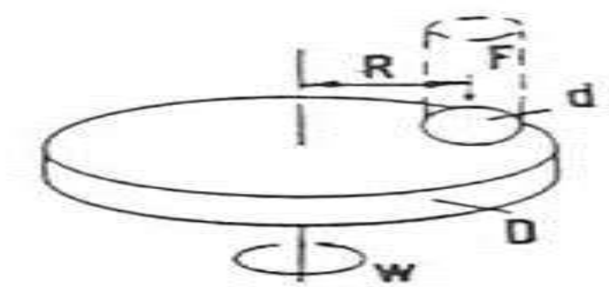

Fig. 3.5 Exploded view of pin on disk wear test system

Where, F-Applied normal force on the pin
d-pin or ball diameter
D-Disk diameter
R-Wear track radius
W-Rotation velocity of the disk

The pin specimen is pressed against the disk at a specified load usually by means of arm or lever and attached weights. According to ASTM standers under the section of G-99 the amount of wear in any system will, in general depend upon the number of system factor such as applied load, machine characteristics, sliding speed sliding distance the environments, and the material properties.

Test Specimen and Sample Preparation

Materials- This test method may be applied to variety of materials. The only requirement is that specimens having the specified dimensions can be prepared and that they will withstand the stresses imposed during the test without failure or excessive flexure. The typical pin specimen is cylindrical or spherical in shape. Typically cylindrical or spherical pin specimen diameter range from 2 to 10 mm. The typically disk specimen diameters range from 30 to 100 mm and have a thickness in the range of 2 to 10 mm.

Wear test conditions

1. Load- Values of the force in Newton at the wearing contact.
2. Speed-The relative sliding speed between the contacting surfaces in meters per second.
3. Distance- The accumulated sliding distance in meter.
3. Temperature- The temperature of one or both specimen at location close to the wearing contact.
5. Atmosphere- The atmosphere (laboratory air, relative humidity, argon, lubricants, etc.) surrounding the wear contact.

Wear Test Procedures

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1. Prior to measurement, testing the specimen were categorized according to the input conditions design matrix via variation in composition of paste applied and welding current with which hard facing was done.
2. The specimen was weighed and corresponding weight was recorded.
3. Disk was mounted on the wear testing machine and checked on ideal conditions (no load) .To check the circularity, ovality etc on the disk.
4. The pin specimen was mounted on the cantilever as per schematic show in the figure.
5. The load was adjusted and kept condition for all the specimen=5kg
6. RPM of the disk was set at 500 rpm and kept constants for all the readings.
7. The revolution counters were set to the desired number of revolutions.
8. Now the specimen is ready for start for were testing and is contact under load the machine was started at fixed rpm and the test was stopped in desired time. That is number of revolution achieve these test was not interrupted.

RESULTS AND DISCUSSION

Experimental Results

The results of the experimentation regarding overlays for hard facing of low carbon steels using hard facing electrode have been discussed in this chapter, the mechanical testing of welded specimens are given in Table 4.1the samples are categorized as 1 to 8 as per the welding conditions which are welding current,electrode and number of layer . From Minitab software L8 orthogonal array is selected and accordingly S/N ratios for responses is calculated.

Table 4.1 S/N ratio for wear rate

Sample no.	Welding current	Electrode	NOL	Weight loss in gms	SNRA
1	160	A	1	0.0413	27.68
2	160	A	3	0.0247	32.15
3	180	A	1	0.0623	24.11
4	180	A	3	0.0147	36.65
5	160	C	1	0.0034	49.37
6	160	C	3	0.0002	73.98
7	180	C	1	0.0008	61.94
8	180	C	3	0.0003	70.46

Table 4.2 Response for Signal to Noise Ratios smaller is better

Level	Electrode	Current	NOL
1	30.15	45.79	40.77
2	63.94	48.29	53.31
Delta	33.79	2.50	12.53
Rank	1	3	2

Main Effects Plot for S/N Ratios

The main effect plots for S/N ratios are shown in figure 4.5. This plot shows the variation of weight loss with change in three parameters: welding current (A), electrodes and no. of welding layers. In the plots, the x-axis indicates the value of each process parameter (at three levels for welding current, electrodes (A& C), and no. of welding layers y-axis the response value (wear rate). Horizontal line indicates the mean value of the response or micro-hardness. The main effects plots are used to determine the optimal design conditions to obtain the optimum Weight loss. Main effects plots for weight loss here are plotted between.
1. Weight loss v/s Welding Current
2. Weight loss v/s Electrode
3. Weight loss v/s no. of electrodes

The effect of each parameter on the Weight loss is plotted on the graph in form of lines. From the figure 4.5 main effects plot for S/N ratios it can be clearly seen that the weight loss increases as the current is increased. Main effects plot for S/N ratios between electrodes, no. of welding layers and Weight loss show that the Weight loss value decreases linearly from low to intermediate composition and again decreases linearly with change the electrode and increasing no. of welding layers from intermediate to high. From this we can easily conclude that the electrodes and no. of

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layers has the most significant effect on the Weight loss the samples. An increase in the value of the current increases the Weight loss due to decrease in the value of hardness.

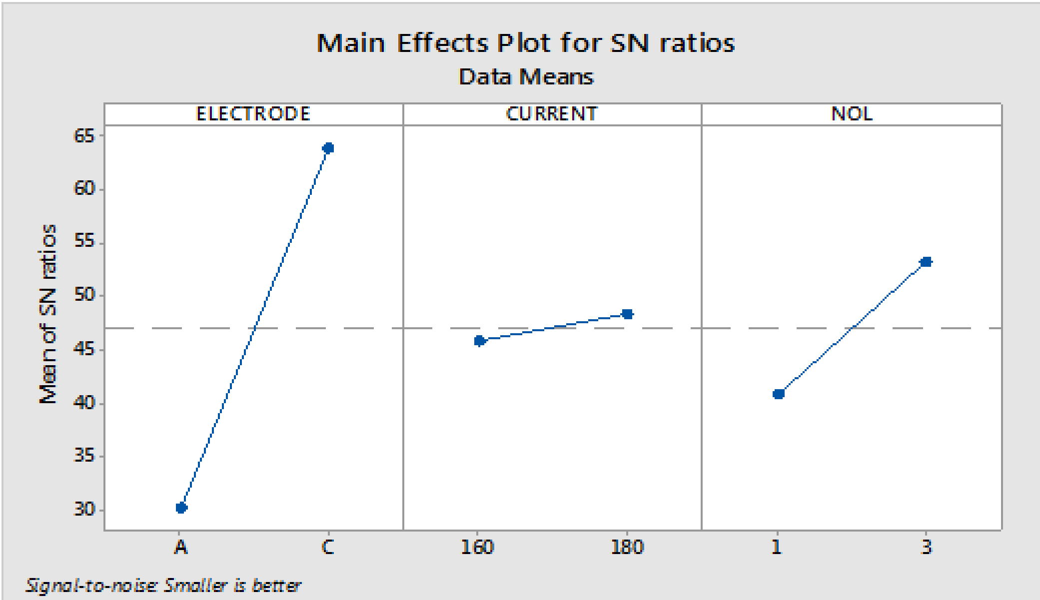

Fig.4. 5 Main effect plots for S/N ratio

Probability Plot for Weight Loss
The probability plot of Weight loss shows that the data approximately adjacent to straight line having a good correlation between experimental results and predicted values. There is minimal variation between the observed value and fitted value.

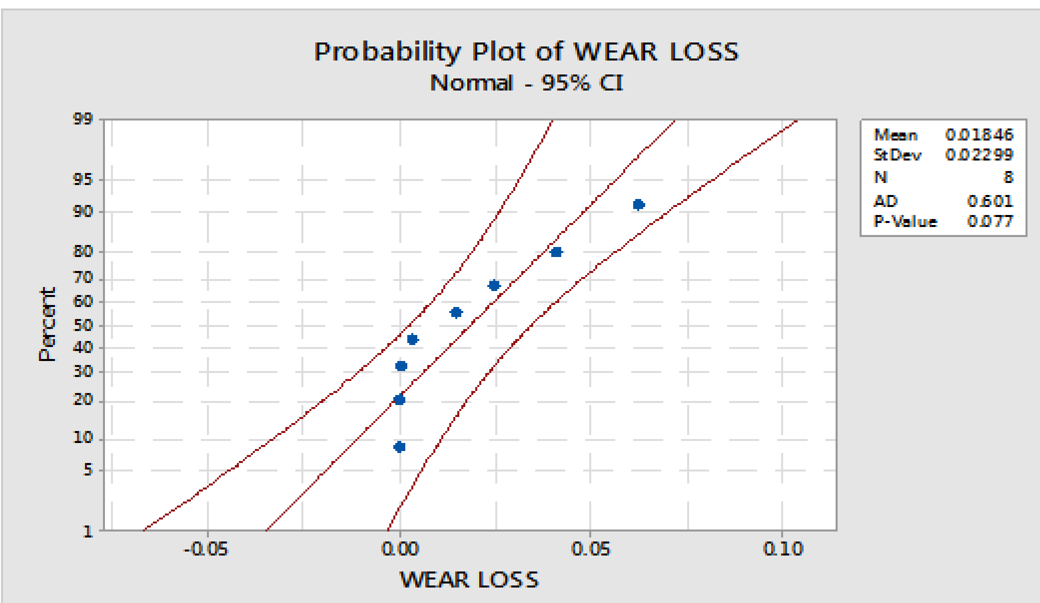

Fig.4. 6 Probability plot for Weight loss

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A normal distribution with a mean of .008744 and a standard deviation of .002661 appears to fit the data fairly well:

- The plotted points form a reasonably straight line.
- The plotted points follow the fitted distribution line fairly closely.
- The p-value for the Anderson-Darling test is above 0.10.

Because the distribution fits the data, we can use the fitted line to estimate percentiles for the population.

Main Effect Plot for Weight Loss:
Main effect of current on Weight loss can be revealed from figure 4.8. As the value of current is increased, the value of Weight loss is increased due to increase in dilution. Further there is slight decrease in Weight loss due to human error i.e. during the depositing of multi layer on the base metal. Weight loss is minimum (0.0002gms) at low value of current (160 amp), electrode C and 3 layers of welding and maximum (0.0623gms) at highest value of current (180 amp), electrode A and 1 layers of welding.

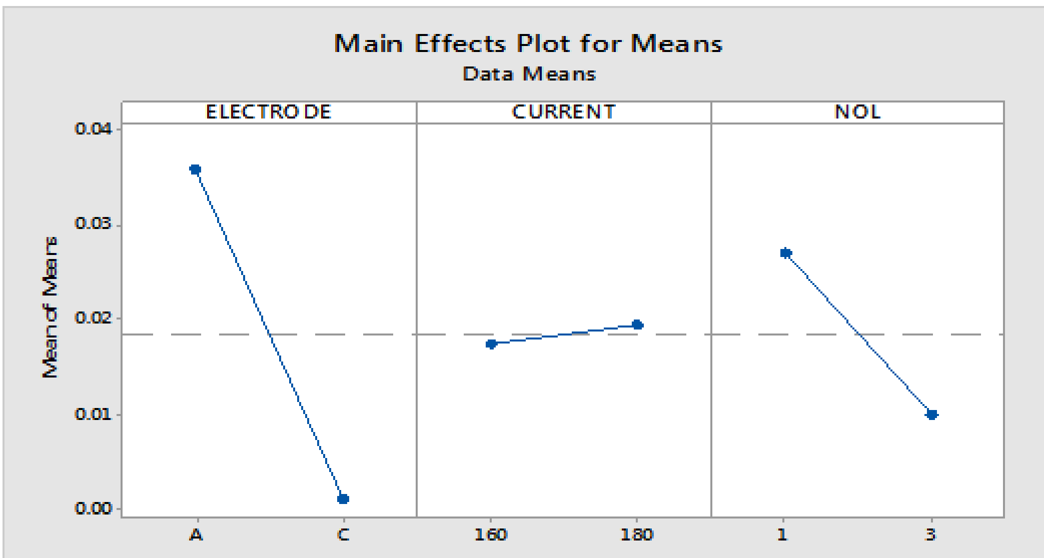

Fig. 4.8 Main effect plot for weight loss v/s current

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