IMPROVED TRIBOLOGICAL PROPERTIES BY UTILIZING ELCTRICAL DISCHARGE MACHINE COATING WITH Hbn, CU & MoS2 USING GREEN COMPACT POWDER BLEND FOR SOLID LUBRICATION

A thesis submitted in
fulfillment of the requirements
for the award of the degree
in

MASTER IN TECHNOLOGY
MECHANICAL ENGINEERING
(PRODUCTION ENGINEERING)

Submitted by
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CERTIFICATE

This is to certify that the report entitled "**IMPROVED TRIBOLOGICAL PROPERTIES BY UTILIZING ELCTRICAL DISCHARGE MACHINE COATING WITH Hbn, CU & MoS2 USING GREEN COMPACT POWDER BLEND FOR SOLID LUBRICATION" (Adm. No.: DTU/MT/19F000402)** a record of bona fide work carried out by him under the supervision and direction of under the supervision and guidance of undersigned is required for the award of the degree of Master of Technology in Production Engineering (PIE). According to Institute norms, we believe the thesis is worthy of consideration for the award of a degree.

The results of this thesis haven't been submitted to any other institution, university or institute for the purpose of acquiring a degree.

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DECLARATION

I, PRASHANT KUMAR SINGH, I hereby confirm that the work presented in this thesis, entitled "IMPROVED TRIBOLOGICAL PROPERTIES BY UTILIZING ELCTRICAL DISCHARGE MACHINE COATING WITH Hbn, CU & MoS2 USING GREEN COMPACT POWDER BLEND FOR SOLID LUBRICATION" Submitted to the Department of Mechanical Engineering, Delhi Technological University, Delhi, the partial fulfilment of requirement for the award of degree of Masters of Technology in Production Engineering is an authentic record of my own work completed between July 2020 and June 2021 under the direction of Dr. N.YUVARAJ, Department of Mechanical Engineering, Delhi Technological University, Delhi.
The matter presented in this thesis has not been submitted in any other University/Institute for the award of M.Tech Degree.

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APPROVAL SHEET

This project report titled "**IMPROVED TRIBOLOGICAL PROPERTIES BY UTILIZING ELCTRICAL DISCHARGE MACHINE COATING WITH Hbn, CU & MoS2 USING GREEN COMPACT POWDER BLEND FOR SOLID LUBRICATION**" by **Prashant Kumar Singh (Adm. No.-DTU/MT/19F000402)** has been granted approval for the M. Tech. in Mechanical Engineering degree. (Production Engineering) from DTU DELHI.

Examiners

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Supervisor

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Head of Department

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Date: ________________

Place: ________________

ACKNOWLEDGEMENTS

It gives me great pleasure to deliver my dissertation paper, "IMPROVED TRIBOLOGICAL PROPERTIES BY UTILIZING ELCTRICAL DISCHARGE MACHINE COATING WITH Hbn, CU & MoS2 USING GREEN COMPACT POWDER BLEND FOR SOLID LUBRICATION." First and foremost, I want to express my thanks to Dr. N. YUVARAJ of the Mechanical Engineering Department, who served as my mentor and provided me with invaluable professional guidance and unflinching support during the whole thesis-writing process. I feel privileged to have the chance to collaborate with them. Understanding the topic and analyzing the findings from the graphs both stimulated the mind much. They showed me kindness and sympathy, and I appreciate it since it allowed me to start the task while still finishing it morally.

I like to thank Professor S. K. Garg, Head of the Mechanical Department. Please, Engineering Department, allow to let me finish this project.

The last and most essential thing I want to do is thank my family for their prayers, support, and encouragement throughout the past several months. These people are who I devote my work to.

ABSTRACT

The electro-discharge machining (EDM) technique is one of the most efficient non-conventional machining methods in the current study for cutting extremely hard materials that are challenging to mill using standard machining techniques. In addition to the surface erosion that occurs during the EDM process, some tool material is also lost as a result of the operation's inherent nature. Electro discharge coating (EDC) was developed as a result of this nature's usage of the EDM process's properties. Ignition erect places tool material on the substrate surface in the EDC technique of surface modification. It functions according to the opposite polarity of EDM.

A layer of disulphide of molybdenum, meahexagonal boron nitride(hbn)(hbn), and copper covering modifies the substrate's surface. With reverse polarity, an electrical discharge machine is used to deposit a coating layer over the substrate surface. The layer thickness was controlled by a number of variables, including peak current amplitude, powder blending ratio, and duty factor. The mixture was mixed for one and a half hours (1:30) hours in a mortar before being used to construct a compacted green electrode made of (hbn/Cu/MoS2) that was used to deposit the layer. After being put through a hot mounting press machine, the powdered mixture created a compacted green electrode with exact specifications. After the trials, a number of investigations were performed to look at the coated surface's morphology. The FESEM image displays the architecture of the coating layer with tiny gaps with a blending ratio of (hbn/Cu/MoS2) (30/40/30), a peak current of 5 ampere, and a 50% duty factor. Additional molecules found by X-ray diffraction studies include MoS2, Hbn, and Cu molecules.

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HIGHLIGHTS

• Making compacted green electrodes using powdered MoS_2, HBN, and Cu and depositing a layer on a substrate using an EDC.

• Evaluation of the coated in a surface's XRD, wear, and FESEM in imaging data.

CHAPTER-1

1.Introduction

The surface of frequently used materials can be modified by coating in order to improve performance characteristics including resistance, corrosion, & abrasion resistance & wear resistance. For instance, hardness and high temperature can be used without affecting the properties of the substrate. With the use of electro-discharge machining, the surface is altered.

The most practical way to modify a substrate's surface has been found to be (EDM). A well-known unusual machining technique is EDM (electric discharge machining). precision machining of partially conductive and electrically conductive materials. Conducive materials can be produced using this approach. Arc discharges between the work piece and the electrode tool, which is coupled to a DC power source, are the process's most common cause of erosion. In the last several years, EDM has solidified itself as a procedure for preparing dies and moulds. However, EDM is a great method for surface modification events for two reasons.

The first is the white coating that is added during EDM, and the second is tool wear or recasting of the layer. With the aid of a compact powder metallurgy tool, a hard ceramic layer is created on the substrate using a standard EDM machine tool. Hydrocarbon oil is used as the dielectric in specific parametric combinations. This method is known as electro-discharge coating (EDC), and it is one of the most promising materials deposition methods because of how easy, dependable, and uniform it is. By raising the hardness value by two to four or even more, the EDC technique may provide substrate surfaces with a higher level of hardness.

Using another substance to cover a substrate is the process of coating. Coating materials, which are typically separate from substrate components, alter the surface behavior of the substrate without changing its bulk properties. Nowadays, it is usual practise to coat the surface properties of the substrate, such as its hardness and anti-friction properties (wear resistance and tear, etc.).

The surface of the substrate is covered using a variety of technologies, including thermal spraying, Synth, coatings for conversion, chemical vapour deposition methods, hot dipping, and Roll-to-Roll coating. These processes have a number of drawbacks, including high production costs, process complexity, setup complexity, higher temperatures, and the need for cooling in certain circumstances, which limit their utility. Additionally, we can produce thick coating using certain methods and thin coating using others.

Electrical discharge coating is a reversal of the electrical discharge machining process. In this method, the polarity of the operation is reversed. Just across from the electrical discharge coating, the electrode is fastened to the negative terminal, while the substrate is fastened to the positive terminal. Additionally dipped into the dielectric liquid with the electrode are the substrates.

The dielectric medium is a hydrocarbon chemical compound, like kerosine. Similar to how it works in the operation of an electrical discharge machine, this dielectric medium facilitates the coating process. For a flat surface and a little area at a time during the coating process, this approach is straightforward to coat.

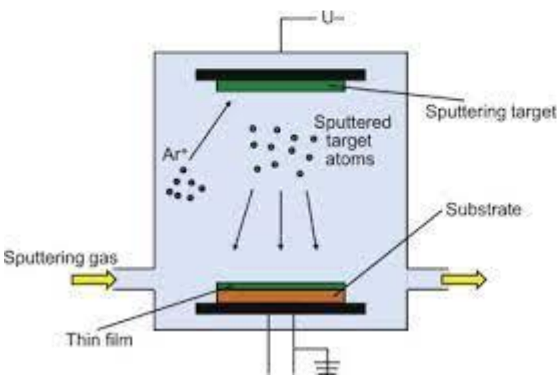
EDC offers a definite advantage over the other coating methods. We don't require any extra hardware to create vacuum or a restricted space around the substrate for EDC. By adjusting a few variable elements, we may also alter the protective coating's thickness and other characteristics. The only equipment needed for surface coating with EDC is an electro discharge device with reverse polarity. The production of layer materials does not require any particular arrangements, according to other considerations. By simply blending the required layer material powder, we may produce our layer producing material for coating.

Lubrication using solid properties has a number of benefits over lubrication using liquid properties, including the ability to make equipment simpler, lighter, and easier to handle by doing away with the need for lubrication distribution mechanisms and seals. Lubrication of solid is also more effective at high temperatures and loads, has a high resistance to wear during prolonged use, has a high level of stability in extreme temperature, pressure, radiation, and reactive environments, and has a higher resistance to deterioration. Solid surface lubrication can be employed in challenging areas where continuous lubrication is impractical by merely covering the rubbing surface with materials that have particular lubricating qualities. Although the coating process results in some processing costs, it also lessens the chance of the winning machine breaking down, which drives down overall operating costs. Additionally, we employ metal cutters in conventional machining, which rub and degrade the surface. The product's surface polish is removed during this rubbing. Therefore, the surface quality of the finished product may be enhanced if tool edges can coat. This is why it seems like the EDC approach is doable and appropriate for surface coating in a range of industrial and research applications. Disulphide of molybdenum, Graphite and hbn are some of the most often used coating materials.

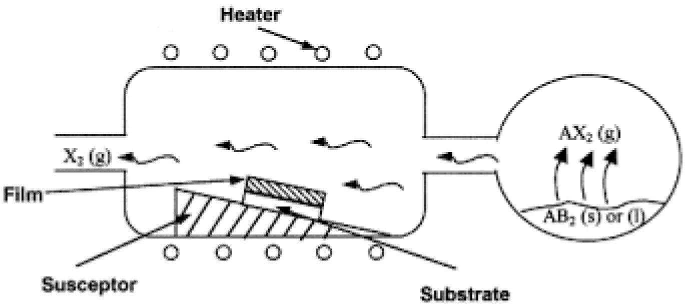
DIFFERENT METHODS OF COATING:

The coating methods that are presently using in industries are Chemical vapour depositions, Plasma Spray Coating, Physical vapour deposition, Electro-plating, etc.

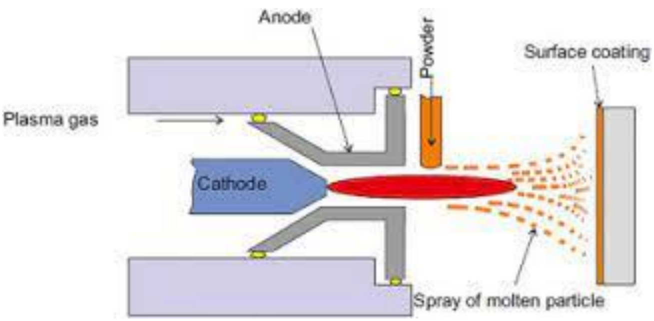
Physical vapour deposition: Different particles are deposited on the work piece using the physical vapour deposition (PVD) technique. It takes place at a temperature of around 400 degrees Celsius in a vacuum chamber. In this case, there is no chemical contact between the particles; instead, they are physically conveyed to the work piece. It helps to increase corrosion resistance.



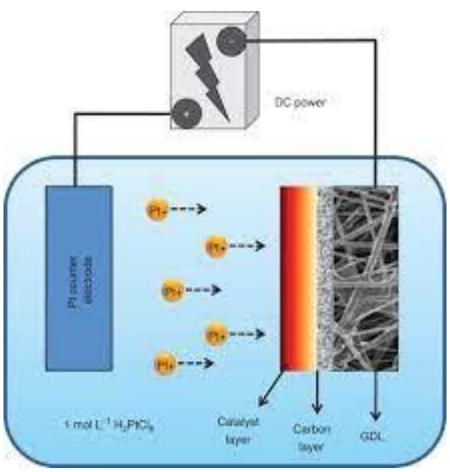
Chemical vapour deposition: CVD is also used to increase corrosion and wear resistance. Temperatures around 800°C are used in a vacuum chamber for CVD, which is largely a thermochemical process. It is necessary to perform the technique in a CVD reactor. The equipment required to produce the high temperatures required for this process, however, makes CVD more costly than the other approaches.



Plasma spray coating: Plasma spray coating is simply a fame spray technique where the material is melted by rapidly injecting powder particles into a plasma stream. The material in molten state is thereby forced onto the work piece's surface and bonded there. This kind of coating is quite beneficial for textile and fabric applications.



Electro-deposition coating: Surfaces pre-treatment techniques must be mechanical or chemical for electroplating, also known as electrodeposition. The separate metal and the work piece are suspended in a basin with a water-based electrolyte solution throughout this process, and as a consequence, the work piece is coated with the separate metal. The fact that different people would experience the coating procedure differently is a drawback. It is not possible to coat tools and molds with other materials, such as silver, gold, platinum, and others.



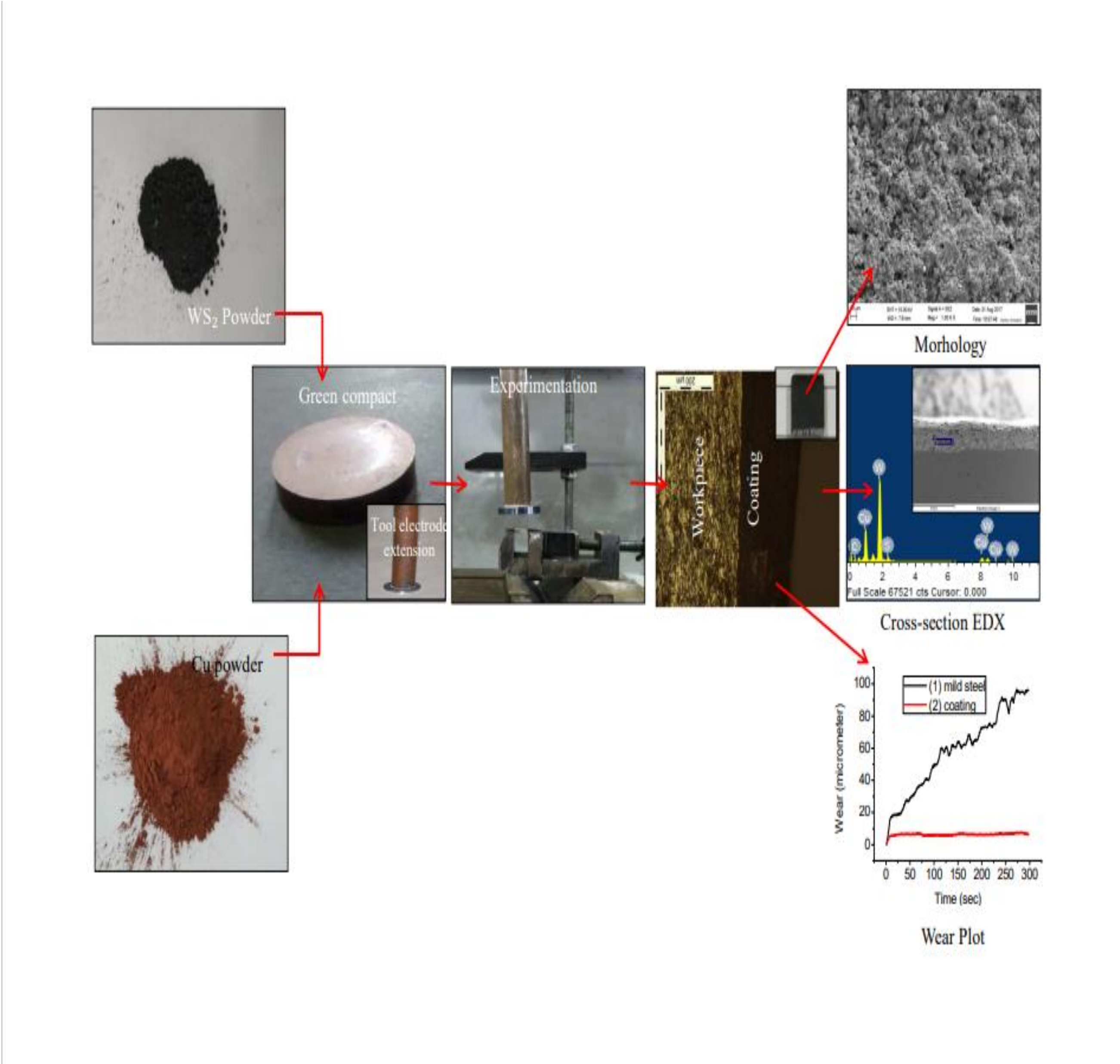
MoS2 and HBN have lubricating properties like:

Like graphite, disulphide of molybdenumhas a hexagonal structure, which contributes to its lubricating qualities. These hexagonal crystals are linked together to create a chain and have a flat hexagonal shape. Each layer has a gap in between. Two hexagonal layers can float over one another with little external force because the space between them is sufficiently big. In the forging industry, MoS_2, is the good known lubricant, is applied to dies to minimize friction between the die and the metal being forged. Disulphide of Molybdenum, a substance like graphite, is routinely added to industrial lubricating oils to improve their tribological qualities. In an oxidizing atmosphere, MoS_2 can withstand temperatures of up to 450 °C, and in a non-oxidizing environment, up to 1200 °C. As a result, when an external force is applied and the vender-walls force between some of the layers is overcome, each layer begins to slide on top of the other. Like the lubricating action of viscous fluids, this sliding produces a lubricating effect that lessens friction. This procedure helps to explain how disulphide of molybdenum has lubricating properties.

Additionally, HBN is used to improve the tribological performance of paints, lubricating oils, and other items. Consequently, it is an excellent substance to use as a coating substance. A form of boron nitride called meahexagonal boron nitride(hbn)(hbn) (HBN), sometimes referred to as "white graphite," exists. Its structural structure is similar to that of graphite and disulphide of molybdenum. HBN outperforms graphite in terms of features like good vacuum performance, low quantum of friction, high thermal stability, high thermal conductivity, high toughness and stiffness, chemical inertness, low wet ability, and low thermal expansion.

WORK SCHEDULE:-

TASK	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR
Literature review	yes	yes	yes	Yes							
Objective determination	yes	Yes									
Material selection		Yes									
Experiment planning			yes	yes	yes	Yes					
Electrode preparation			yes	yes	yes	yes	Yes				
EDC			yes	yes	yes	yes	yes				
Analysis				yes		Yes	Yes				
Writing thesis						Yes		Yes	yes	yes	Yes


WS$_2$ Powder
Green compact
Tool electrode extension
Cu powder
Experimentation
Workpiece
Coating
Morhology
Cross-section EDX
Full Scale 67521 cts Cursor: 0.000
(1) mild steel
(2) coating
Wear (micrometer)
Time (sec)
Wear Plot

Electrical discharge coating working principle:

Electric discharge coating, or EDC, is the complete opposite of electroplating. During the EDM process, material is taken from the work piece rather than the electrode tool and is flushed away by the dielectric fluid flushing pressure. On the other hand, the substrate in EDC (the work piece) is where the electrode tool materials are placed. In the EDC process, the electrode tool is fastened to the anode while the work piece (substrate) is fastened in the fulfillment to make it cathode. In this coating technique, the electrode tool is made using powder metallurgy (P/M). Because the connection between powder particles is so weak, powder particles can easily settle on the surface of the work piece, making powder metallurgical tools particularly useful in this situation. The coating's thickness is influenced by a variety of variables. the chemical make-up of the substrate and electrode materials, the electrical conductivity of the materials, the strength of the binding between compacted green electrodes, and the use of many factors like current, peak current, voltage, duty factor and so on. Electrodes for powder metallurgical tools allow for increased energy discharge during operation. As a result, the white coating becomes thicker and the danger of miniature cracking is highly increases. Powder metallurgical instruments also have the advantage of being easily integrated with a range of powders and at various compaction weights to produce a variety of shapes with less work.

The substrate is attached to the negative terminal, and the electrode to the positive terminal. When a voltage potential is applied between them, the voltage gap causes the dielectric breakdown & spark between the closest part of the substrate & electrode. When the conditions are appropriate, material deposition occurs during ignition. Electromotive force causes the electrode material to melt and settle in the substrate during the spark process. Throughout the EDC process, a continuous spark grows and forms on the substrate's surface layer by layer. Depending on the metallurgy, this white coating might be much tougher than the base material or even have a better surface roughness characteristic. This strong coating is also necessary for engineering materials to increase their wear resistance & corrosion & hardness. This deposition phenomenon might be exploited to develop a new low-cost surface modification approach for commonly used materials in the industry.

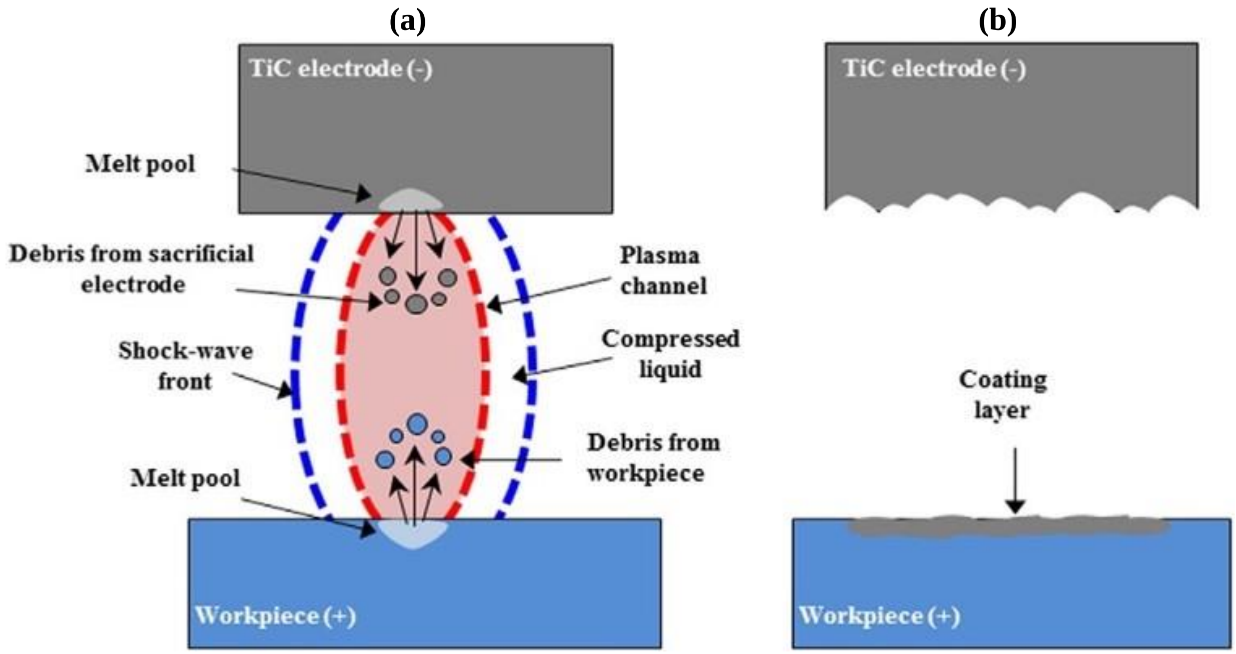


Fig.1. (i) diagram of ignition method, (ii) material deposition after the ignition.

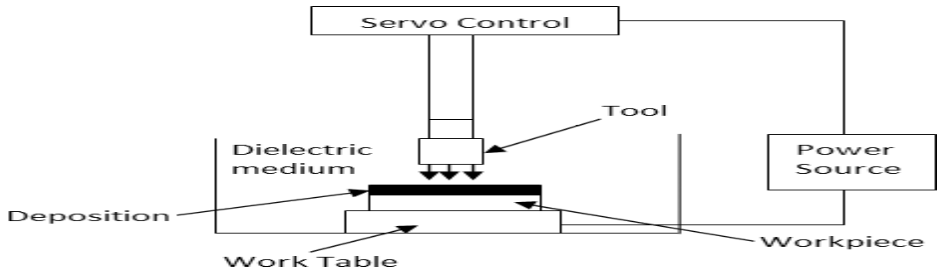


Fig.2. Electro Discharge Machining Mechanism

<u>Electro-discharge coating with help of electrode of compacted green powder:</u> For this operation, a P/M electrode which is a compacted tool linked to the anode of the EDM machine is required. Additionally, the following groups of green compressed powder metallurgical tools can be utilized in the EDC process: In the first case, the tool material shatters and reacts with the carbon in the dielectric fluid. As a result, the product is spread out over the substratum's surface. The instrument is also created in the second scenario, where green powder is crushed. While in use, the tool breaks down into powder and is applied to the substrate surface without coming into contact with any of the di-electronically present hydrocarbons.

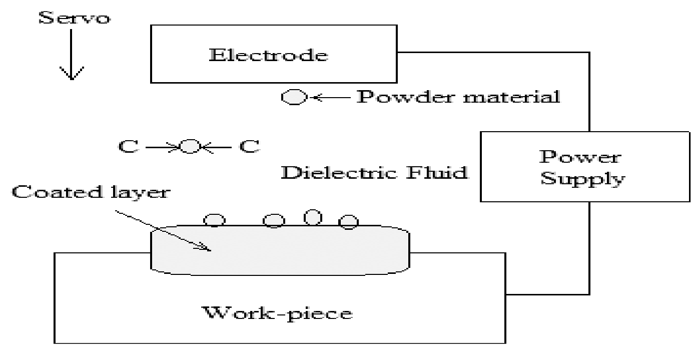


Figure 2: Dielectric with electrode material Reaction

Parameters used in EDC:

Electrode tool composition : The hardness, corrosion resistance, hardness, thermal conductivity, wear resistance, and other properties of the product in the deposited layer are entirely dependent on the powder composition. In certain cases, two or more powdered materials are properly coated to improve the mechanical properties of the layer on the work piece.

Size of the particle: Because small compacted particles are only required when the mesh size of the green compacted electrode is bigger in number, the mesh size is the sign of the polvo parameter for the green compacted electrode.

Pressure: When compacting a powder, this parameter is crucial. The binding strength between the compact particles is stronger the greater the density pressure. The compact is strengthened as a result. Increased compact strength, however, can also reduce the amount of precipitation that falls on the substrate during the EDC process.

Temperature for sintering: The compact is sintered in a few situations to improve the strength of the compact compact. When sintering temperature rises to the recrystallization temperature, the powder material characteristics are altered. The higher sintering temperature makes the compact more difficult, as it enhances and rinses the kernels.

Duty factor: The duty factor is a correlation between the release time and the whole release and recharge time. In this context, the terms "charging time" and "releasing time" refer to the pulse of time and pulse of time, respectively. The instrument electrode & work piece erode more slowly as a result of the increased duty factor. Both the pulse time (ton) and pulse off time are used to calculate the duty factor for the pulse time.

Mean Current: The mean current may be calculated by multiplying the highest current by the duty factor. The peak current is the maximum current appropriate to each generator pulse or power source, while the mean current is basically the mean of the Ampere at to for which the spark gap calculated across the whole deposition cycle. By changing the present configuration, the surface deposition of EDC's characteristics may be changed.

Frequency of the pulse: The quantity of cycles created within a second interstitial gap is known as pulse frequency. The polish on the surface is nice when this frequency is high. The pulse on the to at time length shortens with an increase in cycles/second and of to. Typically, the shorter pulse in time only removes relatively little amounts of material, which results in fewer fractures. The object suffers substantially less heat damage consequently, and the surface's polish is smoother.

Objectives of the research:

Using a powder metallurgical method, copper ,disulphide of molybdenum (MoS_2), and hexagonal boron nitride(hbn) were combined to create a compacted green electric source. EDM is used to cover the substrate's surface with reverse polarity. By adjusting process variables like the maximum current, voltage, and powder blender ratio, among others, we analyze gearbox rates. Using FESEM, we looked at the morphology of the coated layer of the surface layer. We have examined the compounds discovered on the layer surface using XRD. Durability is assessed using the Vickers tester which is used to check for the micro-hardness and of the coated surface. Anti-frictional analysis additionally considers tool wear, mass transfer rate, and layer thickness behavior.

Literature review

Numerous experiments were carried out by various researchers using the electrode materials Ti-C, WS2-Cu, and HBN-Cu. The mass transfer rate, layer thickness, chemical inertness, adhesive strength, and other factors have all been documented by various authors.

Li et al. (2015) Using a small electrode made of Cu-SiC powder, the surface quality of the titanium alloy Ti-6Al-4V was evaluated. Micro-hardness and surface microstructure were the experimental input and output parameters that were chosen and measured. The coated layer is harder than the substratum material as a result of new stage deposits of TiSi2 & TiC found in XRD analysis on the surface..

Srivastava et al. (2012) Electric coating made by the use of cooled copper electrode on high-speed steel dimension 10x10x10mm. In response to the given detailed parameters such as surface roughness, electrode wear rate, was observed the influence of different input factors (i.e. time pulse, gap voltage, time pulse, duty cycles) (SR). Reduction of tool wear by 20 percent and a reduction in surface ruggedness by 27 percent compared to traditional EDM when utilised cryogenic (liquid nitrogen).

Das et al. (2012) Using a CuTiC compacted green electrode, the EDC-induced change to the aluminium surface of a 20x20x5 mm3 aluminium sample was investigated. Pulse on time, peak present, compacted green electrode composition (percent), pressure mounting (MPa), micro-hardness, surface ruggedness, and generated layer thickness are some of the processing input characteristics. EDC was used to produce a surface with a roughness of 7.92 microns and a deposited layer height of 53.44 microns from 168 VHN (material used as base) to 1700 VHN (surface used as capped).

Tyagi et al. (2018) Electrical machining experiment using compacted green electrodes from WS2 and copper in three different pound blending ratios of 60:40, 50:50, and 70:30 on a piece of mild steel that is 10 metres by 10 metres in size. For the chosen input parameters, the powder blending relationship peak current (A), duty factor, and output characteristics such tool rate &, mass transmission growth rate &, micro hardness, and coating thickness were studied. For the WS2:Cu/40:60 powder mix ratio, FESEM analysis showed the best topologies to use were 5A high current and 50% duty factor. The coated surface's XRD pattern shows W, WS2, CuS, & Cu diffraction at the peaks. The coating's macro hardness, 46.12HV, is much lower than the parent material's 186HV.

Algodi et al. (2016) Ti-Fe ceramics electroplated onto nanostructured 304 stainless steel. In these experiments, a powder metallurgical electrode tool from Ti-C (Ryoden koi engineering co.ltd) measuring 20*20*100 mm was used to deposit the material on a dimensional piece of 304 rust-free steel (20*20*12). In place of hydrocarbon oil, a dielectric fluid was used (shell parasol 250). Modern pulses were the input parameters that were measured. In Vicker's hardness test, it was discovered that the substrate was 4–8 times as hard.

CHAPTER 3

3. Experimental set-up & procedure:

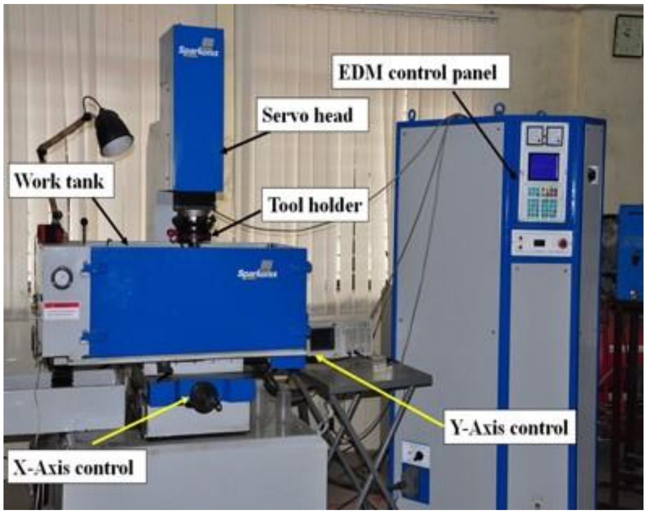
Specification of Materials;

To portray the cleaning and crushing process using a 700 m cleaning paper, a mild steel work plate with a synthesis of (phosphoric, carbon-0.27%, iron, 96.0% copper-0.40%) and manganese-1.04% was employed liked the material substratum (measurement: 10 mm / 11 mm / 6 mm). A compacted green cathode electrode made of nanoparticles of MoS2, hbn, and coppers was created using these materials. Produced by Sisco Research Laboratories in India, MoS2. Cu particles had a density of 9.97 g/cm3, while hbn particles had a density of 9.97 g/cm3..

Experimental set-up:

Figure (Spark India, model ZNC/ENC35) shows the setup for the experiment. Inside the working tank, the EDC experimental set-up includes a piece which is fastener, magnetic defect, an extension of the tool holder and a tool tank & a tool holder. The EDM servo is a head can ensure that the space between the apparatus and substrates is kept constant. The dielectric tank uses a pressure gauge to detect the pressure. With the help of the handle controller, the servo is a head may also be manually moved in the X and Y axes. The die sinking type of EDM has a setup that will reverse polarity for the duration of the test. Typically, the hydrocarbon fluid served as the dielectric medium. Using an oscilloscope, the voltage and current's waveforms were captured during ignition. The tank displays a set up where the substratum is fastened to the negative terminal and the tool-electrode to the positive terminal.

(a) **(b)**



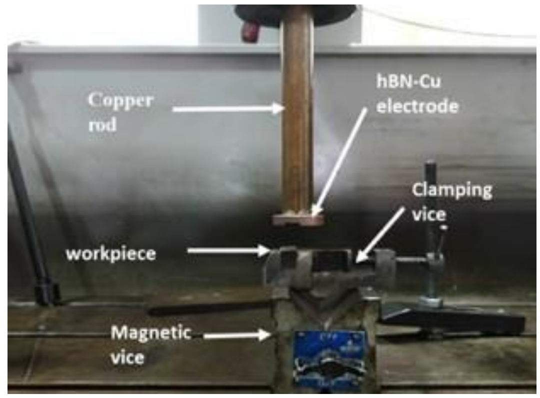


fig.2. (1) die-sinking type of EDM (2) Work tank set-up of EDC

Preparation of compacted green electrode

HBN, MoS2, and Cu powders from India were secured with conventional 12 m and 20 m molecular dimensions, respectively, by Xylem Research Laboratories (XRL). Cu and HBN powder were properly mixed in a mortar for 1 hour and 30 minutes to ensure consistency. For the merging of powders, test trials utilize a 1-hour and 30-minute time decision; a 45-minute time limit for blending is incorrect. Due to inadequate blending, it is almost impossible to obtain even material distribution over the substratum's surface. The time required to mix the powder was so long. Using a mounting press machine which is hot in nature from that point on, the compacted green electrode was formed with in the necessary pressure inserting the blended powder in the machine at this point. Pressure may also plays a significant part in this. This put pressure on the next process to be followed. The pressure is a gauge which indicates the current pressure constantly delivered to the blended portion. And we had maintained the right of pressure manually all the while due to the compaction of the pressure. Afterwards, it is left for chilling for more than 20 minutes were done. For the first 10 minutes were cooling was done normally, and then for the next 10 minutes they were cooled down the thermal bottle by running water which suddenly decrease the temperature. We have chosen a suitable quantity of electricity to make tiny green electrodes 5 mm in size and 15 mm in diameter. The compacted green electrode was then attached with silver paste to the copper electrode.

Because electrical current is used in this coating procedure to flow through the materials, the material used for electrical discharge machining to be a should have a high conductivity. Copper is added to the powder mixture to improve electrical conductivity because hexagonal boron nitride (hbn) and disulfide of molybdenum have low electrical conductivities.

We used the copper electrode as an excellent electrical conductor and the silver paste to adhere the little green electrode. Copper, molybdenum in disulphide applications, and hexagonal boron nitride(hbn) combine to create a high bonding powder strength.

Since copper melts less than and disulphide of molybdenum, hexagonal boron nitride(hbn) the copper is getting melted and releases to the capacity to move in the substrate to create a coating when it get ignites. Copper also offers good ignition so that the substrate may be uniformly covered.

In order to create a proper mixture of the MoS2, Cu, and HBN powder for the production of the compacted green electrode, a number of preparatory experiments were therefore conducted. Cu powder, MoS2, and HBN are blended in varying amounts, with the appropriate blending ratios being 30:50:20, 40:20:40, and 30:20:50, to create the powder combination.

(a) **(b)** **(c)** **(d)**

Fig.3. (i) powder blending in mortar, (ii) Hot mounting press, (iii) compacted green electrode

(iv) compacted green electrode is working as adhesive to electrode of Cu.

Characterization and Experimental techniques:

The green compact work piece is made of 0.36% copper, 97.0% iron, and 0.26% carbon.
For the experiment, a sample measuring 10 mm by 10 mm by 3 mm was employed (manganese: 1.03%; phosphorus: 0.040%). Pilot tests were first carried out utilizing an setup of a EDM (Fig. 1(ii)) to find out the value of the normal valuable parameters ranging of the process for obtaining a surface of the layer of coating. A total of 35 experimental trial runs with various parameter values were scheduled. Table 1 lists the mean values of all the resultant parameters after all experimental runs were performed three times. The various constant parameters were kept constant throughout all of the trials (gap voltage: 50V, machining time: 10min, pulse on time: 35s).

During the EDC method, the waveforms of the usual peak current and gap voltage were recorded. When the gap voltage is applied, dielectric changes from an electrical insulator to an electrical conductor, which results in the formation of a spark. The point at which a dielectric fluid turns into an electrical conductor is known as the ionisation point. The dielectric fluid de-ionizes and returns to its electrical insulator qualities when a pulse is halted. The "ignition gap" is a very small distance between the tool and the location where the work piece is set up. As the peak current moves between the electrode tools and work parts, heat is produced. Heat is applied until the material nearest to the work piece—the area where the spark starts and ends—vaporizes. The electrode melts and vaporizes with every spark, which is what primarily causes the tool material to be deposited on the layer of surface matter. Following each test, the samples were cleaned in an ultrasonic cleaner using an acetone solution to get avoided of any remaining loose particles and di electric oils that had stuck to the surface. Then, several techniques of characterization were used.

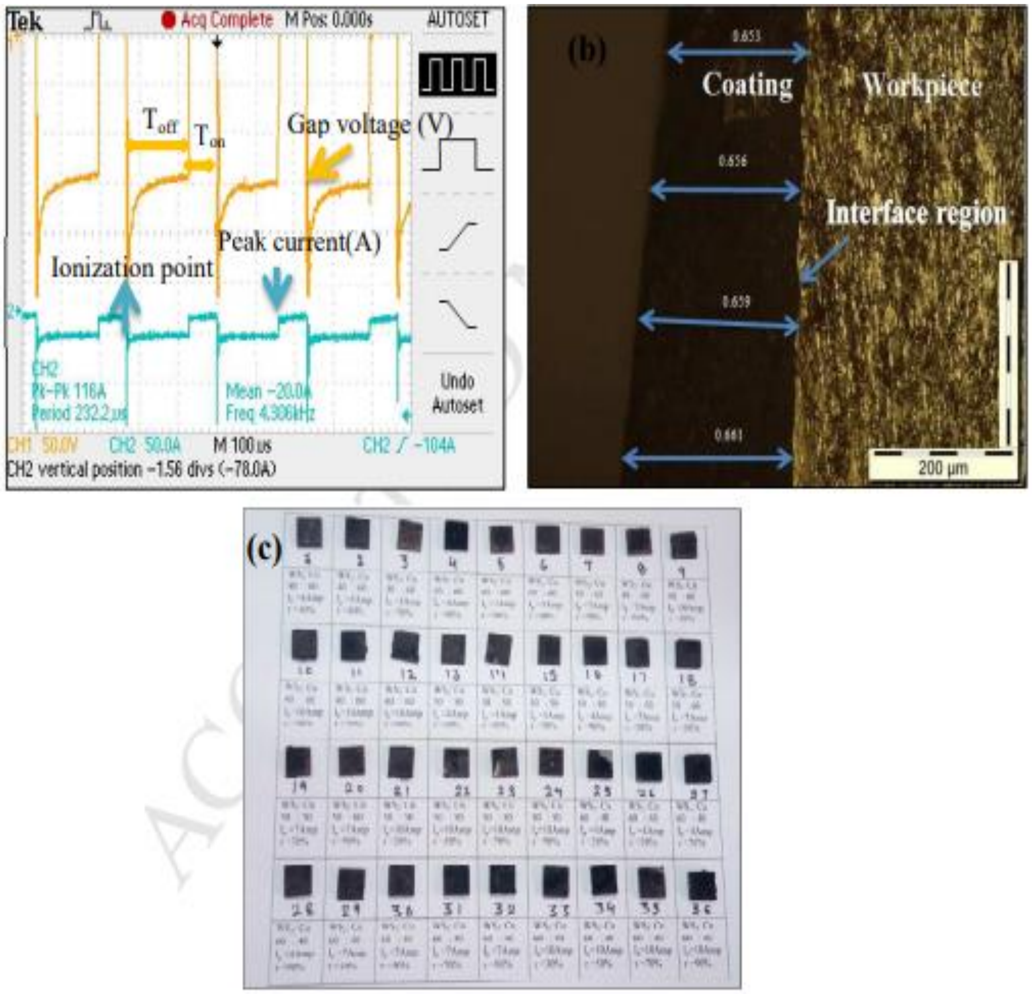


Fig. 4 (a) Typical peak current and gap voltage wave form captured during EDC **(b)** optical image of the cross section of coating **(c)** Image of coated samples.

Parameters and its values:

VALUES	PARAMETERS
210 Kg/cm2	PRESSURE
Cu/Hbn/MOS2	COMBINATION
10+10+5 MIN	TIME
210 CELCIUS	TIME

Table 2. parameters and its values

Process parameters selection:

Various experiments have been carried out in order to get effective parameters of procedures. A positive terminal was related with the substratum, while a negative terminal was associated. A oscilloscope were coupled to the extreme points of the both terminals to scrutinized the spark event, that is anything but a suitable condition for a the procedure. After the trial and error, the most acceptable settings were identified in terms of blending ratios (hbn/Cu/MoS2) – (30/30/40), (20/30/50), (55%), duty factor and peak (max) current (12,9,5 ampere). Beyond those limitations there were numerous difficulties faced in during the experiment, leading to an island type coating between the bulks of the substrates.

CHAPTER-4

4.1. Observation table;

Serial No.	Configuration (hbn/Cu/MoS2)	Currents in (Ampere)	Duty factor (%)	Deposition rate of mass (gram per minute)	Rate of Tool wear (gram per minute)
i	(30/30/40)	5	55	0.02526	0.0319
ii		9	55	0.03977	0.3818
iii		12	55	0.07783	0.7570
i	(30/50/20)	5	55	0.02149	0.3040
ii		9	55	0.06599	0.4618
iii		12	55	0.072276	0.8911
i	(40/40/20)	5	55	0.005285	0.1369
ii		9	55	0.02241	0.1587
iii		12	55	0.03801	0.1266

Table(iii). Observation table for various parameters used in an experiments.

CHAPTER- 5

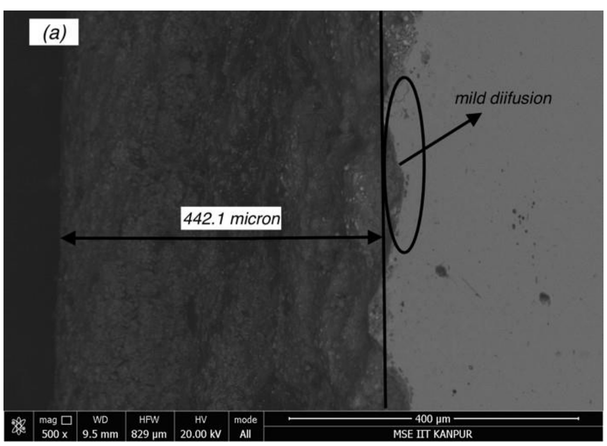
5. Discussion and Results:

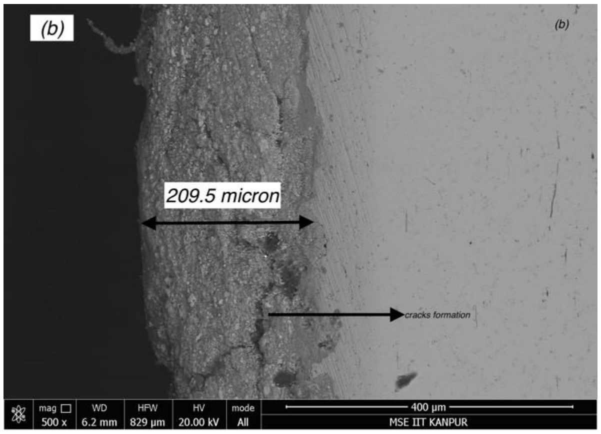
Micro-structure and Chemical Composition of coated material:

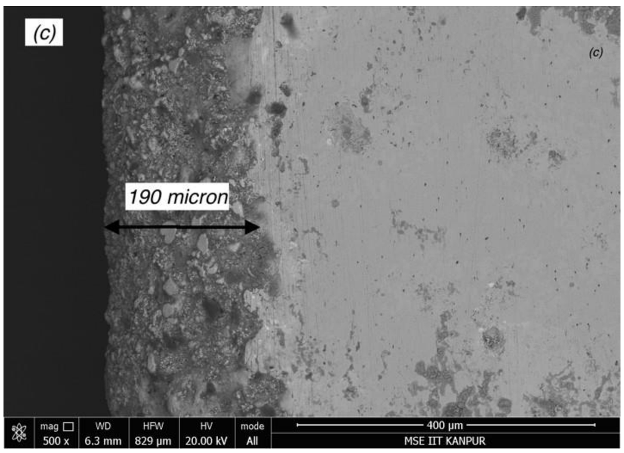
The FESEM machine was used for the fundamental morphology and small scale research (Model: JSM 7900 F, producer: JEOL Ltd, Japan). For changes to the peak current and powder blending proportions, Fig 4 and 5 are seen in the FE-SEM photograph of the coated surfaces. A point by point examination is presented in the accompanying field.

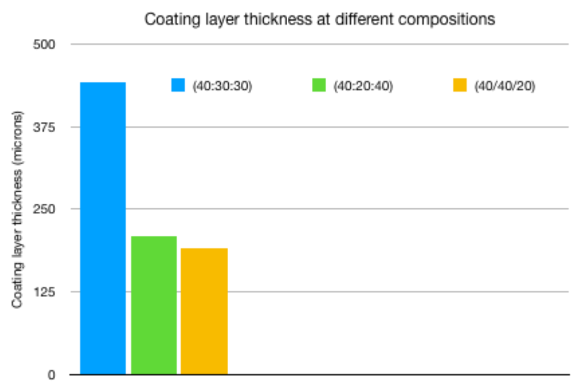
Powder blending ratio with help of variation of cross-section morphology:

The well-defined and well-explained morphology demonstrates that the top coating of in the cross-section has a changed ratio with hbn/Cu/MoS2, 30:30:40, hbn/Cu/MoS2, 30:50:20, and hbn/Cu/MoS2, 40:40:20, respectively (duty factor is 55%).




(b)
209.5 micron
cracks formation
mag 500 x | WD 6.2 mm | HFW 829 µm | HV 20.00 kV | mode All
400 µm
MSE IIT KANPUR


(c)
190 micron
mag 500 x | WD 6.3 mm | HFW 829 µm | HV 20.00 kV | mode All
400 µm
MSE IIT KANPUR


Coating layer thickness at different compositions
(40:30:30)
(40:20:40)
(40/40/20)
Coating layer thickness (microns)
500
375
250
125
0

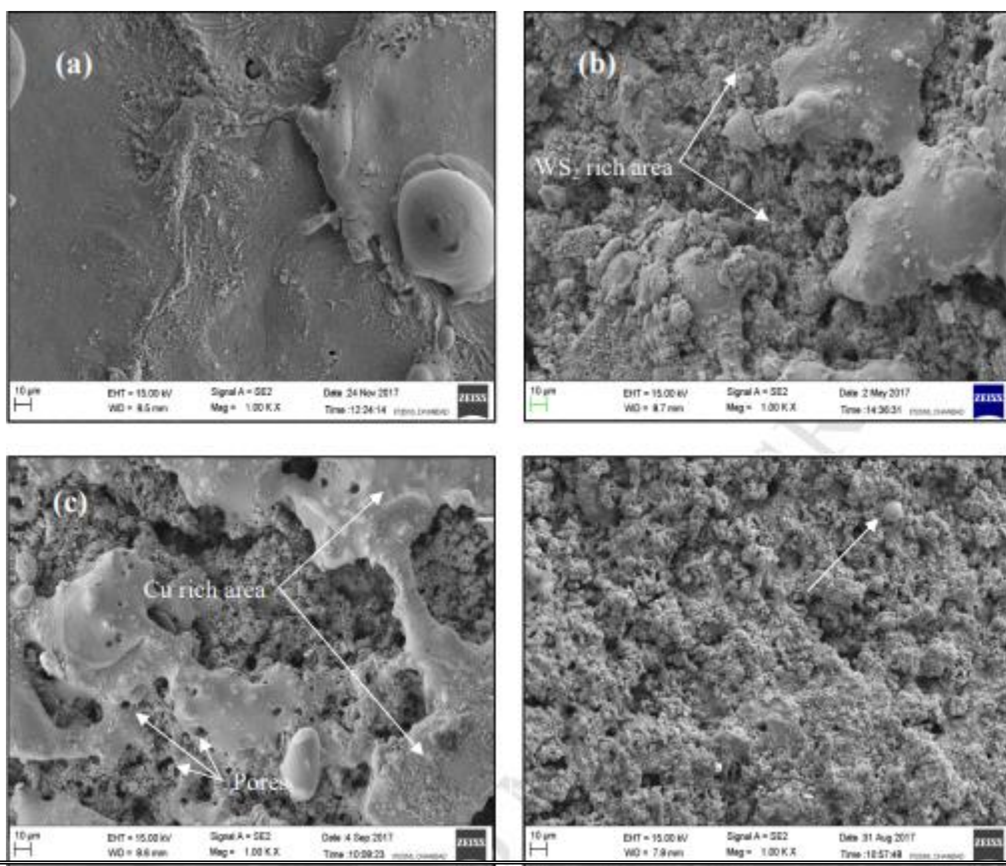

(a)
(b)
WS2 rich area
(c)
Cu rich area
Pores

Fig: (iv). powder blending cross-sectional scene of coated material (hbn/Cu/MoS2) ratio by FESEM image , (1) 30:40:40, (2) 30:50:20, (3) 40:40:20, (4) graph showing the coating layer thickness in relation to the powder blending ratio at 55% duty and 5A current.

With hbn/Cu/MoS2 blending ratios of 30/30/40, the substrate's diffusion is gentler, but the substrate and cover are not broken. There are tiny fissures between the layer and a substrate, as seen in Fig. 4(2). The fact that parameters are crucial to the process may be due to a lack of compatibility between the mixes and the substrate's surface. In Fig. (iii), the substrate and coating of the substance are evenly distributed. Depending on the mixing ratio, the coating's thickness varies as well.

Surface morphology of coating surface

The morphology of a 9A and 12A peak current occurred separately with hbn/Cu/MoS2 30:30:40, as seen in Fig. 5(i-iii). With electrical machining, the flow of the pinnacle may be capable to achieve the ideal ignition temperature to transmit heat from the anode which is negative terminal material to the work piece. In order to deposit a consistent high-density material on the substrate surface at a high transfer rate for the material, an appropriate high current is required. Because the electrical material lacks the necessary energy to fuse, low power might result in uniform overlay with some holes and pores. The molten material on the substratum must exhibit consistent proves, and an anode material must be developed.

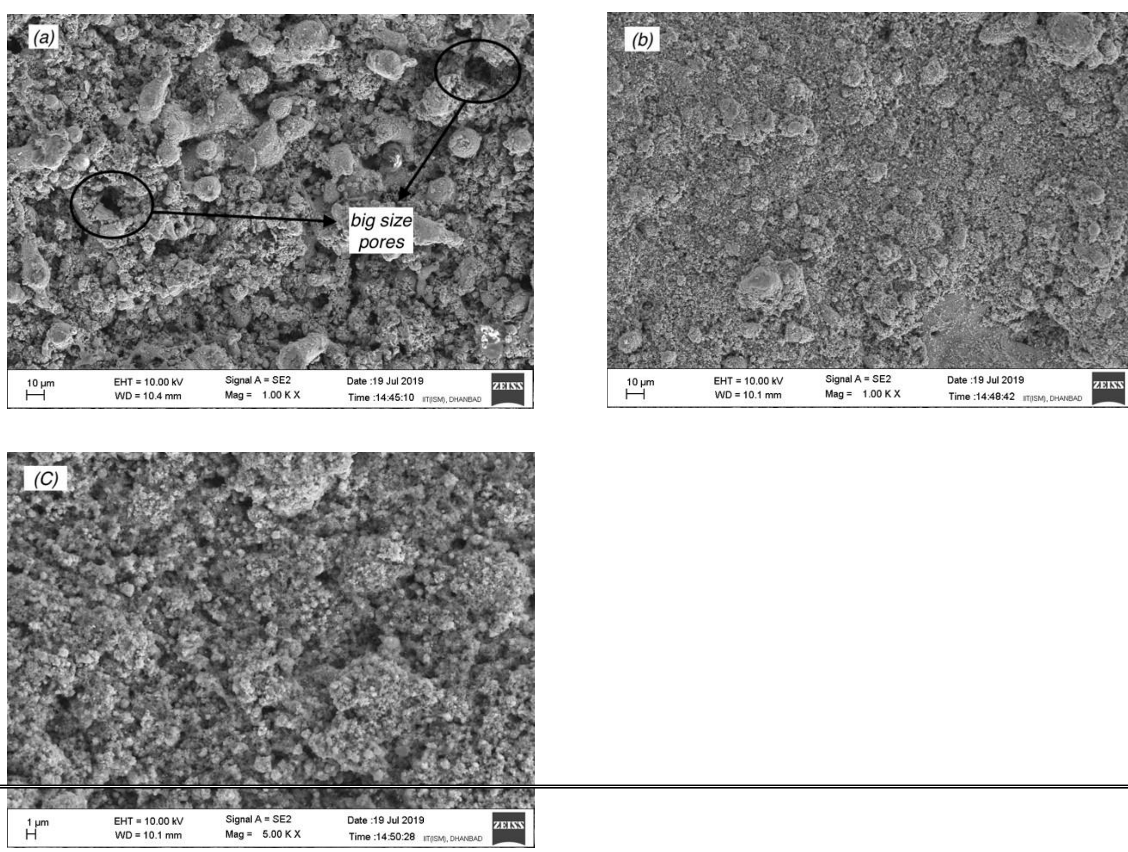


fig.5. Obtaining a covered surface through composition hbn/Cu/MoS_2 (30/30/40) at dissimilar current by FESEM image, (i) peak current of 5A (ii) peak current of 9A (iii) zoomed image of FESEM figure (b), with (parameters of constrained values: composition of a material, duty factor (55%) and ignition time 10 min)

With composition (30/30/40) and 9 A current, fig. 5(i), consistent coating of them aterial deposition may be seen, although many pores are also identified. However, with the similar composition and number of 12, it is discovered that the coating material is currently deposited uniformly and has few pores.

This occurs as a result of increased current and energy levels that generate a bigger spark and help melt more material to form a covering layer on the substrate of the surface.

X-ray diffraction analysis

Utilising XRD analysis, the chemically group of molecules known as compound created by EDC was studied. The diffraction angle (2thetha) range of 20° to 80° was selected in order to analyze X-ray diffraction for the detection of diffraction tops using X'PERT which gives a high score programming language. We discovered MoS2, Cu, hbn CuS, BC CuS, and Fe2B among the coating's constituents.

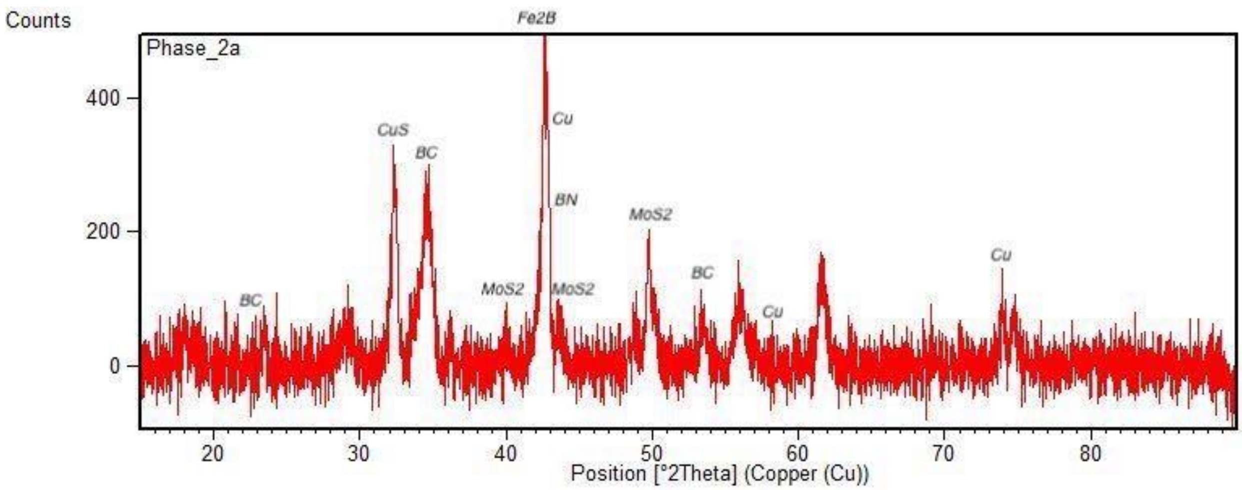
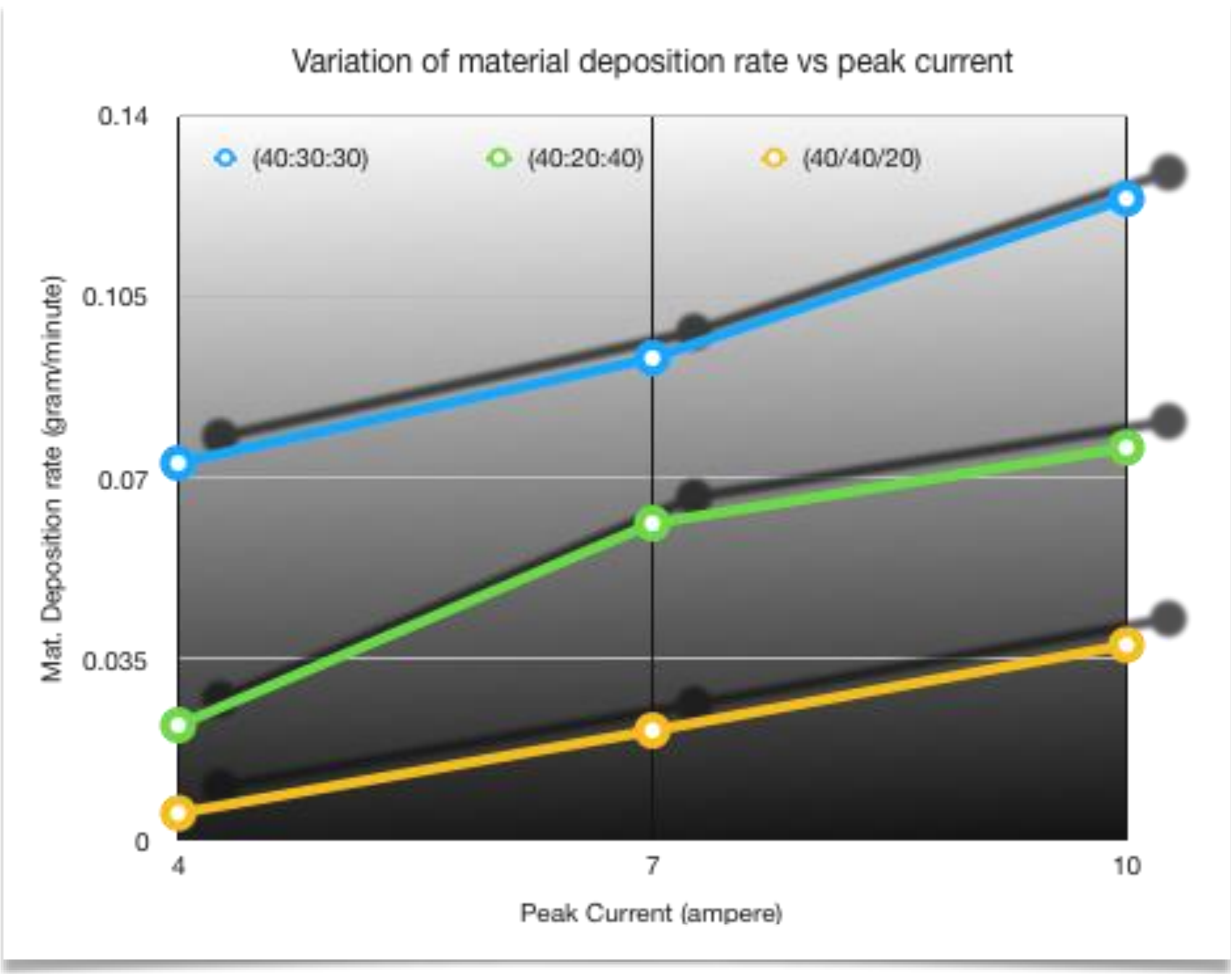


Fig.VI. The image of hbn/Cu/MoS2 (40/30/30) at 12 A current, 55% duty factor and 10-minutes of time machining of XRD analysis .

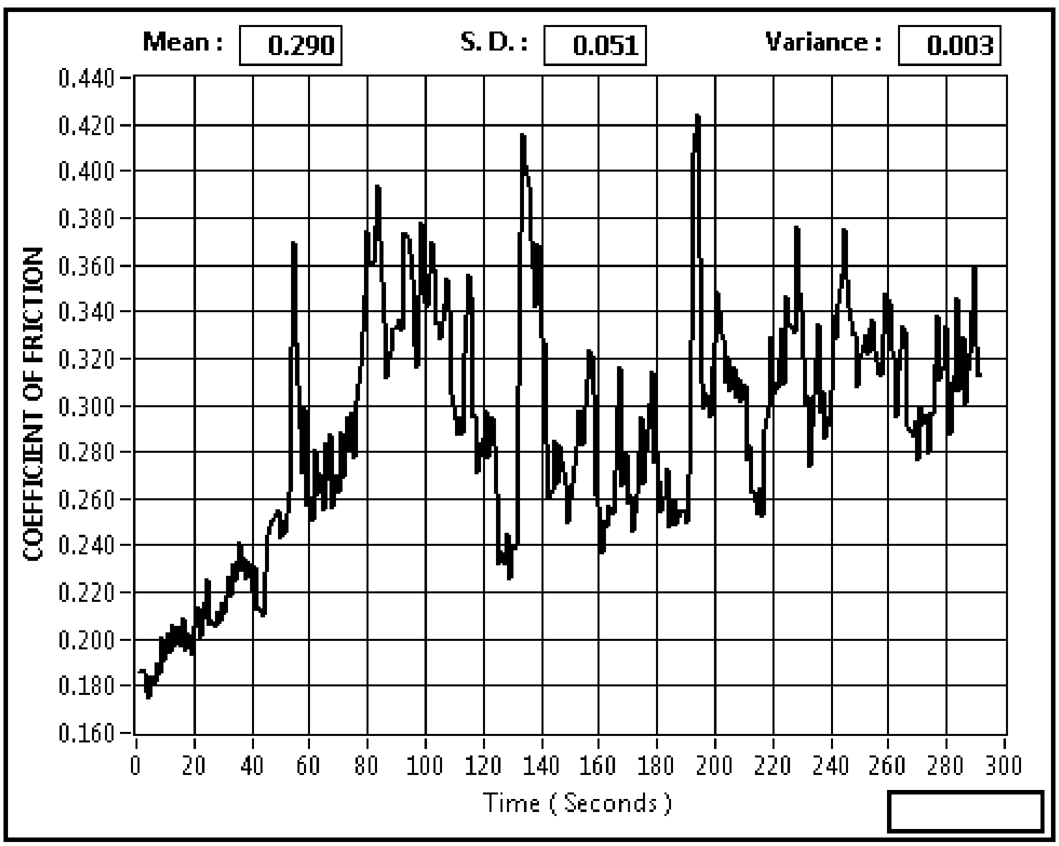
5.1.4. Deposition of material rate varies with peak current:

The graph illustrates how the higher peak current causes variations in the rate of material deposition. Higher currents produce greater temperature, which aids in melting electrode materials, increasing the rate of deposition of material with the composition (hbn/CMoS2)(40/30/40). Additionally, the rate of hbn/Cu/MoS2 (40/20/400) deposition rises from 5 to 9 amperes before falling. On the other hand, the deposition in the rate of the composition hbn/Cu/MoS2 (40/40/20) is marginally increasing in contrast to the existing state.



The coated surface's coefficient of kinematic friction:

As, The amount of kinematic friction between the surface of coated material and mild steel was determined using the disc on pin test, as seen in the graph. The disc was made of mild steel, with dimensions of (20 mm thick, 100 mm radius). The experiment ran for five minutes and had an 80mm radius. Using a 2 kgf (20 N) weight, the test was run. We noticed that as the coating layers were sheared off during the test, the quantum of the kinematic friction changed over time. The mean friction coefficient is 0.290, the variation is 0.003, and the standard deviation is 0.01. Even though the kinematic friction coefficient has increased, the distance between the mild steel surfaces has reduced even though the kinematic friction quantum between the surfaces goes in between zero to one.



Graph.4: variation in kinematic quantum of friction with respect to time.

The coated surface's wear and friction characteristics:

The surfaces with the manufactured coatings were cleaned and gently polished. The samples were then fixed on the flat face of cylindrical pins with a 6 mm diameter and 30 mm length, as illustrated in Fig. 12 (a), with an area of 10 mm x 10 mm and a height of 3 mm. The pin-on-disc wear testing machine (type TR-201LE, make: DUCOM, India) was used to conduct the wear test. For this test, a round EN31 steel disc with a 100 mm diameter and an 8 mm thickness was used as the counter body (spinning disc). The wear test disc has mounting holes around the perimeter so that it could be mounted on the wear testing device.

In order to make contact with the revolving disc, the prepared cylindrical pin was put in a V-slot on the wear testing machine's projecting arm. The installed pin was subjected to a dead load of 2kgf thanks to a pulley string setup. The installed disc's rotating speed might vary from 100 to 1000 rpm, its wear track diameter from 50 to 80 mm, and its applied load from 1kgf to 10 kgf.

Wear track diameter of 75mm, rpm of 250, testing time length of 300s, and test load of 2kgf are the wear testing parameters in the current study. The experiment was run at room temperature.
A computer-connected electronic sensor and data collecting system that monitored wear was used. On the computer, the variation in wear and coefficient of friction data with regard to wear time was documented. The wear of the coated material was calculated based on the thickness of the material that was removed from the prepared pin surface. It was found that a satisfactory quality surface coating was produced at a MoS2:Cu/60:40 mixing ratio.

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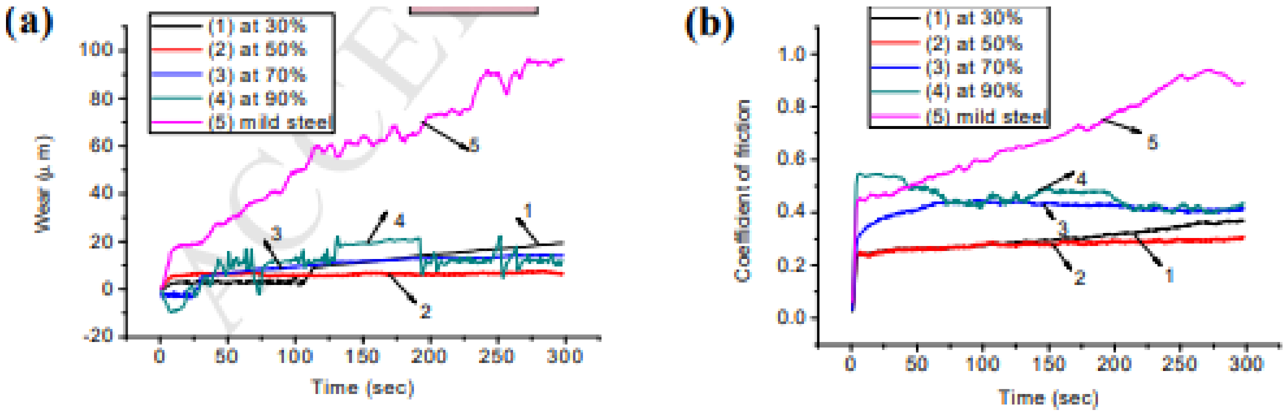
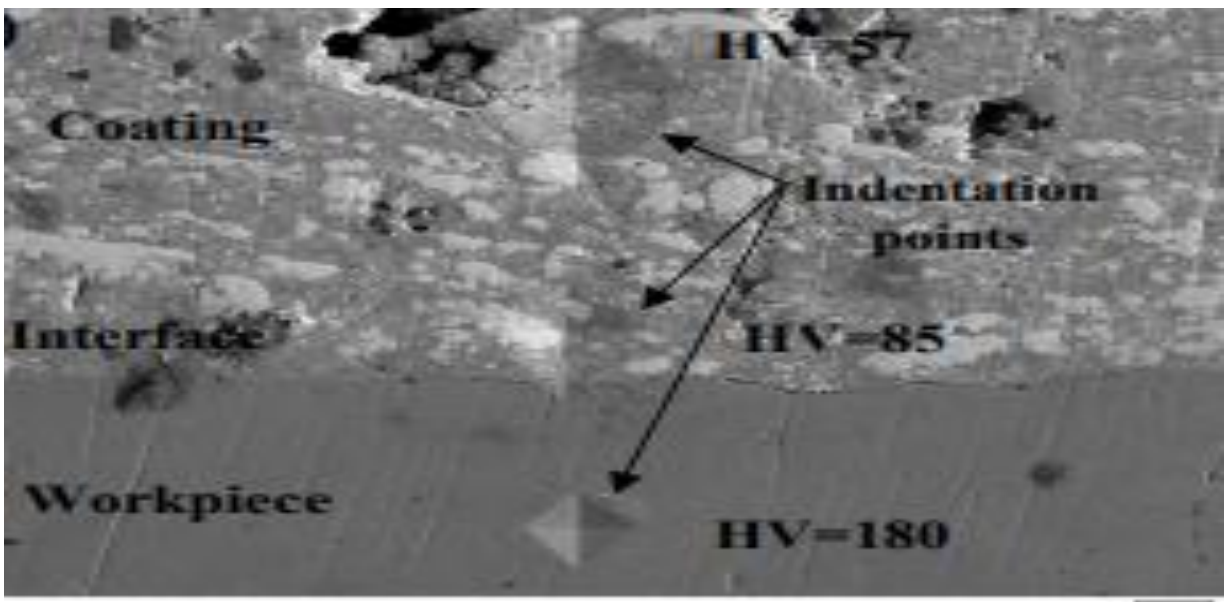
The MoS2 crystal structure, which has a strong bond of covalent bond between the atoms of in the layer, provides high wear resistance. There is a weak linkage among them, like the stacking layers, which causes a low quantum of friction during the sliding contact. Uneven coating surfaces on some samples cause unstable negative wear. However, it stabilizes as the test time continues. As the duty factor gradually increases from 50% to 90%, the degree of quantum of friction & wear of matters climb as well. All coated samples show less wear than the mild steel substrate because the top surface has a self-lubricating layer of MoS2 particles.



Variation in quantum of friction & wear of materials during the course a the test for largely properly considered parameters.



Variation in Micro Hardness at the coating's cross-sectional of various compositions and a FESEM picture of an indent at the cross-section

CHAPTER 6

CONCLUSION:

In this study, (Cu/MoS2/hbn) is used to conduct studies on coating the surface of a substrate using electrical discharge machining. The tiny green electrode was made using a hot mounting press machine. A total of 18 tests were conducted, with numerous methodologies employed to analyses the results. The following is a summary of the findings and conclusions:

1. It is not feasible to employ the Electrical Discharge Coating process to coat a hbn and mos2 powder combination directly on the substrate due to the weak bonding strength and low electrical conductivity of meahexagonal boron nitride(hbn)(hbn) and disulphide of molybdunm and. As a result, additional material powder is required to offer sufficient electrical conductivity and bonding strength. Therefore, in the current investigations, compacted green copper electrodes were produced using a mounting press hot machine.

2. An effective powder coating with acceptable surface morphology was created using the ingredients hbn/Cu/Mos2 with a powder blending of many ratio of 30:30:40, a duty factor of 55%, and a peak current of 12A. However, in order to conduct the experiment, a binder choice with a suitable blender ratio was made in order to enhance the morphology of the coated surface. Improved material fusion between the substrate and coating materials is shown by coating with the mixture hbn/Cu/MoS2 (40/20/40).

3. An X-ray diffraction analysis showed the existence of BN, Cu, MoS2, and transphase of CuS ,Mo, BN, and Cu-S related to the synthesis of intermetallic compounds. The results showed that the chemicals are evenly dispersed throughout the covered surface.

4. The diverse outcomes in metal deposition rate with different process parameters were also examined, indicating that increasing peak current amplitude increases metal deposition rate.

5. Peak current is the most critical component in controlling coating thickness in electrical discharge coating. To get a lot of current, you need a lot of peak current amplitude. Due to the cumulative effect of plasma and gravity, more electrode tools melt down and deposits on the substrate due to spark energy, which is exactly proportional to peak current. As a result, the peak current applied is proportional to the coating thickness produced.

6. FESEM and XRD were used to examine the layer generated on the substrate's surface, and we discovered a uniform coating on the substrate with indications of MoS2, hBN, and Cu.

7. Pins on discs were used in wear tests to evaluate the sliding quantum of friction between the mild steel & coating.

8. To determine the quantum of sliding friction in between the mild steel surface & the coating, wear experiments on pins on discs were also carried out.

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