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Modelling and Optimization of Wire-EDM Process using Integrated Approach of ANN-GA

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Abstract--Productivity and quality are two important aspects have become great concerns in today's competitive global market. Every production/manufacturing unit mainly focuses on these areas in relation to the process as well as product developed. Electrical discharge machining (EDM) process, even now it is an experience process, wherein still the selected parameters are often far from the maximum, and at the same time selecting optimization parameters is costly and time consuming. Surface Roughness (Ra) during the process has been considered as productivity estimate with the aim to minimize it. With an intention of minimizing surface roughness is been taken as most important output parameter. This can be satisfied by selecting an optimal process environment (optimal parameter setting). Objective function is obtained by Neural Network tool of MATLAB. Then objective function is optimized using Genetic Algorithm optimization tool of MATLAB. The model is shown to be effective Surface Roughness improved using optimized machining parameters.

Keywords--EDM, Kerf, MMC, Surface Roughness, and WEDM.

1. Introduction:

It is a non-traditional electro-thermal machining process, in which electrical energy is used to generate electrical spark and material removal occurs due to thermal energy produced by the spark.

EDM is mainly used to machine high strength temperature resistant alloys and materials difficult-to-machine. EDM can be used to machine irregular geometries in small batches or even on job-shop basis. Work material is to be electrically conductive to be machined by EDM.

EDM machining techniques were discovered far back in the 1770s by an English Scientist. However, this technique was not fully taken advantage until 1943 when Russian scientists learned how its erosive effects could be controlled and used for machining purposes. It was developed commercially in the mid-1980s, wire EDM made lot of change that helped shape the metal working industry we see today.

Now the now concept of manufacturing uses non-conventional energy sources like light, sound, chemical, mechanical, electrical and ions. With the technological and industrial growth, devolvement of harder machining materials, which find wide application in nuclear engineering ,aerospace and other industries owing to their high strength to weight ratio, heat resistance and hardness qualities has been witnessed New developments in the field of material science have led to new engineering metallic materials, high tech ceramics and composite materials having good mechanical properties and thermal characteristics as well as sufficient electrical conductivity so that they can readily be machined by spark erosion. Non-traditional machining has improved out of the need to machine these alien materials. The machining processes are non-conventional in the sense that they do not employ traditional tools for metal removal and but they directly use other forms of energy. The problems of high complexity in size, shape and higher demand for product accuracy and surface finish can be solved through non-traditional methods.

EDM has been replacing grinding, milling, drilling and other traditional machining Operations and is now a well-established machining option in many manufacturing industries everywhere in the world. And is capable of machining hard material components or geometrically complex, which are precise and difficult-to-machine such as heat treated super alloys, ceramics, composites, carbides tool steels, heat resistant steels etc. being widely used in mould and die making industries, nuclear industries, aeronautics and aerospace. Electric Discharge Machining has also made its presence felt in the new fields such as medical, sports and surgical, optical, instruments, including automotive R&D areas.

EDM Principle:

Due to erosion caused by rapidly recurring spark discharge that taking place between the tool and work piece metal is removed in this process. About a thin gap of .025mm is maintained between the work piece and the tool by a servo system shown in Fig. 1. Both work piece and tool are submerged in a dielectric fluid. EDM oil/kerosene/deionized water.

The work piece is anode and tool is cathode. In about an interval of 10 micro seconds voltage across the gap becomes sufficiently large to discharge spark. Electrons and positive ions get accelerated, creating a discharge channel that becomes conductive. It is then at this point when the spark jumps causing collisions between electrons and ions creating a channel of plasma. Electrical resistance suddenly drops of the previous channel allows that current density reaches very high values producing an increase of ionization and the creation of a powerful magnetic field. The moment spark occurs sufficiently pressure developed between tool and

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work due to which high temperature is reached and then metal is eroded at that high temperature and pressure.

Material removal occurs due to such extreme localised temperature. Due to instant vaporization of the material as well as due to melting material removal occurs. Molten metal is not completely removed but only partially.

The plasma channel is no longer sustained as the potential difference is withdrawn as shown in Fig 2. It generates shock or pressure waves, which evacuates the molten material forming a crater of removed material all around the region of spark, as the plasma channel collapse.

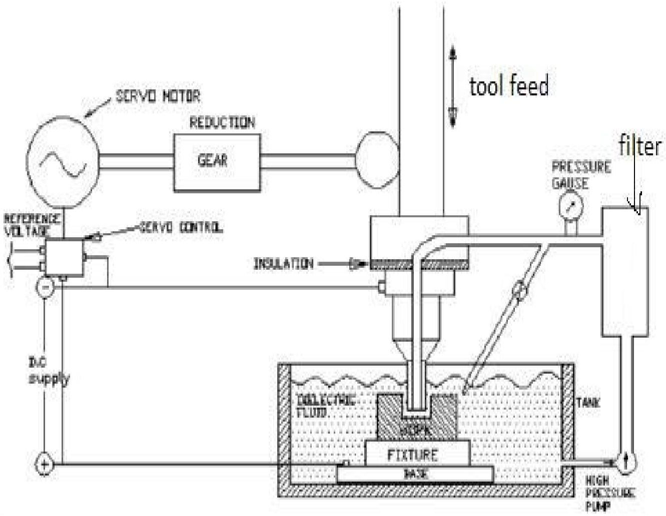

Fig. 1. Electric discharge machining set up

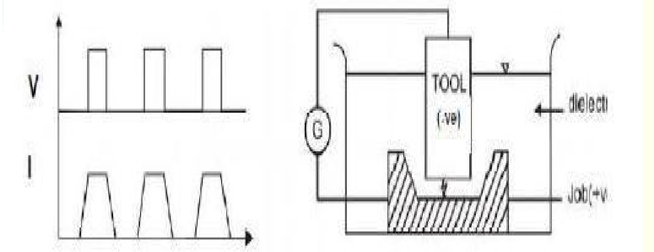

Fig. 2.Working principle of EDM process

2. Related Work:

Atul kumar and Dr D.K. Singh [8] have study variation of cutting performance with pulse on time, pulse off time, open voltage, feed rate override, wire feed, servo voltage, wire tension and flushing pressure were experiment investigated in wire electric discharge machining processes. Brass wire with 0.25 mm diameter and SKD 61 alloys steel with 10 mm thickness were used as tool and work materials. The output considered has been MRR and surface roughness. Experimentation has been competed by using Taguchi's L18 (21×37) orthogonal array under different conditions of parameters. Finally it concluded that the MRR increases with the increase in pulse on time and decrease with increase in pulse off time and open voltage. The effect of feed rate overdrive, wire feed, servo voltage, wire tension and flushing pressure on MRR is not very significant. For the surface roughness it decrease with increase of pulse off time open voltage and wire feed and increases with increase in feed rate override and servo voltage. The effect of other parameter is not significant.

Pujari Srinivasa Rao, Koona Ramji, Beela Satyanarayana [9] studied Wire-cut electric discharge machining of Aluminum-24345. Experimentation has been done by using Taguchi's L18 (21x37) orthogonal array under different conditions of parameters. The response of surface roughness is considered for improving the machining efficiency. Optimal combinations of parameters were obtained by this method. The confirmation experiment shows, the significant improvement in surface finish (1.03µm) was obtained with this method. The study shows that with the minimum number of experiments the stated problem can be solved when compared to full factorial design. All the experiments were conducted on Ultra Cut 843/ ULTRA CUT f2 CNC Wire-cut EDM machine. The size of the work piece considered for experimentation on the wire-cut EDM is 25 mm x 20 mm x 10 mm. Increasing the discharge energy generally increases surface irregularities due to much more melting and re-solidification of materials. Hence, it is found that SR tends to decrease significantly with decrease in IP and TON. The parameters wire tension and spark gap voltage are observed as significant parameters in obtaining better surface finish.

Kuriachen Basil, Dr. Josephkunju Paul, Dr. Jeoju M.Issac [10] investigates the effect of voltage, dielectric pressure, pulse on-time and pulse off-time on spark gap of Ti6AL4V alloy. It has been found that pulse on time and pulse off time have the more impact on the spark gap. The minimum spark gap was obtained as 0.040407mm. The WEDM experiments were conducted in Electronic Ultracut S1 machine using 0.25 mm brass wire as the tool electrode. Pulse on time, pulse off time, voltage and dielectric pressure are the four WEDM parameters that were selected for investigations. In this experimental study two level full factorial experiment is adopted because this gives all possible combinations of machine parameters. It can be noticed from that corresponding to minimum value of pulse off time the spark gap decreases with increase in dielectric pressure, whereas the spark gap increases with increase in dielectric pressure corresponding to maximum value of pulse off time.

Saurav Datta, Siba Sankar Mahapatra [11] experimented with six process parameters are discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate; to be varied in three different levels. A block of D2 tool steel with 200 mm × 25 mm ×10 mm size. Data related to the process responses are material removal rate (MRR), roughness value of the worked surface and kerf has been measured for each of the experimental runs. These data have been utilized to fit a quadratic mathematical model (Response Surface Model) for each of the responses, which can be represented as a function of the six process parameter. Predicted data given by the models as per Taguchi's L18 (3*6) Orthogonal Array (OA) design have been used in search of an optimal parametric combination to achieve desired yield of the process, maximum MRR, good surface finish and dimensional accuracy of the product.

International Journal of Research and Development in Applied Science and Engineering (IJRDASE)
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Grey relational analysis has been adopted to convert this multi-objective criterion into an equivalent single objective function. It has been found that that the spark gap increases with increase in pulse on time, whereas spark gap decreases with increase in pulse off time. The pulse on time, pulse off time, the interaction of dielectric pressure and pulse off time, and interaction of pulse on time and pulse off time are significant parameters which affect the spark gap of WEDM.

Nihat, Can, Gul [12] investigated on the effect and optimization of machining parameters on kerf and material removal rate (MRR) in WEDM operations. Experimental studies were conducted using different pulse duration, open circuit voltage, wire speed, and dielectric flushing pressure. Importance levels of parameters were analysed using analysis of variance (ANOVA). The optimum machining parameter combination was obtained by using the analysis of signal-to-nois (S/N) ratio. The variation of kerf and MRR with machining parameters is mathematically modelled by using regression analysis method. Objective of minimum kerf together with maximum MRR was performed. The experimental studies were performed on a Sodick A320D/EX21 WEDM machine tool. CuZn37 Master Brass wire with 0.25mm diameter was used in the experiments. As work piece material, AISI 4140 steel with 200mm × 40mm × 10mm size was used. The results show that open circuit voltage was three times more important than pulse duration for controlling kerf, while for MRR, open circuit voltage was about six times more important than pulse duration.

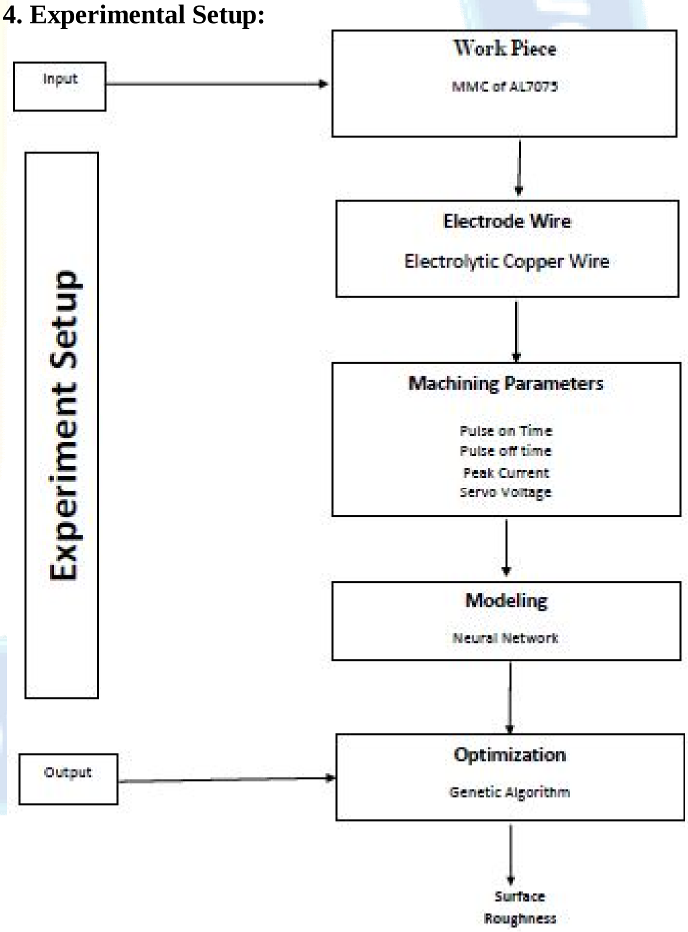
Mustafa Ilhan et al. [13] aims to select the most suitable parameter combination for the wire electrical discharge machining process in order to get the desired surface roughness value for the machined work pieces. A series of experiments have been performed on 1040 steel material of thicknesses 30, 60 and 80 mm, and on 2379 and 2738 steel materials of thicknesses 30 and 60 mm. The test specimens have been cut by using different cutting and offset parameter combinations of the "Sodick Mark XI A500 EDW" wire electrical discharge machine. The related tables and charts have been prepared for 1040, 2379, 2738 steel materials. The tables and charts can be practically used for WEDM parameter selection for the desired work piece surface roughness. And finding out that increasing work piece thickness more stable & better SR characteristics.

3. WIRE ELECTRICAL DISCHARGE MACHINING [WEDM]

This experimental work performed at Hindustan Aeronautical Limited, Lucknow. The experiment work is carried out in wire cut electro discharge machine (CHARMILLES TECHNOLOGIES ROBOFIL 300) of MMC Of Al 7075 reinforced with 10 Wt% of boron carbide (B4C) material by varying machining parameters. The wire cut electric discharge machine is consist of a machine tool, a power supply unit and dielectric supply unit. A schematic diagram of the wire cut EDM is shown in Fig 3.

Fig. 3. Wire Cut EDM.

4. Experimental Setup:



5. Selection of work piece material

Metal Matrix Composites (MMCs) are one of the recent advanced materials having properties of light weight high specific strength, good wear resistance and low thermal expansion coefficient. These composite material are extensively used in structural, aerospace and automotive industries.

Metal Matrix Composite (MMC) of Al 7075 reinforced with 10 wt. % B4C (Boron Carbide) with an average particle size 25 micron were prepared by stir casting methods. MMC composed of Al 7075 as metallic base material called Matrix; which is reinforced with B_4C, a hard ceramic reinforcement. Due to possession of higher hardness and reinforcement strength, composite materials are difficult to be machined by traditional techniques. Composition of Al 7075

Component	Al	Zn	Mg	Cu	Fe	Si	Ti	Cr	Mn	Other Total
Wt. %	87.1-91.4	5.1-6.1	2.1-2.9	1.2-2	Max 0.5	Max 0.4	Max 0.2	0.18-0.18	Max 0.3	Max 0.15

6 Selection of electrode material
Electrode materials generally used:
1) Copper
2) Brass
3) Coated wire
4) Fine wire
Wire selection basically depends on the properties of work piece material, however an ideal wire electrode should possess following characteristics, i.e. High electrical conductivity, Sufficient tensile strength and optimum spark and flushing characteristics. For this dissertation work selected wire is Electrolytic Copper Wire of 10 mm diameter.

7 Machining characteristic:
7.1 Surface Roughness
Surface roughness values of finished work pieces were measured by Mitutoyo Surface Roughness Tester SJ – 201 by a proper procedure. The Mitutoyo Surface Roughness Tester SJ – 201 is an instrument that works by gently dragging a mechanical stylus across a Surface. Surface Roughness Tester acquires data by moving the sample beneath the diamond tipped stylus. Vertical movements of the stylus are sensed by an LVDT, digitalized, and stored in the instruments memory. Its output is a digital display of measured Surface roughness value Ra and other features. Surface Roughness Standard ISO was used for measurement. The temperature of environment was 32 ± 1◦C. In this present study we have taken Ra for measuring Surface Roughness [37].

Table 1: Specification of Mitutoyo surface roughness tester SJ-201

Detector	
Detection Method	Different inductance method
Measurement Range	350µm (-200 µm to + 150 µm) 1370 µin (-7880 µin to + 5900 µin)
Stylus Material	Diamond
Tip Radius	5 µm (200 µin) 2 µm (80 µin)
Measuring Force	4 MN (0.4 gf) 0.75 MN (0,075 gf) (0.75 MN measuring force type)
Radius of skid curvature	40mm (1.57 in)
Drive Unit	
Detector Drive Range	21mm (0.82 in)
Traversing speed Measurement Return	0.25 mm/s, 0.5 mm/s (0.10 in/s, 0.02 in/s) 0.8 mm/s (0.30 in/s)
Detector retraction function	Stylus UP
Bottom configure ration	V – way
Ra	Ra (0.01 µm to 100 µm)

8. Result and Discussion:
The results of work that is based on the development and analysis for model development of surface roughness (SR) estimator for EDM machine using artificial neural network model for SR estimator and genetic algorithm dependent search of optimized input parameters for getting minimum surface roughness.

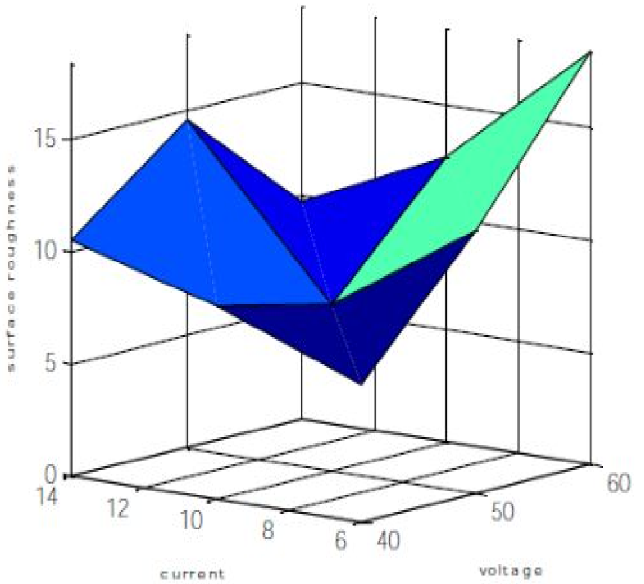


Fig. 4. Surface plot for surface roughness as a function of EDM TON and voltage.

International Journal of Research and Development in Applied Science and Engineering (IJRDASE)
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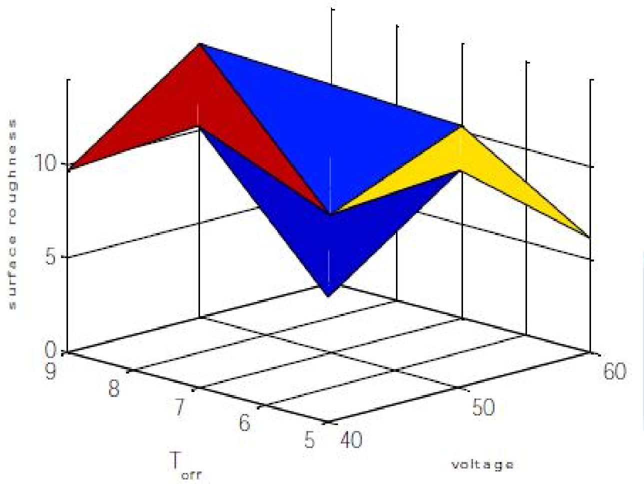

Fig. 5. Surface Plot For Surface Roughness As a Function Of EDM T_{OFF} and Voltage

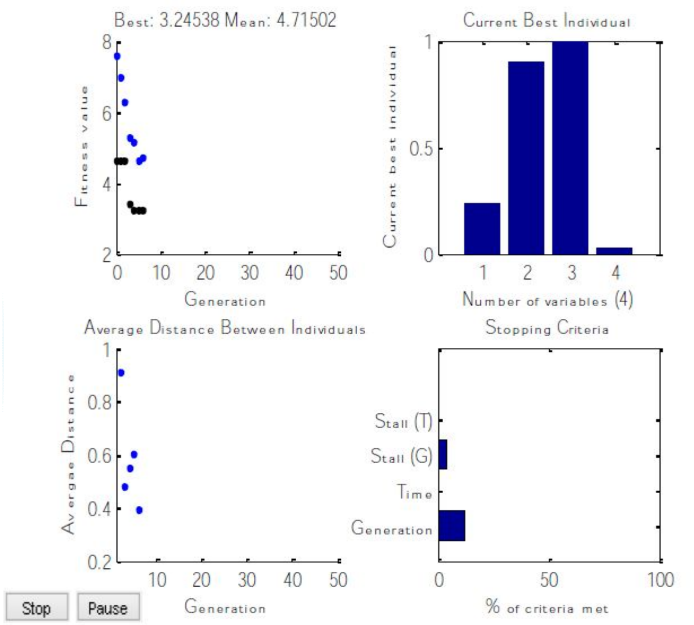

Fig. 6. Plot showing GA initial stage of optimization search.

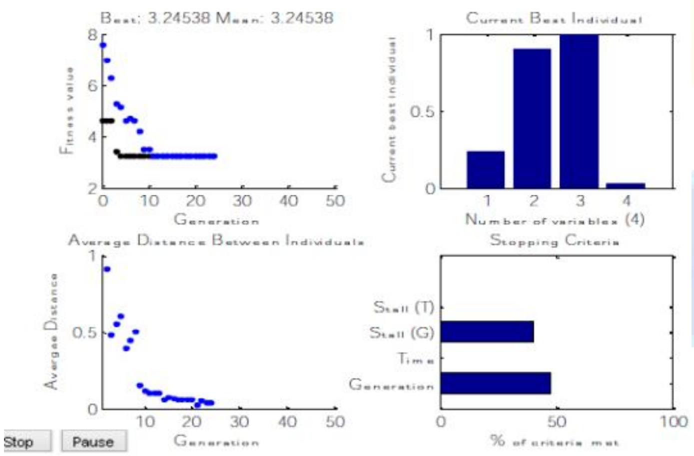

Fig. 7. Plot showing GA in arbitrary stage of optimization search.

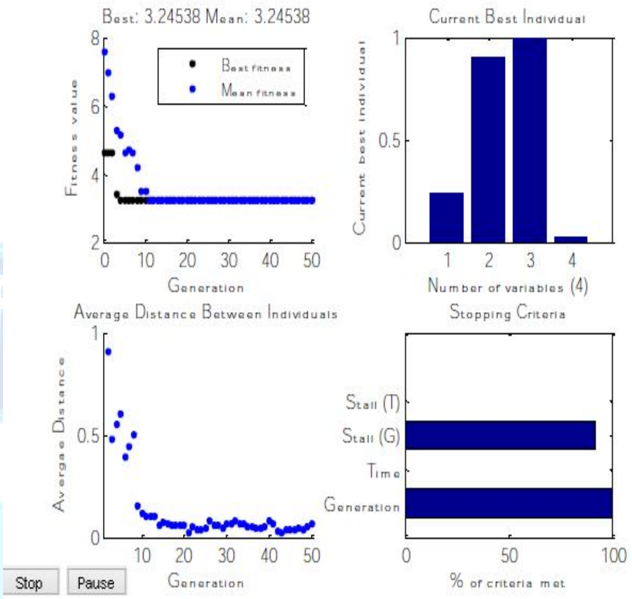

Fig. 8. Plot showing GA final stage of optimization search.

Optimized Result

xoptimum = -1 1 1 -1

Optimum input values: 40 14 8 5

SR at optimized input value: 3.2454

9. Conclusion:

This work used input parameters such as voltage, current, TON and TOFF values processed into three levels -1 to +1 to find the optimum input parameter conditions for minimized surface roughness for EDM machine. The subsequent conclusions can be derived from the experiments and study that were done on the MMC of Aluminium alloy 7075, with zinc as the primary alloying element. Artificial Neural Network is applied as estimation method for efficiently use in quality control by estimating surface roughness during in which the experimental design is combined with the quality loss. Using four input parameters surface roughness estimator is trained using ANN learning by gradient descent method by using experimental set up design result data where two responses mean square error and regression coefficient are used as combined form together to validate training accuracy of ANN model. From the analysis it reveals that surface roughness depends significantly on these factors and hence performance are found affected more on the surface quality. A genetic algorithm based optimization code is developed that utilizes the ANN estimator results and optimal searching has been carried out for input parameters at which we can get minimum surface roughness. After getting the optimal settings of voltage, current, TON and TOFF values as 40, 14, 8, 5 the value of surface roughness was found to 3.2454 µm.

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