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Experimental Analysis of (triaxial /3D) Machining Cutting Forces and Surface Roughness in Turning Operation OF EN8 Steel

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Abstract: The measurement of all machining forces and surface finish during the turning process. All types of machining process the cutting tool, workpiece of surfaces roughness, tool wear, quality, and accuracy of the part of machining the present study.to investigate the effect of machining input parameters (spindle speed, feed rate, depth of cut) on measuring the forces after machining (cutting force, feed force, thrust force) and surface roughness for turning operation. Using of workpieces is EN8 steel and a cutting tool is a carbide tool. experiment stabilized on the lathe machine. The force is measured by a triaxial piezoelectric sensors base dynamometer and data is transmitted by a data aquation system. this is controlled by LAB-VIEW software and stores the forces in the computer. there are 27 experiments, and one parameter is changed and two parameters are constant at an experiment. measured the forces and (Ra) is analyzed is by minitab18 software design a regression equation and (ANOVA). The minimum force and (Ra) the experimental (force &surface roughness is nearest to the predicted value
Keywords: Dynamometer, data equation system, LAB-VIEW software, Minitab 18 software

I. INTRODUCTION

The process of material removal (turning operation) is using the machining component manufacturing required dimension, the accuracy of the workpiece, and surface finish. this experiment uses a triaxial piezoelectric sensor-based dynamometer to measure the machining forces of the turning operation on the lathe machine. Using of workpieces are EN8 steel and the cutting tool is a carbide tool. The dynamometer is mounted on a lathe machine and holds a cutting tool. When the machining input parameter (spindle speed, feed rate, depth of cut) varies according to the lathe machine properties. time of machining workpieces is contacting to the cutting tool the workpiece generates a force on a dynamometer and when the forces is acting on the dynamometer this produces an electric charge and further transfers the charge in the data aquation system through the connecting cable. The data aquation system is change the electric charge to numerical/digital values and this is controlled by LAB-VIEW software and stores the forces in the computer. this research takes 27 experiments to change input parameter spindle speed (186,269,315), feed rate (0.15,0.2,0.25) depth of cut (0.25,0.5,0.75) measured all machining forces (feed force, thrust force, cutting force) and surface roughness is measured by roughness taster after machining of workpieces. all the forces and surface roughness are analysis predicted by using of Taguchi approach .to find the best machining parameter.

II. EXPERIMENTAL SETUP

The experimental setup has been carried out to measure the various triaxial forces, (cutting force, trusted force, and feed forces) generated by the workpiece on the cutting tool during the turning operation on the lathe machine.

The turning operation is performed on the lathe machine (JKLS-LM-500*300) of 50 kilograms. with the selection process of machining parameters according to the machine's limitations. such as some variable parameters on the Machine. The machining parameters are Spindle speed, feed rate, and depute of cut. The cutting tool is used as a carbide tool for the turning operation and the tool is fitted to the dynamometer with a help of a tool holder. and the dynamometer is used (Kristle 9327C) triaxial load cell type. A dynamometer is a triaxial piezoelectric sensor-based, measuring three forces (Fx Fy Fz) Sensors are included in between a tool holding cover plate and base plate fitted on a lathe machine. The dynamometer is connected to a distribution box with a connecting cable and further connects the charge amplifier and data aquation system. DAQ is controlled by LAB-VIEW software on the computer. LAB-VIEW is a graphical programming language this software has created a program on lab-view software to control, and measure the machining forces. measure the surface roughness of the machining workpieces.

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A. Experimental Workpiece.

In this experiment using the workpiece EN8 steel has tensile strength for an unalloyed average carbon steel EN8 is provided the batter surface finish, hardness, and dust resistance treatment of hardness process. EN8 steel is used in engineering field applications. The chemical contributions (%) elements of EN8 steel as shown in the table.

Table 1.
Chemical Composition of EN8 steel.

Elements	S	P	Si	Mn	C	Cr	Ni	Fe
Weight	0.015	0.026	0.2	0.65	0.42	0.01	0.01	Remaining

III.MACHINING PARAMETERS

This is using of lathe machine for the turning operation of the EN8 steel diameter of the workpieces is 24 mm. this experiment is 3^3 types of experiment. Three input variable parameters (spindle speed, depth of cut & feed rate) in a 27 experiment.

Table 2.
Lathe machine input parameters

tool bit material	Carbide
spindle speed (rpm)	186, 269, 315
Feed (mm/rev)	0.15, 0.2, 0.25
depth of cutting (mm)	0.25, 0.5, 0.75

Table 3.
The experiment of the input parameter of turning operation for cutting force

Ex no	Spindle Speed (rpm)	Feed rate (mm/rev)	DOC (mm)
1	186	0.15	0.25
2	186	0.15	0.5
3	186	0.15	0.75
4	186	0.2	0.25
5	186	0.2	0.5
6	186	0.2	0.75
7	186	0.25	0.25
8	186	0.25	0.5
9	186	0.25	0.75
10	269	0.15	0.25
11	269	0.15	0.5
12	269	0.15	0.75
13	269	0.2	0.25
14	269	0.2	0.5
15	269	0.2	0.75
16	269	0.25	0.25
17	269	0.25	0.5
18	269	0.25	0.75
19	315	0.15	0.25
20	315	0.15	0.5
21	315	0.15	0.75
22	315	0.2	0.25
23	315	0.2	0.5
24	315	0.2	0.75
25	315	0.25	0.25
26	315	0.25	0.5
27	315	0.25	0.75

Table 4.
measure Cutting forces on LAB- VIEW Software in computer simulation and surface refresh measure

Ex no	Spindle Speed (rpm)	Feed rate (mm/rev)	DOC (mm)	Cutting force (fz)	Feed Force(fy)	Thrust Force(fx)	Resultant Force(N)	Ra (µm)
1	186	0.15	0.25	182.33	83.64	72.13	213.17	4.824
2	186	0.15	0.5	387.99	145.43	121.54	431.8	5.261
3	186	0.15	0.75	663.59	348.01	133.33	761.07	5.891
4	186	0.2	0.25	236.61	78.96	115	274.67	4.016
5	186	0.2	0.5	407.26	172.12	132.8	461.65	6.658
6	186	0.2	0.75	606.12	282.79	171.88	690.47	7.733
7	186	0.25	0.25	244.55	66.3	108.64	275.68	5.701
8	186	0.25	0.5	489.44	206.35	155.28	553.39	5.942
9	186	0.25	0.75	875.59	406.21	283.91	1006.11	7.969
10	269	0.15	0.25	151.22	64.53	75.15	180.77	5.708
11	269	0.15	0.5	399.98	191.03	117.95	458.68	6.707
12	269	0.15	0.75	694.69	343.52	143.93	788.2	6.951
13	269	0.2	0.25	207.99	65.96	90.75	236.31	3.932
14	269	0.2	0.5	482.79	222.57	154.96	534.45	5.632
15	269	0.2	0.75	694.25	339.08	152.24	787.48	5.987
16	269	0.25	0.25	244.32	63.88	104.57	273.32	4.15
17	269	0.25	0.5	513.12	219.98	194.81	591.29	4.638
18	269	0.25	0.75	809.36	383.04	234.14	925.52	6.002
19	315	0.15	0.25	134.15	45.72	59.99	153.9	3.951
20	315	0.15	0.5	388.06	195.58	88.38	443.45	4.252
21	315	0.15	0.75	484.34	226.54	121.83	548.4	6.651
22	315	0.2	0.25	172.14	61.96	99.16	208.09	4.7
23	315	0.2	0.5	361.27	158.77	172.99	430.87	4.815
24	315	0.2	0.75	657.07	291.09	199.71	745.89	6.122
25	315	0.25	0.25	221.2	55.2	97.17	247.82	4.354
26	315	0.25	0.5	490.41	225.77	197.86	574.99	4.67
27	315	0.25	0.75	787.29	409.05	213.39	912.51	7.255

IV. RESULT AND DISCUSSION

A. *Investigational Result Of The Resultant Forces Of The Dynamometer Is Based On The Triaxial Piezoelectric Sensor*

Table 4 process of the Lathe machine of turning operation and measuring the triaxial forces on the LAB-VIEW Software with Help of a data aquation system and arranging the resultant cutting forces. the minimum resultant force obtained is 153.90N with a spindle speed is 315 rpm, feed 0.15 mm/rev, and depth of cut is 0.25mm, and the maximum resultant force obtained is 1006.11N with a spindle speed is 168 rpm, feed 0.25mm/rev, and depth of cut is 0.75mm. of the 27 experiments the experimental resultant forces and predicted forces are very closeness that the measured cutting force. The reside is different from the resultant forces and predicted force.

Fig. 1 observation order with the plot for the aspect of 27 experiment values. the points were connected not showing a particular model, most of the points across the centreline with negative and positive show the selected variable the limit, and the executed model was good, fig .2 shows the normal probability plot for the experiment of cutting force all point near to the probability line the module is designed by the Taguchi method.

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B. *Regression Equation*

Cutting force (fz) = -244.7 – 0.285 Spindle Speed + 1321 Feed force + 995.1 DOC

Feed Force(fy) = -141.2 – 0.074 Spindle Speed + 435 Feed force + 542.9 DOC

Thrust Force(fx) = -87.2 – 0.0376 Spindle Speed + 728 Feed force + 184.8 DOC

Resultant Force(N) = -292.2 – 0.288 Spindle Speed + 1535 Feed force + 1133.8 DOC

Table 5
ANOVA Analysis of resultant cutting force.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	1498373	499458	89.94	0.000
Spindle speed	1	7319	7319	1.32	0.263
feed	1	95613	95613	17.22	0.000
doc	1	1395441	1395441	251.29	0.000
Error	23	127721	5553		
Total	26	1626093			

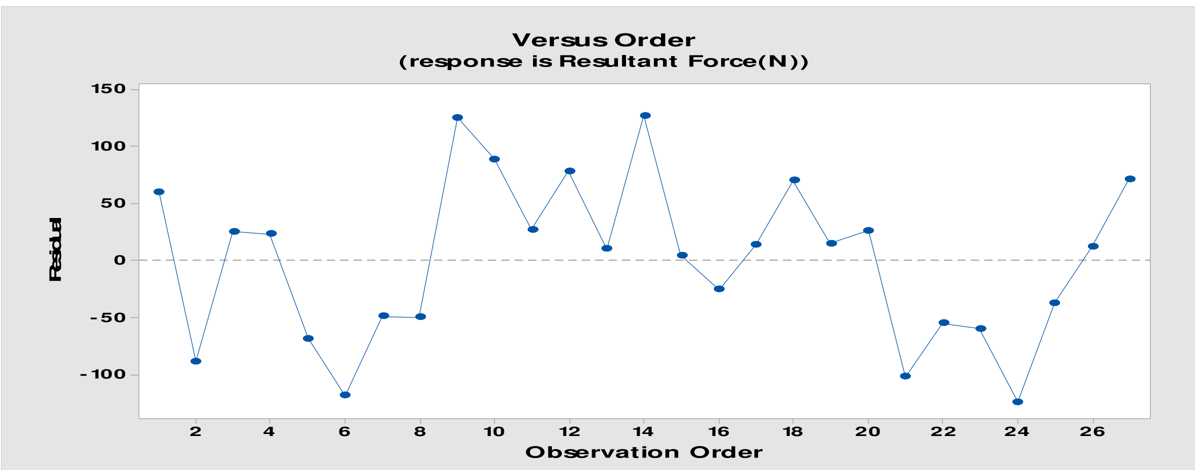

Fig.1. observation order Vs Residual cutting forces.

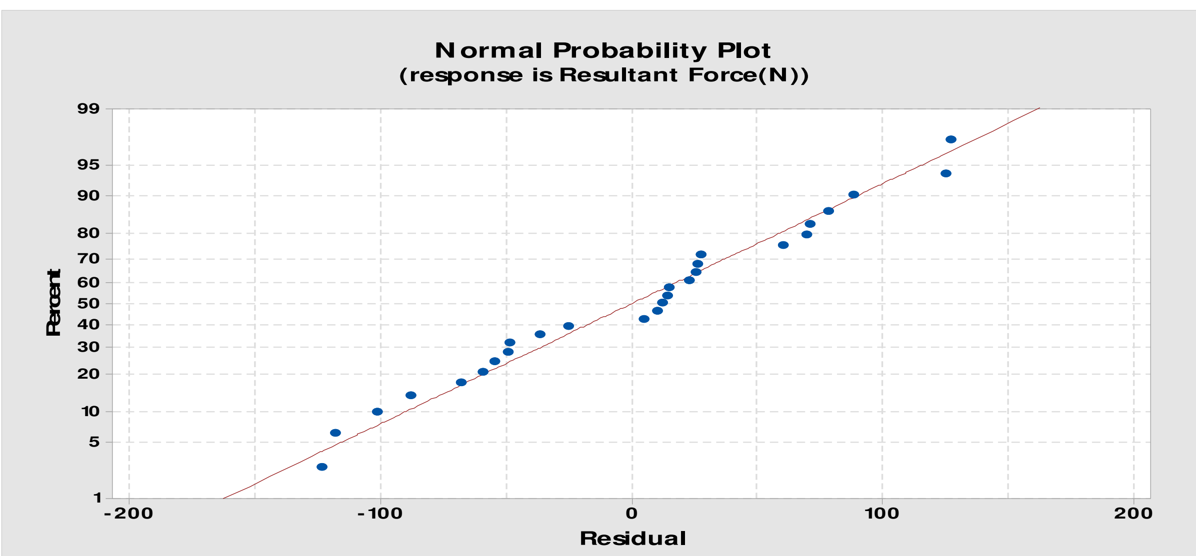

Fig.2. Normal probability plot for cutting force

Table 6
Experimental Resultant cutting force and predicted cutting force.

Resultant Force(N)	Predicted	Residual
238.82	178.77	60.04
368.81	457.22	-88.39
761.07	735.64	25.42
274.67	251.65	23.01
461.65	530.09	-68.44
690.47	808.52	-118.05
275.68	324.54	-48.86
553.39	602.97	-49.58
1006.11	881.4	124.7
241.50	153.17	88.32
458.68	431.61	27.07
788.20	710.04	78.15
236.31	226.05	10.25
631.16	504.49	126.66
787.48	782.92	4.55
273.32	298.94	-25.62
591.29	577.37	13.91
925.52	855.81	69.71
153.90	138.99	14.9
443.45	417.42	26.02
594.32	695.85	-101.53
156.94	211.87	-54.93
430.87	490.31	-59.43
645.06	768.73	-123.67
247.82	284.75	-36.93
574.99	563.18	11.8
912.51	841.61	70.89

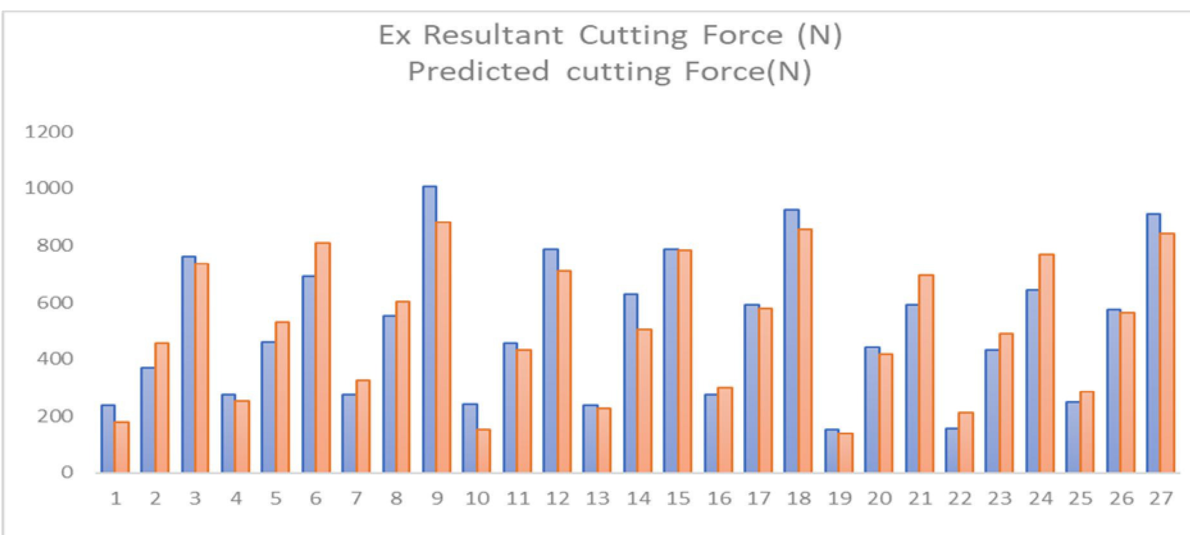

Fig.3. EX Resultant cutting force vs trials

C. Investigational Result Of The Surface Roughens (RA) Of The Workpiece After Machining

Table.4 the workpiece after machining measured the surface roughens by a roughness tester. The minimum (Ra) is (3.932) µm with variable parameters is spindle speed 269N, feed rate 0.2mm/rev, and depth of cut 0.25mm. the maximum (Ra) is (7.969) µm with variable parameter is spindle speed 186N, feed rate 0.25mm/rev, and DOC 0.75mm. the residue is a difference of measured (Ra) and the predicted (Ra) is calculated by the Taguchi equation.

Fig.4 The points across the centreline with negative and positive show the selected variable was within the limit and the executed model is best.

Fig .5 shows the normal probability plot for the measured surface roughness of all points near the probability line the module is designed by the Taguchi method.

D. Regression Equation

Surface roughness = 4.91 – 0.00617 Spindle Speed + 0.54 Feed force + 4.272 DOC

Table 7.
ANOVA Analysis of Surface roughness.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	23.4709	7.8236	13.94	0.000
spindle speed	1	2.9245	2.9245	5.21	0.032
Feed	1	0.0131	0.0131	0.02	0.880
Doc	1	20.5334	20.5334	36.58	0.000
Error	23	12.9096	0.5613		
Total	26	36.3805			

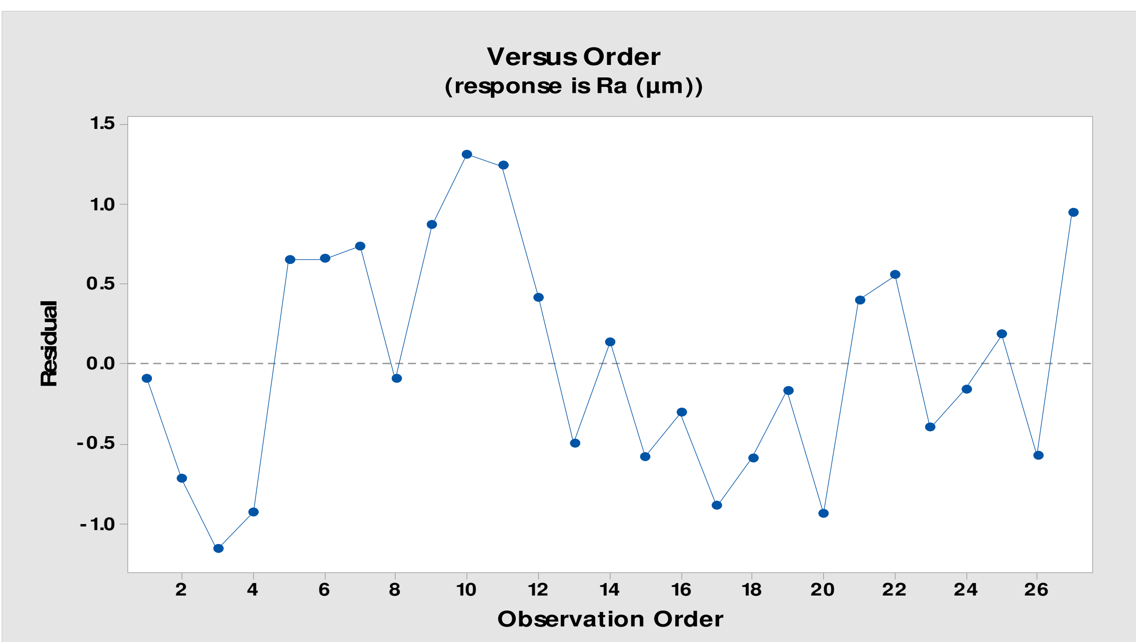

Fig.4. observation order Vs Residual surface roughness.

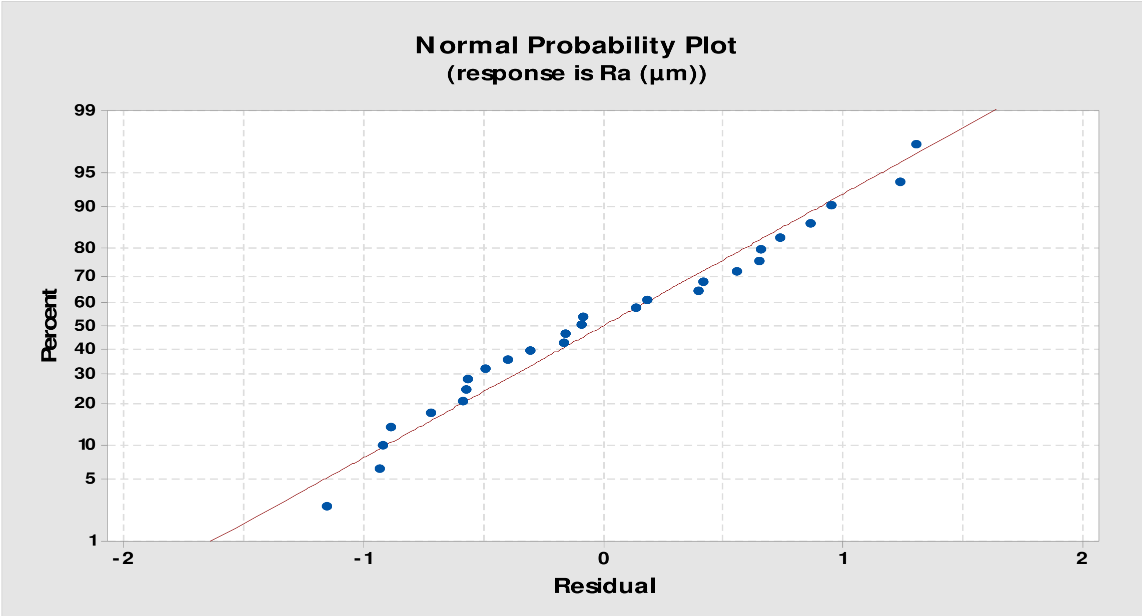

Fig.5. Normal probability plot for surface roughness.

Table 8.
Experimental surface roughness (Ra) and predicted (Ra) .

measured Ra (µm)	predicted Ra (µm)	Resid Ra (µm)
4.824	4.914	-0.09
5.261	5.982	-0.721
5.891	7.05	-1.159
4.016	4.941	-0.925
6.658	6.009	0.649
7.733	7.077	0.656
5.701	4.968	0.733
5.942	6.036	-0.094
7.969	7.104	0.865
5.708	4.402	1.306
6.707	5.47	1.237
6.951	6.538	0.413
3.932	4.429	-0.497
5.632	5.497	0.135
5.987	6.565	-0.578
4.15	4.456	-0.306
4.638	5.524	-0.886
6.002	6.592	-0.59
3.951	4.118	-0.167
4.252	5.186	-0.934
6.651	6.255	0.396
4.7	4.145	0.555
4.815	5.213	-0.398
6.122	6.281	-0.159
4.354	4.172	0.182
4.67	5.24	-0.57
7.255	6.308	0.947

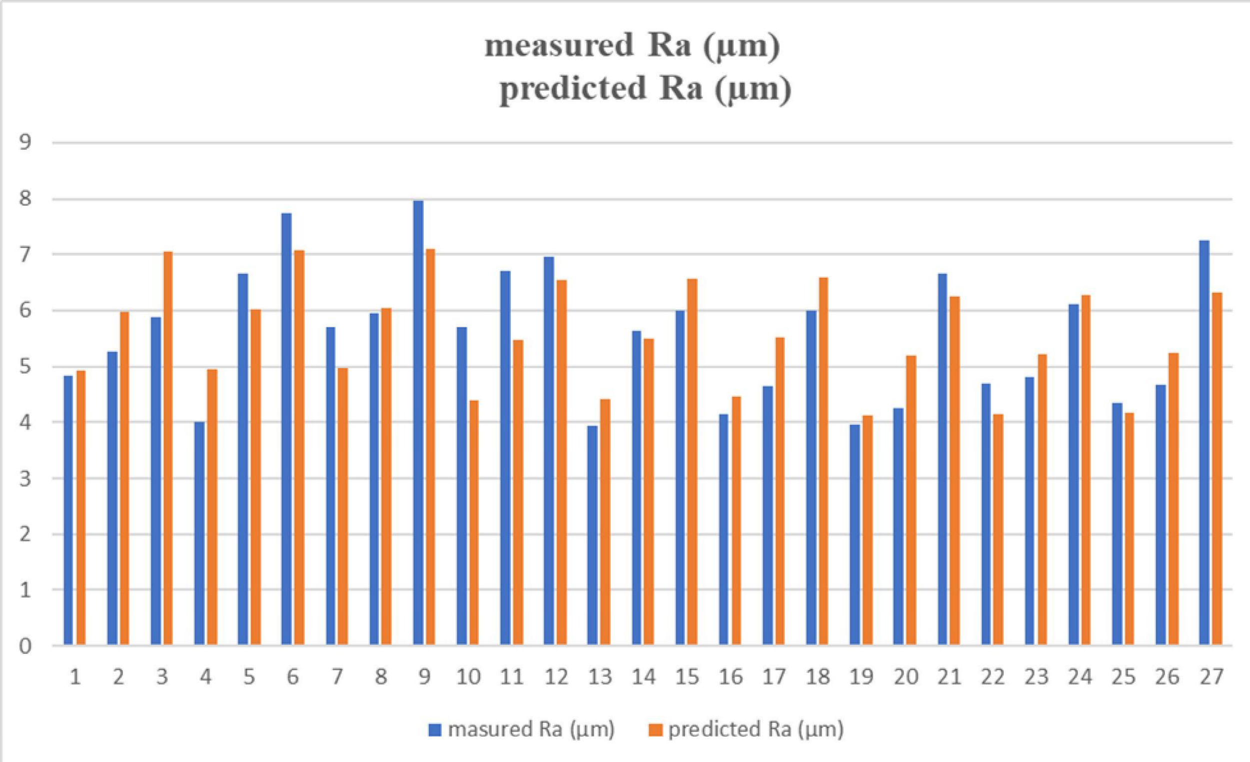

Fig.6. EX surface roughness vs trials

E. Investigational Result Of The Resultant Forces And Suffuse Roughens Of The Experiment

Table 8. shows the 27 experiments' resultant force and surface roughness measured by roughness texture values as analysis of the best surface finish of the workpieces the minimum Ra (3.932, 3.951) µm of the resultant force (236.31,153.9) N and Veraval of machining input spindle speed (269,315) rpm, feed (0.2,0.15) mm/rev and DOC (0.25,0.25) in the parameters.

V. CONCLUSIONS

This study presents on the basis of 27 experimental of machining forces measured by dynamometer and surface roughness measured by roughness texture. The analysis of the value by minitab18 software to design a Taguchi method for the optimization of machining force and surface finish by using a carbide cutting tool on EN-8 steel. generate a regression equation to calculate a predicted value.in this experiment and predicted value of very close. The input parameter spindle speed (269,315) rpm, feed (0.2,0.15) mm/rev, DOC (0.25,0.25) for resultant force is (236.31,153.9) N and Ra is (3.932, 3.951) µm, minimum machining forces, and surface roughness in this experiment for EN 8 steel.

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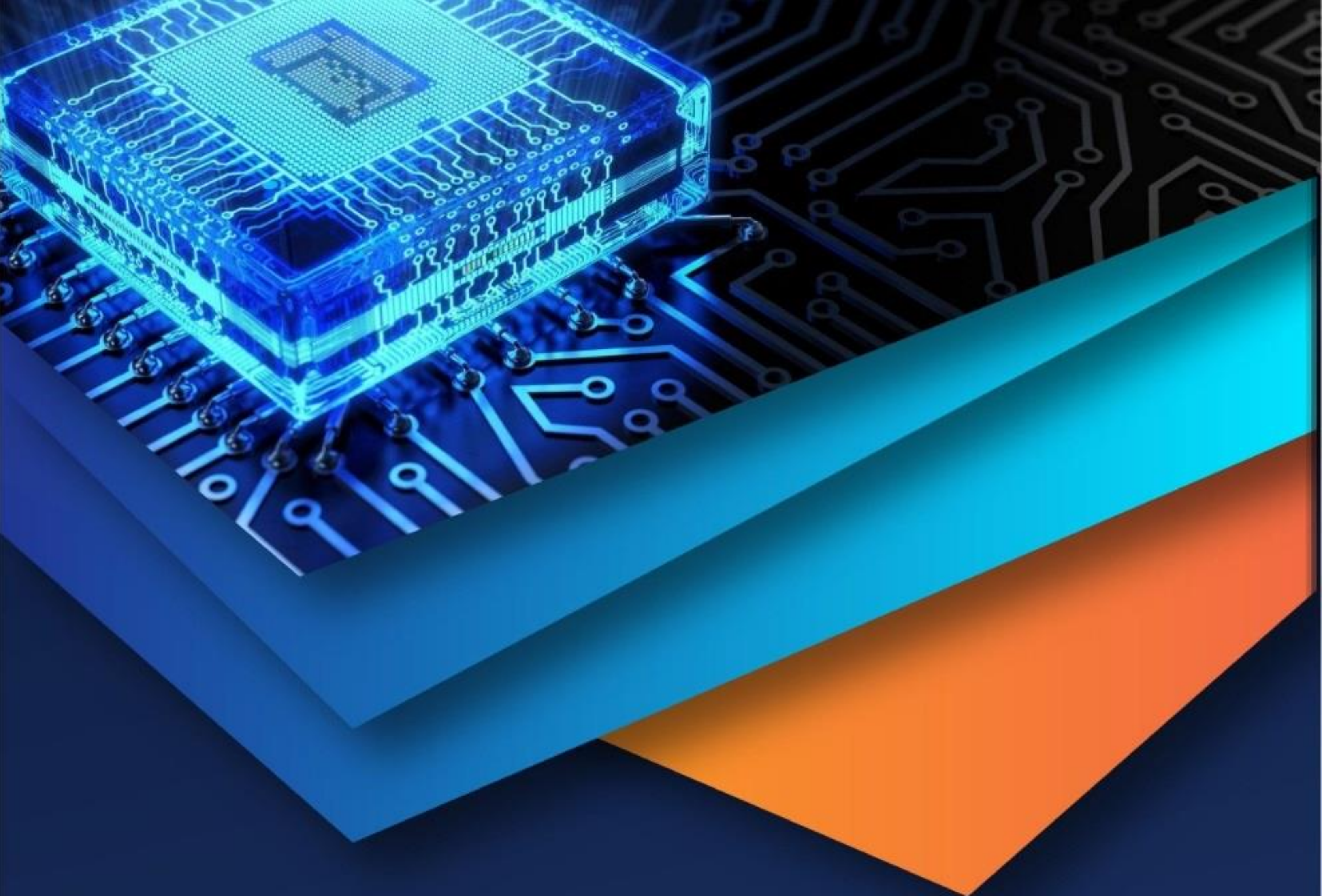

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