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Comparison of Conventional and Wiper Inserts on Surface Roughness During Hard Turning of AISI 410

R. Adithya[1], G. Pradeep Kumar[1], V. Krishnaraj[1*]

[1]PSG College of Technology, Coimbatore, 641004, INDIA

*Corresponding Authors

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Abstract. Reduction in the cost of production is one of the import aspects in the manufacturing field, low production cost and good surface finish are one of the major factors which are often looked into by many industries. This work focuses on the study of the effect of wiper inserts on surface roughness over conventional inserts during turning of AISI 410 steel using the all-gear lathe in dry condition with a constant depth of cut. To evaluate the influence of wiper inserts and to predict the surface roughness, modeling of this process is done. Design of experiments is based on the full factorial design for a three-factorial two-level design. Cutting speed, feed, and type of inserts are taken as input parameters and surface roughness and dynamic force are taken as a response. To evaluate the significance of input parameters and their interactions, ANOVA was used. Type of insert was found to be the most influencing parameter followed by feed influencing surface roughness. Feed was found to be the most influencing parameter affecting dynamic force. The optimum parameters for minimum surface roughness are wiper type insert, cutting speed of 150 (m/min) and feed of 0.15 (mm/rev).

Keywords: AISI 410, hard turning, wiper inserts, surface roughness, full factorial design

1. Introduction

Consideration time and effort have been spent by various manufacturing industries to produce components with suitable surface-finishes. Various improvements such as geometry modification of cutting inserts and new coatings for cutting edges have been made to increase productivity and maintain the high quality of the product. AISI 410 steel is 12% chromium high hardenability martensitic steel with excellent corrosion resistance and strength. It is widely used in applications of steam turbine parts bolts and gas turbine parts. Traditionally AISI 410 is machined by the grinding process to achieve surface finish below 0.3 microns. Generally grinding process is a time-consuming process and is limited due to geometrical constraints of the workpiece. The conventional grinding operations are being replaced by hard turning process in many manufacturing industries. Kumar et al. [1] experimented with the effect of the hard turning of ASI D2 steel on surface roughness and obtained a good surface finish of fewer than 1.2 microns. D'Addona et al. [2] concluded that wiper inserts give superior surface finish over conventional inserts in hard turning of hardened steel. He et al. [3] proposed a theoretical model to predict surface roughness using influential parameters in the turning process. Rao et. Al [4] developed an RSM model to describe the performance of process parameters on surface roughness during turning of niobium alloy C-103. Sivaraos et al. [5] used CCD to create an L32 design to compare the performance between Taguchi and RSM techniques and concluded that RSM provides significant results compared to Taguchi. Patole et al. [6] experimented the turning operation on AISI4340 under MQL and concluded that low feed rate (0.04m/min), cutting speed (75 m/min), depth of cut (0.5mm) and tool nose radius (0.4mm) are the optimal cutting levels of the parameters for better surface finish. Zhang et al. [7] concluded that MRR and surface finish could be improved by using wiper inserts but rapid flank wear is prone to occur in dry turning using wiper inserts. Liu et. Al [8] concluded that the Ra value is decreased by half by using wiper inserts compared to conventional inserts in finish turning. Abouelatta et al. [9] developed two models

**Corresponding author: vkrishnaraj@hotmail.com*
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to predict roughness parameters (Ra, Rt, and Rsk), one with cutting parameters with tool vibration and the other with cutting parameters only and concluded that inclusion of tool vibration significantly increased the accuracy of the model. Rogov et al. [10] experimented on the effect of process parameters and tool overhang on surface roughness and vibration and concluded that process parameters influence the surface roughness and tool overhang and feed rate influences the natural frequency of the tool vibration. Damping materials such as OHNS are used to reduce vibration in tool and provides better surface roughness, reduced cutting force and tool wear [11]. ANOVA is used to estimate the importance of parameters and their interactions by comparing the response variable means at different factor levels. Mahadev et al. [12] used S/N ratio to find out the optimal levels of each process parameter and concluded that spindle speed (220m/min), feed rate (0.1mm/rev) and depth of cut (0.5mm) leads to the better surface finish. In this paper, the effect of wiper inserts over conventional inserts on surface roughness is studied and the influence of the dynamic force of the tool is observed. Cutting speed, feed, depth of cut, type of inserts is taken as input parameters. Surface roughness and dynamic force are taken as a response. The experiment is designed using full factorial design. ANOVA is used to find the most influencing parameter. S/N ratio is performed to find a suitable level of each parameter.

2. Experimentation

The process parameters taken are cutting speed, feed, and insert type with a constant depth of cut. Table 1 shows the factors and levels. From the previous literature reviews, wiper inserts can produce similar or even better surface finish compared to conventional inserts when the feed is doubled. Thus, two levels of feed are taken to check the variation in surface roughness.

Table 1 - Process parameters and their levels

Parameters	Level 1	Level 2
Cutting speed (m/min)	150	200
Feed (mm/rev)	0.15	0.25
Insert type	Conventional	Wiper

The process was designed with an L8 full factorial design with three parameters at two levels. Table 2 shows the L8 factorial design with parameters for the experiment. The experiment is carried out in Pinnacho lathe in dry condition. The types of inserts used are conventional and wiper inserts. The geometry of two inserts is compared in Fig. 1, wiper insert is designed with two wiper edges that are situated where the straight edge meets the corner radius. In comparison to conventional breakers, the surface finish does not deteriorate even if the feed rate is doubled.

Table 2 - L8 Factorial design

Cutting Speed (m/min)	Feed (mm/rev)	Insert type
200	0.15	Wiper
200	0.25	Wiper
200	0.15	Conventional
150	0.15	Wiper
200	0.25	Conventional
150	0.25	Conventional
150	0.25	Wiper
150	0.15	Conventional

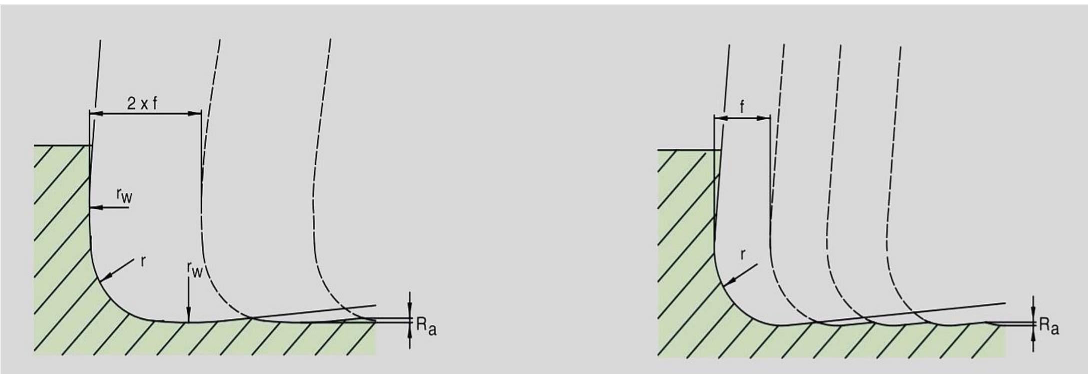


Fig. 1 - Comparison of geometry between conventional and wiper inserts

The accelerometer is mounted on the tool holder to measure dynamic force amplitude along the feed direction and depth of cut. The setup is shown in Fig. 2. Response from the accelerometer is manipulated by using DAQ and interpreted by LabVIEW software. The conventional insert has a smoothly curved tip, whereas the wiper insert nose is slightly flattened. Due to this, the sharp points formed during machining are smoothened which gives an excellent finish. After finishing the turning process, the surface roughness (Ra) was measured using the surface roughness tester (Mitutoyo-Surftest SJ 410). A cut-off length of 0.8mm is used. The drive mechanism on the SJ-410 can be controlled simply by manipulating the icon on the LCD monitor. The measurement was taken at two various positions of the shaft and the average of these two measurements was taken as corresponding roughness value Ra.

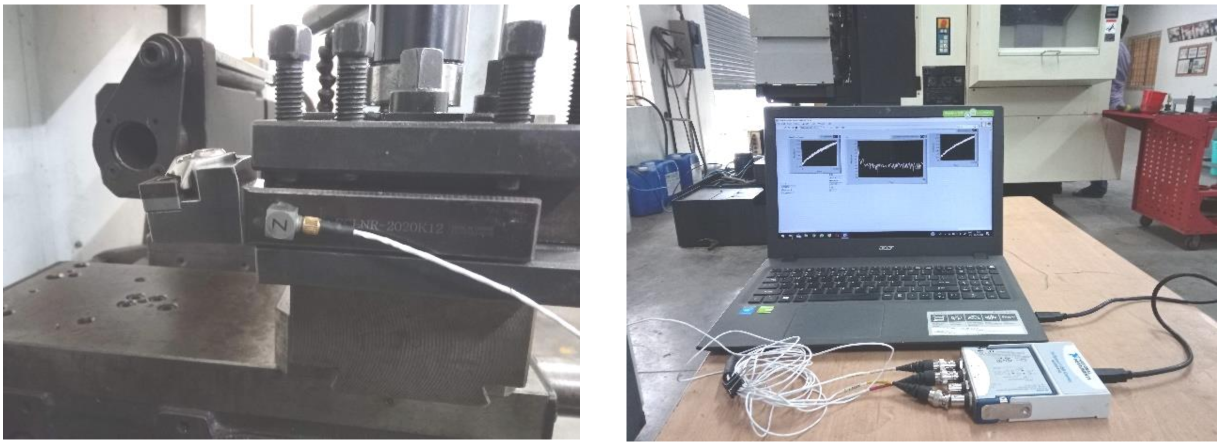


Fig. 2 - Experimental setup of the process

3. Results and Discussion

The experimental plan along with the results from the machined surface is represented in Table 3. The surface roughness is predicted using the Equation (1) as follows:

$$RA = 1.670 + 0.033\, insert\ type - 0.00653\, speed - 0.85\, feed - 0.000315\, insert\ type * speed - 1.652 * insert\ type * feed + 0.02665\, speed * feed \quad (1)$$

Table 3 - Experimental results

Cutting speed (m/min)	Feed (mm/rev)	Insert type	Surface roughness (m)	Dynamic force (m/s^2)
200	0.15	W	0.425	2.590
200	0.25	W	0.6085	0.680
200	0.15	C	0.7685	1.672
150	0.15	W	0.6495	1.090
200	0.25	C	1.029	1.104
150	0.25	C	1.0605	1.365
150	0.25	W	0.6115	1.050
150	0.15	C	0.889	1.980

The R^2 value of the regression equation is 0.997 which is close to 1 shows that the model is effective and provides a good fit of the data. Minitab is used to conduct ANOVA using Ra as a response and is shown in Table 4. The model is tested at 95% confidence interval.

Table 4 - ANOVA for surface roughness

Source	Adj SS	Adj MS	F-Value	P-Value	Cont.%
Model	0.32028	0.05338	54.52	0.103	
Linear	0.29763	0.09211	101.34	0.073	
Insert type	0.24798	0.24798	253.30	0.040	77.42
Speed	0.01407	0.01407	14.37	0.164	4.39
Feed	0.03557	0.03557	36.34	0.105	11.10
2-Way Interaction	0.02265	0.00755	7.71	0.257	
Insert type*Speed	0.00012	0.00012	0.13	0.782	7.07
Insert type*Feed	0.01365	0.01365	13.95	0.167	0.03
Speed*Feed	0.00887	0.00887	9.07	0.204	4.26
Error	0.0009	0.00097			2.76
Total	0.3212				

The model is significant and effective due to the F-value of 54.52. The contribution of error to the model is low at 2.76%, thus supporting the model is valid. All the parameters and two-way interactions (concurrent changes between two parameters) between insert type and feed, speed and feed are significant. The most influencing parameter is the type of insert used. Using dynamic force as a response, ANOVA is conducted, and feed is the only parameter influencing dynamic force.

Table 5 - ANOVA for dynamic force

Source	Adj SS	Adj MS	F- Value	P-Value	Cont.%
Model	2.17927	0.36321	0.79	0.696	
Linear	1.32949	0.44316	0.96	0.616	
Insert type	0.06319	0.06319	0.14	0.774	2.899595
Speed	0.03934	0.03934	0.09	0.819	1.805192
Feed	1.22696	1.22696	2.67	0.350	56.30142
2-Way Interaction	0.84978	0.28326	0.62	0.707	
Insert type*Speed	0.36083	0.36083	0.79	0.538	38.99379
Insert type*Feed	0.07354	0.07354	0.16	0.758	16.55738
Speed*Feed	0.41542	0.41542	0.90	0.516	3.374524
Error	0.45936	0.45936			19.06235
Total	2.63863				

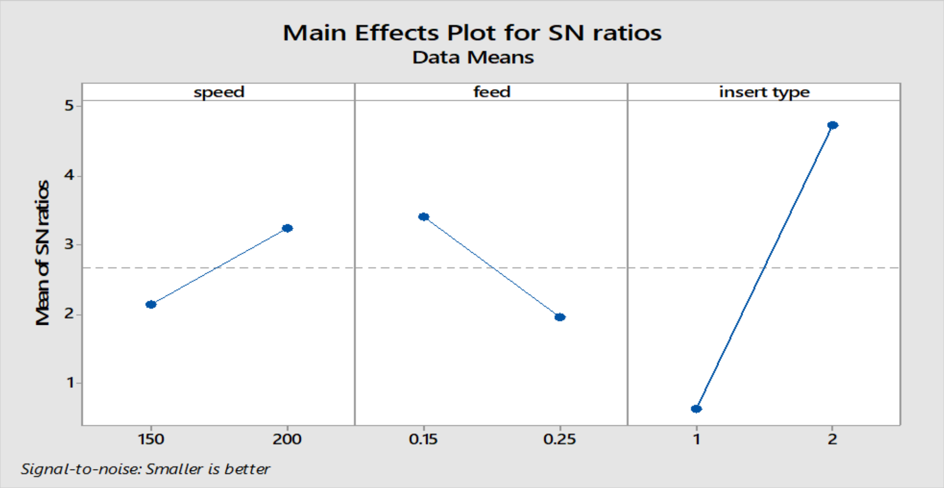


Fig. 3 - Signal to noise ratio

Based upon the measured surface roughness value, S/N ratio is calculated. The influence of each level of the factor on surface roughness is shown in Fig. 3. S/N ratio is calculated using the smaller-the-better principle. The equation for S/N ratio is given by equation (2)

$$S/N = -10\log\left(\frac{1}{M}\sum_{1}^{M} y_i^2\right) \quad (2)$$

The optimum level of each factor is selected based upon the highest S/N value for each parameter. The optimum level for each factor is 200 m/min of cutting speed, 0.15 mm of the depth of cut, and wiper insert type. To enrich the results of ANOVA, surface roughness profile shows that wiper insert has a smoother profile compared to conventional insert as shown in Fig. 4 and Fig. 5, where there is reduced variation in the vertical scale on the wiper insert when compared to the vertical scale on the conventional insert.

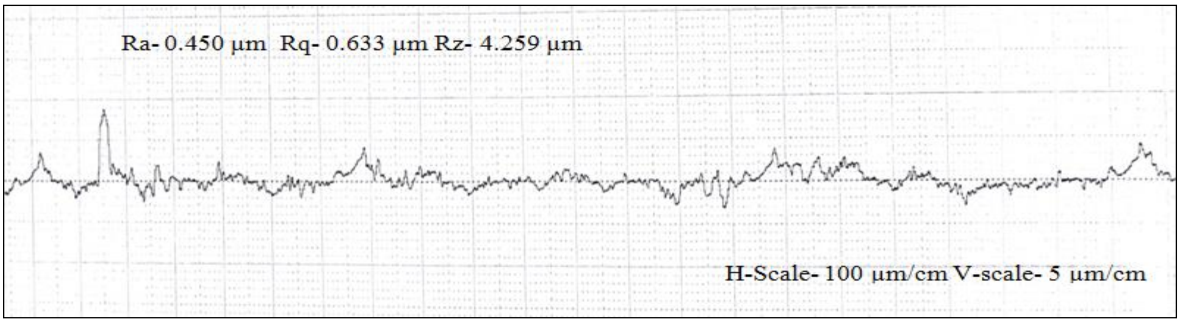


Fig. 4 - Surface roughness profile of the wiper insert

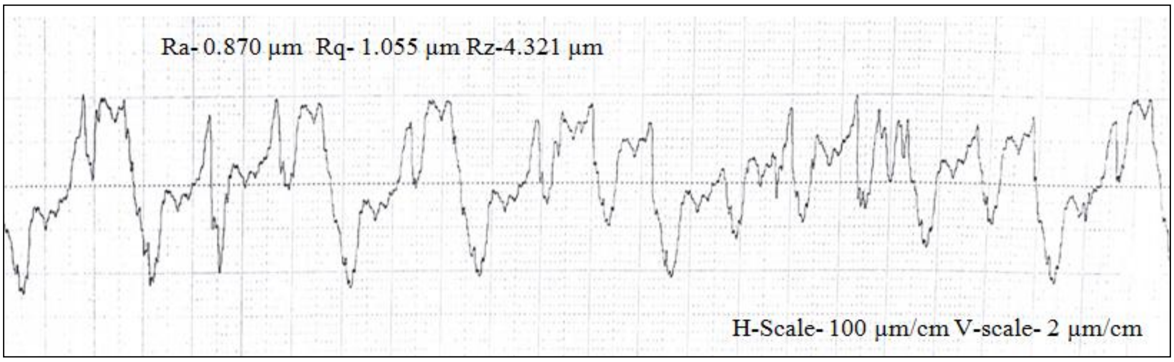


Fig. 5 - Surface roughness profile of the conventional insert

From the contour plot of feed vs. insert type as shown in Fig. 6. the minimum surface roughness value is in the zone of feed (0.15mm/rev) and wiper type of insert. From the contour plot of insert type vs. speed as shown in Fig.7. the minimum surface roughness value is in the zone of cutting speed (200m/min) and wiper type of insert.

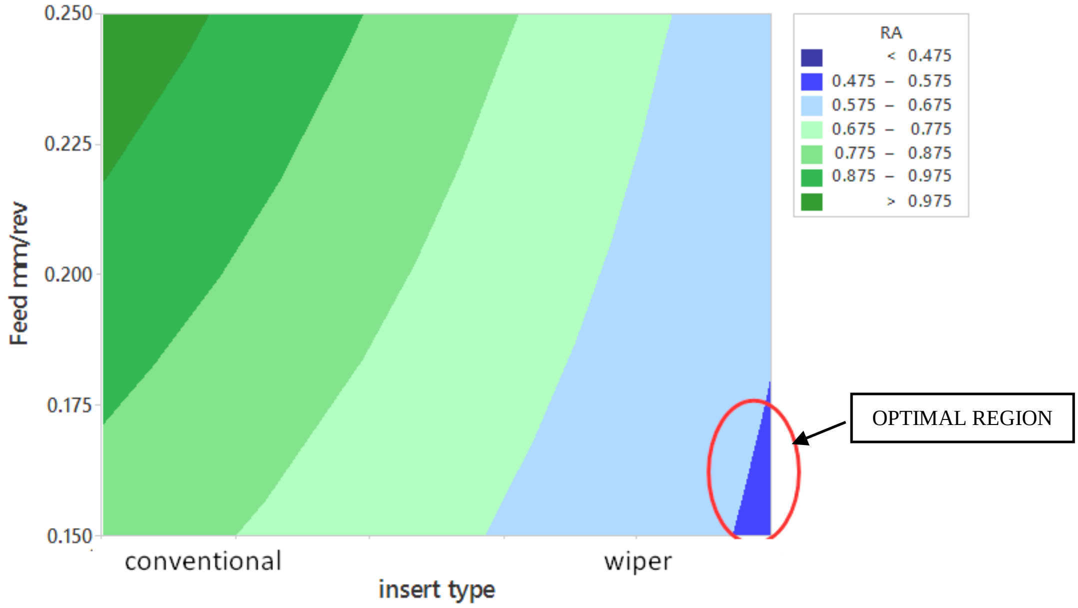


Fig. 6 - Contour plot of surface roughness vs. feed vs. type of insert

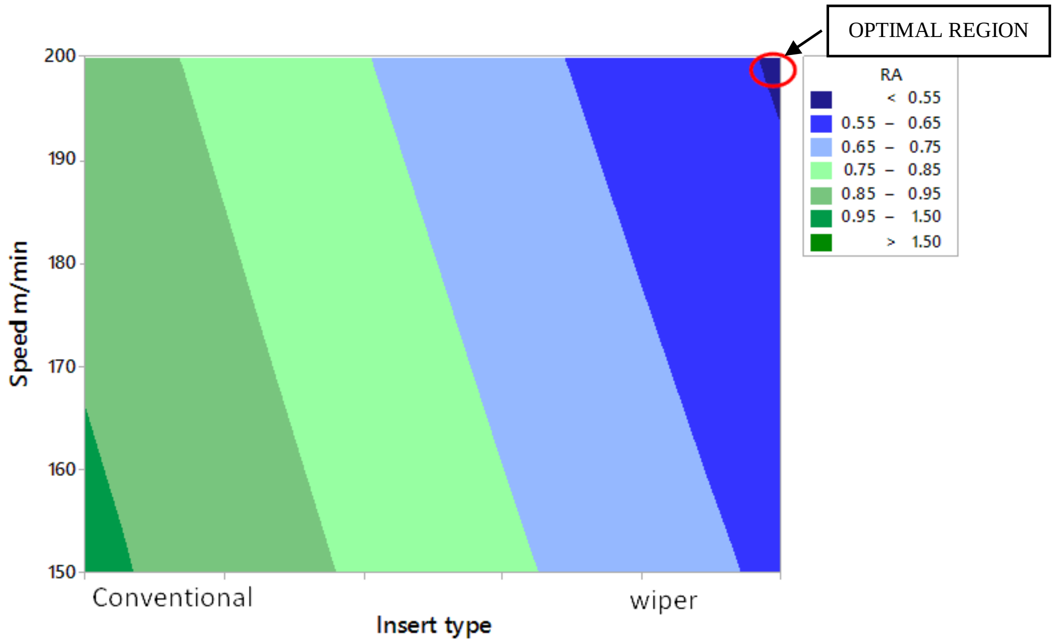
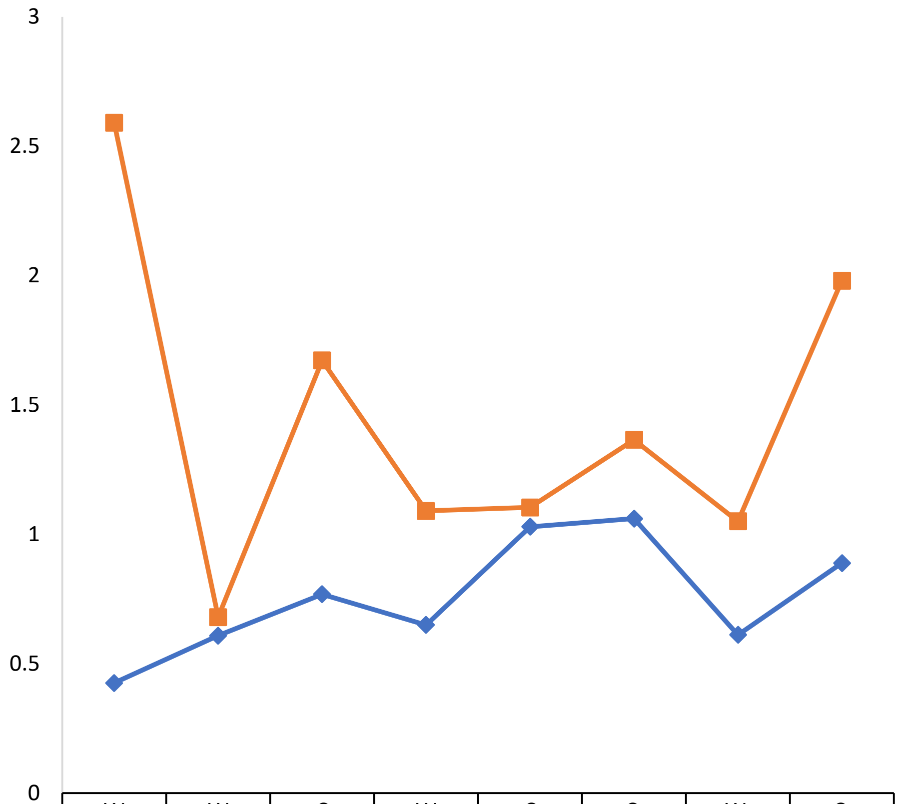


Fig. 7 - Contour plot of surface roughness vs. speed vs. type of insert

From Fig. 8, even though the dynamic force is maximum at the low feed (0.15 mm/rev) and high cutting speed (200m/min), the surface roughness value is minimum. This shows that dynamic force has a limited influence on surface roughness.



	W	W	C	W	C	C	W	C
Surface roughness m	0.425	0.6085	0.7685	0.6495	1.029	1.0605	0.6115	0.889
Dynamic force m/s^2	2.59	0.68	1.672	1.09	1.104	1.365	1.05	1.98

Fig. 8 - Trendline of Responses

4. Conclusion

The turning of AISI410 steel was done using both conventional and wiper inserts in this experiment and the following conclusions can be drawn. The experimental design was done using a full factorial design. A mathematical model between surface roughness and the input variables was produced using regression. The effects of cutting speed (m/min), feed (mm/rev), insert type were experimentally investigated. Inset type followed by feed and cutting speed has a significant influence on surface roughness. Only feed has a significant influence on the dynamic force. Using the signal to noise ratio, the optimum level of each factor for minimum surface roughness is cutting speed (200m/min), feed (0.15mm/rev) and wiper type of insert. Even though low feed produces more dynamic force, the surface roughness obtained is superior compared to high feed thus, dynamic force along the feed has limited influence on surface roughness. Due to the combination of blend radii (r1, r2) show in Fig. 2, the sharp points are knocked off leading to the better surface finish.

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