# Optimization of Turning Process Parameters for AISI (M3) Material: As a Case of Multi response Optimization

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## Abstract

The present study focuses on the multi-objective optimization of turning process parameters for the AISI M3 tool steel material. The turning process is performed using a CNC machine. The experimental conditions are characterized by a lack of moisture in the surrounding environment. The primary objective of this study is to identify the optimal turning process parameters that will provide both the highest surface polish and the highest material removal rate concurrently. The study determined that a cutting speed of 300m/min, a feed rate of 0.15mm/rev, a depth of cut of 0.75mm, and a nose radius of 1.2mm resulted in the optimal values for both Ra and MRR in the turning process. The specified criterion for this step is nominal. Both the values of Ra and MRR exhibit an upward trend as the cutting speed increases. Both the values of Ra and MRR drop as the feed rate increases. The values of Ra and MRR first rise and subsequently decline. The values of Ra and MRR both rise as the nose radius increases.

***Keywords:*** Ra, MRR, CNC, Multi-objective, AISI M3, Dry Turning.

## 1. INTRODUCTION

Advancements in current technology have enabled the practicality of hard turning. The procedure involves the production of solid items using sophisticated gear. The process of high-precision machining is faced with several challenges, one of which pertains to choosing a tool insert that provides improved durability for the tool. Industries including cutting tool manufacture, ball bearing production, automobile manufacturing, gear production, and die making all have a common interest in the technique of using a single-point cutting tool to convert hardened materials. Hard turning offers several benefits over traditional grinding. The benefits include lower equipment costs, shorter setup times, and fewer process steps. As a result, these elements lead to increased flexibility and the ability to create complex shapes. Hard turning often entails the exclusion of cutting fluid, hence decreasing the need for storing, handling, and disposing of this fluid. Facilitating the well-being of operators is advantageous.

The technology of CNC turning machines has seen substantial advancements to satisfy the advanced needs in numerous production industries, particularly in the precision metal cutting business. Turning is a key machining operation among several CNC industrial machining techniques. It is extensively used in several industrial sectors.

The material removal rate (MRR) and surface roughness (Ra) are crucial parameters in machining operations. MRR is a metric that quantifies the level of production. Ra is a metric used to quantify the level of quality. The objective is to reduce the Ra value and increase the MRR value by the ideal choice of cutting speed, feed rate, depth of cut, and insert nose radius.

## 2. LITERATURE REVIEW

This section comprises a curated collection of papers aimed at doing a thorough analysis to identify any gaps in research or potential areas for future expansion in the field of hard turning. The chosen articles for the study are as follows:

Alok, A., & Das, M. (2019) [1] executed a new type of coating material, HSN2 with 12 µm thickness on carbide insert by using physical vapor deposition technique for machining hard AISI 52100 steel of hardness 55 HRC is evaluated. DSC and TGA assess coated carbide insert thermal and oxidative stability. Cutting speed, feed rate, and depth of cut affect primary cutting, radial and feed pressures, maximum flank wear, and workpiece surface quality. Statistics examine how cutting parameters affect machinability. Regression models connect input and output process features. A response surface optimisation and validation test follows. The confirmation test found percentage errors for main cutting force, radial force, feed force, surface roughness, and flank wear. Maximum tool wear is 292 m, which is ISO 3685-compliant. Cutting speed works best among output parameters. The current endeavor is unusual in that it machines AISI 52100 steel with a 55 HRC hardness at 102–287 m/min with a new 12 m-thick HSN2 coating.

Aouici, H., et al. (2012) [2] investigated experimentally the effects of cutting speed, feed rate, workpiece hardness and depth of cut on surface roughness, and cutting force components in the hard turning. Sandvik milled AISI H11 steel with cubic boron nitride (CBN 7020), a 57% CBN/35% TiCN blend. They employed ANOVA for four-factor (cutting speed, feed rate, hardness, and depth of cut) and three-level fractional experiments. This method represents surface roughness and cutting force components mathematically. The depth of cut and workpiece hardness have the greatest impact on cutting force components, while feed rate and hardness affect surface roughness statistically. Finally, industrial production cutting circumstances should be optimised.

Aouici, H., et al. (2011) [3] investigated turning conditions of hardened AISI H11 (X38CrMoV5-1), the effects of cutting parameters on flank wear (VB) and surface roughness (Ra) using the CBN tool. The response surface method is utilised in machining experiments. This study examines how cutting speed, feed rate, and duration affect two performance outputs (VB and Ra) (ANOVA). The ideal cutting conditions for each performance level are calculated using quadratic regression. The findings show that flank wear is primarily affected by cutting time, then speed. Feed rate appears to be the key factor affecting workpiece surface roughness.

Azizi, M. W., et al. (2012) [4] investigated the effect of cutting parameters (cutting speed, feed rate, and depth of cut) and workpiece hardness on surface roughness and cutting force components. Coated Al2O3 + TiC mixed ceramic cutting tools on AISI 52100 steel. The experiment was planned using Taguchi's L27 orthogonal array. The response table and ANOVA helped us validate the linear regression model and discover surface roughness and cutting force components. The statistical investigation found that depth of cut, workpiece hardness, and feed rate affect cutting force components more than cutting speed. Empirical models linked cutting parameters, workpiece hardness, surface roughness, and cutting forces. The desired function technique for multiple response factor optimisation was used to identify the best machining settings for low surface roughness and low cutting force. The presented empirical models were validated via experiments.

Azizi, M. W., et al. (2020) [5] optimized machining parameters to achieve the desired technical parameters such as surface roughness, tool radial vibration, and material removal rate using response surface methodology (RSM). Hard turning EN19 alloy steel with GC3015) cutting tools was studied. Hard and high-precision component manufacturers face a big difficulty in surface finish quality and manufacturing rate. RSM can solve this problem using a mathematical model and tests. A face-centered central composite design (FCCD) with cutting parameters (speed, feed rate, and depth of cut) was used in the statistical analysis. Cutting parameters affected surface roughness, tool vibration, and material removal. The ideal cutting parameters for surface roughness, tool vibration, and material removal rate were found using a desirability function and numerical and graphical optimisation. The mathematical models were validated by experiments.

Bouzid, L., et al. (2015) [6] attempted to statistically model the relationship between cutting parameters (speed, feed rate, and depth of cut), cutting force components (Fx, Fy, and Fz), and workpiece absolute surface roughness (Ra). The AISI 420 martensitic stainless steel is subjected to machining using a chemical vapour deposition (CVD)-coated carbide tool. The full-factorial design with a 4^3 configuration is used to assess experimental outcomes via the application of analysis of variance (ANOVA) and response surface methodology (RSM). The best cutting conditions are determined by the interaction of mutually responsive surfaces and desire functions, while the accuracy of the model is confirmed by the residual values. The surface roughness (Ra: 81%) is influenced by the depth of cut (Fx: 86%), dominance (Fy: 58%), and feed rate (Fz: 81%). The observed cutting force and surface roughness exhibited a strong agreement with the expected values. The results were examined for potential inaccuracies, with the following percentages of inaccuracy identified: Fx (6.51 percent), Fy (4.36 percent), Fz (3.59 percent), and Ra (5.12 percent). Ultimately, it is essential that the ranges for industrial production cutting be optimised.

Cakir, M. C., et al. (2009) [7] examined the effects of cutting parameters (cutting speed, feed rate, and depth of cut) onto the surface roughness through the mathematical model developed by using the data gathered from a series of turning experiments performed. Another research was conducted to investigate the impact of two commonly used coating layers on surface roughness. Two CNMG 120408 carbide inserts, designated according to the International Organisation for Standardization (ISO), were subjected to testing under comparable cutting circumstances. These inserts had identical geometry and substrate, but differed in terms of their coating layers. The machining process was performed using AISI P20 cold-work tool steel. Insert 2 is subjected to a physical vapour deposition (PVD) process, resulting in the application of a thin layer of titanium aluminium nitride (TiAlN) measuring 31 micrometers in thickness. On the other hand, Insert 1 undergoes a chemical vapour deposition (CVD) process, which involves the deposition of a titanium carbonitride (TiCN) underlayer, an aluminium oxide (Al2O3) intermediate layer, and a titanium nitride (TiN) outer layer. The average error of the model was found to be 4.2 percent for Insert 1 and 5.2 percent for Insert 2, indicating a measure of dependability for the equations.

Das, D. K., et al. (2014) [8] investigated surface roughness during hard machining of EN 24 steel with the help of coated carbide insert. Testing was done in dry conditions. The Grey-based Taguchi approach optimised process parameters. The regression-based surface roughness prediction models were also evaluated. Hard machining yields 0.42micron surface roughness. The grey-based Taguchi technique's optimum depth of cut (Ra) and cutting speed (Rz) were 0.4 mm, 0.04 mm/rev, and 130 m/min. Feed matters more for Ra and Rz. The prediction models have high R2 values (0.993 and 0.934). This improves model fit and is important.

Das, S. R., et al. (2015) [9] investigated the dry hard turning of AISI 4140 steel using PVD-TiN coated Al2O3+TiCN mixed ceramic inserts. This ANOVA examines how cutting factors (cutting speed, feed, and depth of cut) affect performance variables like surface roughness and flank wear. Surface roughness is most affected by cutting feed and speed. Though not statistically significant, flank wear is a function of incision depth. The process is established by SEM studies on the machined surface and worn tool. Abrasion dominated wear throughout the range. Also examined were tool wear and surface roughness. It predicted flank wear and surface roughness. With 95% confidence, RSM-based mathematical models for surface roughness (Ra) and flank wear (VB) were created. Tool life was examined under ideal cutting conditions (obtained by response optimisation) to justify coated ceramic inserts in hard turning. TiN coated ceramic has a 51-minute tool life and a reduced anticipated machining cost per item (Rs. 12.31).

Das, S. R., et al. (2017) [10] addressed surface roughness, flank wear, and chip morphology during dry hard turning of AISI 4340 steel (49 HRC) using CVD (TiN/TiCN/Al2O3/TiN) multilayer coated carbide tool. Taguchi's L9 Orthogonal array (OA) and ANOVA examined how cutting parameters affect tool and workpiece flank wear and surface roughness. SEM was utilised to investigate machined workpiece surface topography, coated carbide tool wear, and chip morphology. Thus, multiple regression analysis was utilised to develop a mathematical model for each response, and several diagnostic tests were done to verify its validity and utility. Finally, a Gilbert's method cost analysis (recommended by response optimisation methodology) showed coated carbide tools' economic feasibility in hard turning. Statistics show that feed and cutting speed effect surface roughness and flank wear. Faster cutting improves flank wear and surface polish. Abrasion from flank land rubbing on machined surface and high cutting temperatures damage tools. Saw-tooth chip morphology shows significant serration from cyclic fracture propagation caused by plastic deformation. Hardened AISI 4340 steel with a coated carbide tool costs $0.13 per item to machine. A multilayer TiN/TiCN/Al2O3/TiN coated carbide tool for hard turning in dry cutting circumstances is cheaper than cylindrical grinding, according to the study. Alternatives to CBN and ceramic tools are cheaper.

Davoodi, B., et al. (2015) [11] investigated the effects of cutting parameters on tool life of PVD TiAlN-coated carbide tools, and volume of workpiece material removed during the machining of the N-155 iron–nickel-base superalloy is evaluated. Cutting variables comprised five levels of feed rate and speed. RSM modelled machining parameter-output variable interactions. ANOVA tested the mathematical model and variables. Overall, model projections and actual tool life and material removed matched well. SEM was used to study cutting tool insert wear at various speeds. Adhesion caused most tool failures. Finally, the intended function approach improved tool life and material removal for productivity.

Davoodi, B., et al. (2014) [12] investigated the effects of cutting speed and undeformed chip thickness on cutting and feed force components, and tooltip temperature was experimentally investigated in order to remove the cutting fluid. AA5083-O wrought alloy with 4.5% Mg was machined dry and wet using coated carbide tools. ANOVA was employed in two-factor (cutting speed and undeformed chip thickness) and five-level fractional experiments. Cutting, feed force, and tool tip temperature (RSM) mathematical models were created using this strategy. Results show that undeformed chip thickness influences output variables. AA5083 may be machined without fluid at high speed and low undeformed chip thickness. Cutting speed and chip thickness statistically affect cutting and feed force in dry and wet machining. We finally have industrial production-friendly turning circumstances.

Devi, K. D., et al. (2015) [13] studied an optimization problem that seeks the identification of the best process condition or parametric combination for the said manufacturing process. Single-objective optimisation involves one quality characteristic. When several characteristics are evaluated, choosing the best choice that fulfils all quality requirements is tough. This study solved a Multi-Objective Optimisation problem by straight turning brass bar using Response Surface Methodology. Research sought the best process environment for quality and productivity. Finally, the study evaluates how cutting speed, feed, depth of cut, and coolant type affect output parameters. The predicted optimal setting reduced surface roughness and increased MRR, tool life, and machinability index. The confirmatory test confirmed the perfect result.

Dureja, J. S., et al. (2009) [14] attempted to model the tool wear and surface roughness, through response surface methodology (RSM) during hard turning of AISI-H11 steel with TiN-coated mixed ceramic inserts. Using ANOVA and factor interaction graphs in the RSM, machining parameters such cutting speed, feed rate, depth of cut, and workpiece hardness were examined on flank wear and surface roughness. This model matches experiments best. A desirability function optimizes several response components. Validation trials predicted response factors within 5%. Surface roughness and flank wear depend on feed rate, workpiece hardness, and depth of cut. A toolmaker's microscope monitored tool wear, and SEM-EDX characterized typical inserts. Rubbing and impingement of hard work material particles causes tool surface abrasion, notch wear, and chipping.

On the strength of the review of work done by previous researchers, it is found that a considerable amount of work has been carried out by previous investigators for modeling, simulation and parametric optimization of surface properties of the product in turning operation. Issues related to tool life, tool wear, cutting forces have been addressed to. But no work is found on multi-objective optimization of turning process parameters for AISI M3 tool steel.

## 3. EXPERIMENTAL SETUP

### 3.1 SIZE OF SAMPLE

Nine sample of material AISI (M3) is taken for experimentation. The size of sample is Ø 17× 120.

Figure1.Taper Shank Twist Drill

### 3.2 CHEMICAL COMPOSITION

The chemical composition of AISI (M3) is shown in following table:

Table 1: Chemical Composition of Sample [15]

| Element | Symbol | % |
|---|---|---|
| Carbon | C | 1.15 – 1.25 |
| Chromium | Cr | 3.75 – 4.50 |
| Molybdenum | Mo | 4.75 – 6.50 |
| Tungsten | W | 5.00 – 6.75 |
| Vanadium | V | 2.25 – 2.75 |
| Cobalt | Co | Nil |

### 3.3 CUTTING TOOL AND TOOLHOLDER

The cutting tool selected for present research work is Tin Coated Tungsten Carbide inserts. The inserts used in present work are TNMG 160404,TNMG 160408,TNMG160412 Taegutec company (as per ISO coding).The tool holder used is HCLNL 2525M0904.

### 3.4 EXPERIMENTAL UNIT

ACE Designer Ltd. Make CNC turning centre with Fanuc Oi-mate-TD controller is used to carry out the experimentation.

Figure 2. Experimental Unit

Table 2. Specification of CNC machine

| | |
|---|---|
| Max.turning diameter | 300 mm |
| Max.turning length | 400 mm |
| Max.spinde speed | 3500 rpm |
| Supply voltage | 380 v/4.5v |
| Number of axis | 2 |
| Control voltage | 24 VDC |
| Back up fuse | 63 |
| Rated current | 24/22 Amps |
| Environment | Dry |

## 3.5 PLYSICAL AND MECHANICAL PROPERTIES OF MATERIAL

Table 3: Properties of AISI (M3) [15]

| Properties | Value |
|---|---|
| Density | 8.9 kg/m$^3$ |
| Melting point | 4680$^0$ |
| Hardness | 62-65 HRC |
| Compressive yield strength | 3250 Mpa. |
| Poisson’s ratio | 0.27-0.30 |
| Elastic modulus | 190-210 |

## 3.6 APPLICATION OF MATERIAL

The cutting tool business uses AISI (M3) material for the production of twist drills, reamers, taps, and cold forming tools like extrusion rams and dies. Additionally, it is used in the creation of plastic moulds that need high wear resistance and screw preparation.[16]

### 3.7 EXPERIMENTAL PROCEDURE

AISI (M3) is taken for machining and their weight before machining and after machining were precisely recorded and cycle time is recorded from screen. The MRR is calculated by using formula:

$$MRR = Wi - Wf\ /\rho s * t \quad mm^3/sec \text{(Eq.1)}$$

Where, $W_i$ = Initial weight of work piece in *gm*

$W_f$ = Final weight of work piece in *gm*

$t$ = Machining time in seconds

$\rho s$= Density of mild steel

= ($8.028x\ 10^{-3}$ $gm/mm^3$).

and surface roughness value is recorded with help of Make–Strumentazione, Model-RT10G,L.C.0.001µm

Figure 3. Jobs for Surface Roughness Checking

## 4. DESIGN OF EXPERIMENT

The selection of particular orthogonal matrix from the standard orthogonal array depends on:

1.Number of control factors

2.Nmber of levels for each control factor

3.Total degree of freedom of factor

In present research work consists of four parameters such as cutting speed, feed rate, depth of cut and nose radius and is used three level thereforeaccording to MINITAB software, the most suitable orthogonal arrayis $L_9(3^4)$.

Table 4: Control factors and their levels

| Levels | Control factors | | | |
|---|---|---|---|---|
| | Cutting speed (m/min) | Feed rate (mm/rev) | Depth of cut (mm) | Nose radius (mm) |
| Level 1 | 150 | 0.15 | 0.5 | 0.4 |
| Level 2 | 220 | 0.22 | 0.75 | 0.8 |
| Level 3 | 300 | 0.28 | 0.8 | 1.2 |

After level finalization the selected orthogonal array is designed in following manner.

Table 5: Taguchi’s $L_9$ Orthogonal Array

| Exp.No | Cutting speed (m/min) A | Feed rate (mm/rev) B | Depth of cut (mm) C | Nose radius (mm) D |
|---|---|---|---|---|
| 1 | 150 | 0.15 | 0.5 | 0.4 |
| 2 | 150 | 0.22 | 0.75 | 0.8 |
| 3 | 150 | 0.28 | 0.8 | 1.2 |
| 4 | 220 | 0.15 | 0.75 | 1.2 |
| 5 | 220 | 0.22 | 0.8 | 0.4 |
| 6 | 220 | 0.28 | 0.5 | 0.8 |
| 7 | 300 | 0.15 | 0.8 | 0.8 |
| 8 | 300 | 0.22 | 0.5 | 1.2 |
| 9 | 300 | 0.28 | 0.75 | 0.4 |

On the basis of Table 2 experimental trials are taken to find material removal rate and their related surface roughness values. The response values of each trial along with their S/N ratio is shown in following Table 3.

1. Condition of S/N ratio for surface roughness: smaller is better[17]

$$\eta = -10 \log \frac{1}{n} \sum_{i=1}^{n} yi^2 \qquad \text{(Eq.2)}$$

2. Condition of S/N ratio for Material removal rate: larger is better

$$\eta = -10 \log \frac{1}{n} \sum_{i=1}^{n} 1/yi^2 \qquad \text{(Eq.3)}$$

Where, η - Signal to Noise (S/N) Ratio,Yi – i$^{th}$observed value of the response, n - Number of observations in a trial, y - Average of observed values (responses) s – Variance

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Table 6. Response value table for MRR

| Exp. No | MRR (Trial1) $mm^3/sec$ | MRR (Trial 2) $mm^3/sec$ | Mean MRR $mm^3/sec$ | S/N Ratio dB |
|---|---|---|---|---|
| 1 | 205.011 | 212.79 | 208.901 | 46.39 |
| 2 | 307.51 | 328.53 | 318.020 | 50.03 |
| 3 | 368.90 | 368.90 | 368.900 | 51.33 |
| 4 | 218.87 | 232.51 | 225.690 | 47.05 |
| 5 | 305.96 | 323.08 | 314.520 | 49.94 |
| 6 | 375.60 | 363.15 | 369.375 | 51.34 |
| 7 | 225.91 | 224.21 | 225.060 | 47.04 |
| 8 | 308.29 | 313.74 | 311.015 | 49.85 |
| 9 | 345.90 | 337.28 | 341.590 | 50.66 |

Table 7. Response Value table for Ra

| Exp. No | Ra (Trial1) µm | Ra (Trial 2) µm | Mean Ra µm | S/N Ratio dB |
|---|---|---|---|---|
| 1 | 2.10 | 2.50 | 2.300 | -7.2673 |
| 2 | 2.68 | 2.63 | 2.655 | -8.4817 |
| 3 | 2.35 | 2.32 | 2.335 | -7.3659 |
| 4 | 0.95 | 0.45 | 0.700 | 2.5767 |
| 5 | 3.10 | 3.60 | 3.350 | -10.5250 |
| 6 | 3.50 | 3.38 | 3.440 | -10.7325 |
| 7 | 1.35 | 1.32 | 1.335 | -2.5102 |
| 8 | 1.20 | 1.31 | 1.255 | -1.9812 |
| 9 | 4.10 | 3.53 | 3.815 | -11.6541 |

Table 8. Mean Value Table for MRR

| Levels | Mean Value of MRR | | | |
|---|---|---|---|---|
| | Cutting Speed | Feed Rate | Depth of Cut | Nose Radius |
| Level 1 | 298.6 | 219.9 | 296.4 | 288.3 |
| Level 2 | 303.2 | 314.5 | 295.1 | 304.2 |
| Level 3 | 292.6 | 360.0 | 302.8 | 301.9 |

Table 9. Mean Value Table for Ra

| Levels | Mean Value of Ra | | | |
|---|---|---|---|---|
| | Cutting Speed | Feed Rate | Depth of Cut | Nose Radius |
| Level 1 | 2.430 | 1.445 | 2.332 | 3.155 |
| Level 2 | 2.497 | 2.420 | 2.390 | 2.477 |
| Level 3 | 2.135 | 3.197 | 2.340 | 1.430 |

## 5. MULTI-RESPONSE OPTIMIZATION

From the utility concept, the muti-response S/N ratio of the overall utility value is given by

$$\eta_{Obs} = W_1\eta_1 + W_1\eta_1 \qquad \text{(Eq.4)}$$

Where, $W_1$ and $W_2$are the weights assigned to the Ra and MRR. Assignment of weights to the performance characteristics are based on customer's requirements and their priorities.In the present work equal importance is given for both Ra and MRR. Therefore, $W_1$ and $W_2 = 0.5$

Table 10: Design matrix with multi-response S/N ratio

| Exp. | A | B | C | D | $\eta_{obs}$ |
|---|---|---|---|---|---|
| 1 | 150 | 0.15 | 0.75 | 0.4 | 19.56 |
| 2 | 150 | 0.22 | 0.8 | 0.8 | 20.77 |
| 3 | 150 | 0.28 | 1.5 | 1.2 | 21.98 |
| 4 | 180 | 0.15 | 0.8 | 1.2 | 24.81 |
| 5 | 180 | 0.22 | 1.5 | 0.4 | 19.70 |
| 6 | 180 | 0.28 | 0.75 | 0.8 | 20.30 |
| 7 | 300 | 0.15 | 1.5 | 0.8 | 22.26 |
| 8 | 300 | 0.22 | 0.75 | 1.2 | 23.93 |
| 9 | 300 | 0.28 | 0.8 | 0.4 | 19.50 |

Table 11: mean value of $\eta_{obs}$ at different levels

| Levels | Mean values of $\eta_{obs}$ for process parameters | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Level 1 | 20.77 | 22.21 | 21.27 | 19.59 |
| Level 2 | 21.61 | 21.47 | 21.70 | 21.11 |
| Level 3 | 21.90 | 20.60 | 21.32 | 23.58 |

## 6. RESULTS AND DISCUSSION

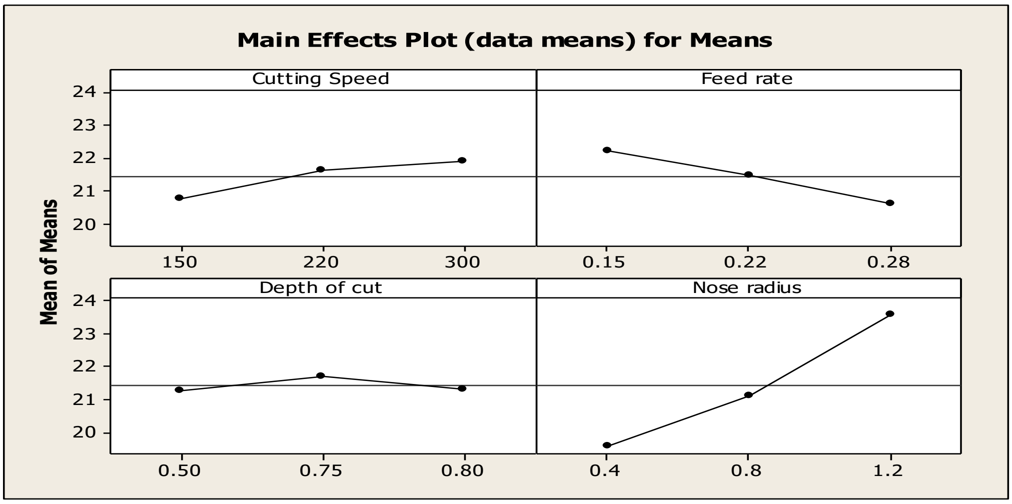

Figure 4. Multi-objective Optimization Output Graph

From above graph, it is concluded that
a) Ra and MRR both values increase with increase in cutting speed.
b) Ra and MRR both values decrease with increase in feed rate.
c) Ra and MRR both values increase first then decrease.
d) Ra and MRR both values increase with increase in nose radius.
The set of turning process parameters at which both factors such as Ra and MRR are at best state is as follows:

- Cutting Speed =300 m/min
- Feed Rate =0.15 mm/rev
- Depth of Cut = 0.75 mm
- Nose Radius = 1.2 mm

In this multi objective optimization stage, we have given equal importance to both values Ra and MRR.

## 7. CONCLUSION

Based on this study, it has been determined that the optimal levels for the multi-objective process parameters are A3, B1, C2, and D3. The optimal turning process parameters for achieving the optimum state of both variables, such as surface roughness (Ra) and material removal rate (MRR), are as follows: Cutting Speed = 300 m/min, Feed Rate = 0.15 mm/rev, Depth of Cut = 0.75 mm, Nose Radius = 1.2 mm.

## REFERENCES

[1]. Alok, A., & Das, M. (2019). Multi-objective optimization of cutting parameters during sustainable dry hard turning of AISI 52100 steel with newly develop HSN2-coated carbide insert. Measurement, 133, 288-302.

[2]. Aouici, H., Yallese, M. A., Chaoui, K., Mabrouki, T., &Rigal, J. F. (2012). Analysis of surface roughness and cutting force components in hard turning with CBN tool: Prediction model and cutting conditions optimization. Measurement, 45(3), 344-353.

[3]. Aouici, H., Yallese, M. A., Fnides, B., Chaoui, K., &Mabrouki, T. (2011). Modeling and optimization of hard turning of X38CrMoV5-1 steel with CBN tool: Machining parameters effects on flank wear and surface roughness. Journal of mechanical science and technology, 25(11), 2843-2851.

[4]. Azizi, M. W., Belhadi, S., Yallese, M. A., Mabrouki, T., &Rigal, J. F. (2012). Surface roughness and cutting forces modeling for optimization of machining condition in finish hard turning of AISI 52100 steel. Journal of mechanical science and technology, 26(12), 4105-4114.

[5]. Azizi, M. W., Keblouti, O., Boulanouar, L., &Yallese, M. A. (2020). Design optimization in hard turning of E19 alloy steel by analysing surface roughness, tool vibration and productivity. Structural Engineering and Mechanics, 73(5), 501-513.

[6]. Bouzid, L.; Yallese, M. A.; Chaoui, K.; Mabrouki, T.; Boulanouar, L. (2015). Mathematical modeling for turning on AISI 420 stainless steel using surface response

methodology. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 229(1), 45–61.

[7]. Cakir, M. C., Ensarioglu, C., &Demirayak, I. (2009). Mathematical modeling of surface roughness for evaluating the effects of cutting parameters and coating material. Journal of materials processing technology, 209(1), 102-109.

[8]. Das, D. K., Sahoo, A. K., Das, R., & Routara, B. C. (2014). Investigations on Hard Turning Using Coated Carbide Insert: Grey Based Taguchi and Regression Methodology. Procedia Materials Science, 6, 1351-1358.

[9]. Das, S. R., Dhupal, D., & Kumar, A. (2015). Study of surface roughness and flank wear in hard turning of AISI 4140 steel with coated ceramic inserts. Journal of Mechanical Science and Technology, 29(10), 4329-4340.

[10]. Das, S. R., Panda, A., &Dhupal, D. (2017). Experimental investigation of surface roughness, flank wear, chip morphology and cost estimation during machining of hardened AISI 4340 steel with coated carbide insert. Mechanics of Advanced Materials and Modern Processes, 3(1), 1-14.

[11]. Davoodi, B., &Eskandari, B. (2015). Tool wear mechanisms and multi-response optimization of tool life and volume of material removed in turning of N-155 iron–nickel-base superalloy using RSM. Measurement, 68, 286-294.

[12]. Davoodi, B., &Tazehkandi, A. H. (2014). Experimental investigation and optimization of cutting parameters in dry and wet machining of aluminum alloy 5083 in order to remove cutting fluid. Journal of Cleaner Production, 68, 234-242.

[13]. Devi, K. D., Babu, K. S., & Reddy, K. H. (2015). Mathematical Modeling and Optimization of Turning Process Parameters using Response Surface Methodology. International Journal of Applied Science and Engineering, 13(1), 55-68.

[14]. Dureja, J. S., Gupta, V. K., Sharma, V. S., & Dogra, M. (2009). Design optimization of cutting conditions and analysis of their effect on tool wear and surface roughness during hard turning of AISI-H11 steel with a coated—mixed ceramic tool. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 223(11), 1441-1453.

[15]. otaisteel.com/products/high-speed-steel/aisi-m3-steel-class2-2/

[16].Pawar, K., & Palhade, R. D. (2015). Multi-objective optimization of CNC turning process parameters for high speed steel (M2) using Taguchi and ANOVA method. International Journal of Hybrid Information Technology, 8(4), 67-80.

[17] Pawar, K., Selokar, G. R., & Deshmukh, A. (2017). Experimental Investigation to Minimize Resultant Vibration Signal in CNC Turing Operation of Hard AISI M2 Tool Steel. Int. J. Res. Appl. Sci. Eng. Technol., 5, 307-318.

[18] Pawar, K., Selokar, G. R., & Deshmukh, A. Optimization of Resultant Cutting Force in CNC Turning Process for Hard (62-64 HRC) AISI M2.