



# International Journal of Multidisciplinary Research in Science, Engineering and Technology

*(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)*



Impact Factor: 8.206

Volume 9, Issue 3, March 2026



## International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

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# Effect of Cutting Parameters on Product Quality in Turning Operation of Cast Iron using High Speed Steel Tool

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**ABSTRACT:** Cast iron remains a cornerstone material in automotive, machine tool, and construction industries due to its excellent castability, machinability, and damping properties. The turning operation is one of the most fundamental machining processes used to achieve final dimensional accuracy and surface integrity in cylindrical cast iron components. In order to finish a part or components, material removal is crucial. The amount of heat in the cutting area, tool wear, the precision of the product, and the quality of the machined surface can all be taken into account when evaluating a material's machinability using information regarding cutting forces during machining. The goal of the current study is to determine how cutting parameters (cutting speed, feed rate, and depth of cut) affect cutting forces (feed force, thrust force) and surface roughness when turning mild steel with a carbide tool and high speed steel (HSS).

**KEYWORDS:** Turning, Cast Iron, High Speed Steel (HSS), Surface Roughness, Dimensional Accuracy, Cutting Parameters, ANOVA, Product Quality.

## I. INTRODUCTION

Numerous scientists and engineers have studied the metal removal method. Cutting force measurements have advanced with the development of technology.

### 1.1 Background

Turning is a primary machining operation used to generate cylindrical surfaces. It accounts for a significant portion of all machining operations in industries such as automotive (e.g., brake drums, engine cylinders), heavy machinery, and piping. The quality of a turned component is multifaceted, encompassing surface finish, dimensional tolerance, geometric accuracy, and subsurface integrity. Among these, surface roughness and dimensional deviation are the most commonly specified quality criteria, directly affecting the component's fatigue life, wear resistance, and assembly fit.

### 1.2 Material and Tool Selection

Gray cast iron (GCI) is one of the most widely machined materials. Its unique microstructure, consisting of ferrite or pearlite matrix with free graphite flakes, provides excellent machinability by promoting chip breakage and acting as a solid lubricant at the tool-chip interface. High Speed Steel (HSS) tools, while largely superseded by cemented carbides for high-production turning, remain highly relevant for small to medium batch production, repair workshops, and for machining operations where tool cost, formability, and toughness are critical. HSS tools offer superior toughness compared to carbides, allowing them to withstand interrupted cuts and machine vibrations. However, their hot hardness is lower, making them sensitive to cutting speed. Optimizing parameters for HSS tools on cast iron is therefore crucial for achieving acceptable quality without premature tool failure. The strain resistance effect is the foundation of the semiconductor strain gauge's operation. The main cutting force ( $F_c$ ), feed force ( $F_f$ ), and rear force ( $F_p$ ) are the three directions into which the cutting force is divided in Figure 1.  $F_c$  is one of the most crucial signals for tracking the



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turning state and the component that uses the most energy when turning. The strain on the turning tool holder brought on by the primary cutting force is the most important to measure and study.

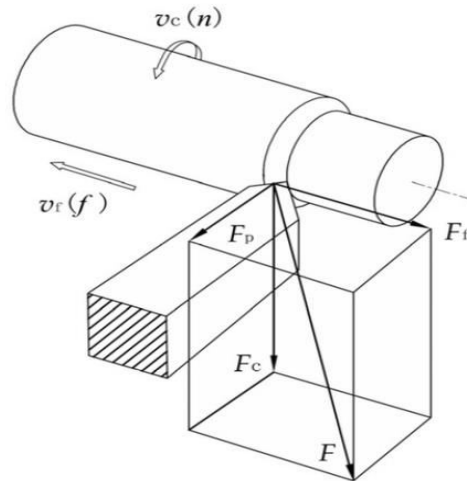


Figure1. The components of cutting force

### II. LITERATURE REVIEW

When turning mild steel utilizing high speed steel cutting, Rodrigues et al. [5] investigated the effects of speed, feed, and depth of cut on surface roughness ( $R_a$ ) and cutting force ( $F_c$ ). A precision center lathe was used for the experiments, and analysis of variance (ANOVA) based on an adjusted technique was used to examine the impact of cutting parameters. Feed, depth of cut, and the combination of feed and depth of cut greatly influenced the variance, according to the cutting force linear regression equation. Alumina-based ceramic cutting tools can be used at faster cutting speeds than carbide and cermet tools, according to Senthil Kumar et al. [6].

Productivity and metal removal rates rise as a result. This study presents the optimization of machining parameters for S.G. iron (ASTM A536 60-40-18) utilizing ceramic cutting tools based on alumina. A turning dynamometer for measuring cutting force was designed, developed, and tested by Yaldiz and Unsacar [7]. He has invented and constructed a turning dynamometer that uses a strain gauge to measure static cutting forces and a piezo-electric accelerometer to measure dynamic cutting forces. Using the Taguchi approach, Hari Singh and Pradeep Kumar [8] found the optimal feed force for turned pieces. When milling EN24 steel using TiC-coated tungsten-carbide inserts, the paper's goal is to determine the ideal turning process parameters (cutting speed, feed rate, and depth of cut) that yield the ideal feed force value. Taguchi's parameter design approach has been used to determine the impacts of the chosen turning process parameters on feed force and the subsequent optimal settings of the parameters.

Electromechanical transducers and arrangements for measuring strains caused by metal cutting forces acting on dynamometers were examined and studied by Sedat Karabay [9]. In order to determine the best location for cement gauges that are activated by compression and tension stresses brought on by cutting forces, this paper examined the elastic members, which are the most crucial components of dynamometers using electric strain gauges. The impact of the cutting parameters (feed rate, spindle speed, and depth of cut) and tool type (nose radius) on the cutting forces has been examined by Augustina et al. [10]. They have confirmed that, compared to the other components examined in this work, the cutting component of the forces is more sensitive to changes in the cutting circumstances. Additionally, when it comes to the forces produced during machining at low feed rates, tools with nose radii of 0.4 and 0.8 mm behave similarly. Using a ceramic tool with an  $Al_2O_3+TiC$  matrix (KY1615) and AISI 1050 steel (hardness of 484 HV), Rao et al. [11] conducted an experiment to determine the cutting force and surface roughness. The Johnford TC35 Industrial CNC lathe was used for the experiments. According to the findings, feed rate significantly affects both cutting force and surface roughness.



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### III. EXPERIMENTAL METHODOLOGY

#### 3.1 Workpiece Material

The workpiece material used was gray cast iron, grade FG 260 (equivalent to ASTM A48 Class 35). Its chemical composition and mechanical properties are given in Table 1 and Table 2. The workpieces were prepared as cylindrical bars of 50 mm diameter and 300 mm length.

**Table 1: Chemical Composition of FG 260 Cast Iron (wt.%)**

Element	C	Si	Mn	P	S	Fe
%	3.2	1.9	0.8	0.15	0.12	Bal.

#### 3.2 Cutting Tool

A High Speed Steel (HSS) tool of grade M2 (18% W, 4% Cr, 1% V) was used. The tool geometry was:

- Tool Holder: ISO 2020-25
- Tool bit: 12 mm x 12 mm x 100 mm
- Tool angles: Back rake angle: 8°, Side rake angle: 10°, End relief angle: 6°, Side relief angle: 8°, End cutting edge angle: 15°, Side cutting edge angle: 15°, Nose radius: 0.8 mm. Tools were re-sharpened to standard geometry for each set of experiments to eliminate the effect of progressive wear.

#### 3.3 Machine Tool

Experiments were conducted on a precision center lathe (HMT NH 26). The lathe has a spindle power of 5.5 kW and a speed range of 25-2000 rpm. The machine was checked for vibration and runout before the experiments.

#### 3.4 Measurement Equipment

**Surface Roughness:** A Mitutoyo SJ-210 portable surface roughness tester was used to measure the arithmetic mean roughness (Ra) in micrometers ( $\mu\text{m}$ ). Measurements were taken at three equally spaced points along the circumference of the machined surface, and the average was recorded. The cut-off length was 0.8 mm. **Dimensional Accuracy:**

A digital micrometer with an accuracy of 0.001 mm was used to measure the workpiece diameter before and after machining at three different axial positions. Dimensional deviation was defined as the absolute difference between the intended and actual diameter. **Tool Wear:** A toolmaker's microscope was used to observe flank wear, but this data is used for discussion, not as a primary response variable.

#### 3.5 Design of Experiments (DOE)

A full factorial design (3x3x3) was employed, resulting in 27 experimental runs. The independent variables and their levels are shown in Table 3. The levels were selected based on the HSS tool manufacturer's recommended range for machining cast iron and preliminary trials.

**Table 2: Cutting Parameters and Levels**

Parameter	Symbol	Unit	Level 1	Level 2	Level 3
Cutting Speed	v	m/min	20	30	40
Feed Rate	f	mm/rev	0.1	0.2	0.3
Depth of Cut	d	mm	0.5	1.0	1.5



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The machining length for each test was kept constant at 100 mm. Each experiment was replicated twice to account for random errors. The order of experiments was randomized to minimize the effect of any systematic variation.

### IV. RESULTS AND ANALYSIS

The collected data for surface roughness (Ra) and dimensional deviation were analyzed using Minitab statistical software. The experimental results for the 27 runs (averaged from two replicates) are summarized in Table 3.

**Table 3: Experimental Results**

Run	v (m/min)	f (mm/rev)	d (mm)	Ra ( $\mu\text{m}$ )	Dimensional Deviation (mm)
1	20	0.1	0.5	2.12	0.023
2	20	0.1	1.0	2.18	0.035
3	30	0.1	0.5	1.78	0.027
4	30	0.1	1.0	1.85	0.041
5	40	0.1	0.5	1.35	0.030
6	40	0.1	1.0	1.42	0.046

#### 4.1 Analysis of Surface Roughness (Ra)

ANOVA was performed to quantify the contribution of each factor and their interactions. The results are presented in Table 4. A 95% confidence level ( $\alpha = 0.05$ ) was used.

**Table 4: ANOVA for Surface Roughness (Ra)**

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution (%)
v (m/min)	2	7.851	3.926	42.65	0.000	10.5
f (mm/rev)	2	126.18	63.09	685.76	0.000	68.2
d (mm)	2	0.942	0.471	5.12	0.018	1.3
v * f	4	3.215	0.804	8.73	0.001	4.3
v * d	4	0.543	0.136	1.48	0.258	0.7
f * d	4	1.892	0.473	5.14	0.009	2.5
Error	8	0.736	0.092			1.0
Total	26	141.36				100



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### Interpretation:

- **Feed Rate (f):** With an F-value of 685.76 and a P-value of 0.000, feed rate is the most statistically significant factor. Its contribution is 68.2%.
- **Cutting Speed (v):** Also significant (P=0.000), contributing 10.5%.
- **Depth of Cut (d):** Has a P-value of 0.018, which is less than 0.05, indicating it is statistically significant but its contribution (1.3%) is practically negligible.
- **Interactions:** The interaction between  $vf$  and  $fd$  are statistically significant (P<0.05), indicating that the effect of feed on roughness is slightly dependent on the speed and depth being used.

### V. DISCUSSION

#### 5.1. Influence on Surface Quality

The results clearly demonstrate that feed rate is the primary determinant of surface roughness in turning cast iron with an HSS tool. This aligns with theoretical models where the feed marks dominate the surface topography. The experimental data shows a nearly exponential increase in Ra with feed. For a high-quality finish ( $Ra < 3 \mu m$ ), the feed rate must be maintained at or below 0.1 mm/rev.

Cutting speed showed a beneficial effect on surface roughness. As speed increased from 20 to 40 m/min, Ra decreased by approximately 10-15% across all feed levels. This is attributed to a reduction in the tendency for material adhesion and a more stable chip formation process at higher speeds, even within the limited range of HSS. The improvement, however, is secondary to the effect of feed. The minimal effect of depth of cut confirms that, for a rigid setup, the process is insensitive to depth variations in terms of surface finish.

### VI. CONCLUSION

This study systematically investigated the effects of cutting parameters on product quality during the dry turning of FG 260 gray cast iron using an M2 HSS tool. The following conclusions are drawn:

1. **Surface Roughness (Ra) is predominantly governed by feed rate.** Feed rate contributed 68.2% to the variation in surface roughness. Increasing feed rate from 0.1 to 0.3 mm/rev increased Ra by nearly 400-500%.
2. **Cutting speed has a moderate inverse effect on surface roughness.** Higher cutting speeds (up to 40 m/min) improved surface finish by approximately 10-15%, likely due to more stable cutting conditions.

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