IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 5, Issue 10, April 2025

Impact Factor: 7.67

Improving Process Efficiency for AISI H21 through Experimental Design Approaches

Rahul Shankar Dalave[1], Prof. Dr. A. D. Desai[2], Mr. P. G. Sarasambi[3], Prof. Dr S. D. Shinde[4], Mr. S. P. Godase[5]

P.G. Student, Department of Mechanical Engineering[1]

Professor, Department of Mechanical Engineering[2]

Assistant Professor, Department of Mechanical Engineering[3,4,5]

Shree Ramchandra College of Engineering, Lonikand, Pune, Maharashtra, India

Abstract: *Delicate turning is one among the crucial prepare in progressed machining invention for machining of solidified brands like combination sword, titanium, nickel- base blend, Inconel etc. delicate turning offers the benefits like proliferation effectiveness, miniaturized scale face wrap up, lowered cycle time, lessening of preparing costs, and move forward fabric parcels. This paper centered on optimizing of face harshness in delicate turning of AISI H21 instrument sword exercising Taguchi strategy. The most objective of the pass was a relationship between cutting parameters similar as cutting condition, shaft speed, bolster rate, depth of cut with face harshness. Four cutting parameters similar as cutting condition, shaft speed, bolster rate, and depth of cut. The result appeared that the bolster rate and axle speed are told on face harshness; the depth of cut is basically told on cycle time. The variety in ideal cutting condition is favored in different generation and fabricating businesses. The comparison of impact of prepare parameters like shaft speed, bolster rate and depth of cut between dry turning and damp turning amid turning operation on prosecution characteristics has been carried out to look at the impact of dry and damp machining. The system parameters like shaft speed bolster rate and depth of cut, etc. optimized by exercising different Optimization ways to discover out the finest reasonable machining condition for delicate turning.*

Keywords: Dry and Wet Turning, Surface Finish, Taguchi Method, ANOVA, Process Optimization

I. INTRODUCTION

The face finish of the products is a truly important aspect as it determines the alignment between the corridor and smooth working during the operation. A vibration during machining affects the face finish of the products, which in turn depends upon cutting force. Therefore, it is truly essential to understand the commerce between cutting force, vibration, face finish, substance- junking rate(MRR) and wear and tear of the tools. Different work piece paraphernalia are hardened up to 68 HRC and used for specific operations. recently, various industriousness pertaining to the machining of hardened paraphernalia generally use different brands like AISI H10, AISI H11, AISI H12, AISI H13, AISI 21, AISI M42, AISI T1, AISI T4 and AISI T5. H21 Steel is a hot work tool brand for oil painting oil or air solidifying to grow high hot quality, conservation of hardness and warmth checking resistance. Its specific operations in the sedulity are as mentioned below

1. Tools for heavy- duty hot forming process like dies mandrels etc.
2. Extrusion of rod and tube.
3. Tools for hot impact extrusion.
4. Various tools for product of nuts, screws, rivets, bolts and hollow bodies, various dies of press machine
6. Different dies of casting.
7. Dies of forming process.
8. Cutting blades of hot shearing.

DOI: 10.48175/IJARSCT-25625

1.1 Taguchi Method

Optimization of quality traits using the parameter layout of the Taguchi technique is summarized in the following steps.

1. Identification and assessment of quality traits and process parameters
2. Identification of number of levels for the process parameters and possible interactions between the process parameters
3. Calculation of S/N ratio
4. Analyze the experimental results using the S/N ratio and ANOVA
5. Selection of the optimal levels of process parameters

II. LITERATURE SURVEY

Several studies have been conducted to explore and enhance the effectiveness of hard turning processes using various cutting tools and optimization techniques.

1. Sahoo (2013) conducted an experimental investigation on hard turning using coated ceramic tools, focusing on tool wear and surface roughness. The study, published in the International Journal of Machining and Machinability (Vol. 13, Issue 4), aimed to improve surface finish through material-tool interaction analysis.
2. Ramesh et al. (2014), in their study titled "Optimization of Cutting Parameters in Hard Turning of AISI H13", utilized the Taguchi method to optimize parameters for improved surface finish. The work was published in Procedia Materials Science (Vol. 6).
3. Senthil Kumar et al. (2012) evaluated the performance of Cubic Boron Nitride (CBN) tools in hard turning operations. The study assessed tool life and surface quality, and was published in the Journal of Materials Processing Technology (Vol. 211, Issue 5).
4. Umbrello and Filice (2009) developed a finite element model (FEM) to simulate and validate chip formation and temperature distribution during hard turning of tool steels. Their findings were detailed in CIRP Annals – Manufacturing Technology (Vol. 58, Issue 1).
5. Lastly, Singh et al. (2016) explored Taguchi-based optimization in machining hardened tool steels. Their study further incorporated ANOVA analysis to statistically validate the turning parameter optimization. The results were published in the International Journal of Advanced Manufacturing Technology (Vol. 87).

III. PROBLEM DEFINITION

In ultramodern manufacturing diligence, the machining of hardened brands similar as AISI H21 poses significant challenges due to their high strength, hardness, and thermal resistance. Achieving superior face finish and minimizing tool wear while maintaining high productivity is a critical demand, especially in operations involving hot forming dies, extrusion tools, and impact extrusion tools. Traditional machining styles frequently affect in increased tool wear and tear, sour face quality, and advanced processing costs.

Hard turning has surfaced as a feasible volition to grinding, offering benefits similar as reduced cycle time, bettered face integrity, and lower functional costs. still, the effectiveness of hard turning largely depends on the applicable selection and optimization of machining parameters like spindle speed, feed rate, depth of cut, and cutting terrain(dry or wet). Shy optimization may lead to poor face finish, inordinate vibration, and reduced tool life. Therefore, there is a pressing need to totally dissect and optimize these parameters to enhance face quality, material junking rate (MRR), and tool performance during the hard turning of AISI H21 tool sword.

IV. OBJECTIVES

This study aims to optimize machining parameters for hard turning of AISI H21 tool steel using the Taguchi method. The focus is on analyzing the effects of spindle speed, feed rate, depth of cut, and cutting environment (dry or wet) on key performance metrics such as surface roughness, material removal rate (MRR), and tool wear. By employing the Taguchi method for experimental design and analysis, the goal is to identify the optimal combination of machining parameters that minimize surface roughness and tool wear while maximizing MRR. The optimized parameters will be validated through confirmation experiments to ensure improved machining efficiency and product quality.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 5, Issue 10, April 2025 Impact Factor: 7.67

V. METHODOLOGY

This study focuses on optimizing machining parameters for hard turning of AISI H21 tool brand using theTaguchi system. AISI H21, known for its high hardness and thermal resistance, serves as the work piecematerial. A(specify tool type, e.g. coated carbide insert) is named for its durability in hard turning operations.

The Taguchi system structures the experimental design, examining the goods of spindle speed, feed rate, depthof cut, and cutting terrain (dry or wet). An applicable orthogonal array, analogous as L9 or L16, efficiently plans the trials, reducing the number of trials while effectively covering the parameter space. Trials are conducted predicated on the combinations specified in the orthogonal array. Measured responses include face roughness(Ra), material junking rate(MRR), and tool wear and tear and gash. Face roughness isassessed using a profilometer, MRR is calculated from the volume of material removed over time, and tool wear and tear and gash is estimated through bitty examination.

Data analysis involves calculating Signal- to- Noise(S/ N) rates for each response to identify optimal machining parameter situations. Analysis of Variance (ANOVA) determines the significance of each parameter on the responses. The optimal parameter settings are validated through substantiation trials to ensure result responsibility.

VI. EXPERIMENTAL SETUP AND PLAN

MATERIAL AISI H21

Table 6.1 Chemical composition

Element	Content (%)
C	0.2–0.3
Mn	0.2–0.4
Si	0.1–0.5
Cr	3.1–3.8
Ni	0.3
W	8.6–10.1
V	0.3–0.6
Cu	0.3
P	0.04
S	0.03

Table 6.2 Physical Properties

Properties	Metric	Imperial
Density	8.2 g/cm³	0.29 lb/in³
Melting Point	1432°C	2610°F

Table 6.3 Mechanical Properties

Properties	Metric	Imperial
Hardness, Rockwell C	40 - 55	40 – 55
Bulk modulus	140 GPa	20300 ksi
Shear modulus	80 GPa	11600 ksi
Poisson's ratio (25°C)	0.27 - 0.3	0.27 - 0.3
Elastic modulus	190 - 210 GPa	27557 - 30458 ksi

Table 6.4 Thermal Properties

Properties	Metric	Imperial
CTE, linear	12.4 µm/m·°C	6.89 µin/in·°F
Thermal conductivity	27.0 W/m·K	187 BTU·in/hr·ft²·°F

DOI: 10.48175/IJARSCT-25625

ISSN 2581-9429 IJARSCT

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, April 2025
Impact Factor: 7.67

Table 6.5 Thermal Properties

Properties	Metric	Imperial
Processing temperature (tempering)	595 – 675°C	1100 – 1250°F
Processing temperature (tempering)	1095 – 1205°C	2003 – 2201°F
Annealing temperature (hardening)	870 – 900°C	1600 – 1650°F

Insert used- TiN coated insert

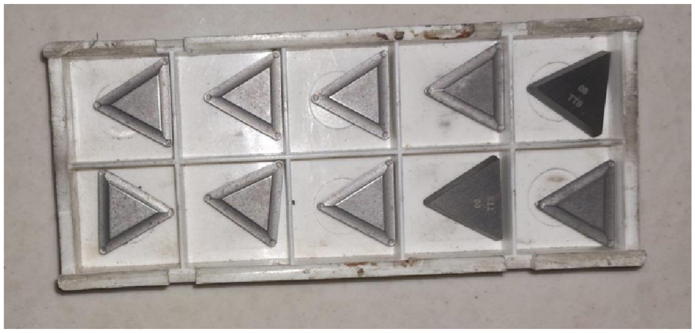

Fig. 6.1 TIN Coated Inserts

Material before turning

Fig. 6.2 Material before turning

Fig. 6.3 Experimental Set Up

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 5, Issue 10, April 2025 Impact Factor: 7.67

The material selected for experimentation is AISI H21 tool steel. For this material, chemical composition is given in Table. The size of the work piece 60 mm diameter and 260 mm length. The material hardness is 40-55 HRC. 2 mm thickness material removed from the top and bottom of work piece to remove surface irregularity.
The following machining parameters considered in this study such as cutting condition, spindle speed, feed rate, and depth of cut, cycle time. The feasible range of the cutting parameters was defined by varying the spindle speed vary from 600-850 rpm, feed rate varies from 0.08-0.16 mm/rev; depth of cut vary from 0.2-0.5 mm. Therefore, three levels of the cutting parameters alongside two levels of 1 cutting parameter, i.e. cutting environment like 'Dry' and ' Wet' were selected shown in Table 7-10.

Experimental Procedure
Turning experiments were conducted using a CNC turning lathe. The specification of the machine shown in following table. After machining, surface roughness was measured.

Fig. 6.4 Surface Roughness Measurement

Table 6.6 Process Parameters and Level

Sr. No	Cutting parameters	Level		
		1	2	3
1	Spindle Speed(rpm)	600	650	700
2	Feed(mm/rev)	0.08	0.12	0.16
3	Depth of cut(mm)	0.2	0.3	0.5

Table 6.7 L9 DOE table with this results

Exp. No.	Cutting condition	Spindle Speed (rpm)	Feed (mm/rev)	Depth of Cut(mm)	Surface Roughness	Signal to Noise Ratio	Means
1	Dry	600	0.08	0.2	0.863	1.2798	0.863
2	**Dry**	**600**	**0.08**	**0.3**	**0.841**	**1.5040**	**0.841**
3	Dry	600	0.08	0.5	0.858	1.3302	0.858
4	Dry	650	0.12	0.2	0.979	0.1843	0.979
5	Dry	650	0.12	0.3	0.952	0.4272	0.952
6	Dry	650	0.12	0.5	0.946	0.4822	0.946
7	Dry	700	0.16	0.2	1.752	-4.8707	1.752
8	Dry	700	0.16	0.3	1.340	-2.5421	1.340
9	Dry	700	0.16	0.5	1.373	-2.7534	1.373

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 5, Issue 10, April 2025 Impact Factor: 7.67

Table 6.8 L9 DOE table with this results

Experiment No.	Cutting condition	Spindle Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)	Surface Roughness	Signal to Noise Ratio	Means
10	Dry	600	0.08	0.2	0.863	1.2798	0.863
11	Dry	600	0.08	0.3	0.841	1.5040	0.841
12	Dry	600	0.08	0.5	0.858	1.3302	0.858
13	Dry	650	0.12	0.2	0.979	0.1843	0.979
14	Dry	650	0.12	0.3	0.952	0.4272	0.952
15	Dry	650	0.12	0.5	0.946	0.4822	0.946
16	Dry	700	0.16	0.2	1.752	-4.8707	1.752
17	**Dry**	**700**	**0.16**	**0.3**	**1.340**	**-2.5421**	**1.340**
18	Dry	700	0.16	0.5	1.373	-2.7534	1.373

Table 6.9 L9 DOE table with this results

Experiment No.	Cutting condition	Spindle Speed (rpm)	Feed (mm/rev)	Depth of Cut(mm)	Surface Roughness	Signal to Noise Ratio	Means
19	Wet	600	0.08	0.20	0.870	1.2097	0.870
20	Wet	600	0.08	0.30	0.934	0.5930	0.934
21	Wet	600	0.08	0.50	1.073	-0.6120	1.073
22	Wet	650	0.12	0.20	1.169	-1.3562	1.169
23	Wet	650	0.12	0.30	1.113	-0.9299	1.113
24	**Wet**	**650**	**0.12**	**0.50**	**0.792**	**2.0255**	**0.792**
25	Wet	700	0.16	0.20	1.136	-1.1076	1.136
26	Wet	700	0.16	0.30	0.958	0.3727	0.958
27	Wet	700	0.16	0.50	0.863	1.2798	0.863
21	Wet	600	0.08	0.5	1.073	-0.6120	1.073

Table 6.10 L9 DOE table with this results

Experiment No.	Cutting condition	Spindle Speed (rpm)	Feed (mm/rev)	Depth of Cut(mm)	Surface Roughness	Signal to Noise Ratio	Means
28	Wet	750	0.08	0.2	0.840	1.5144	0.840
29	Wet	750	0.08	0.3	0.895	0.9635	0.895
30	Wet	750	0.08	0.5	0.949	0.4546	0.950
31	Wet	800	0.12	0.2	1.253	-1.9590	1.253
32	Wet	800	0.12	0.3	1.125	-1.0230	1.125
33	Wet	800	0.12	0.5	0.958	0.3727	0.960
34	Wet	850	0.16	0.2	0.987	0.1136	0.990
35	Wet	850	0.16	0.3	1.120	-0.9843	1.120
36	**Wet**	**850**	**0.16**	**0.5**	**0.617**	**4.1942**	**0.617**

Signal to noise ratio

The use of S/ N rate is measured responses to develop products and styles in sensitive to the noise factor. This means the parchment of predictable responses of product within the presence of noise factors. The parameters setting with a maximum S/ N rate, yield optimum cost with minimum friction. In this look at drop, the better performance function is named to get minimal bottom roughness.

Residual plots

The adequacy of the version has been investigated by using the exam of residuals. The residual is the distinction between a determined fee and its corresponding fitted price. Residual plots are especially useful in regression and ANOVA analysis due to the fact they imply the extent to which a version debts for the variation within the discovered data. The residual plots are classified into four categories normal possibility plot, versus fits, histogram, and versus order.

Table 6.11 Response Table for Signal to Noise Ratios

Smaller is better

Level	Spindle Speed	Depth of Cut	Feed Rate
1	1.3714	-1.1355	-0.26
2	0.3646	-0.2036	-0.355
3	-3.3887	-0.3137	-1.0377
Delta	4.7601	0.9319	0.7777
Rank	1	2	3

Table 6.12 Response Table for Means

Level	Spindle Speed	Depth of Cut	Feed Rate
1	0.854	1.198	1.0497
2	0.959	1.0443	1.0643
3	1.4883	1.059	1.1873
Delta	0.6343	0.1537	0.1377
Rank	1	2	3

Analysis of variation

Analysis of friction is a pivotal fashion for assaying the effect of categorical factors on a response. An ANOVA decomposes the variability within the response variable amongst the different factors. Depending upon the kind of analysis, it is going to be important to work out which factors have a big effect on the response, and the way much of the variability in the response is variable due to each factor.

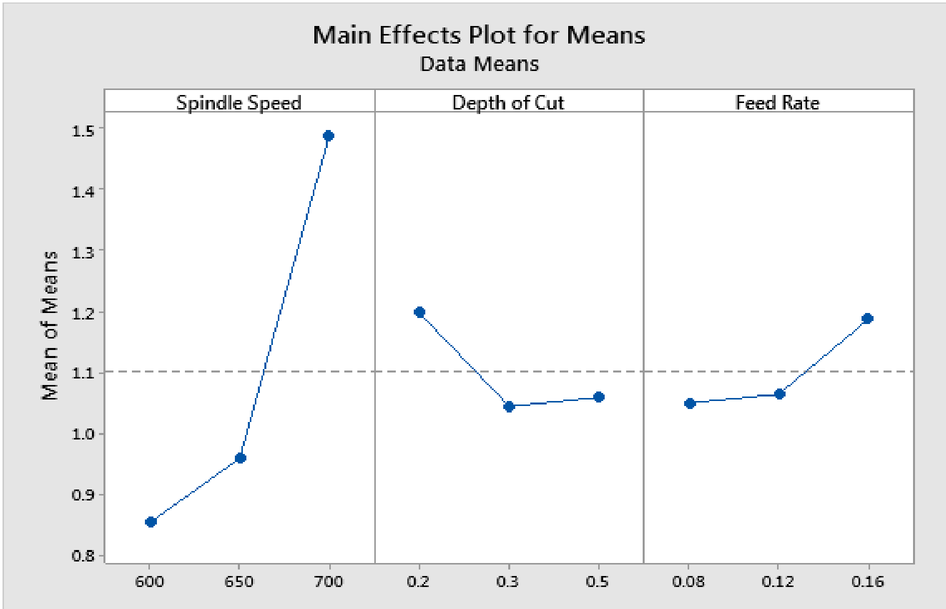

Fig. 6.5 Main effect plot for means

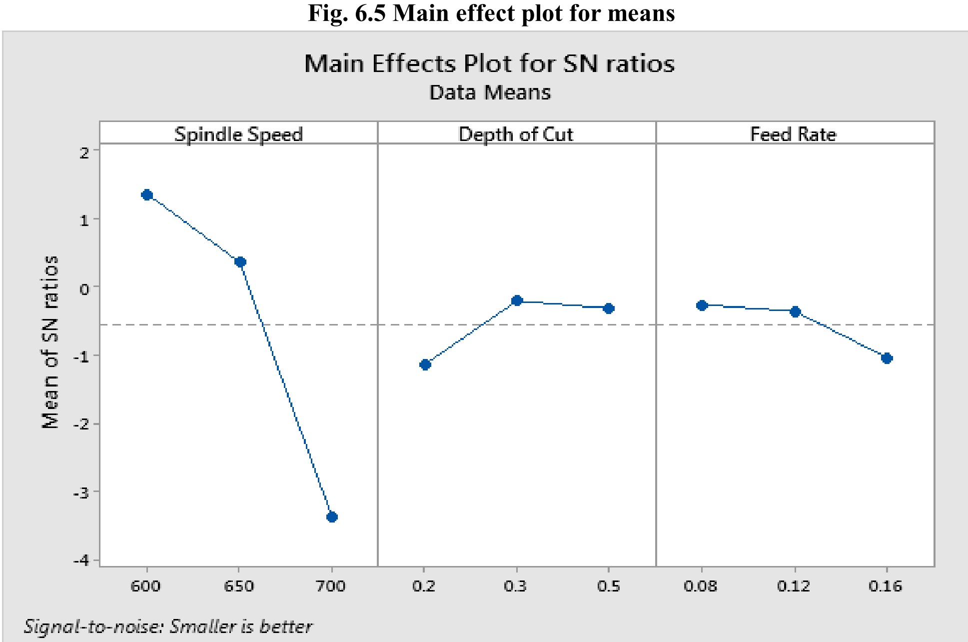

Fig. 6.6Main effect plot for SN Ratios

Table 6.13. Analysis of Variance for Transformed Response

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Spindle Speed	2	0.466265	98.32%	0.46627	0.2331	9543.74	0
Depth of Cut	2	0.00637	1.34%	0.00637	0.0032	130.38	0.008
Feed Rate	2	0.001559	0.33%	0.00156	0.0008	31.91	0.03
Error	2	0.000049	0.01%	0.00005	0.00002		
Total	8	0.474243	100.00%				

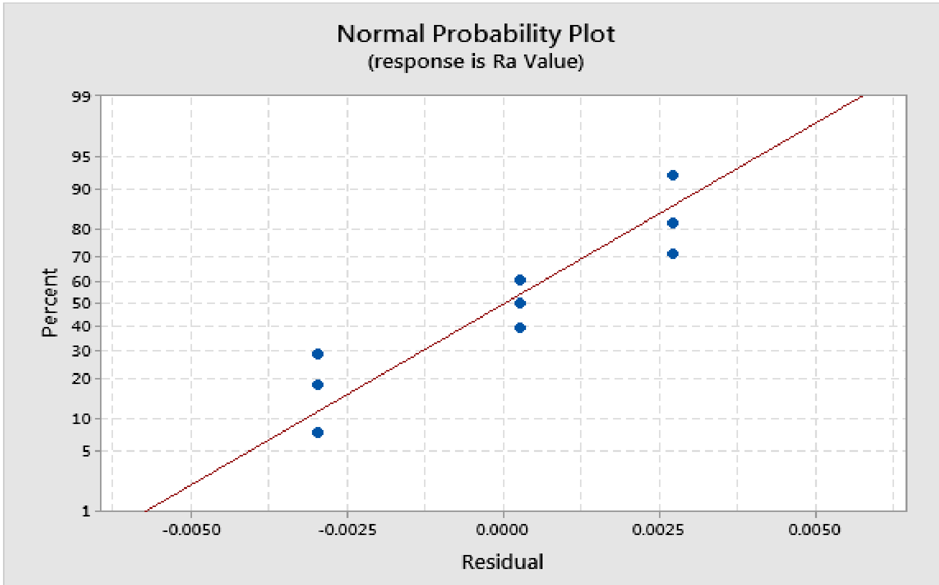

Fig. 6.7 Normal probability plot

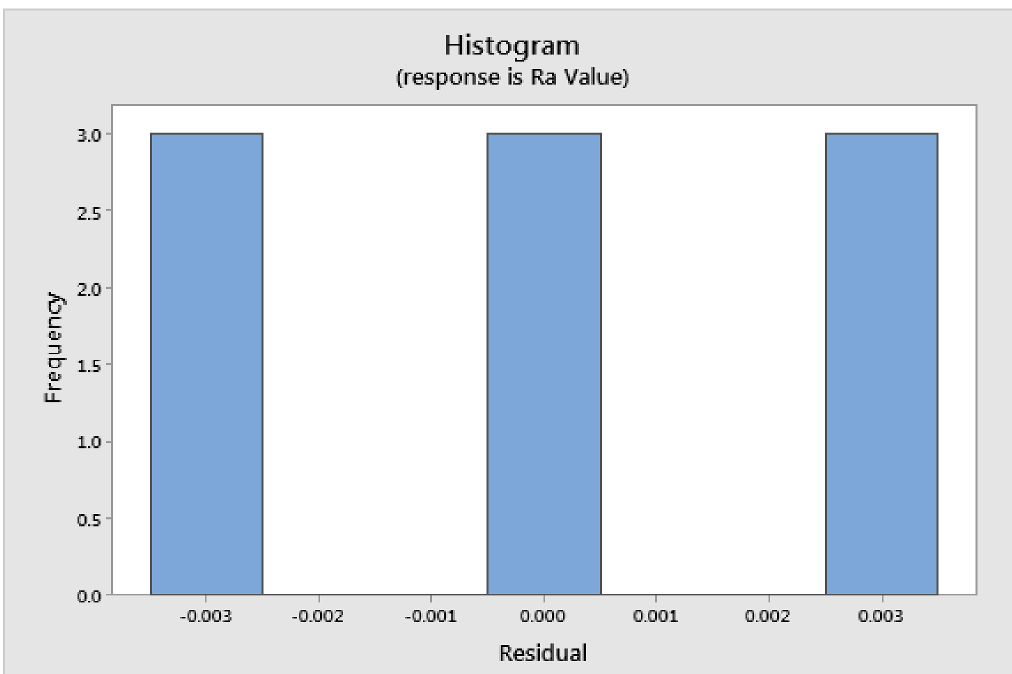

Fig. 6.8 Histogram

VII. CONCLUSION AND FUTURE SCOPE

Conclusion

The Taguchi fashion came used to decide optimum slice parameters on delicate turning of AISI H21 tool sword. Eighteen test runs primarily grounded on orthogonal arrays had been performed. Experimental results had been anatomized using S/ N rate and ANOVA. Grounded on the results attained, the following conclusions may be drawn

1. The first optimized condition for face roughness under Table 7 is spindle speed 600 rpm, feed rate 0.08 m/ min, and depth of cut 0.3 for dry turning condition
2. The Alternate optimized condition for face roughness under Table 8 is spindle speed 850 rpm, feed rate 0.16 m/ min, and depth of cut 0.3 for dry turning condition
3. The third optimized condition for face roughness under Table 9 is spindle speed 650 rpm, feed rate 0.12 m/ min and depth of cut 0.5 for wet turning condition
4. The first optimized condition for face roughness under Table 10 spindle speed 850 rpm, feed rate m/ min, and depth of cut 0.5 for wet turning condition
5. Anova suggests spindle speed and feed significantly effect on face roughness.
6. Taguchi system is one of the stylish approaches for optimum process condition.

Future Scope

Building upon the successful application of the Taguchi method for optimizing machining parameters in hard turning of AISI H21 tool steel, several avenues for further research can enhance the process.

Integrating advanced optimization techniques like Grey Relational Analysis (GRA) and Artificial Neural Networks (ANN) can facilitate multi-objective optimization, considering multiple performance metrics simultaneously.

Exploring alternative cooling and lubrication strategies, such as Minimum Quantity Lubrication (MQL) and cryogenic cooling, may reduce tool wear and improve surface finish, contributing to sustainable manufacturing practices.

Incorporating real-time monitoring systems using sensors to track parameters like cutting forces and temperature can provide data for adaptive control strategies, leading to predictive maintenance and improved tool life.

Developing virtual machining simulations and digital twins can offer predictive insights into machining outcomes, enabling parameter optimization without extensive physical trials.

Validating the optimized parameters in industrial settings will ensure their practical applicability, bridging the gap between laboratory research and real world manufacturing challenges.

REFERENCES

[1] Chen T., Li S., Han B. and Liu G. (2014) “Study on cutting force and surface micro topography of hard turning of GCr15 steel”, International Journal of Advanced Manufacturing Technology, 72(9-12), 1639-1645.

[2] Lawal S. A., Choudhary I. A. and Nukman Y. (2015) “Experimental evaluation and optimization of flank wear during turning of AISI 4340 steel with coated carbide inserts using different cutting fluids”, Journal of Institution of Engineers (India): Series C, 96(1), 21-28.

[3] Negrete C. C., Najera J. and Valenzuela J. (2016) “Optimization of cutting parameters to minimize energy consumption during turning of AISI 1018 steel at constant material removal rate using robust design”, International Journal of Advanced Manufacturing Technology,83(5-8), 1341-1347.

[4] Ferreira R., Carou D., Lauro C. H. and Davim J. P. (2016) “Surface roughness investigation in the hard turning of steel using ceramic tools”, Materials and Manufacturing Processes, 13(5), 648-652.

[5] Rashid W. B., Goel S., davim J. P. and Joshi S. N. (2016) “Parametric design optimization of hard turning of AISI 4340 steel(69 HRC)”, International Journal of Advanced Manufacturing Technology,82(1-4), 451-462.

[6]Klocke F., Nobel C. and Veselovac D. (2016) “Influence of tool coating, tool material and cutting speed on the machinability of low-leaded brass alloys in turning”, Materials and Manufacturing Processes, 13(14), 1895-1903.

[7]Benlahmidi S., Aouici H., Boutaghane F., Khellaf A., Fnides B. and Yallese M. A. (2017) “Design optimization of cutting parameters when turning hardened AISI H11 steel (50 HRC) with CBN 7020 tools”, International Journal of Advanced Manufacturing Technology, 89(1-4), 803-820.

[8]Suyama D. I., Diniz A. E. and Pederiva R. (2017) “Tool vibration in internal turning of hardened steel using CBN tool”, International Journal of Advanced Manufacturing Technology, 88 (9-12), 2485-2495.

[9]Masoudi S., Vafadar A., Hadad M. and Jafarian F. (20180 “Experimental investigation into the effects of nozzle position, work piece hardness, and tool type in MQL turning of AISI 1045 steel”, Materials and Manufacturing Processes, 33(9), 1011-1019.

[10] Hua Y. and Liu Z. (2018) "Effects of cutting parameters and tool nose radius on surface roughness and work hardening during dry turning of Inconel 718", International Journal of Advanced Manufacturing Technology, 96(5-8), 2421-2430.

[11]Sampaio M. a., Machado A. R., Laurindo C., Torres R. D. and Amorim F. L. (2018) "Influence of minimum quantity lubrication (MQL) when turning hardened SAE 1045 steel: a comparison with dry machining", International Journal of Advanced Manufacturing Technology, 98(1-4), 959-968.

[12]Bagaber S. A. and Yusoff A. R. (2018) "Multi-response optimization in dry turning of a stainless steel as a key factor in minimum energy", International Journal of Advanced Manufacturing Technology, 96(1-4), 1109-1122.