Machinability Analysis of Forged Steel-45 (GOST 1050-88) Alloys

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Abstract — This study examines CNC turning machinability of Forged C45 (GOST 1050-88) medium carbon steel. The goal is to examine how cutting speed, feed rate, and depth of cut affect performance metrics including surface roughness (Ra) and material removal rate. Using the Taguchi L9 orthogonal array, experiments were devised to explore numerous factors with fewer trials. PVD-coated carbide cutting inserts were used to machine forged C45 steel specimens, and Minitab statistical software was used to analyse the findings using Signal-to-Noise ratio and ANOVA. Surface quality and productivity were enhanced by identifying optimal machining parameters. This research helps manufacturers choose effective machining conditions for forged C45 steel.

Keywords: CNC, Anova, Taguchi method, Minitab, Forged C45 (Gost 1050-88).

I. Introduction

Machining is a vital production operation that turns raw materials into components with the designer's desired dimensions, surface polish, and tolerances. Machining shapes an object by cutting material with drills, grinders, mills, and turns. Material properties, tool material, cutting parameters, and environmental conditions affect machining efficiency. In today's industrial industry, machining efficiency must be enhanced to cut production costs, boost productivity, and improve product quality. To improve machining efficiency, engineering material machinability must be understood. Russian standard GOST 1050-88 defines Forged C45 as medium carbon structural steel. It's comparable to FORGED C45 (GOST 1050-88) steel in quality. The 0.42-0.50 percent carbon content balances its ductility, hardness, and strength.

II. Design of Experiment

DOE is a method for determining the optimal combination of variables in an experiment by specifying and exploring all of the possible permutations. This identifies several factors and the amounts of each. Combining factors at suitable levels, each within its own acceptable range, to generate the greatest results while exhibiting minimal fluctuation around the optimal results is another valuable application of design of experiments. The various conditions to be researched are laid out using the design of experiment. First, the number of trails has to be defined; second, the circumstances for each trail need to be stated; these two objectives must be met by an experiment design. Acquiring familiarity with the product or process under study is crucial prior to developing an experiment in order to determine what variables are most likely to impact the result. One way to find out what matters most in a process, where the issue lies, and whether or not there are any interactions amongst estimates is to use the Design of Experiments (DOE) approach.

A. *Taguchi design*

To save time and resources, Taguchi proposed an experimental design that uses an orthogonal array to organise the process parameters and the levels at which they should be varied. This design allows for the collection of data needed to determine which factor most affects product quality with minimal experimentation.

B. *Process Parameters*

Input Parameter:
1) Factor A: Speed (rpm)
2) Factor B: Feed Rate (mm/min)
3) Factor C: Depth of Cut (mm)

Output Parameter:
Surface Roughness (Ra) & MRR

Factor	Level-1	Level-2	Level-3
Speed (rpm)	800	1200	1600
Feed (mm/rev)	0.10	0.20	0.30
DOC (mm)	0.5	1.0	1.5

Table I: Process Parameter Level

Ex. No.	Speed (rpm)	Feed (mm/rev)	DOC (mm)
1	800	0.10	0.5
2	800	0.20	1.0
3	800	0.30	1.5
4	1200	0.10	1.0
5	1200	0.20	1.5
6	1200	0.30	0.5
7	1600	0.10	1.5
8	1600	0.20	0.5
9	1600	0.30	1.0

Table II: Taguchi Design Factor

III. Experimental Work

A. *Workpiece Material*

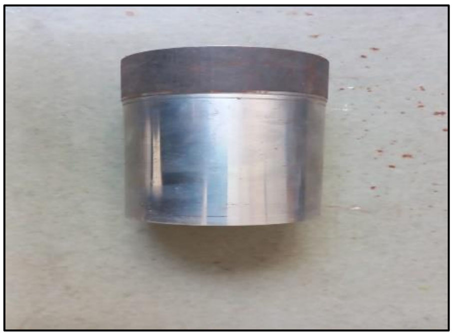

Fig. 1: Workpiece

Shafts, gears, couplings, and structural machine parts are frequently made from Forged C45 (Gost 1050-88), a medium carbon steel that is known for its good strength and moderate machinability.

B. Material Specifications

Standard: GOST 1050-88
Carbon Content: ~0.45%
Initial Diameter: 30 mm
Length of Specimen: 120 mm
Number of Specimens: 9 (as per L9 design)

Before machining, each specimen was properly cleaned to remove rust, dust, and oil.

C. Study of machining setup

Turning studies are carried out on a Forged C45 (GOST 1050-88) (GOST 1050-88) with PVD Coated Carbide inserts and Mega coat Nano - PR1535 CNMG 120408 tool inserts in cryo-genic and dry cutting conditions. Cryogenic machining involves the use of a nozzle to apply cutting fluid to the work area. Below you can see the CNC turning center that we use in our workshop.

Fig. 2: CNC machine

Ex. No.	Speed (rpm)	Feed (mm/rev)	DOC (mm)	Ra (µm)	MRR (mm³/min)
1	800	0.10	0.5	1.79	9995
2	800	0.20	1.0	2.45	10595
3	800	0.30	1.5	3.77	12394
4	1200	0.10	1.0	1.59	11993
5	1200	0.20	1.5	2.70	17375
6	1200	0.30	0.5	3.10	14510
7	1600	0.10	1.5	1.38	18307
8	1600	0.20	0.5	2.21	15563
9	1600	0.30	1.0	2.91	21630

Table III: Experiment

IV. OBJECTIVES

1) To study the machinability characteristics of Forged C45 (Gost 1050-88) under different machining conditions.
2) To analyze the effect of cutting speed, feed rate, and depth of cut on:
   – Surface Roughness (Ra) & Material Removal Rate (MRR)
3) To design experiments using appropriate DOE technique (such as Taguchi method) in Minitab.
4) To identify the most significant cutting parameter influencing:
   – Surface quality
   – MRR
5) To determine the optimal combination of cutting parameters for:
   – Minimum surface roughness
   – Maximum material removal rate

V. RESULTS & DISCUSSION

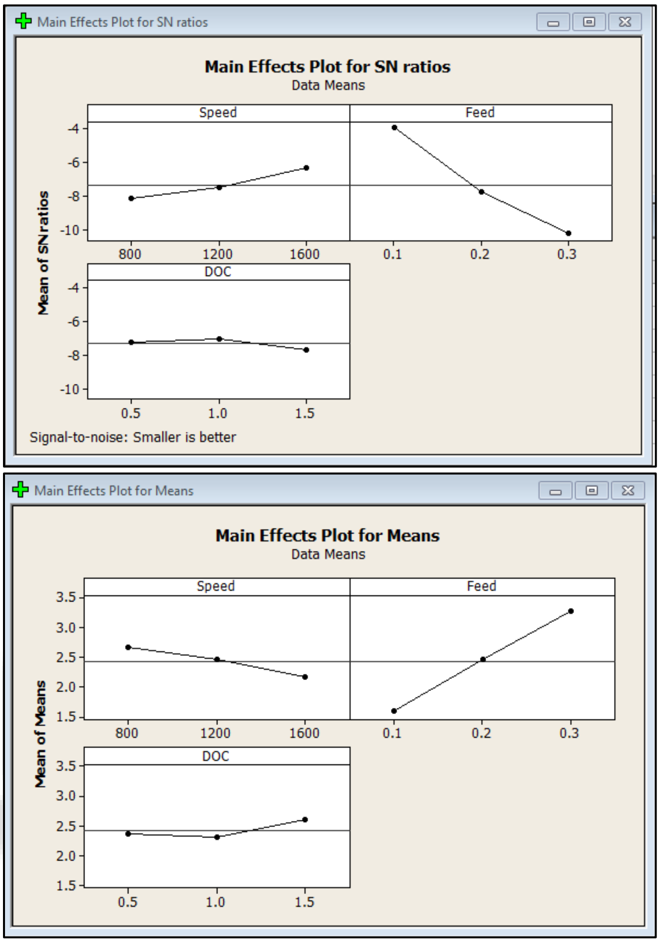

Fig. 3: Surface Roughness Minitab Analysis Graph

A. Main Effects Plot for S/N Ratios (Surface Roughness)

The primary impacts graphic for S/N ratios shows how cutting parameters affect surface roughness using the "Smaller is Better" criterion. This graph shows the parameter level with the highest S/N ratio that produces the least surface roughness.

The plot illustrates that cutting speed improves surface smoothness by increasing S/N ratio. Thus, 1600 rpm is ideal.

The S/N ratio lowers considerably when the feed rate is increased from 0.10 to 0.30 mm/rev. Increased feed produces rougher surfaces. Thus, 0.10 mm/rev is best for minimal surface roughness.

The S/N ratio for depth of cut (DOC) is highest at 1.0 mm, implying better surface polish than 0.5 and 1.5 mm.

The S/N ratio study suggests Speed = 1600 rpm, Feed = 0.10 mm/rev, and DOC = 1.0 mm for the lowest surface roughness.

B. Main Effects Plot for Means (Surface Roughness)

The means significant influences graphic shows how machining parameters affect average surface roughness.

The graph shows that 800–1600 rpm cutting speed reduces surface roughness. This illustrates that quicker cutting speeds smooth surfaces.

Mean surface roughness increases significantly from 0.10 to 0.30 mm/rev feed rate. Rougher surfaces result from higher feed rates.

Compared to speed and feed, mean surface roughness barely affects cut depth. Surface polish is greatest at 1.0 mm cut depth.

Cutting speed and feed rate affect surface roughness most, while depth of cut matters little.

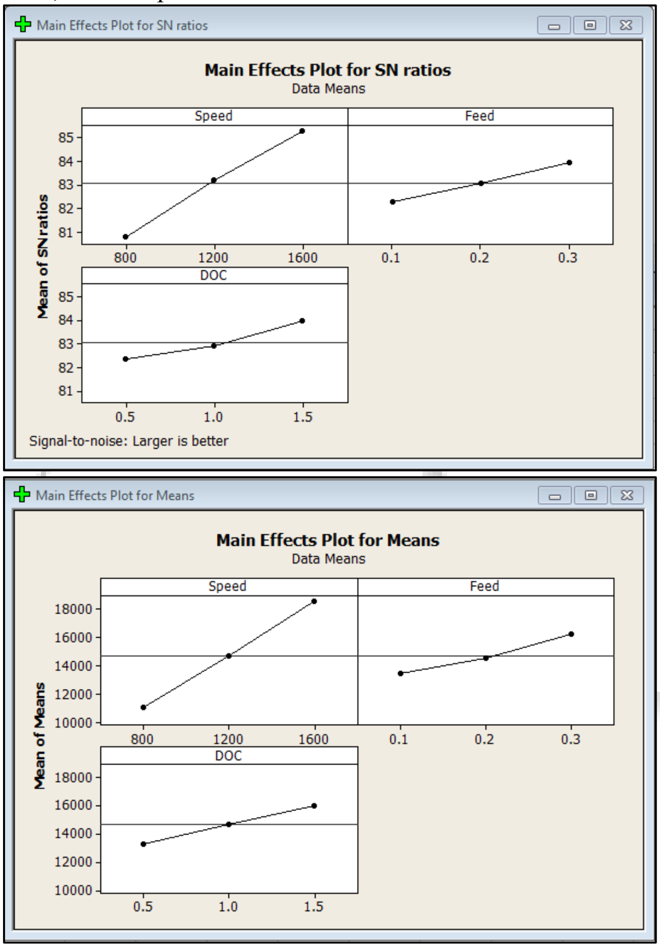

Fig. 4: MRR Minitab Analysis Graph

C. *Main Effects Plot for S/N Ratios (MRR)*

Cutting parameters affect Material Removal Rate (MRR) using the "Larger is Better" criterion in the S/N ratio primary impacts graphic. In this study, the highest S/N ratio for each parameter yields the highest MRR.

The graphic shows how the S/N ratio quickly increases from 800 to 1600 rpm. This suggests that faster cutting rates remove more material. Thus, 1600 rpm is ideal.

From 0.10 to 0.30 mm/rev, the S/N ratio increases, showing that a higher feed rate increases MRR.

Similarly, the S/N ratio increases with depth of cut (DOC) from 0.5 mm to 1.5 mm, indicating that a deeper cut accelerates material removal.

The S/N ratio analysis found that Speed = 1600 rpm, Feed = 0.30 mm/rev, and DOC = 1.5 mm maximise MRR.

D. *Main Effects Plot for Means (MRR)*

The primary effects graphic for means shows how machining parameters directly affect average material removal rates.

The graph shows that increasing the cutting speed from 800 to 1600 rpm greatly increases the mean MRR. Thus, cutting speed boosts machining productivity.

From 0.10 to 0.30 mm/rev, the mean MRR increases, indicating higher material removal in a given time.

The mean MRR increases from 0.5 mm to 1.5 mm, indicating that a deeper cut removes more material.

The results demonstrate that cutting speed, feed rate, and depth of cut most affect MRR. Material removal and machining productivity increase with these parameters.

VI. Conclusion

Minitab statistical analysis and the Taguchi method were used to evaluate Forged C45 (Gost 1050-88) turning machinability. Cutting speed, feed rate, and depth of cut were examined in relation to surface roughness (Ra) and material removal rate (MRR).

The Taguchi L9 orthogonal array reduced the number of experiments while still allowing an effective analysis of the specified parameters. ANOVA and S/N ratio analysis were used to determine the relevance of each machining parameter.

The results show that feed rate and cutting speed affect surface roughness more than depth of cut. Lower feed rates during turning produce smoother, better surfaces.

Cutting speed affects material removal rate (MRR) the most, followed by feed rate and depth of cut. Raise these settings to boost MRR and machining productivity.

The S/N ratio analysis indicated that Speed = 1600 rpm, Feed = 0.10 mm/rev, and DOC = 1.0 mm minimised surface roughness. For highest MRR, Speed = 1600 rpm, Feed = 0.30 mm/rev, and DOC = 1.5 mm were optimal.

This study shows that Taguchi optimisation and statistical analysis improve machining performance. Best surface quality and machining productivity can be achieved by turning forged C45 (Gost 1050-88) with the right cutting parameters.

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Verbalising gratitude is short of conveying the full extent of one's emotions. Despite the fact that words, when spoken from the heart, can accomplish much. Here's another modest attempt at the same. I would like to begin by sincerely thanking my esteemed advisor, Professor Nirav Barevadiya, for all of the time and effort he has put in as an assistant professor in the mechanical engineering department at Monark University. While we were working on the project, he provided me helpful suggestions and encouraged me to speak my mind. Starting with the first phase of my dissertation—searching for a topic—was an excellent educational experience.

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