# Optimization of Drilling Parameters for Aluminium Alloy to Minimize Ovality and Surface Roughness Using a Multi-Objective Approach

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**Abstract**

*One of the major obstacles in the drilling process is choosing the right drilling settings. These days, quality and productivity can be maintained and increased through the use of optimization techniques. Aluminum alloys are used in about half of the world's industrial and commercial processes. Due of their great excellent ductility, strength, and limited heat conductivity, materials like austenitic stainless steel are difficult to manufacture. The experimental investigation of the performance features of the AA6101 T6 aluminum alloy while drilling will be covered in this paper. Performance metrics like ovality and surface roughness during the drilling process are influenced by variables including drill bit diameter, spindle speed, and feed rate. The ideal level of variables must be chosen carefully to accomplish the lowest possible ovality and surface roughness. This paper presents the optimization of multi-objective parameters in aluminum alloy drilling to achieve minimal ovality and surface roughness using Grey Relational Analysis. The experiments will be performed in accordance with the experiment design. Minitab17 is a statistical program used to collect and analyze the experiment findings.*

**Key words-.** *Aluminum alloy AA6101-T6, surface finish, Drilling operation, Minitab 17 software, Grey relational methodology, and analysis of variance (ANOVA).*

## 1. Introduction

The drilling process is a manufacturing process. A drilling tool creates chips by removing undesirable material throughout the drilling operation to create the desired hole. A variety of methods is covered for creating cylindrical holes in the work item. Hole production is arguably the most significant machining process yet, concentrated procedures are needed to provide the best cutting conditions in order to produce an efficient hole. Drilling machines are frequently employed as metal removal equipment in the manufacturing sector.

Therefore, it is crucial to maximize both production and quality at the same time [1-4]. Productivity is correlated with the pace at which material is removed throughout the machining process, and quality is correlated with customer satisfaction due to the desirable qualities of the result. Numerous research papers about boring, reaming, and drilling are accessible. Performance factors include material removal rate (MRR) and surface roughness, according to a number of studies [5-7]. To obtain the lowest surface roughness value and the highest MRR, the authors also determined the ideal values for input parameters like speed, feed, and various cooling conditions. The hole's quality is the other crucial aspect of the drilling procedure.

Enhancing the worth and productivity of company-wide initiatives, design quality can be raised [8]. Productivity and quality are the two main factors that are connected. Optimization can also benefit from the Taguchi-based DOE. For machining operations, Taguchi methods are among the most widely utilized optimization approaches, despite the fact that there are many others [9–11]. In addition, Taguchi parameter design offered a productive way to optimize many quality and cost-related factors in a variety of machining processes.

Metal cutting involves multiple phases of impact, plastic deformation, fracture, and both continuous and sporadic several points of contact, as well as friction. Sensors are employed to check quality because human eyes cannot be able to do visual inspection of chip and work piece obstructions. We must choose the best cutting parameters in order to get exceptional quality. We also know that drilling is a complicated process that is linked to other machining operations because drill tools can wear down and become stuck in work pieces . Important factors that might potentially impact the quality of the hole include cutting speed, temperature, feed rate, and geometrical parameters. The impact of these factors on the tool life in drilling has also been thoroughly examined in a number of relevant investigations.

## II. Materials and Methods

A. Used Materials

In experiment, we use aluminum alloy sheets of AA6101 T6 grade, with a thickness of 10mm and dimensions of 255mm x 100mm.

B. DRILL TOOLS OR BITS

These tools with multiple cutting edges are commonly used in industries to drill holes of different sizes while efficiently removing material. They are available in different shapes and sizes, and we are able to create holes in a range of sizes and materials. The procedure for making holes is straightforward: first, drill bits are fastened to a drill, which rotates them to cut through the work piece. In the chuck, the drill will grab the top end of a bit known as the shank.

These are available in the market in a variety of typical sizes. Metric and imperial drill bit sizes are included alongside the necessary screw tap sizes in an extensive drill bit and tap size chart. Additionally, some specialty drill bits are capable of producing holes with a non-circular cross-section.

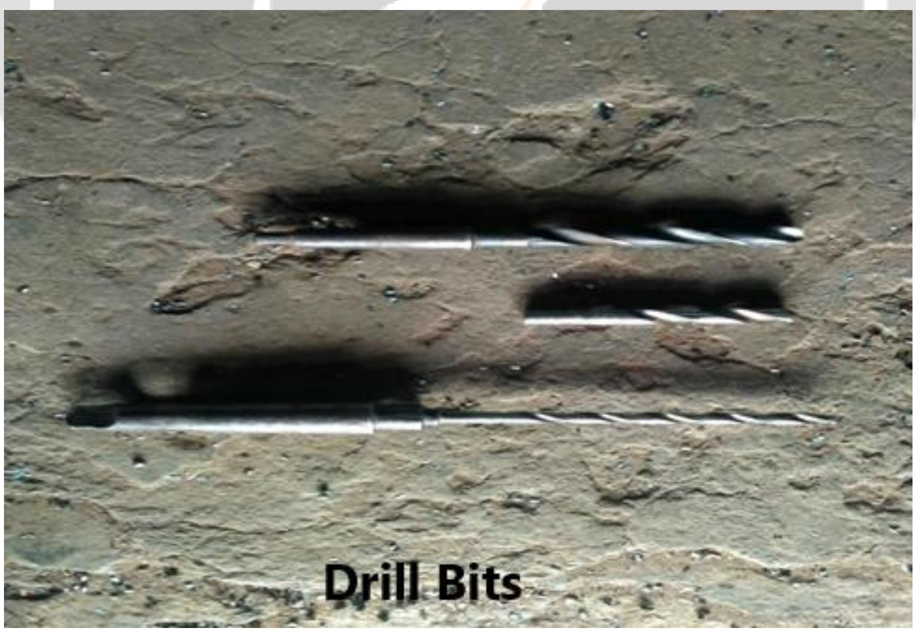


Fig. 1. HSS drill bit for drilling

C. UTILIZED MACHINERY

The VMC-400, a vertical milling/drilling machine made by HMT, was used for the experiments. To carry out programming, this vertical machining center is outfitted with an O-M controller from the Fanuc India series. The machine can reach a maximum feed rate of 2000 mm/min and a spindle speed of 4000 rpm.


Fig. 2. The VMC400 machine

D. Operational Parameters and Their Limits

In this experiment, we will use a CNC drilling machine equipped with a high-speed steel tool to carry out drilling operations. The objective is to use the Taguchi method and L9-based techniques to optimize a number of process parameters, Design of Experiments (DOE), with ANOVA applied to analyse the importance and proportion of the contribution of each factor in achieving the desired surface finish.

For this study, spindle speed, feed rate, and drill bit diameter have been selected as the process variables.

E. EXPERIMENTAL DESIGN

Using three criteria at three distinct levels, for an aggregate of nine experimental combinations have been created with Taguchi's L9 Orthogonal Array (OA) in Minitab for Design of Experiments (DOE). These combinations involve variations in, drill bit diameter feed rate and spindle speed. Each experimental trial's ovality and surface roughness will be measured and analyzed. The table below outlines the cutting conditions used for drilling operations on an aluminium alloy, with data being recorded for each trial.

## III. **Result**

Using the Taguchi-based GRA analysis, it is suggested that parameters be optimized for surface roughness and ovality while taking into account various drilling process performance factors.

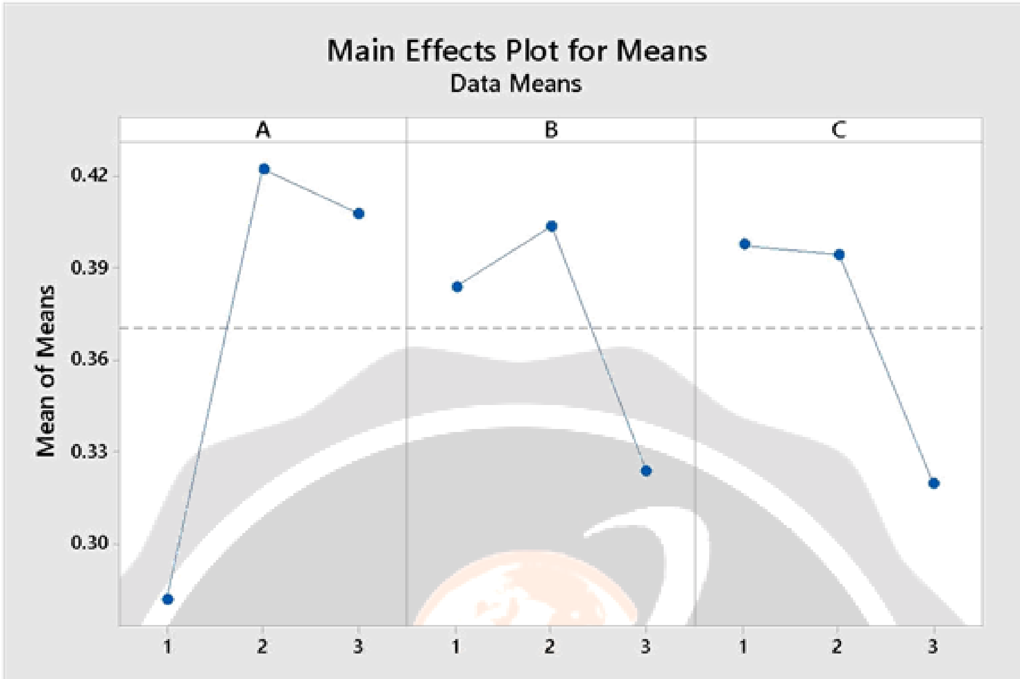


Fig. 3. Parameter effects on ovality and surface roughness

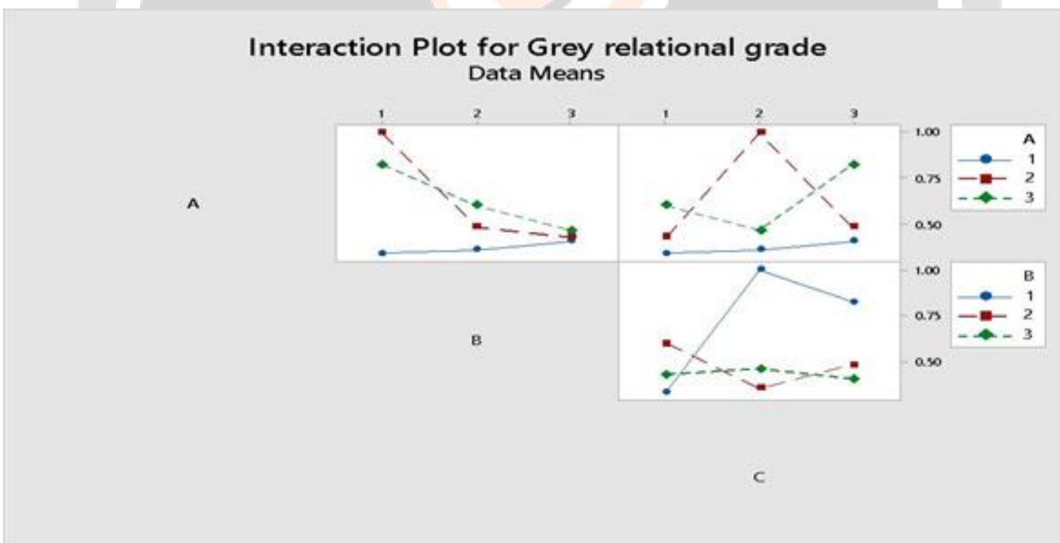


Fig. 4: Surface roughness Interaction plot

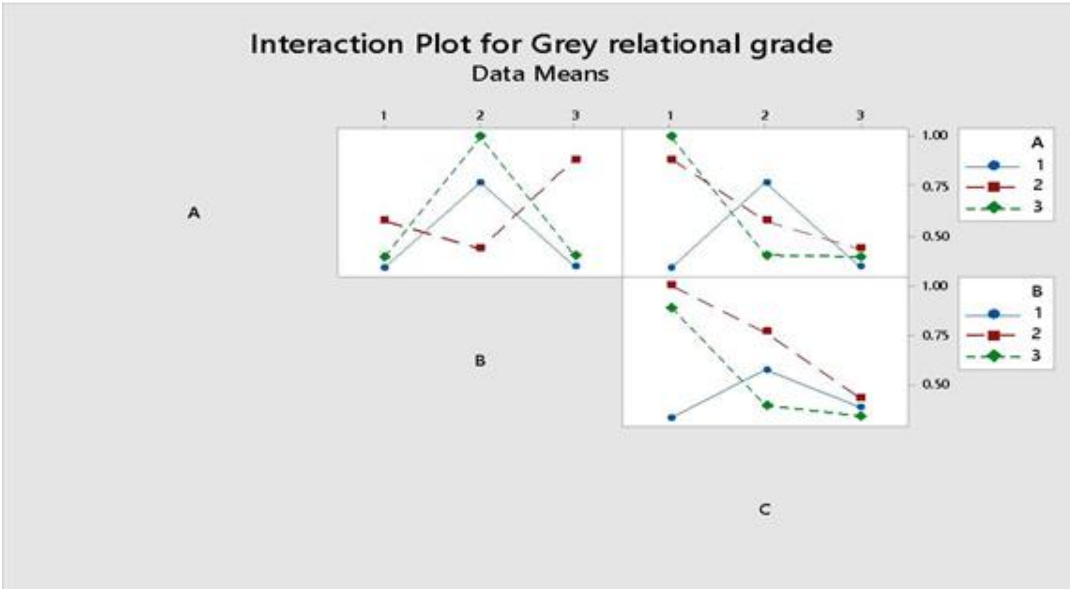


Fig. 5: Interaction plot of ovality

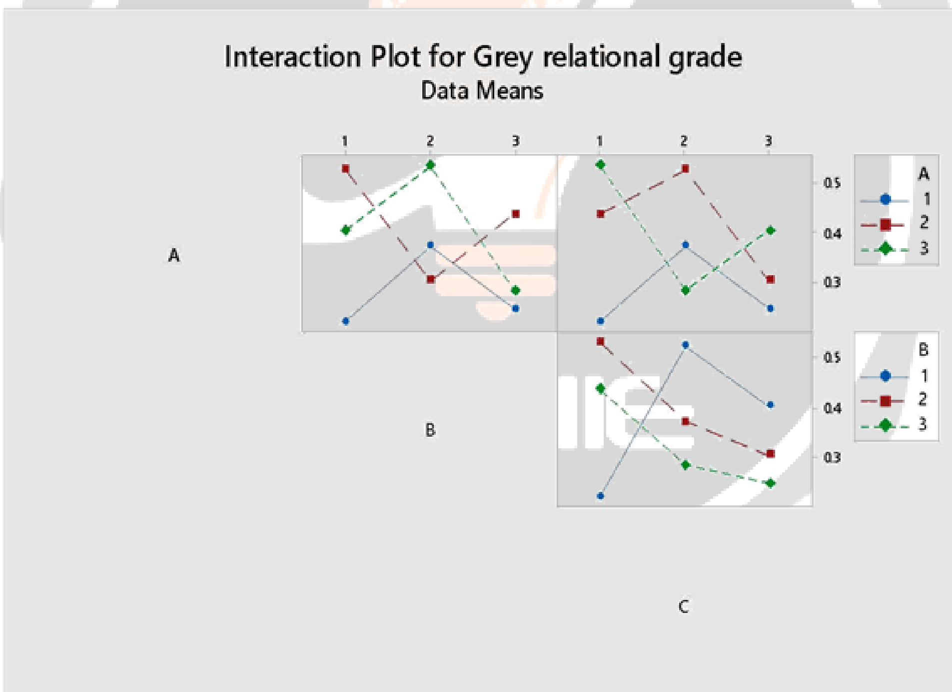


Fig. 6: Interaction plot of surface roughness and ovality

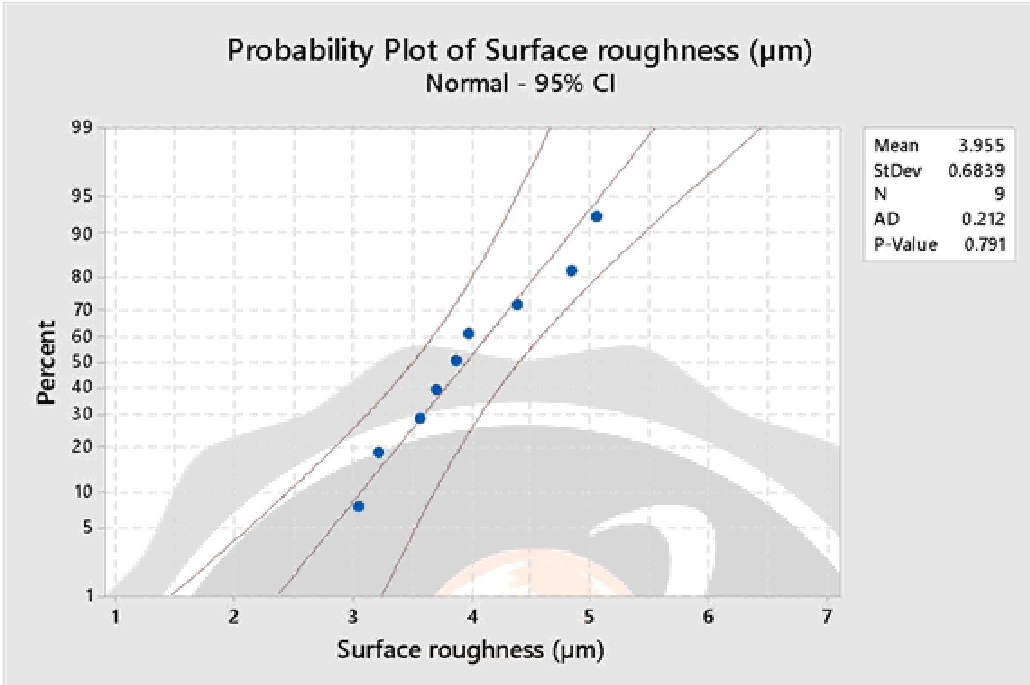


Fig. 7: Plot of the surface roughness residuals using normal probability

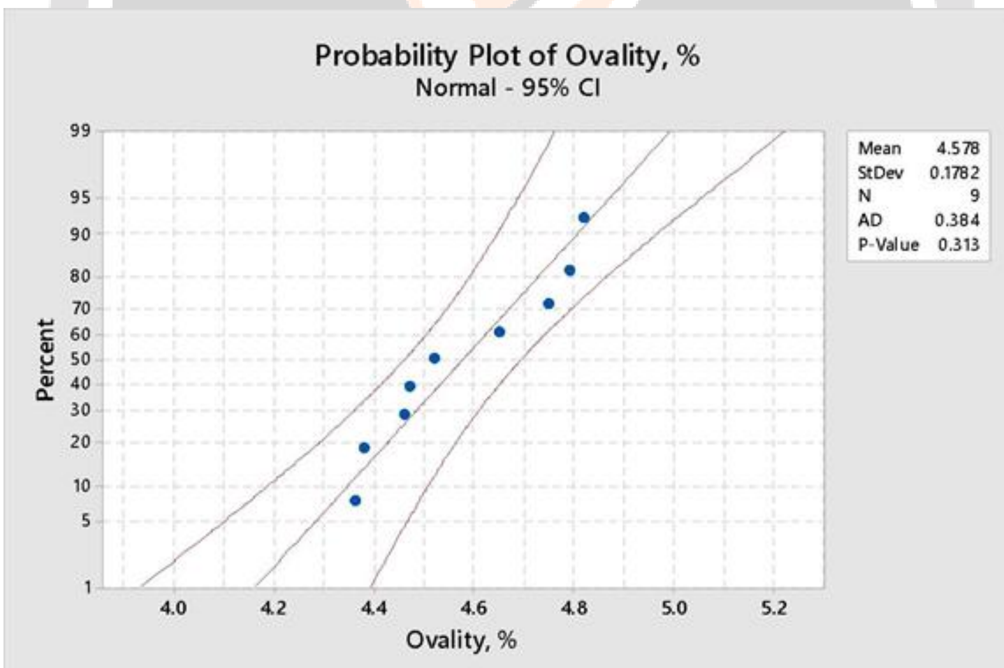


Fig. 8: Plot of the residuals for ovality with normal probability

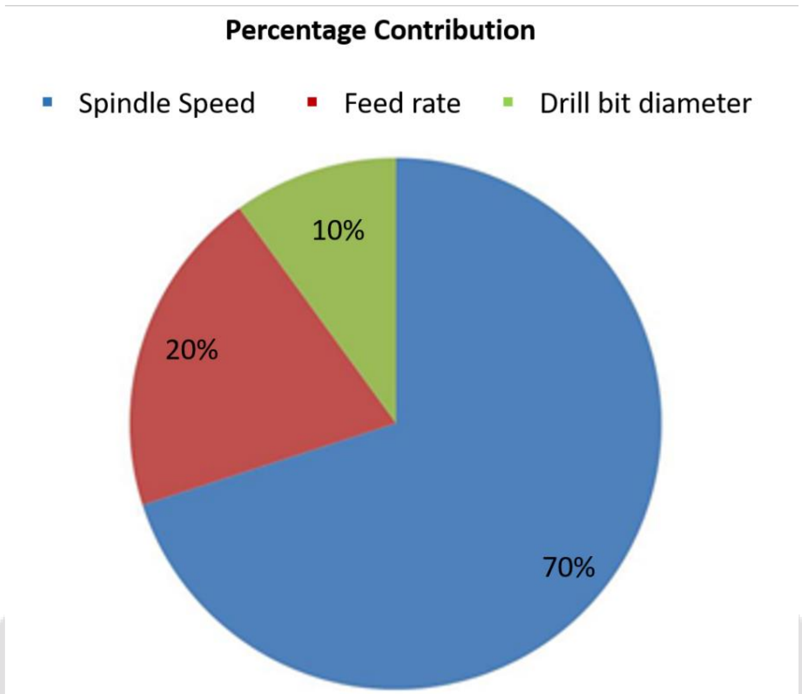


Fig. 9: Factors' percentage contributions to the grey relational grade

## IV. Conclusion

The GRA based on the Taguchi method's response table was presented in order to investigate the drilling process parameter optimization. The grey relational grade has determined that ovality and surface roughness are the best machining parameters for multi-objective performance. DOE has been conducted on a L9 orthogonal array. From this investigation, the following conclusions can be made.

1. The most important factor is spindle speed, and even a slight change will result in a significant decrease in the surface roughness.

2. The largest Grey relational grade value is obtained with a spindle speed of 300 rpm, feed rate of 20 mm/min, and drill bit diameter of 8 mm, according the Grey relational grade graph. Therefore, it is the suggested level of drilling operation input parameters to achieve the best possible hole accuracy and the least amount of surface roughness.

3. When it comes to surface roughness, it displays a decline in the x-axis response values as the y-axis parameter values change. Here, the numbers are declining as the amount of feed increases. The ovality grows quickly as the spindle speed increases in these interactions. The response values on the x-axis drop as the y-axis of the parameter values varies, in contrast to the interactions of point angle, where the values are increasing.

4. According to the primary effect figure, surface roughness rises as feed changes. The surface roughness (Ra) values decreased as spindle speed increased. Surface roughness decreases with increasing parameter values.. The ovality is diminishing as the parameters' values grow. Therefore, the most important process parameter is spindle speed.

5. It can be as demonstrated by the GRG versus level graph, the GRG value gradually rises as spindle speed increases and rapidly falls as feed rate increases.

6. According to variance data analysis, spindle speed is the main drilling parameter that has the biggest impact on the output responses, accounting for 66.66% of the total. The feed rate, which contributes 19.04 percent, is the second influencing factor.

7. The normal probability plots of the residuals compared to the expected response for surface roughness demonstrate that the errors are normally distributed, as the residuals usually lie on a straight line. This suggests that the results are satisfactory and that there is no reason to question the validity of the continuous modification or individuality assumptions.

8. The spindle speed must be maintained at 300 rpm with a 40 mm/min feed rate in order to meet the lowest possible surface roughness and ovality.

9. Ovality reduces as feed rate and spindle speed increase.

10. We have effectively forecasted the primary impacts and interaction charts of several factorial machining parameter combinations utilizing the DOE method.

11. This method is more practical for maximizing the drilling parameters when drilling aluminum alloy at the levels under investigation.

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