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Analysis of Cutting Forces in Single-Point Machining with Varying Rake Angles

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ABSTRACT

This experimental study explores how various parameters—namely tool rake angle, depth of cut, workpiece material, and cutting tool type—affect the primary cutting force (Fc) during turning operations. The materials selected for the work pieces were EN 31, Mild Steel (MS), and Aluminum, while the cutting was performed using High-Speed Steel (HSS) and Carbide tools. Each combination of material and tool type underwent 45 experimental trials, maintaining a consistent spindle speed of 550 rpm and a feed rate of 0.2 mm/rev. The experiments involved varying the depth of cut between 0.2 mm and 5 mm and adjusting the rake angle from 0° to 16°. Findings revealed that, for both EN 31 and MS, the cutting force reduced as the rake angle increased but rose with deeper cuts. Machining EN 31 beyond 3 mm with HSS and 4 mm with Carbide resulted in excessive noise and vibration, making it unfeasible. MS could be machined up to 4 mm using HSS and 5 mm with Carbide. In the case of Aluminum, cutting force increased with rake angle at shallower depths (0.2–0.8 mm) but showed minimal variation at greater depths (1.5–5 mm). Aluminum could be machined up to 5 mm using both tool types. Across all materials, Carbide tools consistently exhibited higher cutting force values than HSS for the same cutting depth.

Keywords- Rack angles, Depth of cut, High-Speed Steel, Carbide tool

1. INTRODUCTION

Turning is a machining operation used to shape components with a cylindrical profile using a single-point cutting tool on a lathe. In this process, the cutting tool moves either in a straight line parallel or perpendicular to the axis of the rotating workpiece, or follows a specific path to create intricate rotational profiles. The main cutting movement in turning comes from the rotation of the workpiece, while the secondary movement is the linear feed of the tool. This technique is commonly employed to produce cylindrical surfaces. During the process, the workpiece is mounted on a spindle and rotated, while the cutting tool advances either radially, axially, or in both directions simultaneously to achieve the desired geometry. Generally, the term "turning" refers to the formation of cylindrical surfaces using a single-point tool. Specifically, it is associated with the machining of external surfaces aligned mostly parallel to the axis of the workpiece. When surfaces are machined that are primarily perpendicular to the axis, the operation is termed "facing." In turning, the feed motion is mainly along the axial direction of the spindle, whereas in facing, it predominantly follows a radial direction.

2. PROBLEM IDENTIFICATION

Machinability is an important parameter to understand cutting mechanism for any given material. It is related with the cutting forces developed during machining process. Therefore, understanding the interrelationship between various parameters—such as cutting speed, feed rate, depth of cut, tool geometry (including rake and clearance angles), nose radius, tool material, and workpiece material—and their influence on cutting force is an important area of research.

In previous works following combinations have been considered for analysis

1. Feed rate and rake angle V/s cutting force keeping cutting speed constant and using same work piece material

2. Cutting seed V/s cutting force keeping other parameters constant.

3. Depth of cut and rake angle V/s cutting force keeping feed rate constant and using different materials. Max depth of cut considered so far is up to 2.5 mm only.

In this work we have considered following parameters:

1. Depth of cut, rake angle, different tool and work piece material.

2. Max depth of cut considered is 5 mm.

3. Different work materials have been considered namely EN 31, MS and Al.

4. Different tool materials have been considered namely HSS and carbide.

3. OBJECTIVES OF THE RESEARCH WORK

The rake angle is a critical parameter in cutting and machining operations, representing the angle between the cutting tool's face and the surface of the workpiece. It plays a significant role in determining cutting efficiency and chip flow. Additionally, the influence of different depths of cut, along with variations in workpiece and tool materials, on cutting forces is also extensively analyzed in machining studies.

 To investigate the variation in cutting forces with different depths of cut while maintaining a constant rake angle and cutting speed.

 To examine the influence of various workpiece materials on the cutting force during the turning process.

 To evaluate the effect of different cutting tool materials on the cutting force under similar machining conditions.

4. RESULT AND DISCUSSION

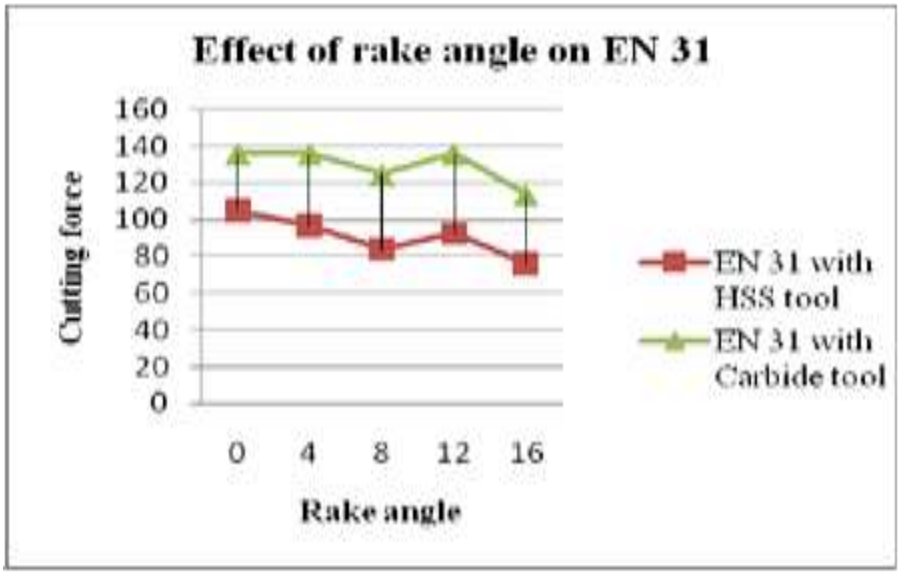

Figure 1: Influence of Rake Angle on Cutting Force during Machining of EN 31 Steel

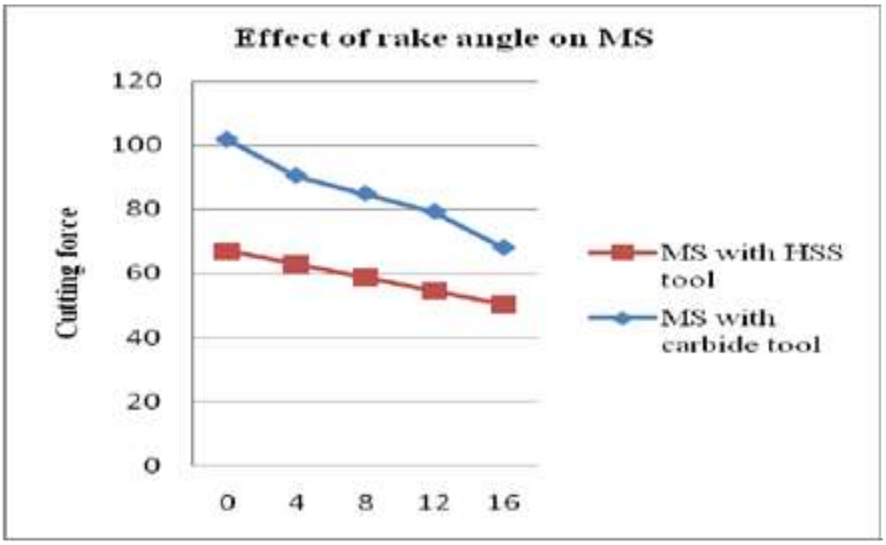

Figure 2: Effect of Rake Angle on Cutting Force during Machining of Mild Steel (MS)

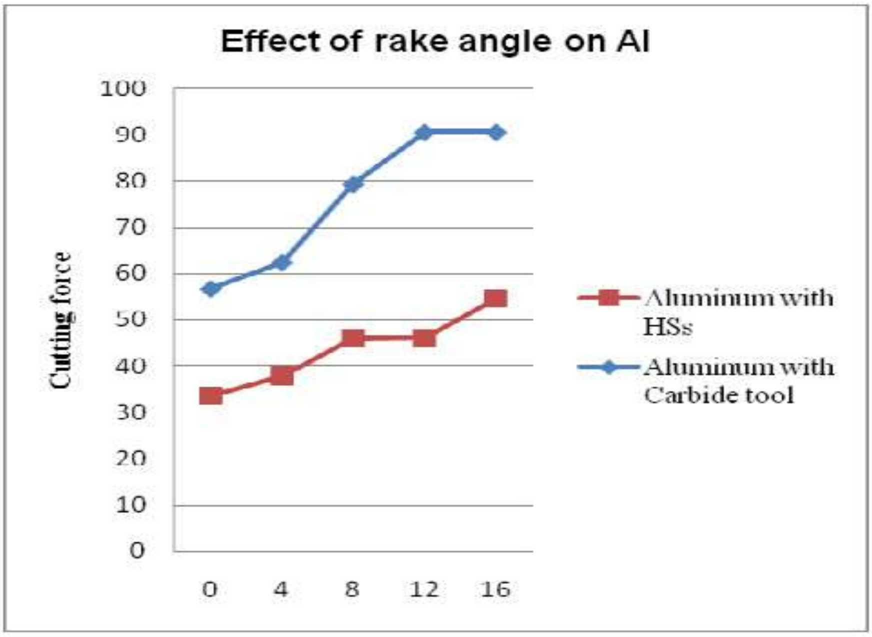

Figure 6.3: Effect of Rake Angle on Cutting Force during Machining of Aluminium (AL)

5. CONCLUSION

The conclusions presented in this study are based on a detailed analysis of the experimental data. The key findings are summarized below:

- For EN 31 and Mild Steel specimens, the primary cutting force shows a decreasing trend with an increase in tool rake angle from 0° to 16°. In contrast, for Aluminum, the cutting force increases with rake angle at shallow depths of cut (0.2 mm and 0.8 mm). However, for higher depths ranging from 1.5 mm to 5 mm, the cutting force remains relatively constant, regardless of whether High-Speed Steel (HSS) or Carbide tools are used.
- Across all tested materials, the main cutting force increases linearly as the depth of cut increases from 0.2 mm to 5 mm, for both HSS and Carbide tools.
- Aluminum work pieces can be successfully machined up to a 5 mm depth of cut using both HSS and Carbide tools under identical machining conditions.

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