Business, Society and Technology
IFE, 3rd semester

LAB REPORT
MANUFACTURING

Lab no. 10	Title: Cutting Tool Design and Sharpening
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INTRODUCTION

Cutting tools are fundamental components in machining operations, and their geometry directly affects the efficiency, quality, and economics of the metal removal process. The design and maintenance of cutting tools require a thorough understanding of tool angles and their influence on cutting performance. This laboratory exercise focused on the geometry of turning tools and the methods used to sharpen various types of cutting tools.

The geometry of a cutting tool is characterized by several important angles, each serving a specific purpose in the cutting process. The rake angle influences chip formation and cutting forces, with positive rake angles reducing cutting forces but weakening the cutting edge. The relief angle prevents rubbing between the tool flank and the newly machined surface, reducing friction and heat generation. The cutting edge angles determine the direction of chip flow and affect surface finish quality.

Tool sharpening is an essential maintenance operation that restores the cutting edges to their optimal condition. Different types of cutting tools require specific sharpening techniques and equipment. This laboratory provided practical demonstrations of sharpening methods for twist drills, shell end mill cutters, form relieved mill cutters, and hob cutters, each presenting unique challenges due to their complex geometries.

EXPERIMENTAL

Task 1: Turning Tool Angle Measurement

The objective of this task was to measure the angles of a single-point turning tool using a protractor and angle measuring instruments. The measured values were recorded and used to compose the tool signature according to ISO designation standards.

Table 1. Results of measurements

Name of an angle	Value	Units	Symbol
Back rake angle	1.5	[°]	λ_s
Side rake angle	14	[°]	γ_0
End relief angle	5	[°]	α'_0
Side relief angle	5	[°]	α_0
End cutting edge angle	17	[°]	κ'_r
Side cutting edge angle	20	[°]	ψ
Nose radius	0.4	[mm]	r_ε

The measured angles indicate that this turning tool has a relatively small back rake angle of 1.5°, which provides a stronger cutting edge suitable for harder materials or interrupted cuts. The side rake angle of 14° is moderate, providing a good balance between cutting efficiency and edge strength. The relief angles of 5° each are sufficient to prevent rubbing while maintaining adequate support for the cutting edge. The cutting edge angles of 17° and 20° determine the approach direction and chip flow characteristics.

Based on the ISO designation system, the tool signature can be expressed as: 1.5 - 14 - 5 - 5 - 17 - 20 - 0.4 (λs - $\gamma 0$ - $\alpha'0$ - $\alpha 0$ - $\kappa'r$ - ψ - $r\varepsilon$).

Calculated Tool Geometry Parameters

Using the measured angles, additional geometric parameters of the cutting tool can be calculated:

The wedge angle (β) represents the angle of the cutting wedge and is calculated as:

$$\beta = 90° - \gamma_0 - \alpha_0 = 90° - 14° - 5° = 71°$$

The cutting angle (δ) is the angle between the rake face and the cutting direction:

$$\delta = 90° - \gamma_0 = 90° - 14° = 76°$$

The tool included angle (ε) between the main and auxiliary cutting edges:

$$\varepsilon = 180° - \kappa_r - \kappa'_r = 180° - 20° - 17° = 143°$$

Where $\kappa_r = 90° - \psi = 90° - 20° = 70°$ is the main cutting edge angle.

Table 2. Calculated tool geometry parameters

Parameter	Formula	Value	Symbol
Wedge angle	$90° - \gamma_0 - \alpha_0$	71°	β
Cutting angle	$90° - \gamma_0$	76°	δ
Main cutting edge angle	$90° - \psi$	70°	κ_r
Tool included angle	$180° - \kappa_r - \kappa'_r$	143°	ε
Sum of angles (verification)	$\alpha_0 + \beta + \gamma_0$	90°	-

The relationship $\alpha + \beta + \gamma = 90°$ is verified: 5° + 71° + 14° = 90°, confirming the measurements are consistent.

The wedge angle of 71° indicates a relatively strong cutting edge suitable for machining harder materials. A smaller wedge angle would provide a sharper edge but with reduced strength. The cutting angle of 76° is within the typical range for turning operations on steel and other common engineering materials.

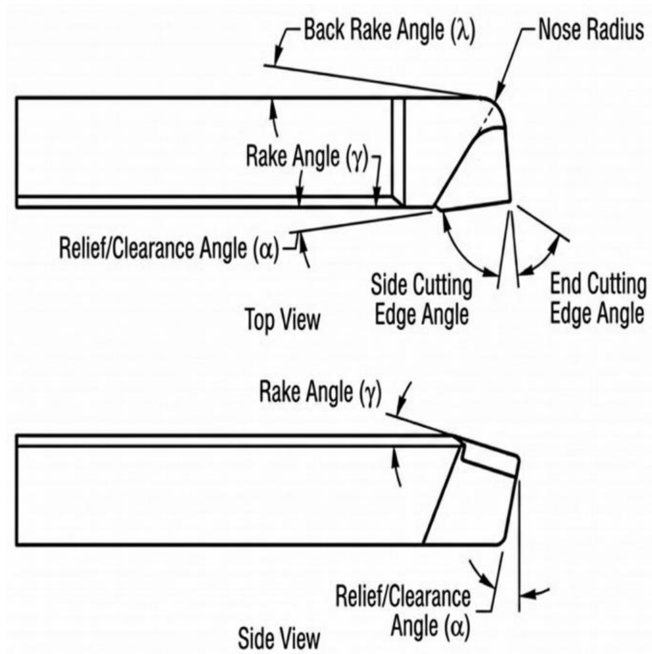

Figure 1. Schematic drawing of a single-point turning tool with the main angles marked: back rake angle (λ), side rake angle (γ), relief angles (α), and cutting edge angles.

Task 2: Sharpening of a Twist Drill

The demonstration covered the sharpening of a twist drill, which is one of the most commonly used cutting tools in manufacturing. Twist drills require periodic sharpening to maintain their cutting efficiency and produce accurate holes.

The key aspects of twist drill sharpening include maintaining the correct point angle, which is typically 118° for general-purpose drilling but may vary for specific materials. The lip relief angle should be maintained at approximately 8-12° to provide clearance behind the cutting lips. Both cutting lips must be ground to equal length to ensure the drill cuts on center and produces round holes. For larger drills, web thinning may be necessary to reduce thrust forces. The sharpening was performed on a bench grinder with appropriate wheel selection and coolant application to prevent overheating of the cutting edges.

Task 3: Sharpening of Shell End Mill Cutter

Shell end mill cutters are multi-flute cutting tools used for face milling and peripheral milling operations. The demonstration focused on sharpening the relief angles on the cutting teeth.

The primary relief angle, typically 4-8°, provides the first clearance behind the cutting edge, while the secondary relief angle of 12-15° provides additional clearance to prevent heel contact. Maintaining uniform tooth spacing during grinding ensures equal cutting load distribution among all teeth. Specialized tool and cutter grinders with indexing fixtures were used to ensure accurate and consistent relief angle grinding on each tooth, producing a keen cutting edge at the intersection of the rake face and relief surface.

Task 4: Sharpening of Form Relieved Mill Cutter

Form relieved cutters are specialized tools that produce complex profiles, such as gear teeth or thread forms. These cutters have a distinctive geometry where the relief is built into the tooth profile rather than ground as a flat surface.

The critical consideration when sharpening form relieved cutters is that grinding must be performed exclusively on the rake face to preserve the form-relieved profile. Grinding must be performed parallel to the cutter axis to prevent distortion of the tooth profile, and the same amount of material must be removed from each tooth to maintain concentricity. The relief surface must never be ground, as this would destroy the precisely manufactured form that defines the profile being produced.

Task 5: Sharpening of Hob Cutter

Hob cutters are specialized gear cutting tools that generate gear teeth through a continuous rolling action. Hob sharpening is a critical operation requiring high precision.

Like form relieved cutters, hobs are sharpened only on the rake face. Care must be taken to maintain consistent flute depth across all teeth, and the generating profile must be preserved exactly to produce accurate gear teeth. A fine surface finish on the sharpened face is essential for quality gear production. Specialized hob sharpening machines with precise indexing mechanisms and diamond or CBN grinding wheels were demonstrated during the laboratory.

CONCLUSIONS

This laboratory exercise on cutting tool design and sharpening provided valuable practical insights into the geometry and maintenance of cutting tools used in manufacturing operations.

The measurement of turning tool angles demonstrated the importance of each geometric parameter in defining tool performance. The measured tool exhibited a back rake angle of 1.5°, side rake angle of 14°, relief angles of 5°, end cutting edge angle of 17°, side cutting edge angle of 20°, and nose radius of 0.4 mm. These angles combine to create a tool suitable for general-purpose turning operations, with the tool signature 1.5-14-5-5-17-20-0.4 providing a standardized description of the geometry.

The practical demonstrations of sharpening methods for various cutting tools highlighted the diversity of techniques required for different tool types. Twist drill sharpening emphasizes the importance of symmetric lip grinding and proper point angle maintenance. Shell end mill cutters require careful relief angle grinding while maintaining tooth-to-tooth consistency. Form relieved cutters and hob cutters present unique challenges as they can only be sharpened on the rake face to preserve their precision-manufactured profiles. These concepts are essential for effective tool management in manufacturing environments.