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Design and Analysis of Deep Drawing Die for Copper Cup

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Abstract: *The deep drawing process is widely used in manufacturing for shaping metal sheets into complex geometries. This study focuses on the design and analysis of a deep drawing die for the production of copper cups. Copper, known for its excellent ductility, thermal conductivity, and corrosion resistance, presents unique challenges during the deep drawing process, such as controlling thinning, wrinkling, and tearing. The design of the die was optimized to achieve precise dimensional accuracy, ensure uniform material flow, and minimize defects. Key parameters, including blank holder force, die clearance, punch radius, and others, were carefully analyzed using simulation software to predict material behavior during deformation. Important parameters were selected to analyze their effect on various machining parameters using the Taguchi design of experiment technique. Finite Element Analysis (FEA) was employed to evaluate stress distribution, strain rates, and potential failure points in the copper blank. The design was carried out using CATIA software and Ansys V15. The results showed that proper die design significantly influenced the formability of the copper sheet and the quality of the finished cup. The study highlights critical considerations in the die design process and provides guidelines for improving the efficiency and reliability of deep drawing operations for copper. These findings contribute to enhancing product quality and reducing production costs in industries utilizing copper components.*

Key Words: *Deep drawing process, Finite Element Analysis, Taguchi design, Ansys V15.*

I.INTRODUCTION

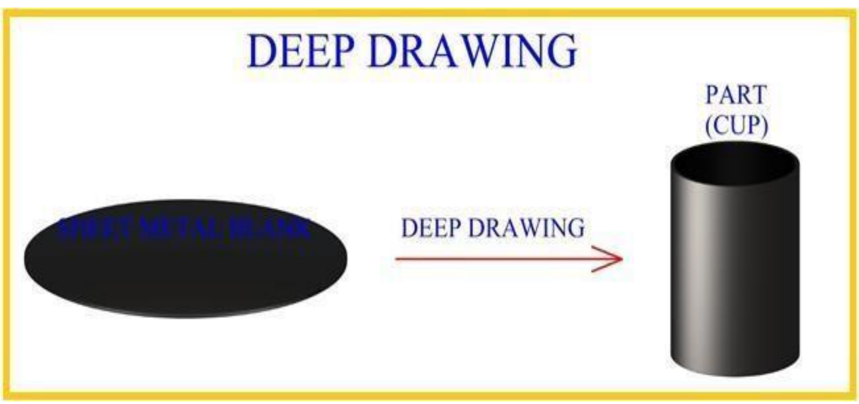
1.1. Overview

Deep drawing is a manufacturing process widely used for forming sheet metal into cup-like or box-like structures. Items such as pots, pans, holders, sinks, vehicle parts, and gas tanks are produced through this process. The process involves a punch and die setup, with the punch defining the final shape of the part, and the die cavity allowing the punch to pass through with some clearance.

The process is complex and the shape of the drawn part can be circular, square, or more complex. However, the complexity of the part often increases manufacturing challenges. The deep drawing process aims to design parts with simple geometry to reduce challenges and improve efficiency.

1.2. Problem Statement

The size of the deep-drawn component is influenced by several factors, such as anisotropic material properties, die clearance, corner radius, and drawing speed. As these factors are interdependent, achieving accurate results can be a challenge. The process typically relies on trial and error, which is costly and time-consuming.

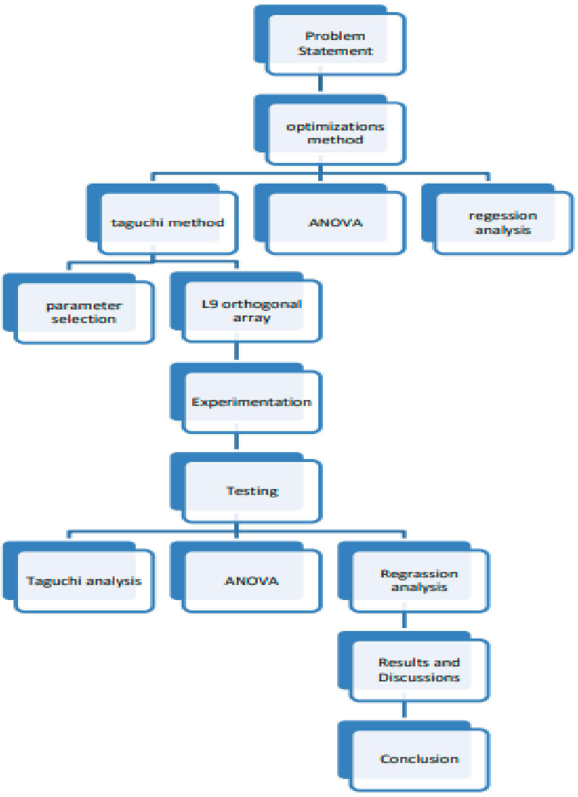


1.3. Objectives

1. Design of the deep drawing blank for the given component shape.
2. Statistical analysis using the Taguchi method to find optimal deep drawing force, die clearance, drawing speed, and drawing radii.
3. Validation of theoretical design and ANSYS workbench16.0 results via experimentation.
4. Experimental validation of the results using optimal values determined through simulation and statistical analysis.

1.4. Methodology

The design and analysis are carried out using CATIA software for die design and Ansys V15 for simulation. The Taguchi design of experiments (DOE) methodology is used to optimize process parameters, such as blank holder force, punch radius, die clearance, and others. Results are validated through both theoretical calculations and experimental data.



II.LITRATURE REVIEW

2.1. Recent Studies on Deep Drawing Process.

Several studies have been conducted on the deep drawing process, highlighting the role of process parameters on the final product's quality. Adnan I. O. Zaid (2016) discussed the influence of die profile radius, radial clearance, and punch load on drawing force and the quality of the drawn parts. Pradeep M. Patil (2013) highlighted the role of punch speed and blank-holder force on depth of draw and product quality. S. V. Modanloo (2016) investigated the effect of friction and die parameters on the forming force required for drawing brass-steel laminated composites.

2.2. Gap in Literature

Despite several studies, there has been limited research focusing on detailed FEA analysis of deep-drawn components, especially using ANSYS workbench. This study aims to bridge this gap and enhance the understanding of stress and strain distribution during the deep drawing process.

III.DESIGN OF EXPERIMENT (DOE)

3.1. Taguchi Method

The Taguchi method is employed to analyze the effect of process parameters on the deep drawing process. By using orthogonal arrays, we systematically investigate the process variables that affect product quality and optimize them for robust design.

3.2. Selection of Process Parameters

The following parameters are selected for analysis:

- Die clearance

- Punch radius
- Blank holder force
- Drawing speed

3.3. Analysis of Variance (ANOVA)

ANOVA is used to analyze the variance in the data and validate the optimal parameters derived from the Taguchi method.

3.4. Signal to Noise (S/N) Ratio

The S/N ratio is used to evaluate the impact of each factor and select the optimal conditions for minimum variation and maximum performance.

IV.RESULTS AND DISCUSSION

4.1. Salient Features

- Design of the deep drawing blank for the component shape.
- Statistical analysis of optimal deep drawing force.
- Design and analysis of the component without holding force.
- Optimization of die clearance and drawing radii.

4.2. Advantages

- Optimized drawing speed reduces press power consumption.
- Optimal die clearance reduces rework and die costs.
- Lower material costs due to optimal die size.
- Prevention of defects like wrinkles and tears.

4.3. Applications

- Domestic utensils and containers.
- Industrial machine components.
- Defense components.

4.4. Future Scope

- Use of explicit dynamics in ANSYS for better optimization.
- Application of Grey Relation Analysis to predict component thickness during drawing.

V.SUMMARY

This study applied the Taguchi method to optimize the deep drawing process for copper cups. By using ANSYS simulation and statistical analysis, the optimal values for process parameters were determined, reducing the number of iterations required and minimizing cost and time. Experimental results validated the simulation data, confirming the effectiveness of the optimized parameters.

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