Cold Tube Drawing Process

Selected chapters of theories of forming and machining

Implementation of innovative learning methods and practical training to education in the field of production technologies and production management to increase the attractiveness of study and support the key competencies of the students

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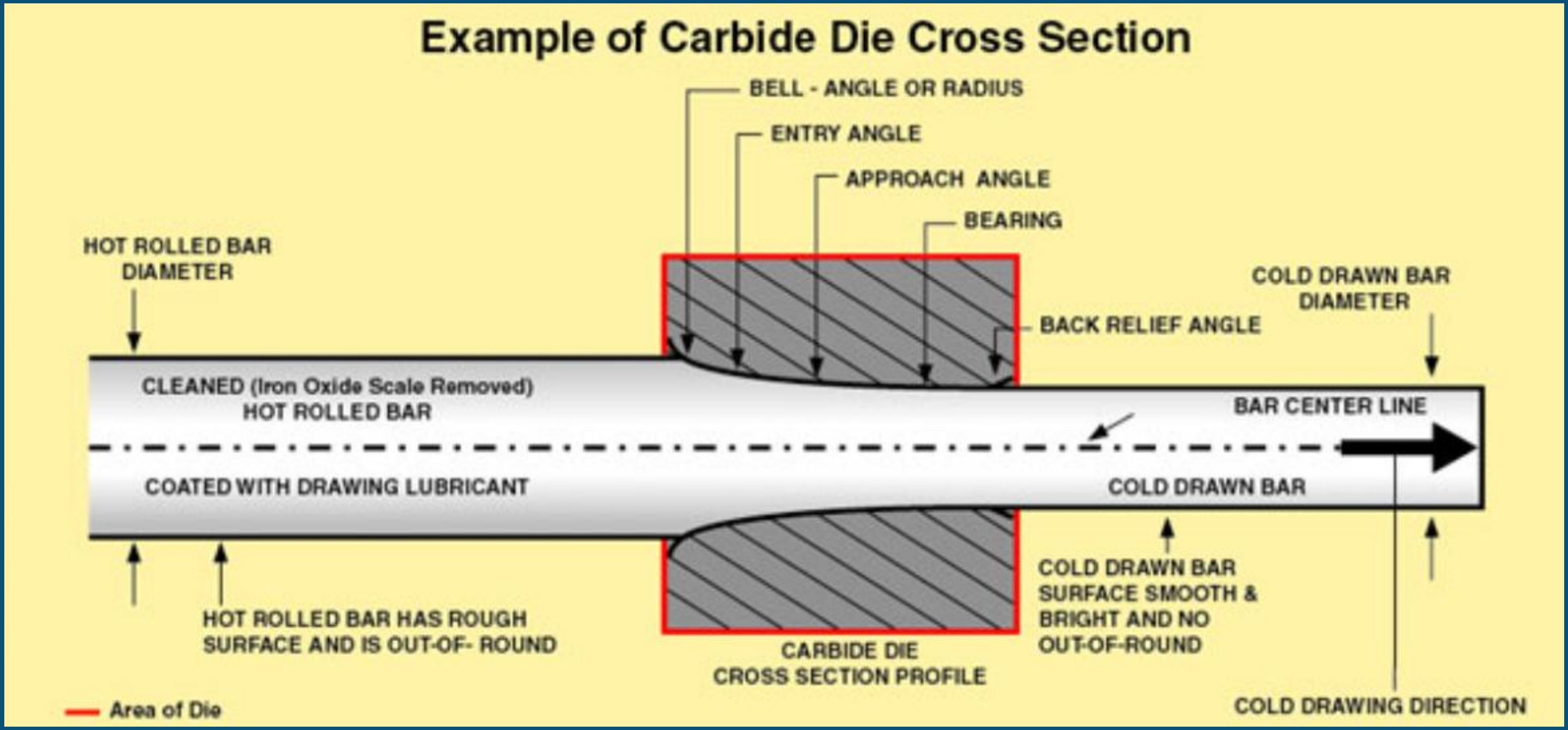
Cold Tube Drawing Process

- Forming Theory – Detailed Overview
- Precision cold forming process reducing diameter and wall thickness while improving surface finish.

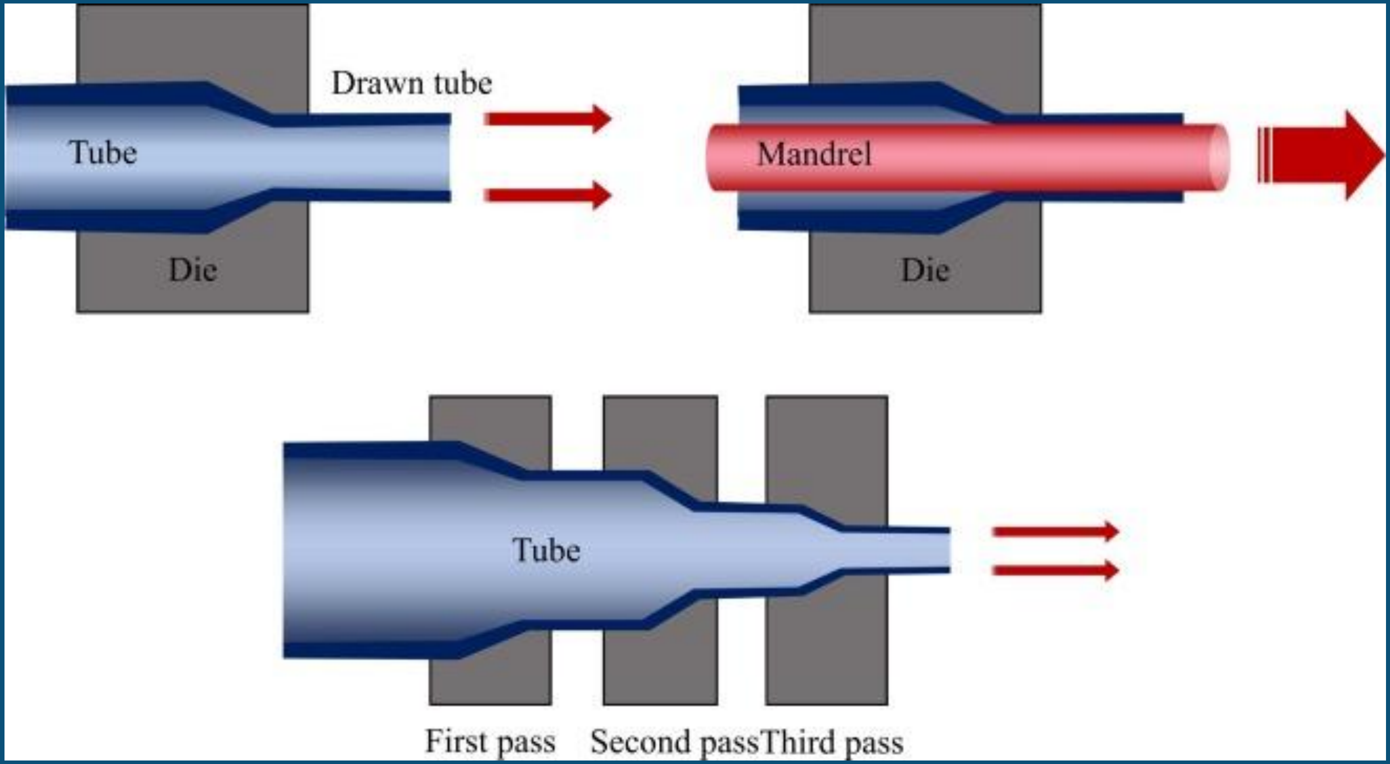


Definition & Overview

- Cold tube drawing is a cold plastic deformation process used to reduce the outer diameter and wall thickness of seamless or welded metal tubes.
- It is performed at room temperature, unlike hot forming, which allows precise dimensional control and eliminates oxidation or scaling.

- During drawing, the tube (called the pre-tube) is pulled through a die with a smaller bore using a drawing bench. The die exerts radial compressive forces, while the machine applies tensile stress to pull the material through.
- The cold working process leads to strain hardening, increasing the tube's yield strength and hardness.
- Cold-drawn tubes are used in industries requiring precision and reliability, such as automotive brake lines, hydraulic systems, and heat exchangers.

Process pronciple



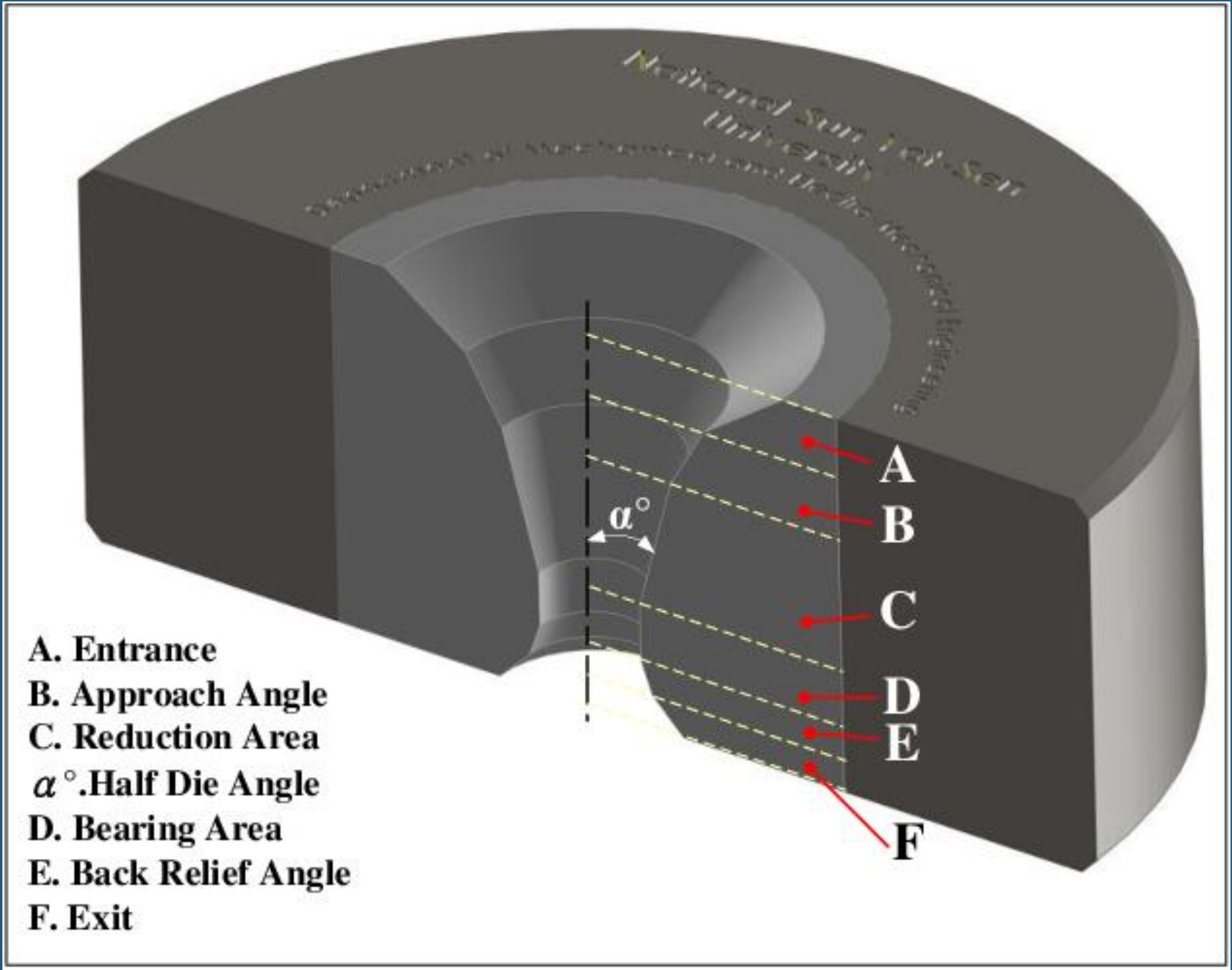
- Cold tube drawing is a cold-forming manufacturing process in which a metal tube is drawn (pulled) through a smaller bore die to reduce its outer diameter and/or wall thickness.
- Because it is performed at or near room temperature, advantages include improved dimensional accuracy, excellent surface finish, and work-hardening of the material.

Process Principle & Key Components

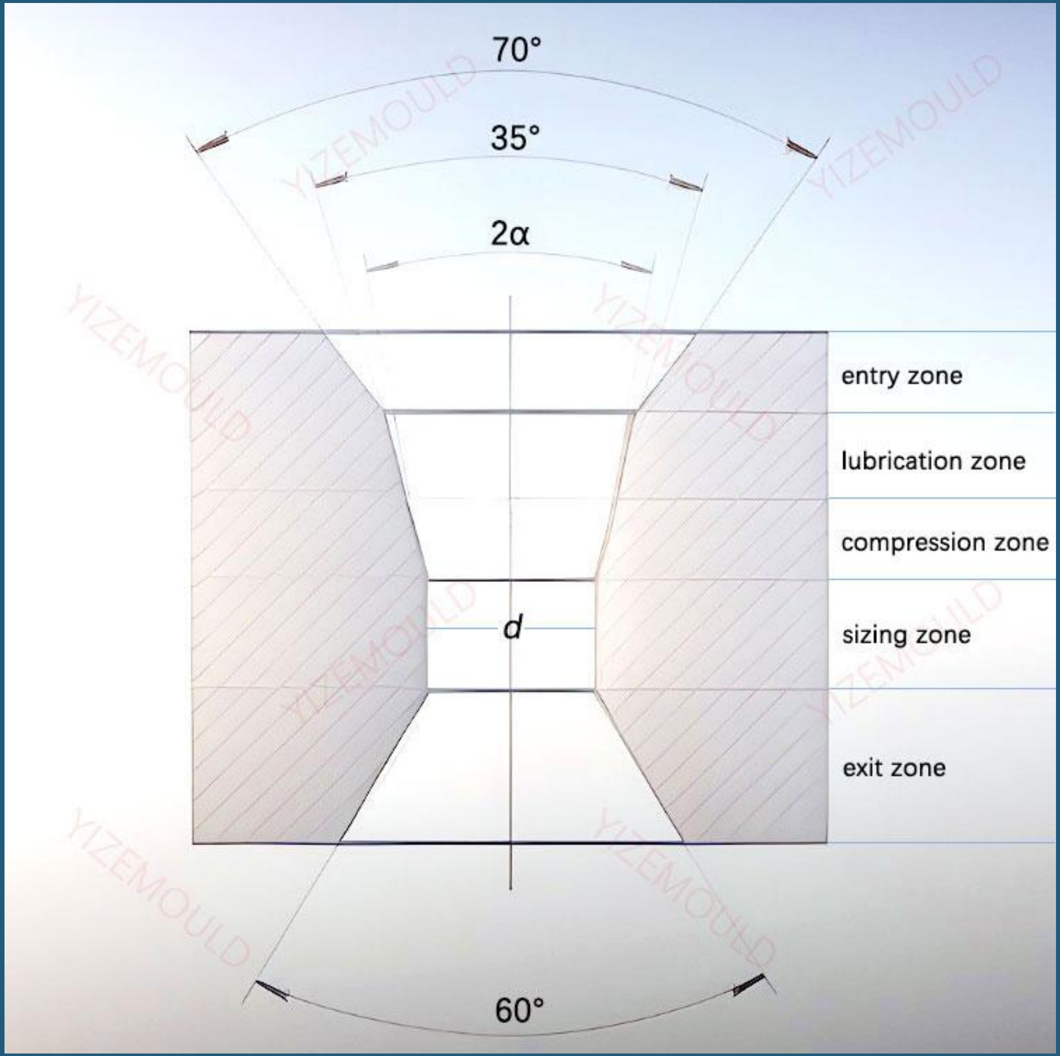
- The tube (pre-tube) is pulled through a die. Critical components include:
- Drawing die: entry zone, reduction zone where deformation occurs, bearing/calibration zone for final diameter, exit zone.
- Mandrel or plug (optional): inserted inside the tube to control internal diameter or wall thickness.
- Lubrication system: essential to reduce friction, wear and surface defects.

- The material undergoes plastic deformation: radial compression by the die, axial tensile force from drawing machine, and tangential compression due to constraint of flow. Proper balance of stresses prevents defects like cracks or ovality.

Process Principle & Key Components



Process Principle & Key Components



Article Title & Authors

A Statistical Approach in the Analysis of Geometrical Product Specification during the Cold Tube Drawing Process

Authors: Ladislav Morovič; Michaela Kritikos; Daynier Rolando Delgado Sobrino; Jozef Bílik; Robert Sobota; Maria Kapustová. MDPIPublished in Applied Sciences, Vol. 12, Issue 2, Article 676 (2022). DOI: 10.3390/app12020676.

Research Aim and Motivation

- To evaluate the influence of pre-tube factors (outer diameter, wall thickness) and tooling factor (die diameter) on key geometrical outcomes after cold tube drawing: final outer diameter, wall thickness, roundness.

- To assess whether a single-pass drawing process can deliver acceptable geometrical precision, potentially reducing time and cost in manufacturing.

- To apply statistical techniques (design of experiments, ANOVA) to understand factor effects and interactions in the cold tube drawing process.

Experimental Design & Materials

- Material: E235 low-carbon steel normalized at 890 – 950 °C (ferrite–pearlite).
- Experimental design: full 2^3 factorial (3 factors each at 2 levels) → 8 runs, with replicates. Factors: A = Pre-tube diameter (16 / 18 mm), B = Wall thickness (1 / 2 mm), C = Die diameter (12 / 14 mm).
- Equipment: Hydraulic drawing machine (EU 40, 400 kN), drawing speed 60 mm/min, lubricant: mineral oil. Measurement via ZEISS CenterMax CMM.

Factor	Level 1	Level 2
A – Pre-tube diameter	16 mm	18 mm
B – Wall thickness	1 mm	2 mm
C – Die diameter	12 mm	14 mm

Measurement

Coordinate measuring machine ZEISS CenterMax was used for roundness and diameter measurement.

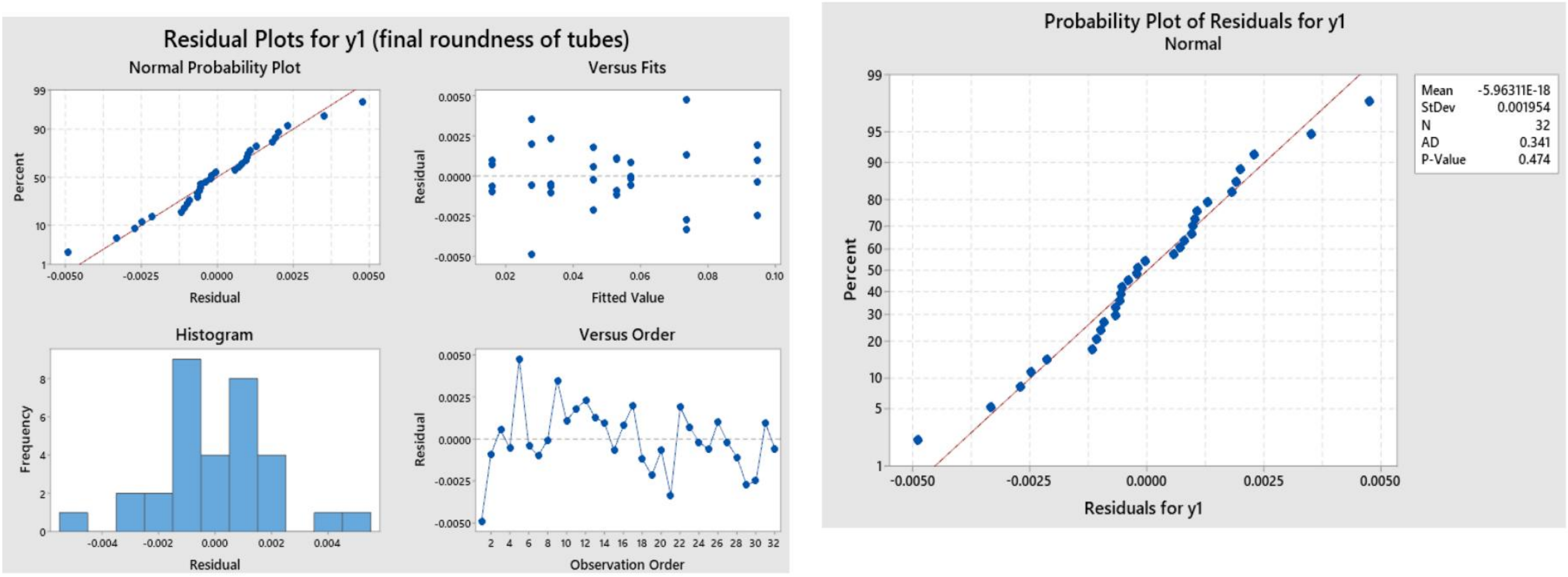
Data Collection & Statistical Methods

- Response variables: final outer diameter, final wall thickness, roundness deviation.
- Data collected via CMM, processed in Minitab 19. Conducted ANOVA, regression modelling, residual analysis to verify normality, homoscedasticity, independence.
- Interaction effects and main effects analyzed to understand how combinations of factors influence outcomes.

Key Results

- All main factors and many two-way interactions were statistically significant ($p < 0.05$).
- Pre-tube diameter (factor A) had the greatest influence on roundness.
- Die diameter and wall thickness strongly impacted final outer diameter and wall thickness.
- The single-pass drawing under conditions studied did not meet desired precision limits; multi-pass or optimized tooling/lubrication needed.

Types of Tube Drawing



(a) (b)

From the previous **Figure a**, it is possible to see that the normal probability plot exhibits a very good fit to the straight line, and there is no relevant outliers that may affect the subsequent ANOVA. Further, if also taking into account that the sample plotted is not small in size, then it is possible to say the residuals are normally distributed. This previous statement is also confirmed if looking at the results of the Anderson–Darling test for normality shown in **Figure b**.

Conclusions & Practical Implications

- Single-pass cold tube drawing process, under the studied conditions, is not sufficient for high-precision tube production.
- Optimization of die geometry, lubrication, and possibly incorporating multi-pass drawing is required for geometric accuracy and repeatability.
- Demonstrated effectiveness of applying DOE and ANOVA in forming process optimisation—helping reduce experimental time and cost.
- Manufacturers of precision tubing can leverage these findings to better control process parameters, improve quality, and reduce scrap/waste.

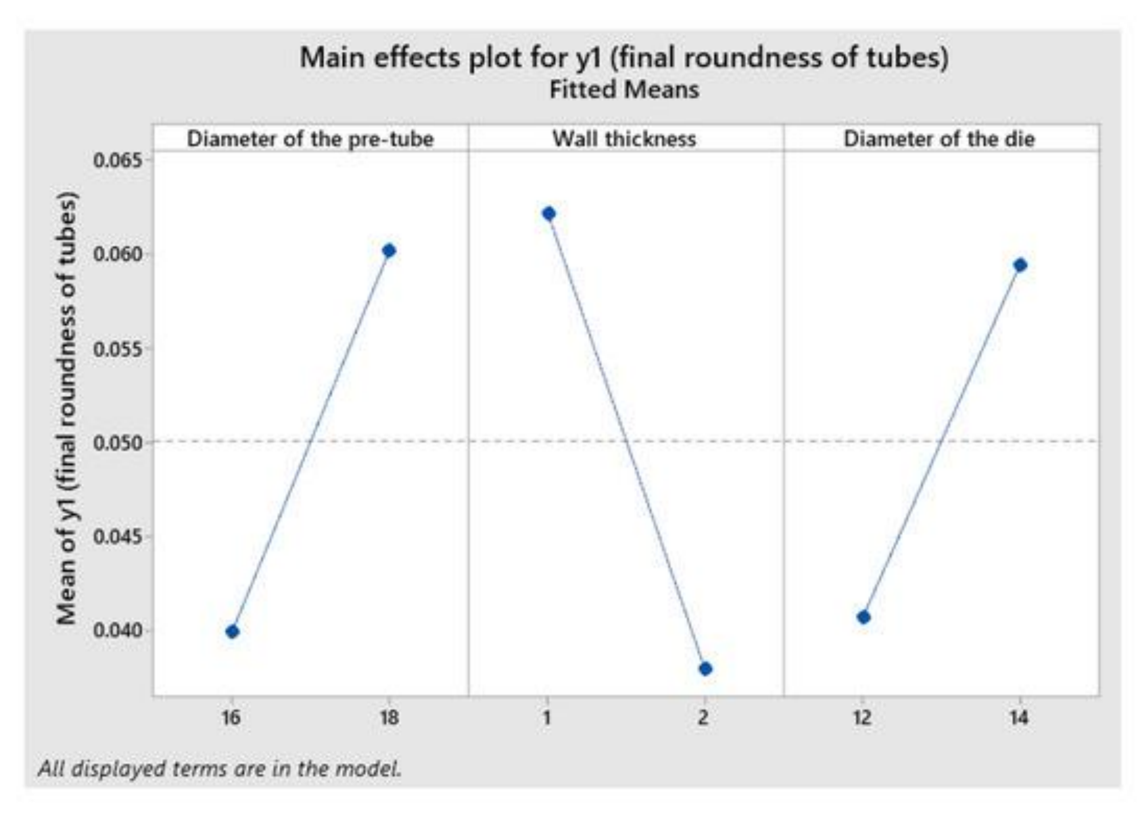
Significance & Outlook

- This research bridges forming-technology and statistical-metrology domains: combining process forming, measurement (CMM), and statistical modelling.

- Indicates pathway for data-driven manufacturing; allows prediction of outcomes instead of purely trial-and-error.

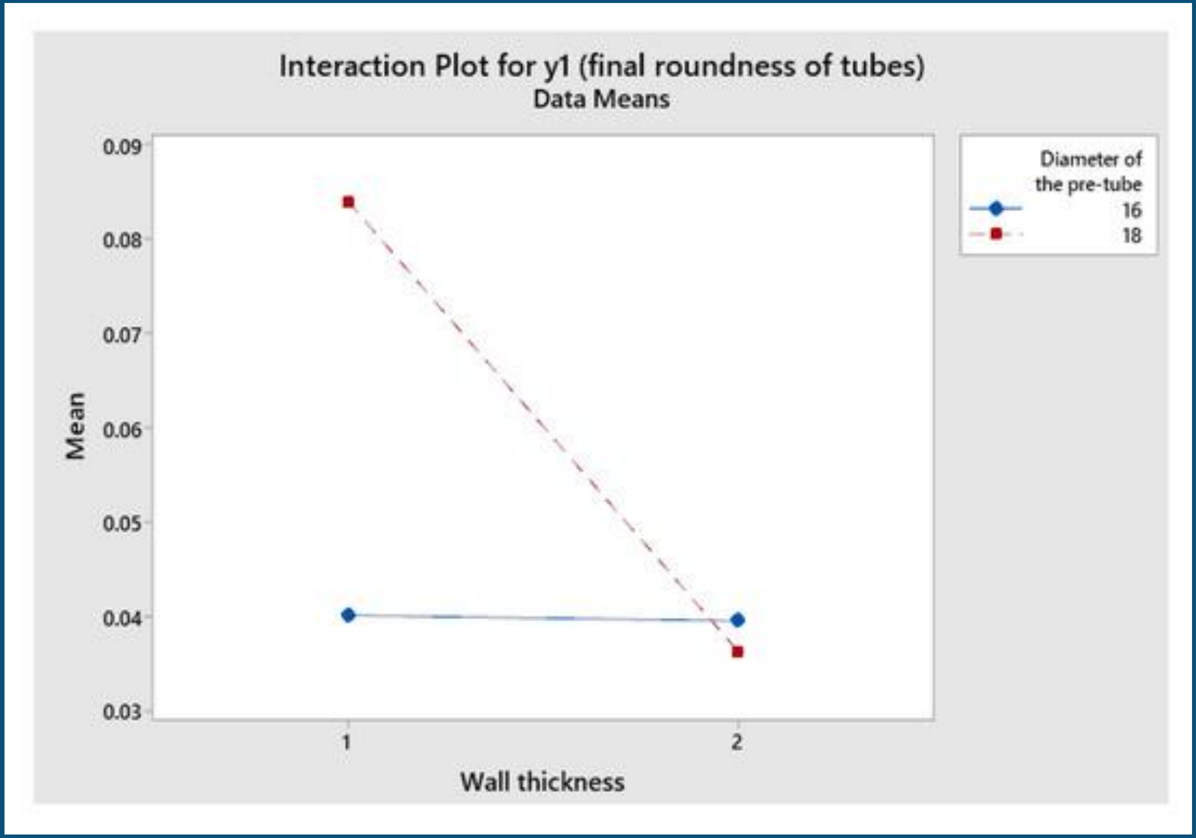
- Future work: explore multi-pass drawing, advanced lubrication systems, real-time process monitoring, and integration with Industry 4.0 data analytics.

Main effects plot for the variable y1, or the final roundness of the tube



It is possible to see that the lower level of the diameter of the pre-tube (factor *A*) has the lowest effect on the response variable y_1, or the final roundness of the tube, while its upper value behaves in the opposite manner. A similar analysis applies for the diameter of the die (factor *C*), while in the case of the remaining factor (factor *B*), its lower value influences the response variable the most.

Interaction plot for the variable y_1, or the final roundness of the tube, considering two categorical factors.



It is extremely important in the context of the specific cold tube drawing process that the relationship between the response variable y_1 and the wall thickness also depends on the diameter of the pre-tube.

THANK YOU FOR YOUR ATTENTION

References

- Morovic et al., 2022 – Applied Sciences 12(676)
- EN 10305-1: Precision steel tubes
- Montgomery, 2019 – Design and Analysis of Experiments