Building a doctor blading device for material deposision

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Abstract

This project focuses on the design and fabrication of a custom doctor-blading device tailored for coating materials onto substrates. The device integrates a replaceable blade, an adjustable mechanism to customize blade positioning, and a sliding rail system to facilitate smooth, controlled motion. The compact design, with dimensions approximately 10 cm $\times$ 10 cm $\times$ 10 cm, ensures adaptability and precision, allowing users to modify the setup based on specific requirements. This manual, aluminum-based construction emphasizes both functionality and versatility for material coating applications.

1 Introduction

Doctor blading, also referred to as tape casting, is a key technique for producing thin films on large-area surfaces. Originally developed in the 1940s, this method was initially applied to fabricate thin ceramic sheets for capacitors, marking its importance in early material processing innovations [Howatt and Breckenridge, 1947]. The process involves spreading a well-mixed slurry, composed of ceramic particles, binders, and other additives, over a substrate using an adjustable blade to regulate the thickness of the resulting film [Gaskell et al., 1997].

The wet film thickness can range from 20 microns to several hundred microns, and precise control is achieved by varying the gap between the blade and substrate. This adaptability allows the technique to meet the diverse requirements of coating processes, which include applications in ceramics, solar cells, and barrier layers [Pitchumani and Karbhari, 1995].

Advancements such as dual doctor blades and spiral film applicators further enhance the versatility and precision of the technique, making it suitable for coating flexible materials like textiles and plastics [Abbott, 2002, Runk and Andrejco, 1975]. As a result, doctor blading remains a widely utilized and highly adaptable tool in advanced material manufacturing.

Working Principle of a Doctor Blade Device

The doctor blade device operates on the principle of controlled slurry deposition to create uniform thin films on substrates. This widely used method, also referred to as tape casting, is essential in applications requiring precise film thickness and homogeneity.

1. Slurry Preparation

A homogenous slurry is prepared, typically comprising particles (such as ceramics, polymers, or metals), binders, plasticizers, and solvents. This slurry must exhibit specific rheological properties to ensure smooth spreading and proper adhesion to the substrate. The properties of the slurry play a critical role in achieving the desired film quality [Pitchumani and Karbhari, 1995].

2. Deposition on Substrate

As in the Figure 1 the slurry is placed ahead of the doctor blade, often within a reservoir. The substrate, which may include glass, plastic, or metal, is positioned beneath the blade. The blade and substrate interaction spreads the slurry evenly across the surface [Gaskell et al., 1997].

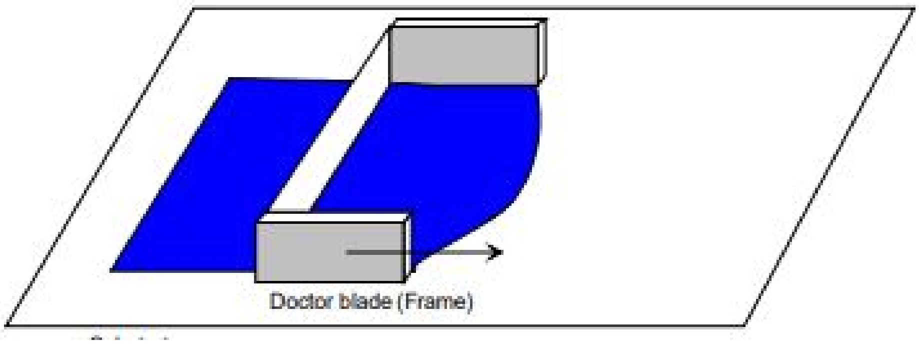


Figure 1: Deposition of material on substrate

3. Film Formation

The doctor blade, typically a rectangular or adjustable frame, maintains a precise gap above the substrate. Either the substrate moves under the stationary blade or the blade moves across a stationary substrate, distributing the slurry uniformly to form a wet film as in Figure 2 [Howatt and Breckenridge, 1947].

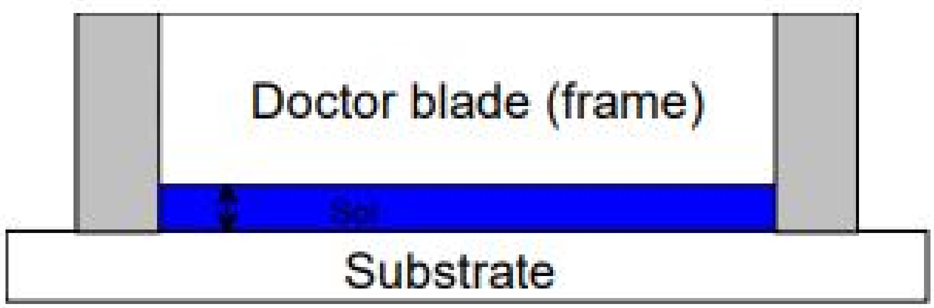


Figure 2: Film Formation

4. Thickness Control

The wet film thickness is determined by the gap between the blade and the substrate. Fine adjustments to this gap provide precise control over the film thickness, allowing for a wide range of coating thicknesses from a few microns to several hundred microns [Pitchumani and Karbhari, 1995].

5. Drying and Solidification

Once deposited, the wet film is dried to remove solvents, leaving a solidified layer. Depending on the application, additional curing or heat treatments may be applied to enhance the film's mechanical or chemical properties [Abbott, 2002].

6. Precision and Flexibility

Advanced features like dual blade setups and automated slurry reservoirs enhance precision and ensure continuous, uniform coatings. These modifications improve the scalability and repeatability of the process for industrial applications [Runk and Andrejco, 1975].

Key Applications and Advantages

Doctor blade devices are valued for their versatility, precision, and scalability. They are widely used in creating films for solar cells, capacitors, sensors, and protective coatings. Their ability to deposit uniform coatings across diverse materials makes them indispensable in both research and industrial environments [Pitchumani and Karbhari, 1995, Abbott, 2002].

Methodology

The fabrication of the doctor blade device was carried out using precise machining and assembly techniques to adhere to the CAD design specifications provided in the annex.

Materials

- **Aluminum:** 6 mm thick aluminum plates for the main structural components.
- **Copper:** 2.5 mm diameter rods for guiding components.
- **Fasteners:** 3 mm Phillips flat-head screws, 1.5 cm in length, for assembling the device.

Tools and Machines

- **Milling Machine:** Used for shaping and contouring aluminum plates.
- **Lathe Machine:** Utilized for machining copper rods into guiding components.
- **Drilling Machine:** Employed to create holes in aluminum plates for screw connections.

Procedure

1. **Material Preparation:** Aluminum plates and copper rods were cut to approximate dimensions.
2. **Machining:**
    - Aluminum plates were shaped and smoothed using a milling machine.
    - Copper rods were processed into guiding rods on a lathe machine.
    - Holes for screws were drilled into the aluminum plates at specific locations.

3. **Assembly:**
    - Components were aligned and connected using 3 mm Phillips flat-head screws of 1.5 cm length.
    - Screws were tightened to ensure a stable and secure structure.
4. **Final Output:** The completed device was inspected and validated against the CAD design. The final assembly is shown in Annex 2.

This method ensured the accurate fabrication of the doctor blade device, adhering to the specifications for material coating applications.

2 Results and Analysis

The final assembled doctor blade device, fabricated using precision machining and manual assembly techniques, is shown in Figure 5. This device consists of several key components, each carefully designed and manufactured to ensure optimal performance:

- **Main Structure:** Fabricated from 6 mm aluminum plates, the structure provides durability and a lightweight design, ensuring stability during operation.
- **Guiding Rods:** Constructed from 2.5 mm copper rods, these rods facilitate smooth and precise motion of the blade assembly, enabling consistent coating thickness.
- **Adjustable Blade Mechanism:** The adjustable mechanism allows the blade to be positioned with high accuracy, meeting various coating requirements.
- **Fasteners:** The components are securely joined using 3 mm Phillips flat-head screws (1.5 cm in length), ensuring the device remains robust under operational loads.

The device was assembled following the CAD design specifications (refer to Annex for detailed designs). The completed structure aligns with the intended dimensions and functional requirements, demonstrating successful fabrication and assembly. The incorporation of aluminum and copper materials ensures both durability and resistance to wear, while the compact design (approximately 10 cm $\times$ 10 cm $\times$ 10 cm) enhances portability and usability.

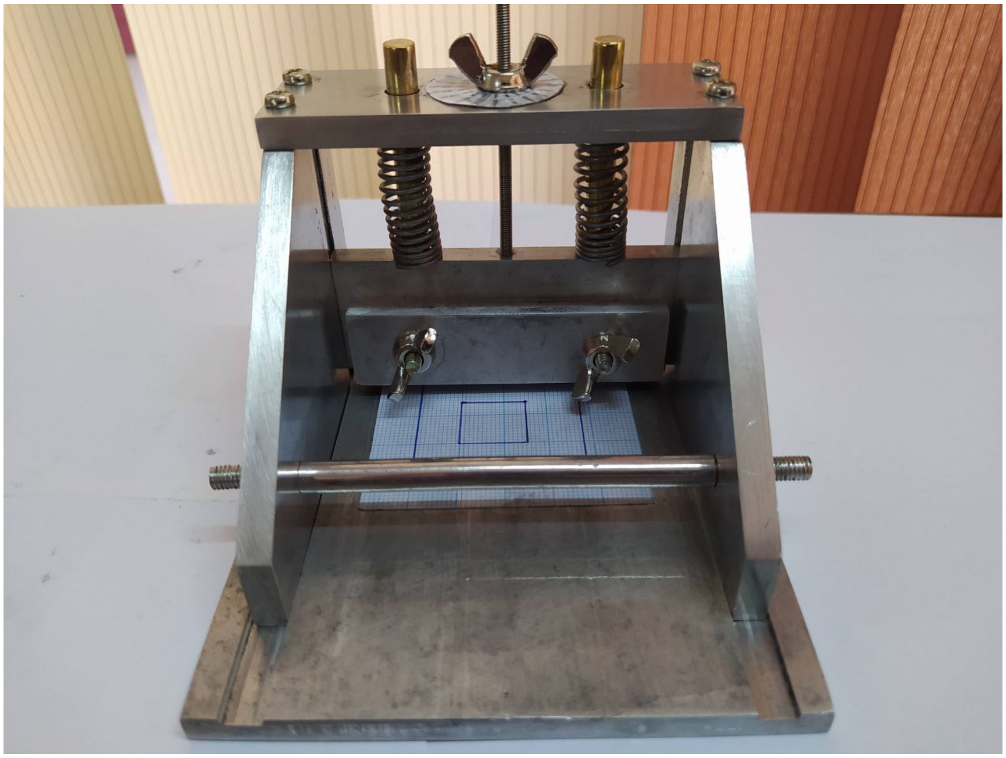


Figure 3: Final product - front view

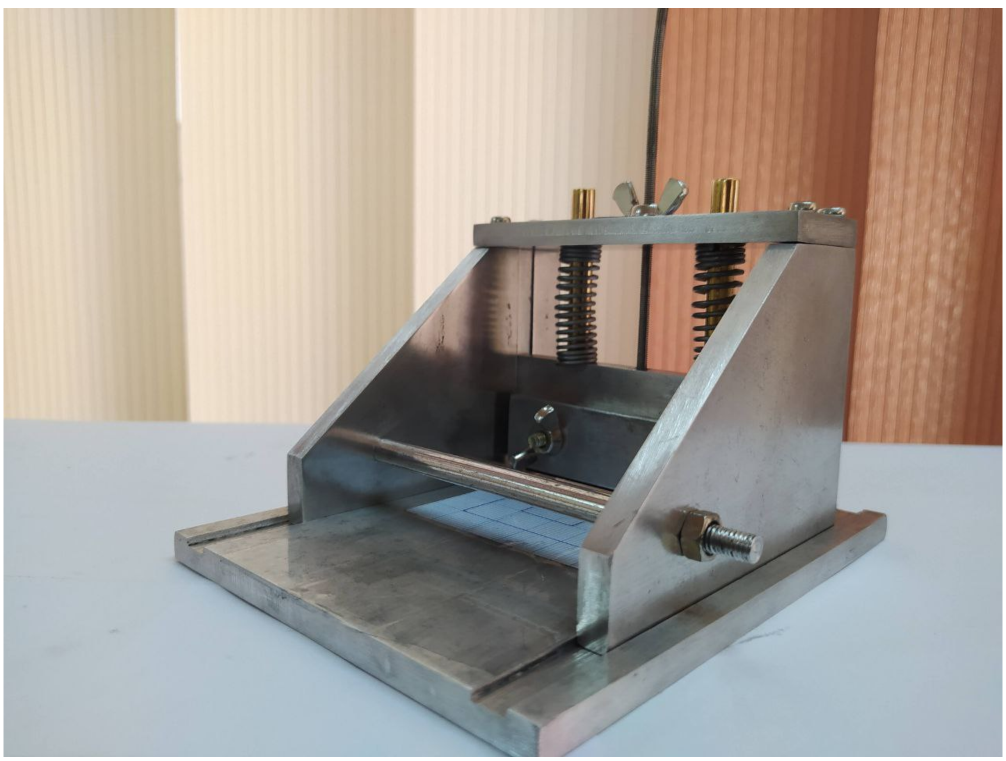


Figure 4: Final product - side view

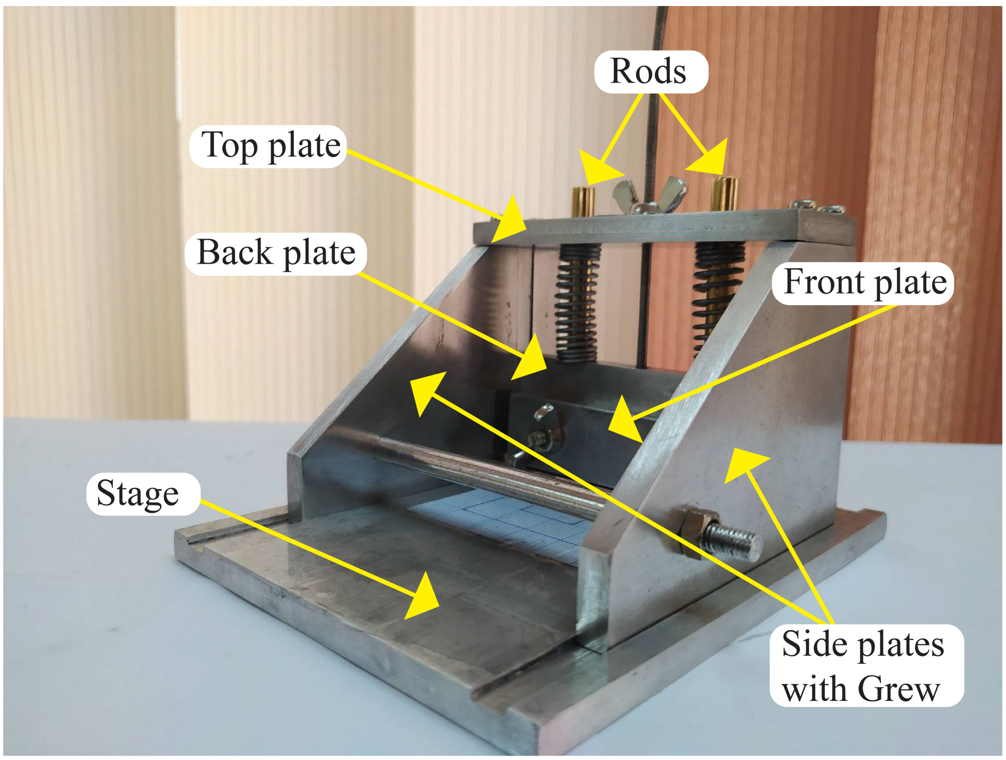
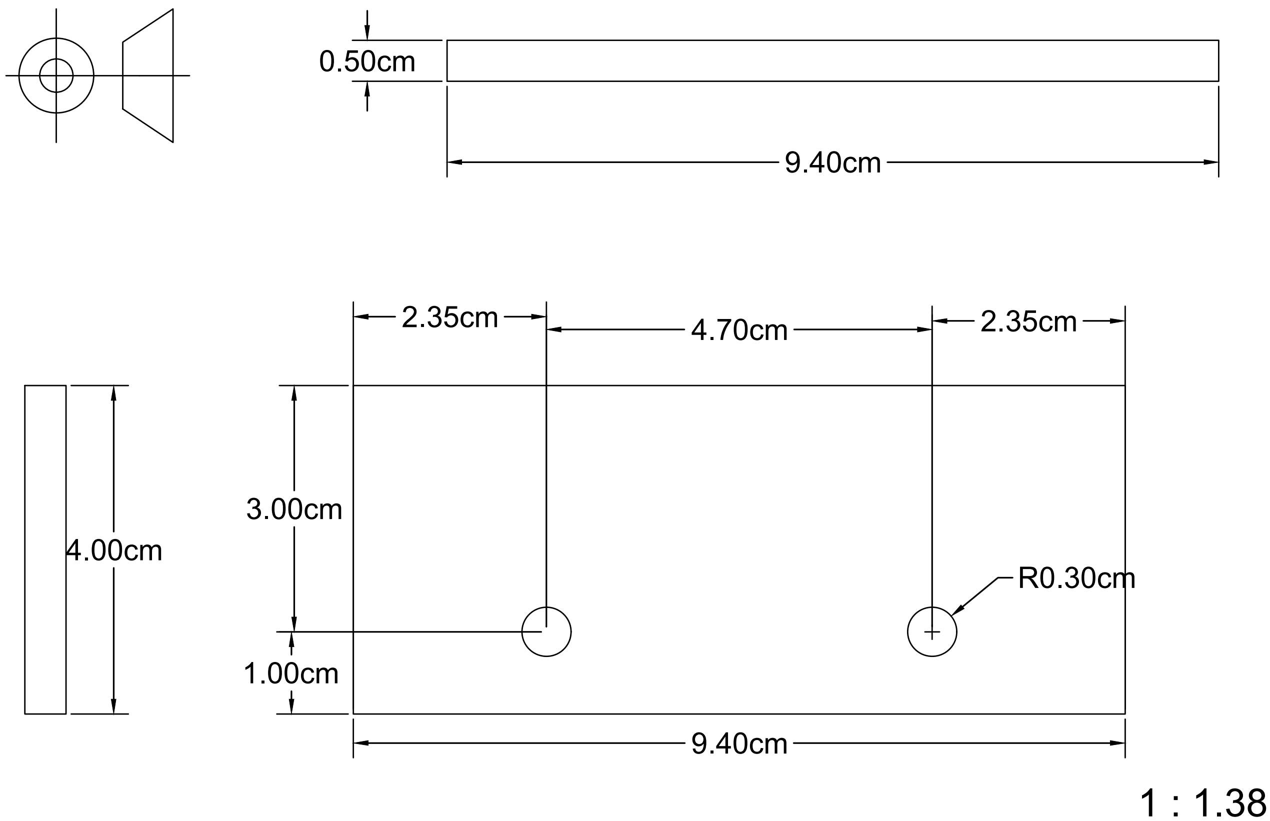


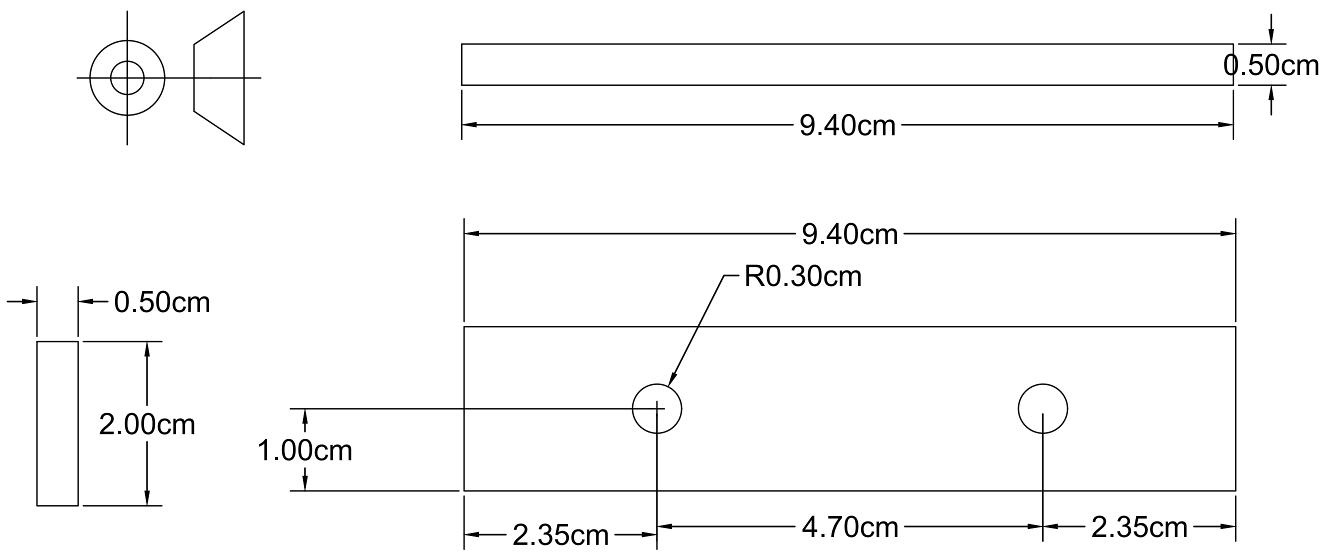
Figure 5: Parts of Final product

Annex

Back Plate

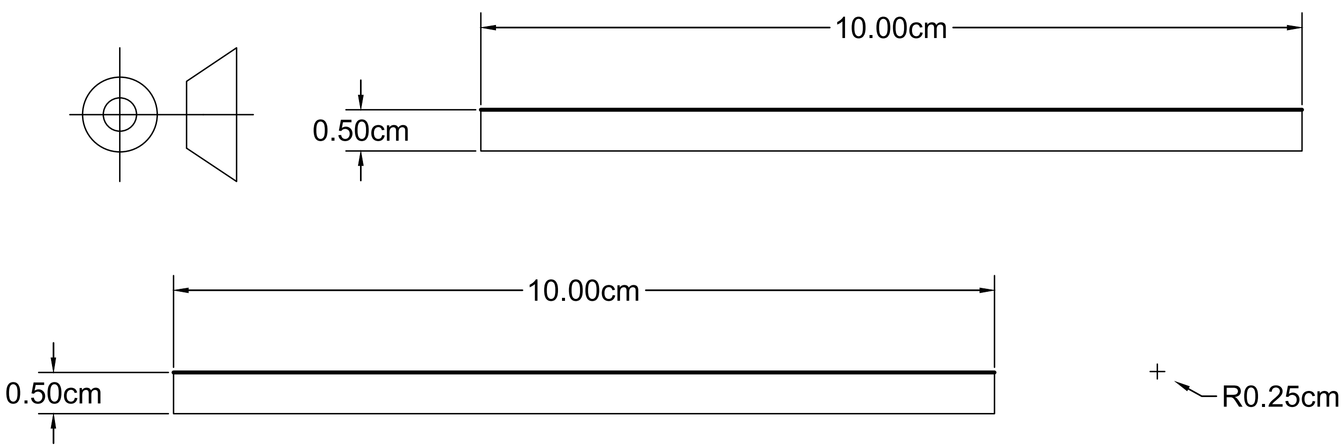

0.50cm
9.40cm
2.35cm
4.70cm
2.35cm
3.00cm
4.00cm
R0.30cm
1.00cm
9.40cm
1 : 1.38

Front Plate



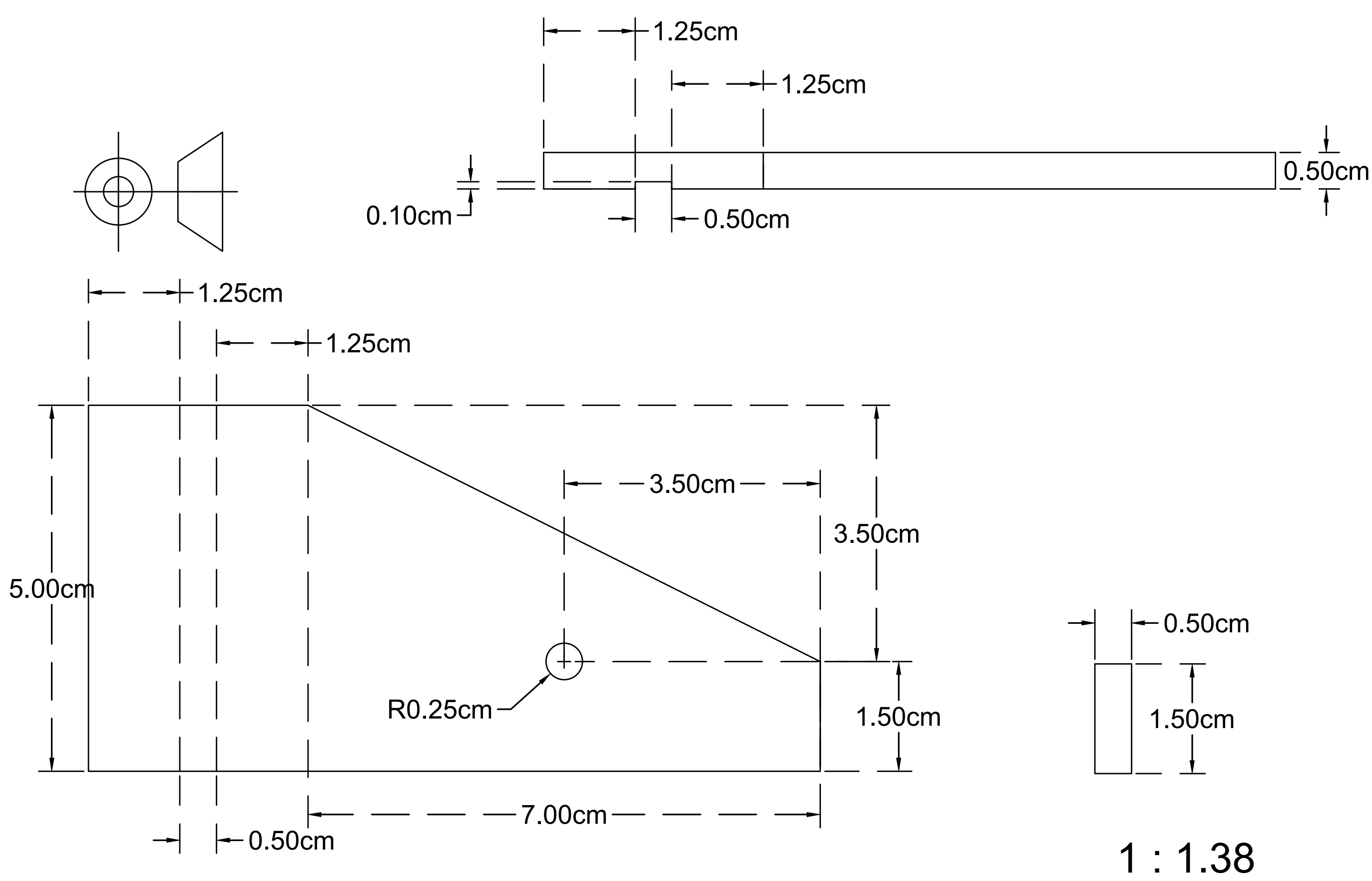
1 : 1.38

ROD

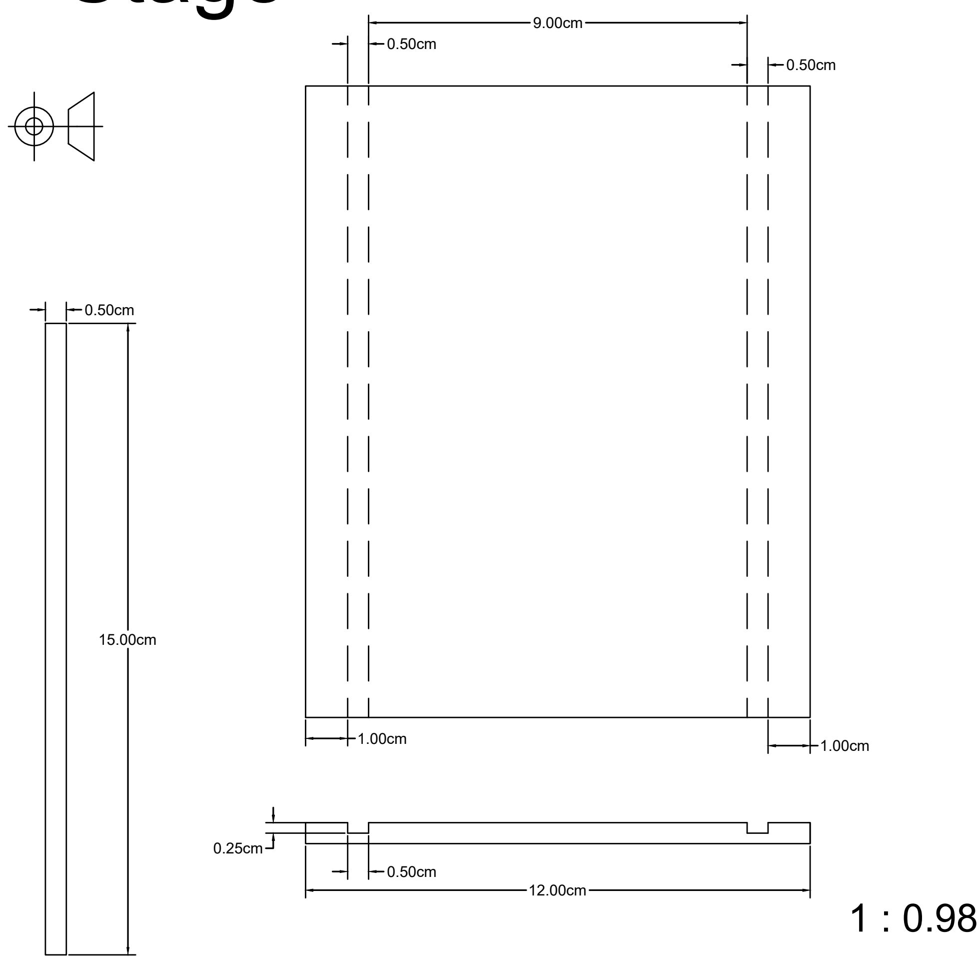


1 : 1.258

Side plate with Grew

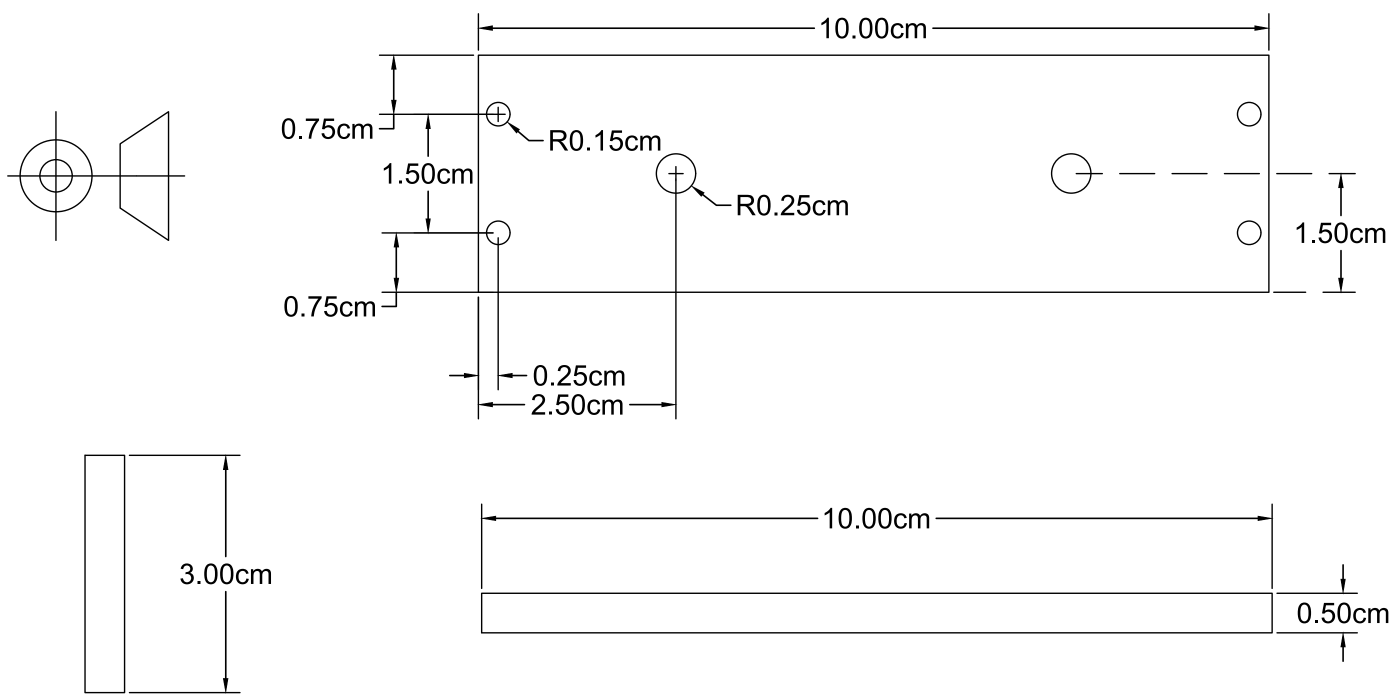


Stage



9.00cm
0.50cm
0.50cm
0.50cm
15.00cm
1.00cm
1.00cm
0.25cm
0.50cm
12.00cm
1 : 0.98

Top Plate



1 : 1.382

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