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MEASUREMENT OF THE THICKNESS DISTRIBUTION BY DIGITAL IMAGE PROCESSING TECHNIQUES

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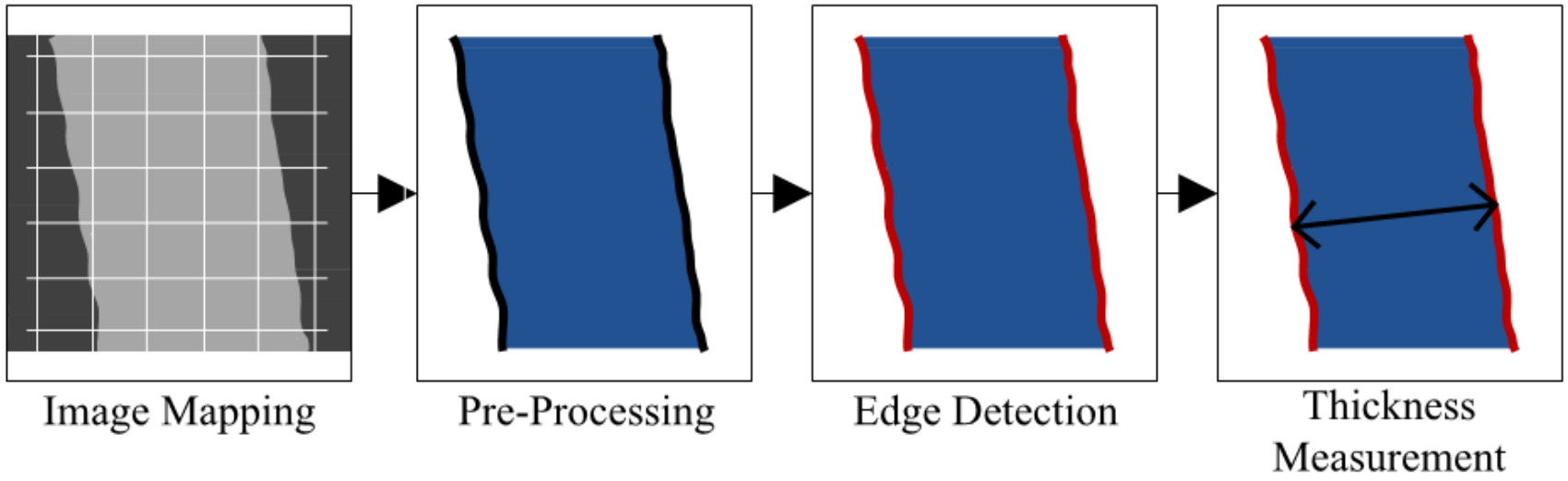
Measuring Thickness Distribution to Validate Numerical Results

- Numerical simulation is widely used in the design and optimization of **sheet metal forming** processes to reduce **costs.**
- The success or failure of this process is highly related with the performance of failure models, that enable the predicted of defects such as **necking**.
- The evaluation of the **thickness distribution** is crucial for the validation of numerical methods.

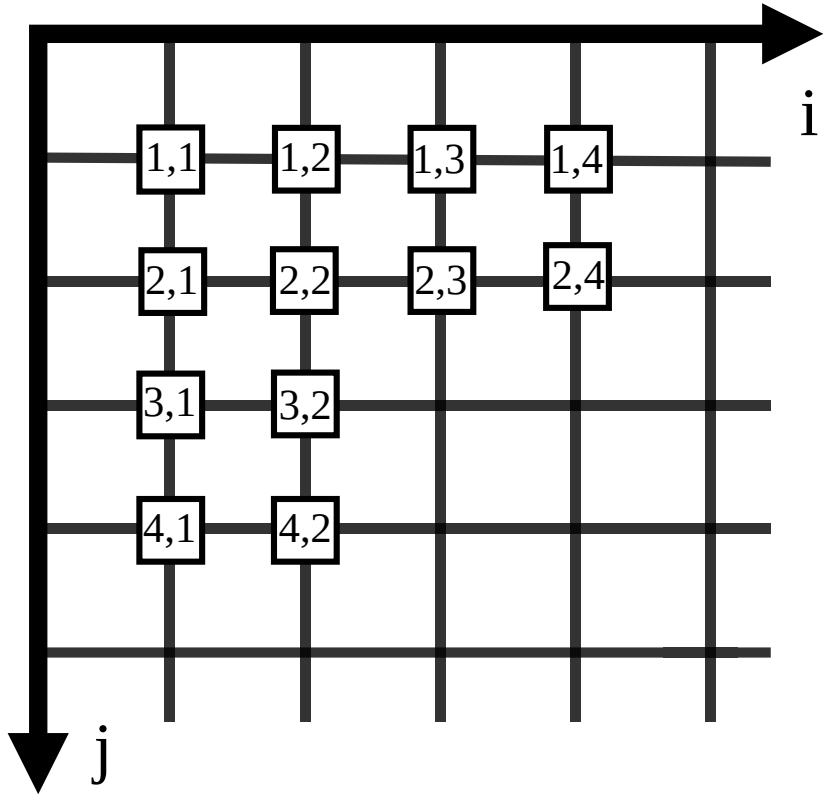
Measuring Thickness Distribution to Validate Numerical Results

- Several methods exist to measure thickness such as: Calipers, Coordinate Measuring Machines, Ultrasonic and Optical based techniques.
- This study proposes an image processing approach to evaluate the thickness distribution in specific cross sections of a cylindrical cup. The proposed method requires an image of the cross section containing the component profile.



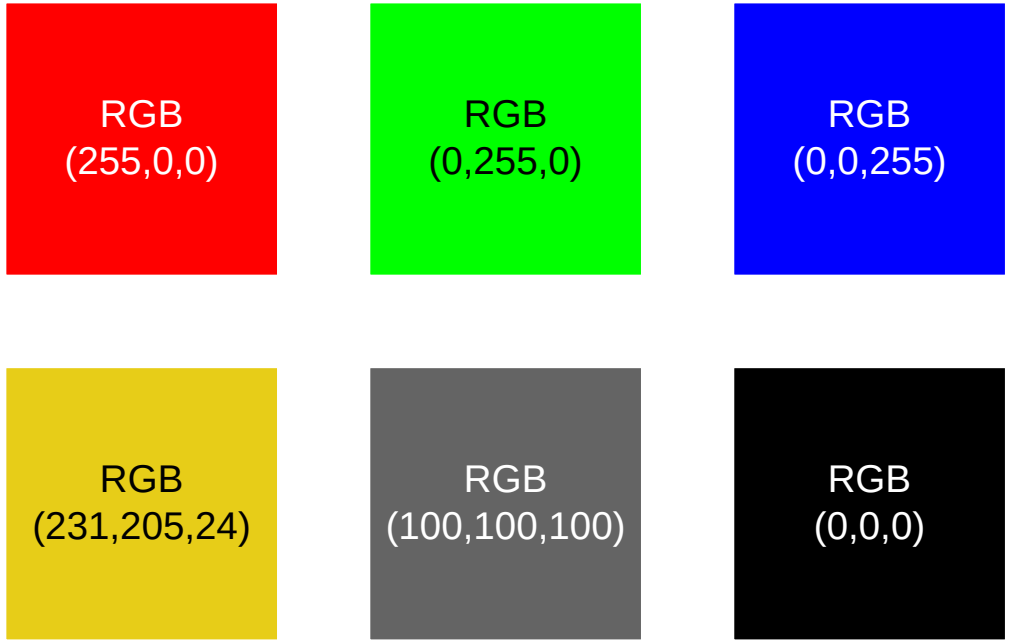
Images as Matrixes of Pixels

- Each microscope image, covering a sheet cross-section, contains millions of pixels.
- Introducing a **coordinate system** to the image allows to identify the position of each pixel.



RGB Color System

- In the RGB Color System each color is characterized by a numerical value - between 0 and 255 - of **R**ed, **G**reen and **B**lue.
- For each pixel, the **numerical values** of the respective color can be stored, enabling the characterization of each pixel.

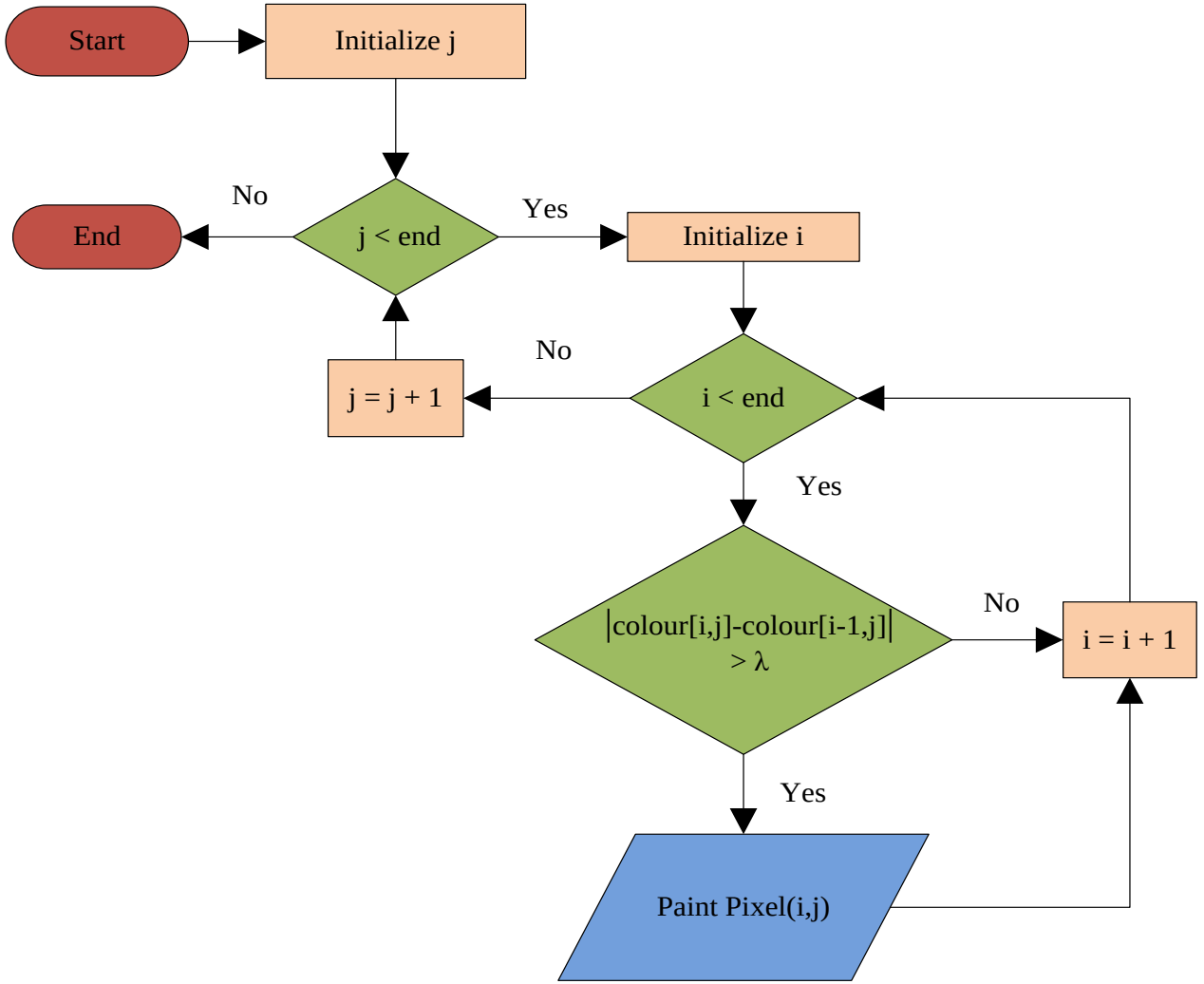


Avoiding Artificial Edges

- Sheet metal edges can be found **through the abrupt variation of color** on the transition from the sample resin to the metal.
- Performing an initial edge detection procedure allows to identify **all** the color discontinuities in the image.

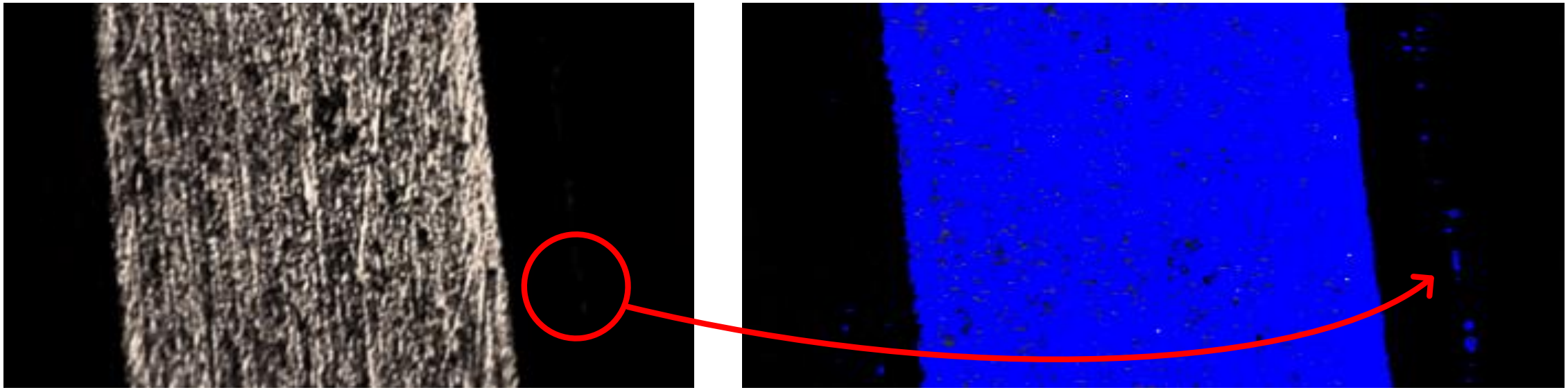
Avoiding Artificial Edges

- To prevent the detection of artificial edges, the picture is scanned line by line to compare the colour of two consecutive pixels. If the colour gap surpasses a threshold value (λ), the pixel under analysis is painted with **pure blue**.
- However, in the following comparison the reference to estimate the colour gap is the original image.



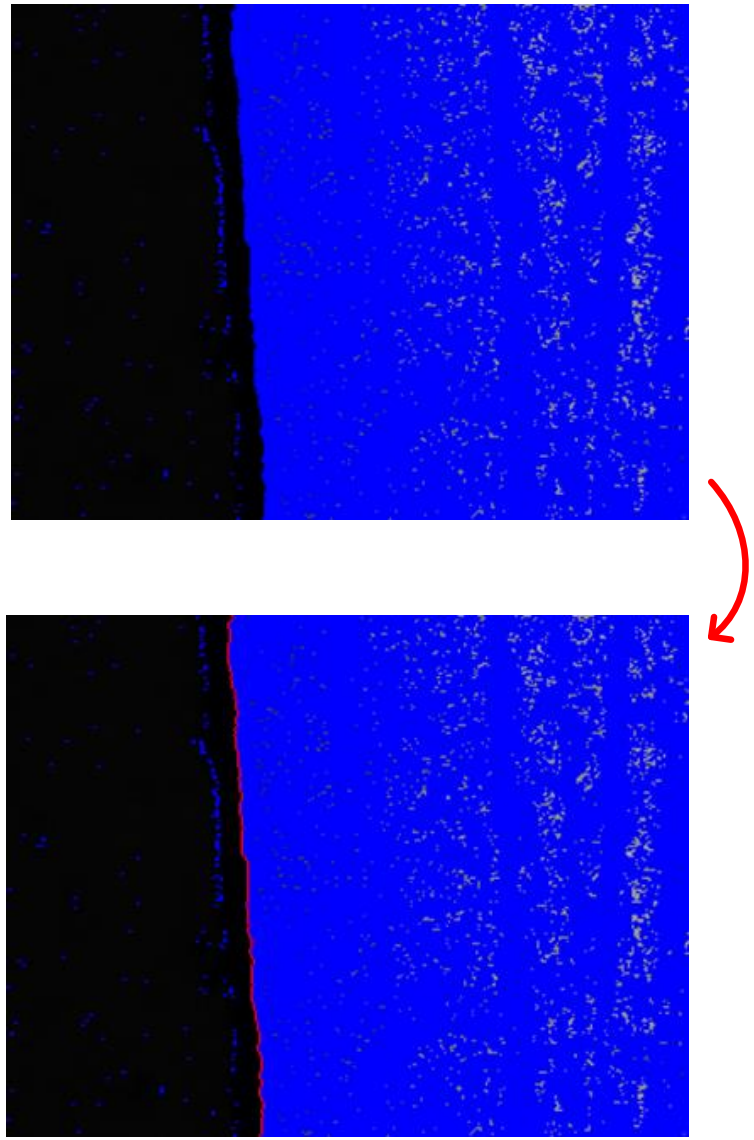
Avoiding Artificial Edges

- Due to polishing anomalies or resin defects several erroneous edges can be identified in the image.



Sheet Boundary Detection

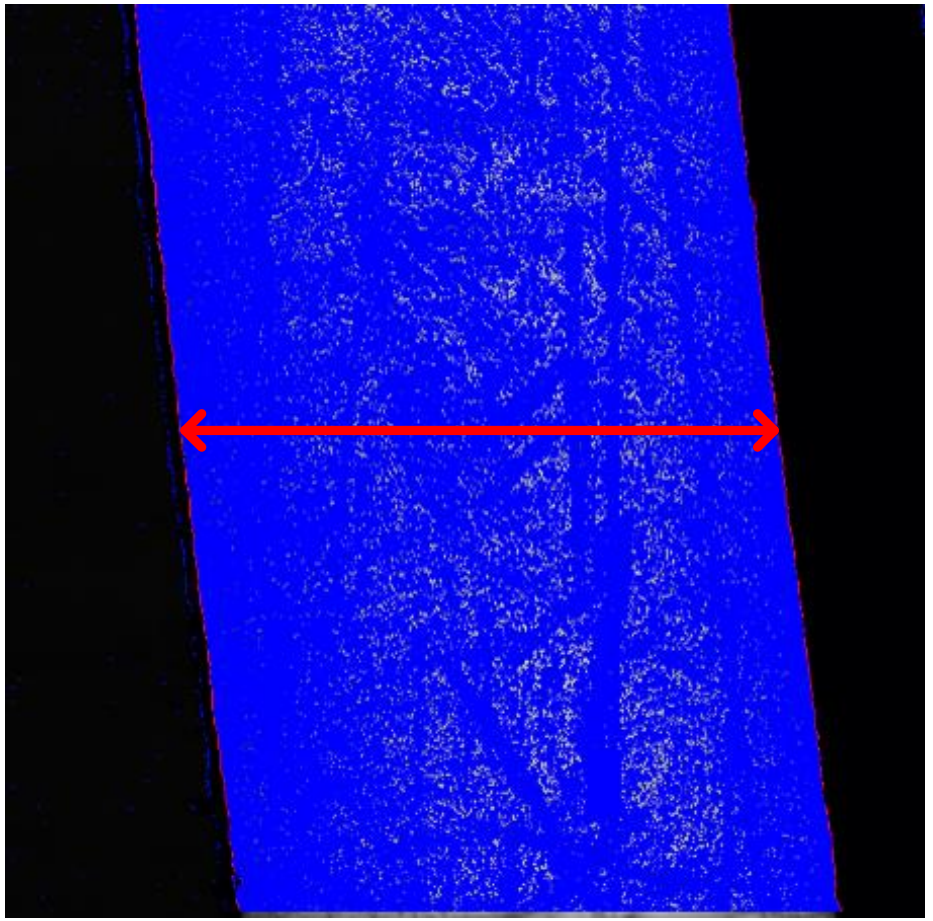
- The undesired edges are characterized by **thin lines** of pixels with large color gaps, followed by relatively vast spaces of constant colors (or differences too small to be detected).
- Within the metal, the color changes occurs in **thick lines** of pixels. Thus, the boundary is associated to a discontinuity with a **minimum number of pixels**. The boundaries are identified with **red pixels**.



Measurement of Thickness

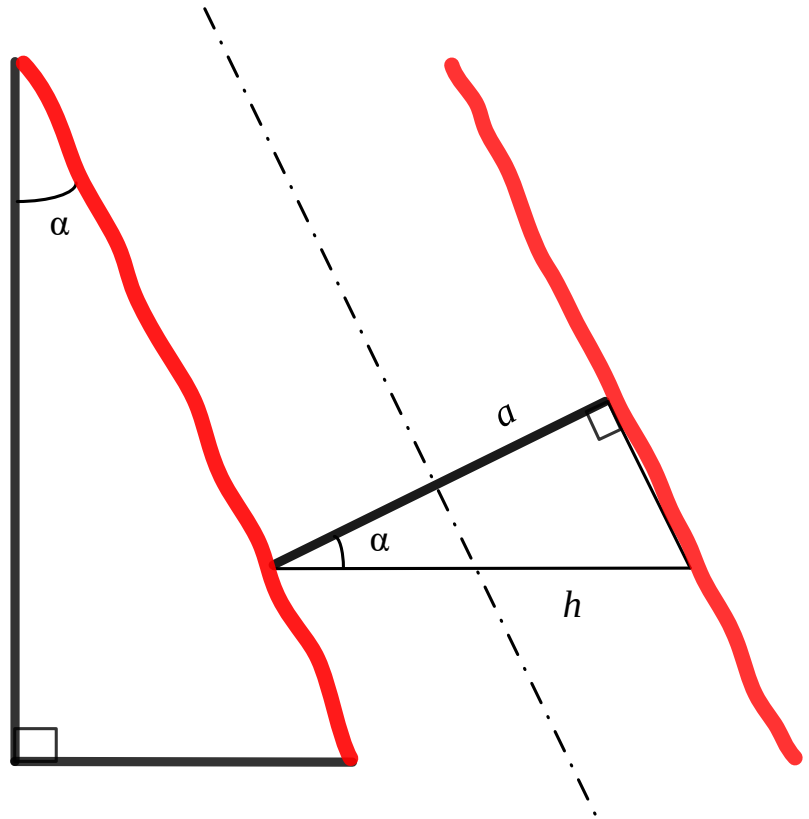
- The number of pixels between two consecutive red lines enables the **identification of the sheet edges**, which can be measured.

- A procedure was designed to measure the length of the scale bar and calculate the scale factor. Thus, the thickness, in pixels, is converted to length dimensions.



Slope of the sheet on the image

- When the sheet is misaligned with the vertical direction, measurements of thickness are made in **directions apart from the normal to the surface**. Real thickness is attained through the measurement of the angle between metal edge and the vertical direction.
- As the slope of the sheet may not be constant over the picture, the application of the algorithm may be confined to portions of the image.

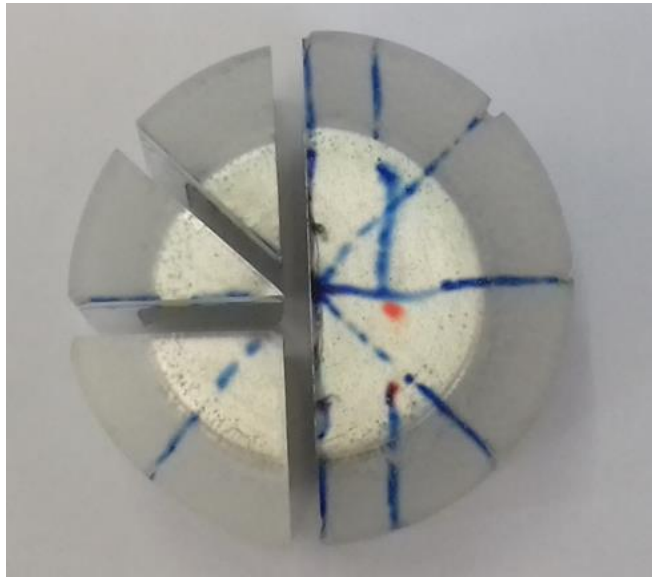


$$a = \cos(\alpha) \times h$$

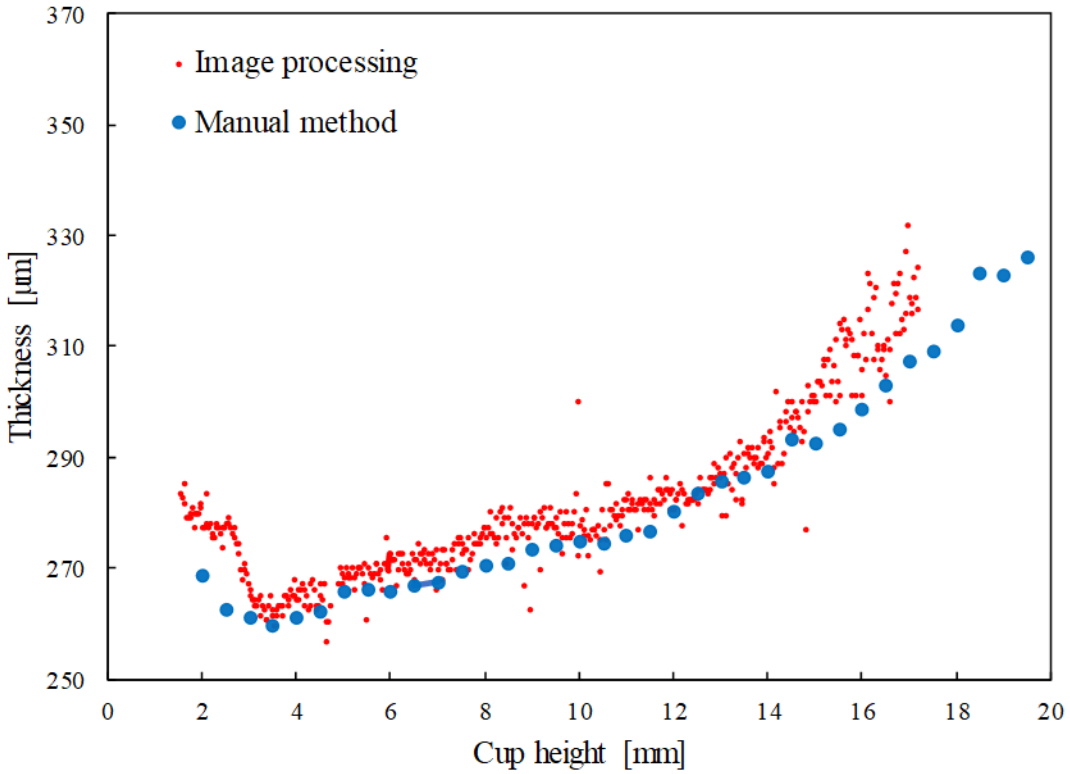
Experimental Procedure

- The designed algorithm was tested in a thin (274 μm) aluminum cup produced by **deep drawing**.
- The cup was imbued in resin. The directions at 0º, 45º and 90º with the rolling were marked. The sample was cut and polished.

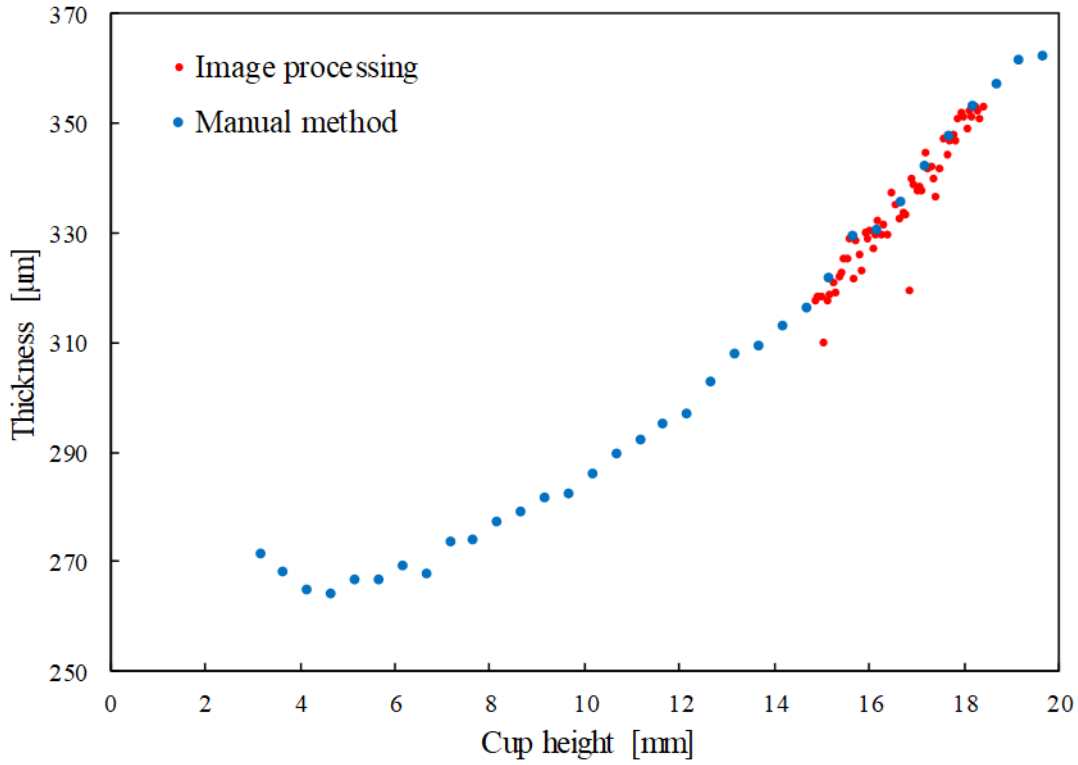
- Each selected section was photographed in a microscope. The zoom was of 200x and several light conditions were tested, to improve the image(s) quality.



Results analysis and discussion



0º RD. Results were affected by powders acumulation, but still were close.



90º RD. Only a small region was free enough of powders to be measured.

- The used resin did not **stick firmly**, thus **powders were trapped in the rift** between metal and resin during polishing. This highly affected the results.

- The results show that the algorithm produces **very good results** when the image quality and measuring conditions are optimal. In this context:
  - ❑ Light conditions at the microscope are crucial to the effectiveness of the method.
  - ❑ Resins which stick to metal should be used to avoid powder accumulation.
  - ❑ Abrupt color changes should be avoided near of the edges.

Acknowledgements

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Thank you for your attention!