Development of a Digital Twin Framework for the Steel Bending Process

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Intoduction

In the evolving landscape of technological advancements and as part of Industry 4.0, digital twinning has emerged as a transformative force, reshaping physical environments into measurable digital spaces through the seamless integration of analytics, modelling, simulation, and information technologies[1]. This paradigm shift facilitates descriptive analysis, diagnosis, prediction, and decision-making. Digital twin maximizes its value in diverse industrial and engineering settings by establishing an interactive mapping and closed-loop control between the digital and physical spaces.

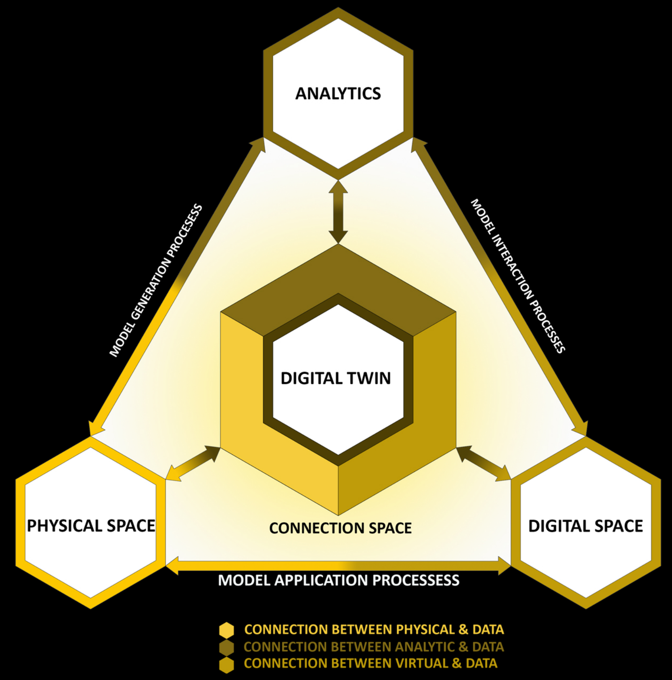


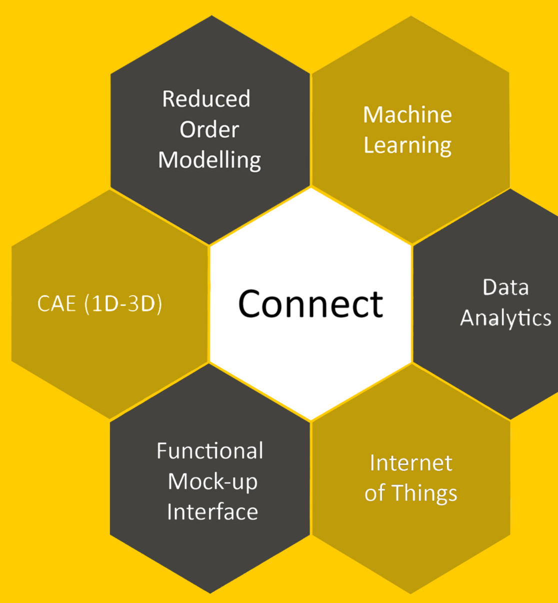
Fig 1. Digital twin visual abstract.

What is a Digital Twin?

A digital twin (DT) is a virtual replica of a real-world object that is run in a simulation environment to test its performance and efficacy[2]. The DT model is composed of the physical product, its representation as a digital twin, data flowing from the physical to the DT, and facilitating a continuous exchange of data from the digital to the physical twin and vice versa.

Experimental Methodology

The methodology involves a systematic process covering material characterization (destructive and non-destructive tests), data acquisition, sensor utilization, and real-time data pre-processing. Employing advanced modelling and simulation techniques, and integration with control systems for continuous monitoring to ensure efficiency, precision, and reliability.



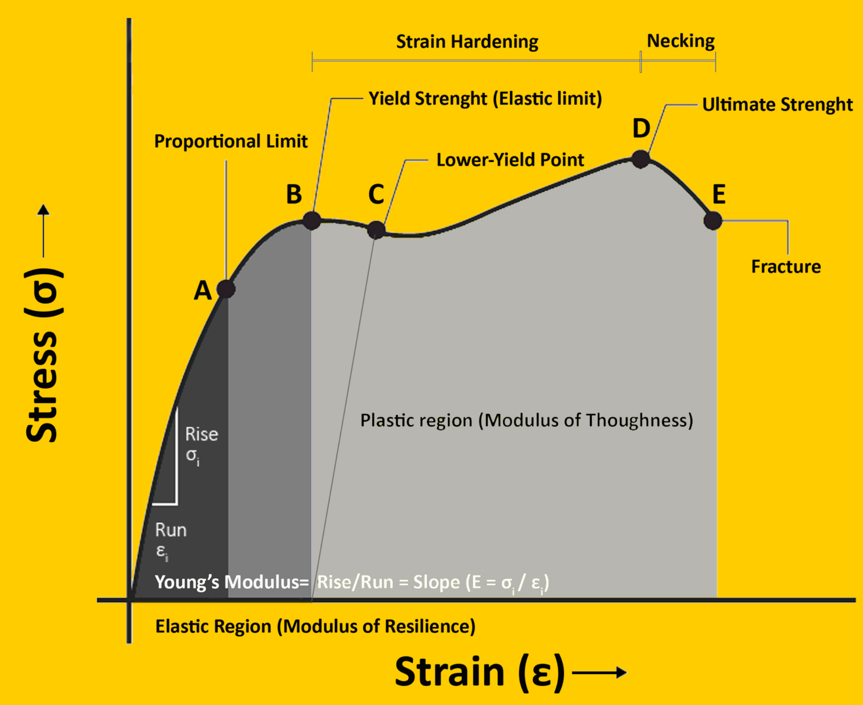


Fig 2. Stress-Strain curve for a ductile material.

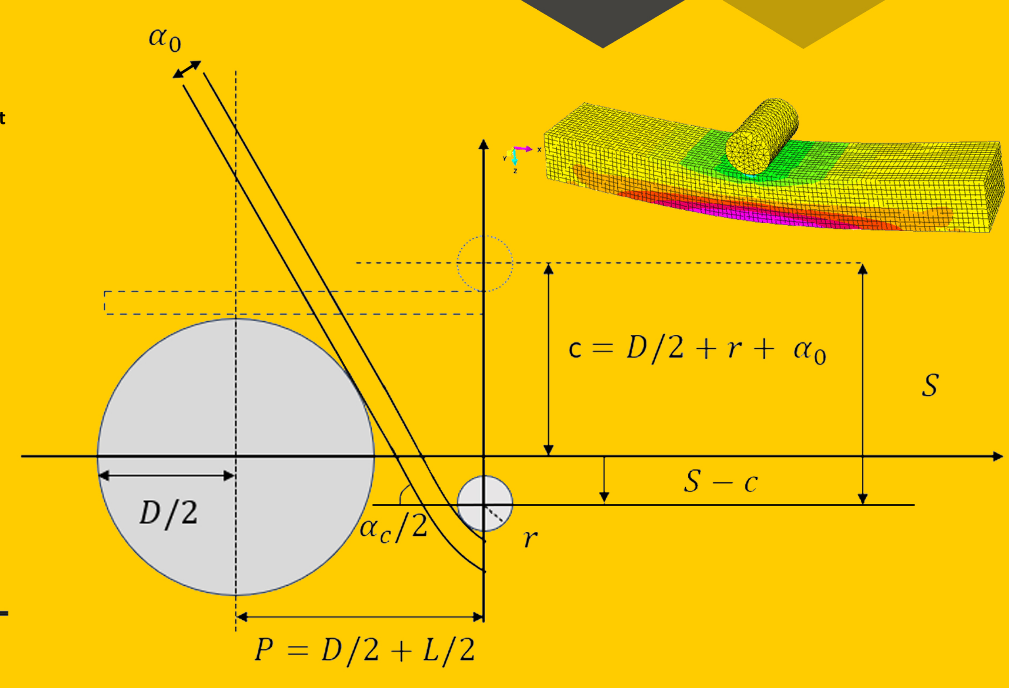
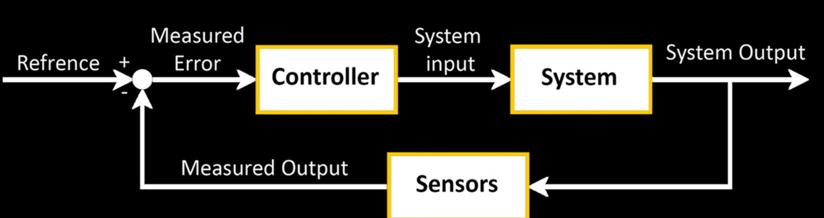


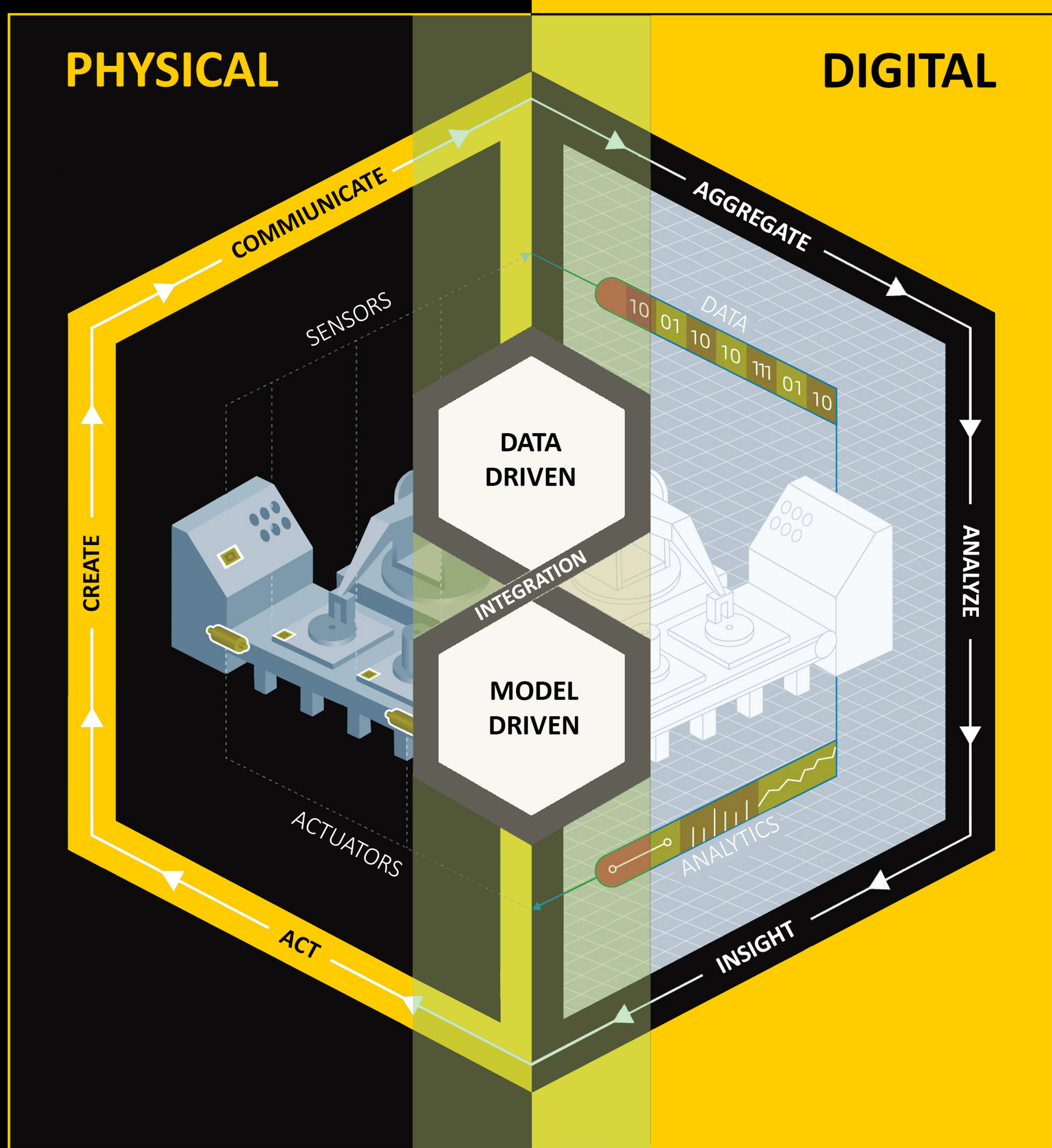
Fig 3. Values for the calculation of the bend angle, α.

Project Aims & Objectives

The project aims to explore and propose a practical framework for implementing DT technology in manufacturing, focusing on the 3-point bending (3PB) forming process according to VDA 238-100 and ISO-7438 standards[3]. It seeks to establish a closed-loop control system that adjusts output, such as predicted bending angle or springback, based on input parameters like material properties (material strength, rolling direction, thickness variations and etc), tooling, and process parameters.



Also, this project aims to seamlessly integrate DT technology to bridge the gap between physical and digital spaces, facilitating informed decision-making and optimizing manufacturing processes.



Results

Experimental data incooprating force, displacement, strain, and bend angle for 1.2-mm steel sheets were measured and analysed(loading-unloading cycles).

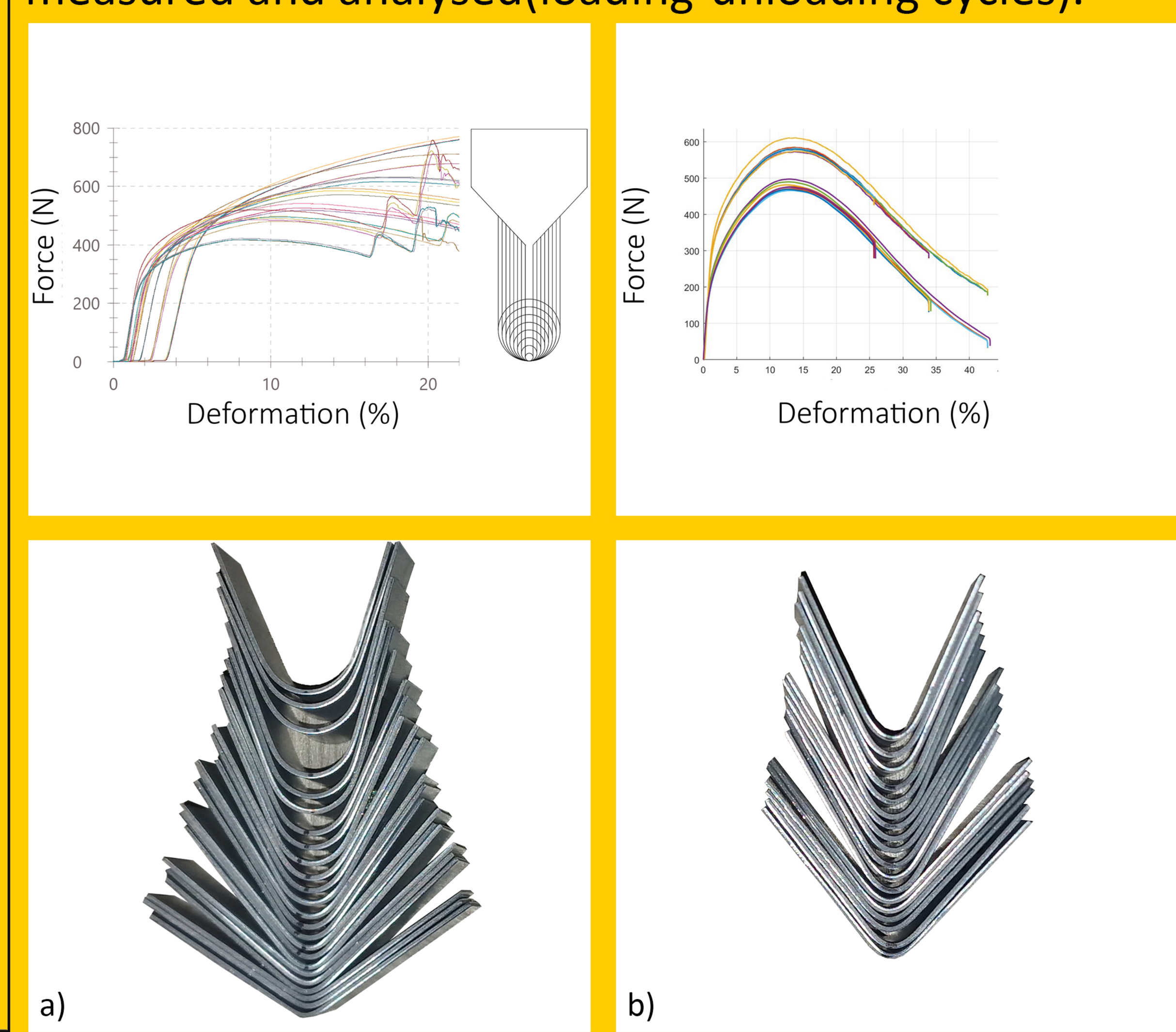
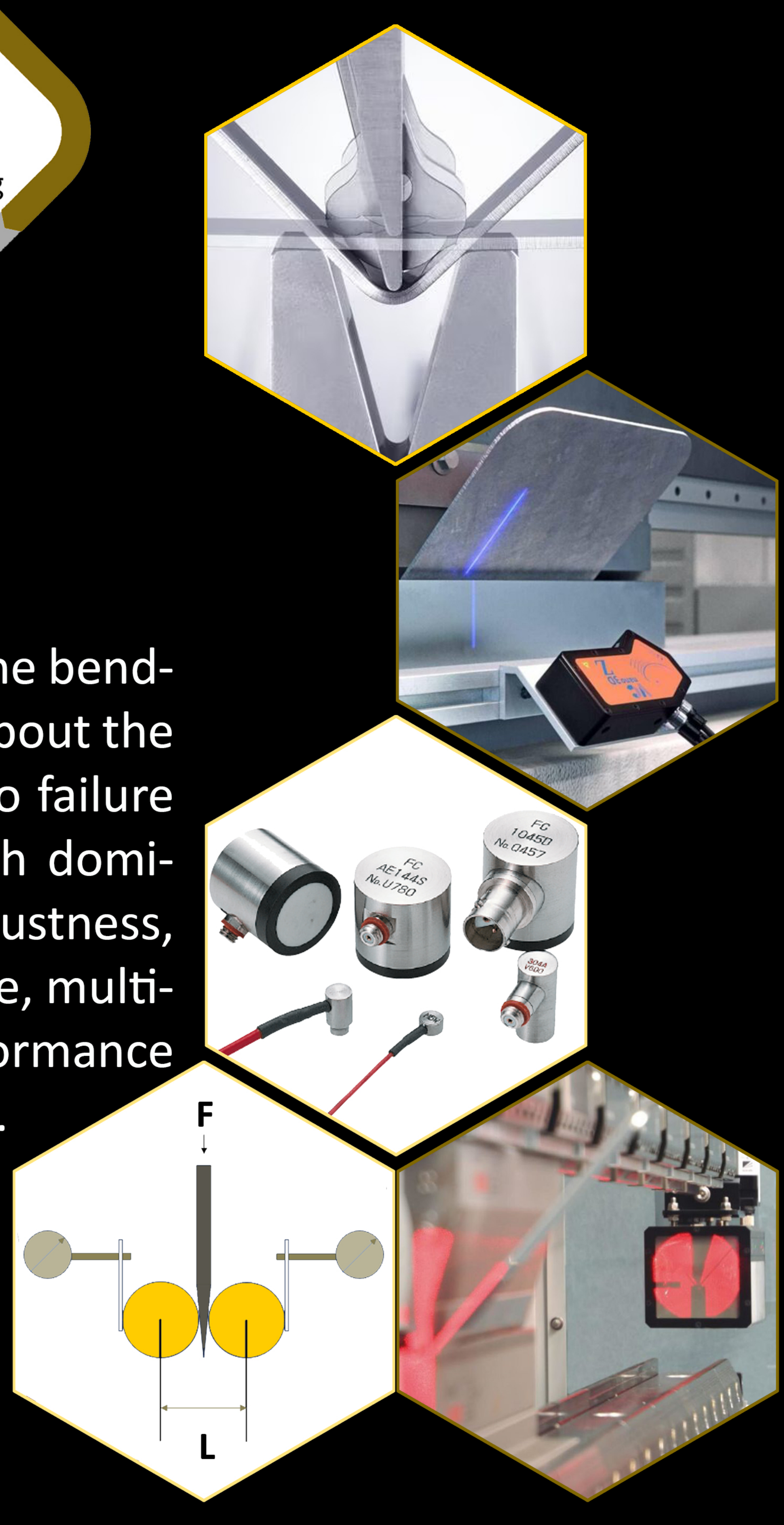


Fig 4. Force vs Displacement, a) different punch radius sizes (1mm-8mm),b) different speeds (10mm/min & 10mm/s) & 3 different displacements (25,30 and 40%), 1.2 mm DP600.

Bending Simulation & Data Accuracy

The 3-point bending test is used to determine the bending angle with the aim of drawing conclusions about the deformation behaviour and the susceptibility to failure of metallic materials in forming processes with dominant bending proportions[3,4]. To ensure the robustness, reliability, and data accuracy of results over time, multiple measurement systems, techniques, performance metrics, and trade-offs are carefully considered. This approach is specifically tailored to continually generate accurate data, thereby contributing to the advancement of digital twinning technology in the manufacturing industries.

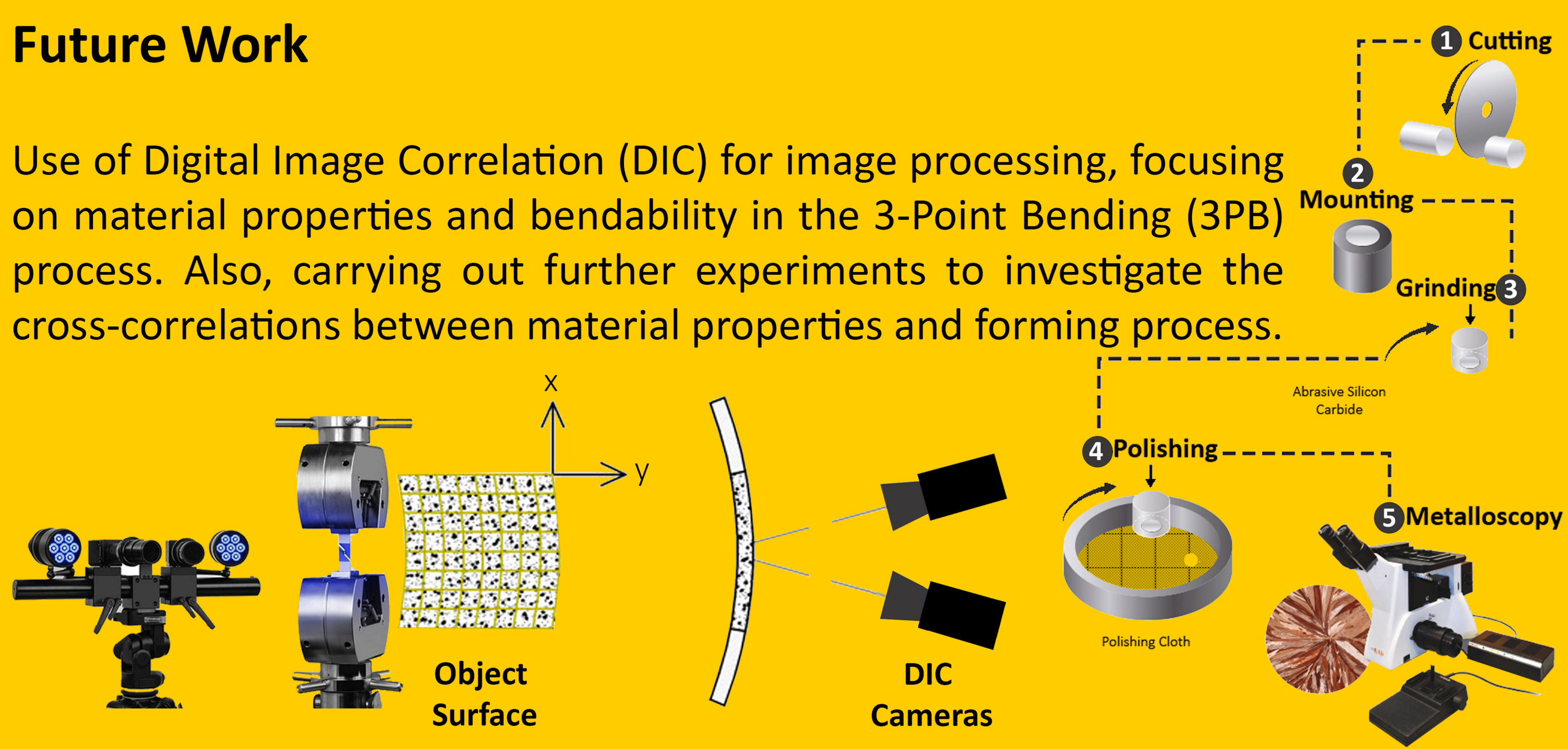


Conclusion

The 3PB test aims to standardize testing approaches, enhance result reliability, and draw conclusions about deformation behaviour (predict material failure). Concurrently, DT technology ensures accurate and measurable representations of physical spaces, facilitating real-time connections with physical assets which facilitates data exchange to reflect real-world changes. It optimizes operational efficiencies, anticipates changes, reduces errors, and enables more accurate predictions, contributing to informed decision-making.

Future Work

Use of Digital Image Correlation (DIC) for image processing, focusing on material properties and bendability in the 3-Point Bending (3PB) process. Also, carrying out further experiments to investigate the cross-correlations between material properties and forming process.



References

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[3] VDA 238-100 test specification draft:Platebending test for metallic materials. 06/2017
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