Flexible Digital Manufacturing for Freeform Fabrication of Thermoplastic Composites

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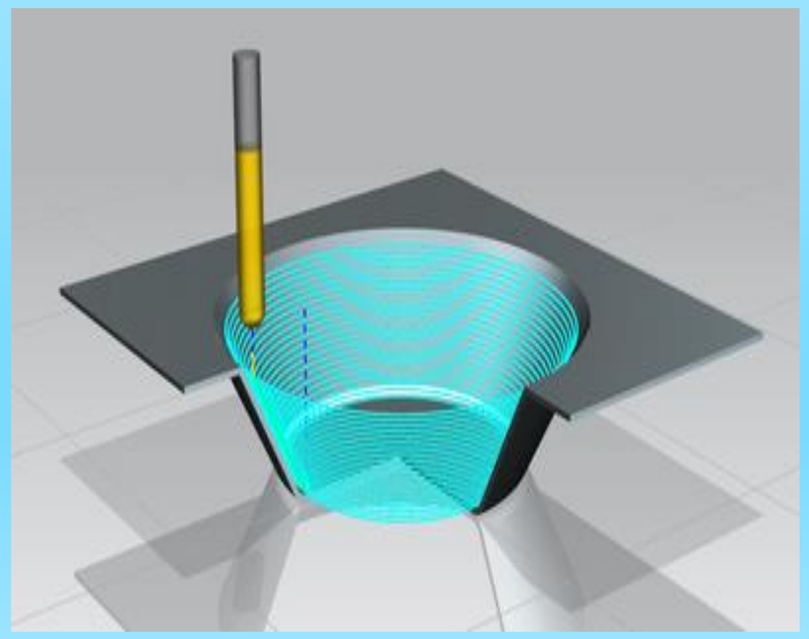
Introduction

Fibre Reinforced Composites (FRCs) are considered as the materials of the future mainly because of the possibility to produce stronger and lighter structures. However, there is little in terms of traceability and limited feedback to improve manufacture which limits composite's spread. In addition, even though several techniques might be suitable for small batches, individual customization is penalized due to the production of new and sometimes expensive moulds.

Incremental Sheet Forming

Recently, Incremental Sheet Forming (ISF), a new sheet metal manufacturing technique has evolved to overcome the need of expensive and complex moulds due to an incremental or step-by-step deformation to achieve a specific geometry as illustrated in Figure 1. Furthermore, to our knowledge, this technique has not been implemented in FRCs.

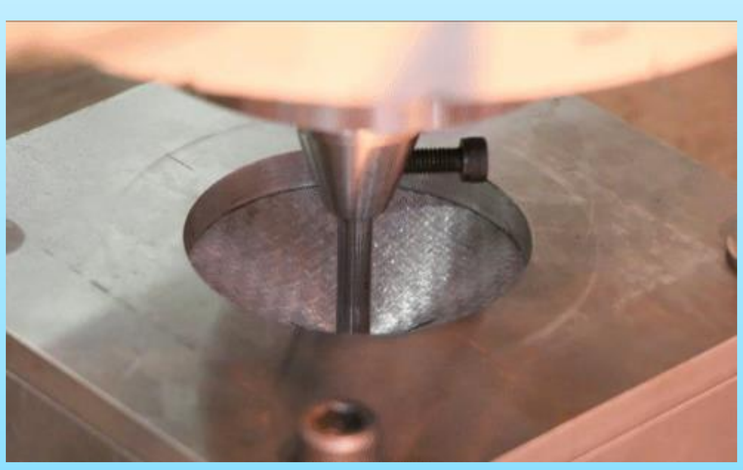


Preliminary Experiments

Indentation Forming

In order to test the applicability of Incremental Sheet Forming to FRCs, a simplification of incremental forming machine was developed to perform single and multiple indentation forming operations as shown in Figure 2. The first used and external oven, while the second implemented a temperature controlled chamber.

Single Indentation Forming



Multiple Indentation Forming

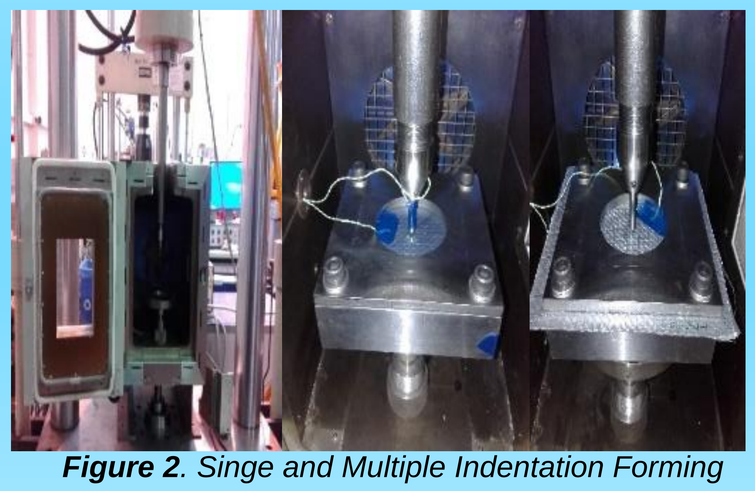


***Figure 2**. Singe and Multiple Indentation Forming*

Preliminary Experiments

Self-Reinforced Composites

The material used was a Self-reinforced thermoplastic composite laminate made a co-extruded all-polypropylene tape-Armodon™ (Figure 3).

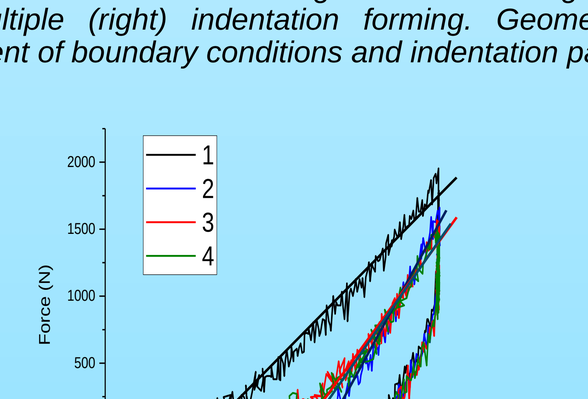


***Figure 3**. Self-reinforced composite fabrication*

Results

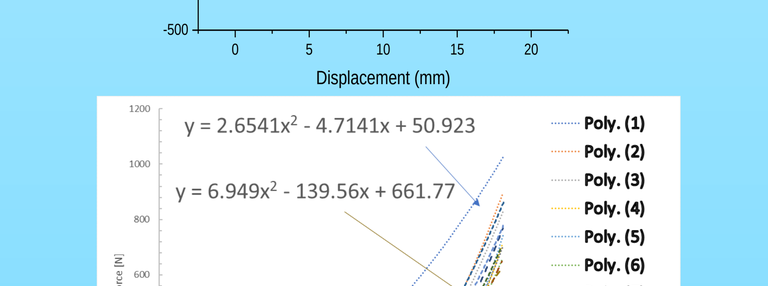


***Figure 3**. Mould free resultant geometries for single (left) and multiple (right) indentation forming. Geometry is dependent of boundary conditions and indentation pattern.*

***Figure 4**. Forming Forces: 4 (Top) and 13 (Bottom) indentations in a 15-layer laminate. The flexibility of deformation increases for subsequent indentations.*

Conclusions

- Mould Free cone-like composites were created via single and multiple indentation forming operations
- The final geometry achievable is dependent in the boundary conditions such as:
  - Clamping Condition influence the wrinkles
  - Support geometry influence the overall shape of the final geometry
  - Indentation patter influence geometric details.
- The forming forces measured during the test revealed a change in the flexibility to deformation of the material for each indentation. This means that the location of the point of contact and the state of material around at each indentation are relevant factors in the mechanism of the forming process .

Objectives

Based on the success of Indentation forming, the aim of this study is to implement machine learning algorithms for flexible digital manufacturing via Incremental Forming to create mould free composites for low cost, high-quality, and individual customization.

The following objectives are proposed:

1. To build and adapt a prototype machine to produce mould free and data rich fabrication of composites.
2. To construct a design of experiments based on machine and material parameters suitable to obtain enough data.
3. To apply learning strategies to discover an approximate function that construct the input-output behavior observed in the data.

Future Work

Robotic Prototype

The robotic set up is in the design stage to perform single and/or double point forming operations covering the following aspects:

- Kinematics
- Dynamics
- Heating
- Mechanism
- Actuation
- Control
- Sensing
- Learning

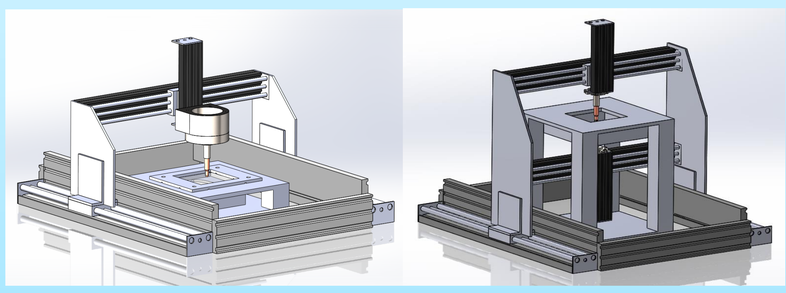


***Figure 5**. Robotic single (left) and double point (right) incremental forming*

Machine Learning

An agent is learning if it improves its performance on future tasks based on previous observations.

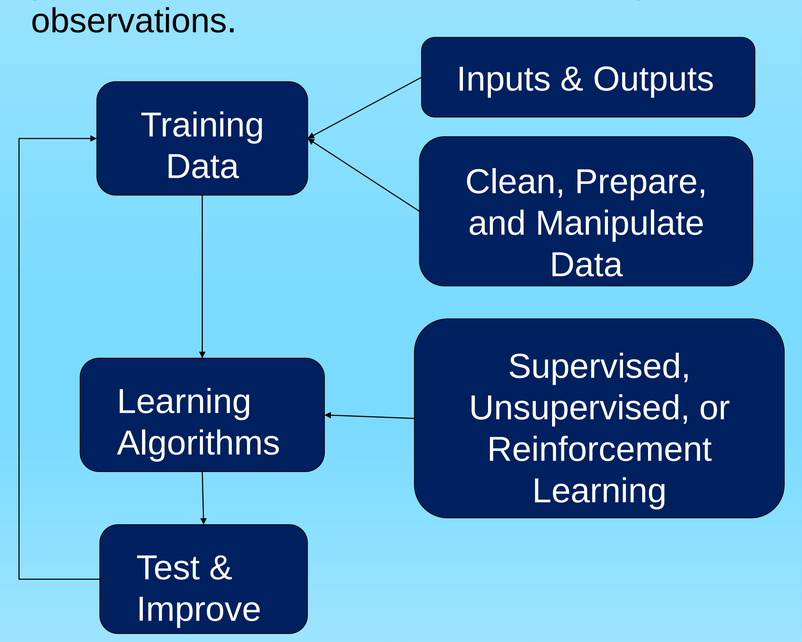


***Figure 5**. Typical Machine Learning Flow*

Acknowledgements

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