University of BRISTOL
Bristol Composites Institute

Building and commissioning of a data rich forming platform

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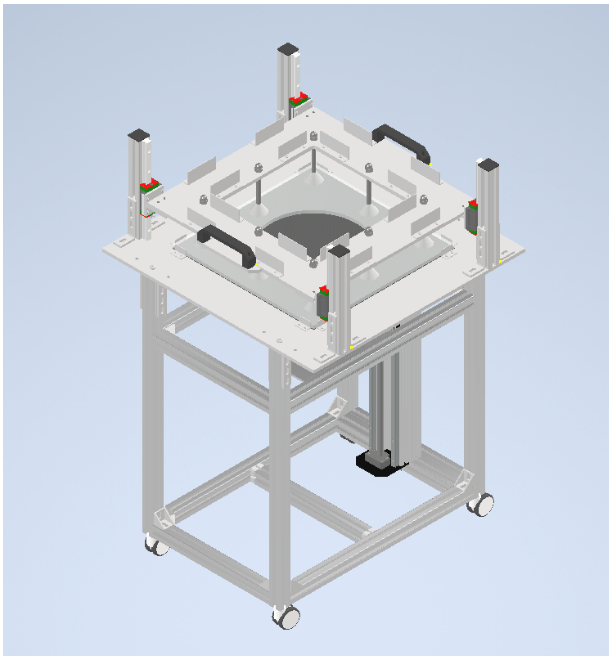

Abstract

This report details the forming process of composite materials, specifically using the process of punch forming. This aims to give an overview of current issues with this process to identify why a solution is necessary. This focuses on the design parameters and the implications of this work for Bristol composite institute and further institutions.

1. Introduction

The purpose of this research is to eliminate material defects during the forming process of composite materials. Currently, there stands an unintended deviation between predictive modelling of composite materials to the actual forming result. The gap in modelling, results in second material properties for a given application, often meaning material is discarded so further forming must occur. To overcome this, the building of a test-rig will allow for a large amount of data collection for a variety of test set-ups depending on pressure variation, actuation force and fabric location and layup. Eventual data collected will help to bridge the gap, providing more accurate predictive results. This report will focus on the research and design process of the test-platform.

2. Methodology

The use of composite materials has been rising in a wide range of applications, due to its desirable structural properties coupled with low density. Recent-generation military advancements, have began to use composites for their equipment, such as composite shells within combat helmets. The use of composites has become extensive across commercial aviation, the Boeing's 787 is primarily composed of composites such as carbon fibre re-inforced plastics (CFRP). There is a range of techniques used to mould composite fibres, this includes vacuum forming, this project is based around punch forming. Punch forming is a forming process used for composite materials, a punch mould is loaded on an actuator system to provide a forming force into a pre-preg sheet of composite lay-up. This is demonstrated in the figure below:

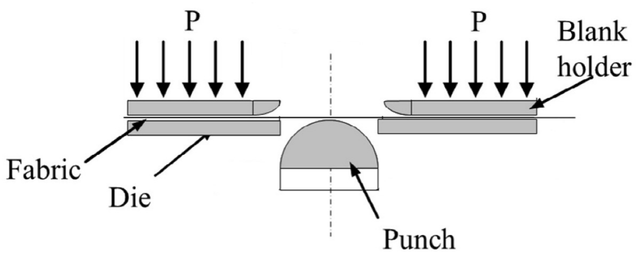

Figure 1: Forming Illustrated

Below further illustrates the process with the forming rig design.

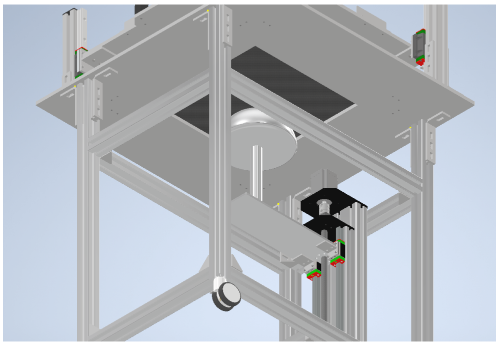

Figure 2: Actuator

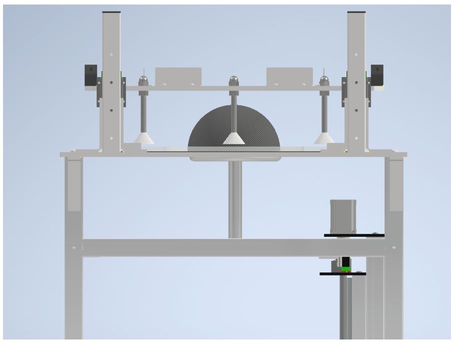

Figure 3: Spherical mould

As a process, punch forming has an associated risk of errors. There are three main errors that undermine the performance of punch forming, wrinkling; 'transition zones'; slippages.
Variations in pressure, pressure distribution and application points as well as material lay-up are variables which directly impacts these errors. The increasing use of composites generates motivation to replace traditionally, costly experimental trial and error based methods with computational optimisation modelling, creating the void for numerical solutions to accurately portray these results, reducing errors. Despite this, there does not currently stand a software to provide ideal parameters for specific applications. Illustrated below, there remains a gap between the predictive models and the test-results.

Figure 4: Test results

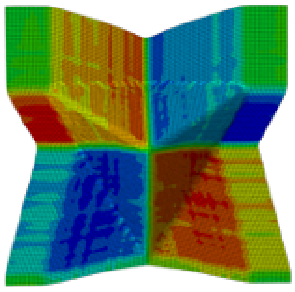

Figure 5: Predictive model

This disagreement is not favourable, local wrinkling results in unintended shapes for specific applications, discarding its use. Shape variations can alter structural properties making the formed part insufficient for the desired application. Ultimately, these defects result in the need for further forming to be conducted, not only expending time but also resources. This issue is empathised by the lack of recycling available for composite materials. To address this, the trial solution to this is to design and build a specific forming rig for the utilisation of data collection for a variation of parameters, which can be used to build the numerical solutions to eliminate this gap.

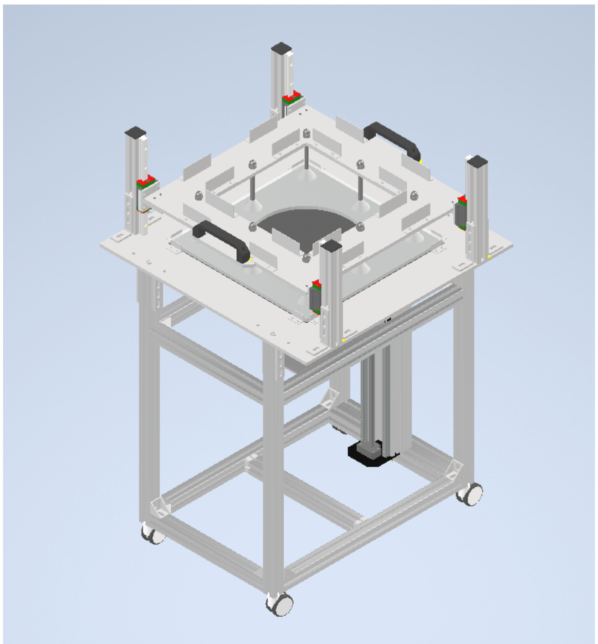

Figure 6: DIC frame set up

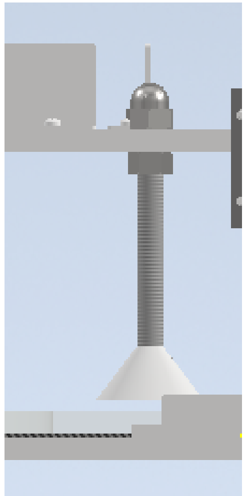

Figure 7: DIC camera

Initially, this begun with research into the varied design approaches to punch forming, their benefits and applications. Common approaches involve individually retractable pressure pads to apply tension across the sheet during forming. This technique requires pressure sensors to be placed beneath the fabric in order to correctly adjust each pad. Additionally, each pressure pad must be tensioned individually prior to a forming test being conducted, this significantly increases the time between tests reducing the amount of tests which can be conducted.

The aim of the rig is to be user friendly, for a wide range of experience enabling students to conduct separate tests using the machine, whilst simultaneously collecting large amount of data from forming, hence meaning time between tests, changing fabric, must be reduced.

The integration of these aims resulted in the rig featuring an all moving top plate, mounted on to a *HIWIN* linear rail system. Forming pressure is provided by calibration weights across fixed pressure pads and the rail system allows for reduced period between test.

As mentioned previously, pressure variation and application points are influential variables for the forming outcome. To outline, there is no doubt that a wider pressure variation will allow for more precisest testing to be conducted. Although, there becomes a trade-off, by which an increase in the number of application points and their location will reduce the viewing area for the Digital Image Correlation (DIC) cameras, how the data will be collected. Using this and the data from stress analysis tests, the trade off favoured the DIC camera viewing space, in order to collect data across a wider area, which is ultimately the task behind this.

To address the latter variable, there will be a series of electronic stress sensors mounted onto the bottom plate to allow for minimal pressure variation using the set up of the calibration weights.

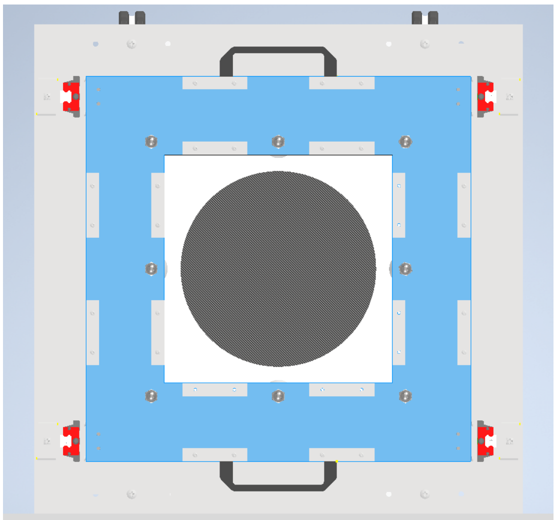

Figure 8: DIC viewing area

Next stages for project, how data will be collected and used.

With the main focus of this project being data collection, we must now turn the attention to how this shall be conducted. The figures beneath demonstrate the set-up that will be used in parallel with the equipment for this.

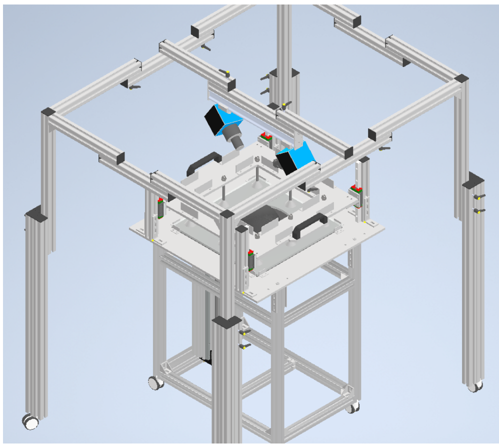

Figure 9: DIC frame set up

Figure 10: DIC camera

As a process overview, DIC will be used to track strain on the composite during the forming process, these results can be directly uploaded to *LabView* for analysis. DIC is an optical tracking technique common for this application, super-high frame rate imaging tracks incremental movements to provide deformation, strain and vibrational characteristics. To collect data, prior to forming each composite sheet will feature a speckled pattern. The DIC cameras will use this to record quantitative measurements, appropriate for data analysis. As show-n, this will feature two synchronised DIC cameras at angles to the sheet, this is in order to provide a 3D result and data collection.

The rig is currently in construction and this space will be updated as the data is collected.