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Analysis of a Forming Press for Composite Panel Fabrication

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ABSTRACT

Modern day engineering has incorporated composites in every facet of the growing technological applications. Not only is the strength comparable to the conventionally used materials, its low mass characteristic has made it an integral part of many manufactured goods and engineering applications. Pneumatic and hydraulic presses can be used in composite forming. Pneumatic presses are preferred, as the process is much faster than hydraulic presses and their flexibility helps in reducing fabrication time. The present study aims at optimizing the existing design of a pneumatic press in an attempt to remove redundant material and make it more economical. Changes are made to the existing model to ensure portability, ease of handling the composite post curing, and ability to handle fatigue loads, larger load carrying capability and faster processing time. Accessories that enable fabrication of larger sized composite panels are also incorporated. Comparisons of the press with an identical design using different materials to achieve cost effectiveness and longer machine life are also examined.

Keywords: Composites, pneumatic press, forming, fabrication, optimizing.

I. Introduction

The concept of composites is not a new invention. Wood is a natural composite material consisting of cellulose fibres with good strength and stiffness present in a resinous matrix [1]. These are the two basic constituents of a composite: a matrix and a reinforcement material. In the simplest sense, it is an amalgamation of two or more components in a prescribed proportion. Composites form a part of the non-conventional materials for manufacturing. The individual characteristics of the components used to make the composite are not lost, however, when combined, the properties together become enhanced and as a result, they have replaced many conventional metals and metal alloys leading to a great deal of optimization and has also paved the way for frugal engineering methods that are in sync with the cost and quality of the product. A designer can make use of tougher and lighter materials, with longer life and easy replicability and such properties can be tailored to suit particular design requirements. Flexibility of a part model increases, with lower tooling cost. Composites also provide high specific stiffness and corrosion resistance.

Synthetic fibres like carbon fibres, glass fibres and aramid fibres have been used extensively in the engineering applications. Based on the directional properties, a composite's properties can be altered. Manufacturers also use fibre weaves that apply strength equally in all directions [2].

Another group of composites is natural fibre reinforced biodegradable polymer composites. It has high a scope for future as it is a green material and their development is independent of petroleum based products [3]. Agricultural crop residues can be used as effective reinforcement materials in the forming of composites. Fully degradable materials such as Polylactide (PLA), thermoplastic starch, cellulose, PHAs can be used as a matrix [4].

Several methods are practiced for composite forming. Some constituents require pressing for certain property requirements; others can be cured without the application of any external loads. Moulding of the constituents under load or pressure is the most common practice. In case of cost effective formation process, we can make use of hydraulic or pneumatic presses [5]. Hydraulic presses are not as quick as pneumatic presses and cannot match their speed even with the use of double acting piston assemblies [6]. Liquids exhibit greater inertia and viscosity than gases. The cylinder, thus, bears larger frictional pressure. The hydraulic oil poses a problem when sudden valve position changes are required and when sudden acceleration and deceleration of the actuators takes place [7].

The objective of this work is to optimize the pneumatic press model prepared as the design analysis was not undertaken. The frequent use of the machine caused a few design problems

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to surface. The issue of handling the composite pre and post curing was tedious because of the overhung arm, and has been addressed. The design analysis showed that the model could withstand loads much higher than what it was bearing during the compression process and hence, optimization was carried out. The maximum force that can be handled has been ascertained.

II. Methodology

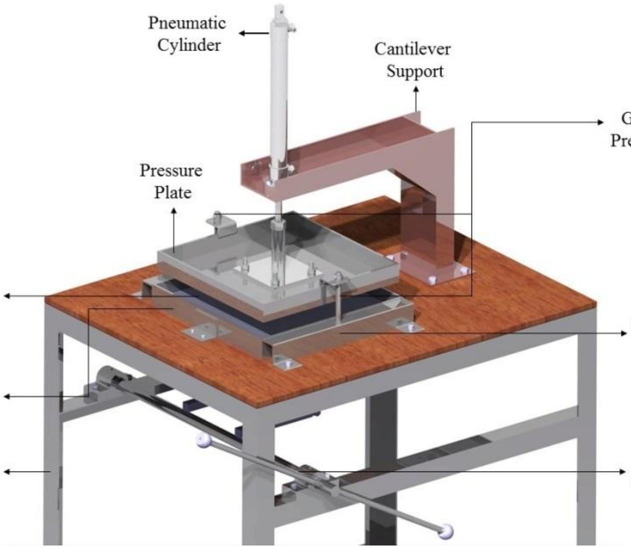

Fig. 1: Initial Design Assembly

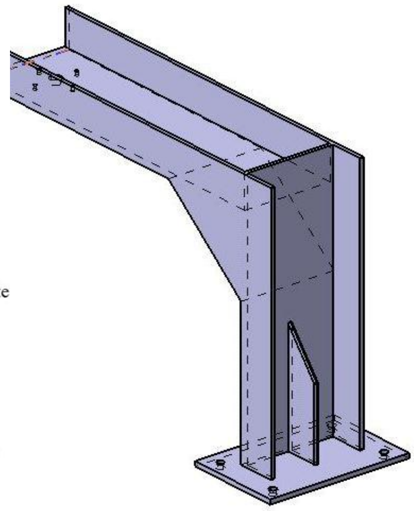

Fig. 2: Cantilever support

A. Initial Design

The initial design which was proposed mainly consisted of the cantilever support, pressure plate, composite receiver plate, bottom plate and a mechanism which would enable ejection of the composite receiver plate after compaction. For a given specimen size, the cantilever support and the bottom plate supports are fixed in place to the work table using standard fasteners. The pneumatic cylinder is held in position using a uni-axial support which is in turn fixed to the cantilever arm using standard fasteners. Two vertical rods are provided on the bottom support plates which act as guides for the pressure plate so that there is proper alignment between the pressure plate and the receiver plate. The entire assembly is mounted on a table skeleton of which is constructed by standard 'L' sectioned beams, Fig. 1 shows the proposed design with all parts labelled. An ejector mechanism is installed on the table which enables ejecting of the specimen plate after compaction is completed so as to separate the finished composite product from the compaction assembly.

The cantilever support was constructed using standard channel section LC100 according to IS808 [8]. The material used is of IS steel 1875 grade 2A having yield limit as 250 MPa [9]. Two standard sections of different lengths were taken and welded together using an

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intermediate triangular sheet of the same material as shown in Fig. 2.

3-D models of all the proposed designs were modelled using CATIA V5 R19 and structural analysis of the same were performed using ANSYS Workbench 14.5.For the Initial Design, the main focus of the analysis was to obtain the stresses and deformations of the cantilever arm and the pressure plate assembly. The force exerted on the composite receiver plate was calculated to be around 250 N. For analysis purpose, fixed support was given to the bottom of the table top. The contacts between the screws which hold the cantilever arm and the table were assumed to be bonded.

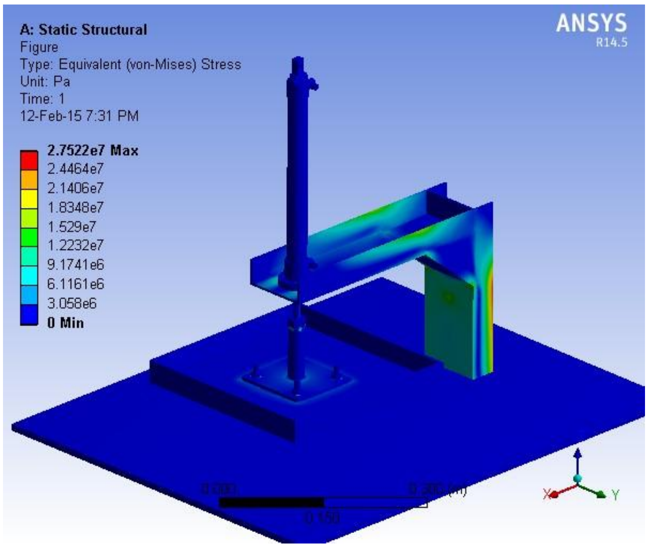

Fig. 3: Stress Distribution of Initial Design

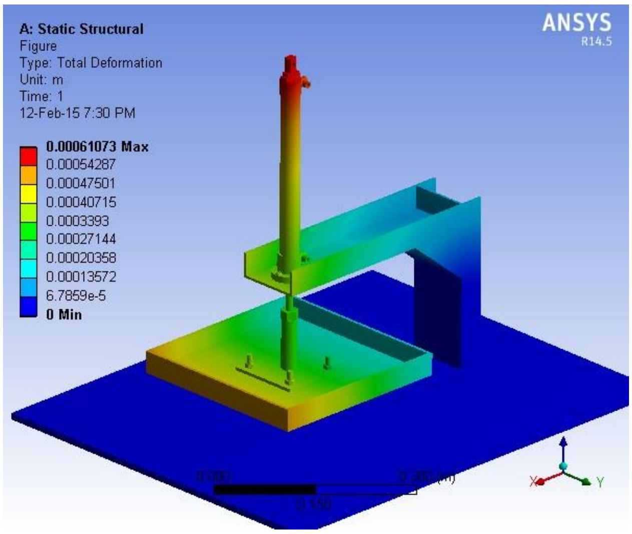

Fig. 4: Total Deformation of Initial Design

B. Modified Design

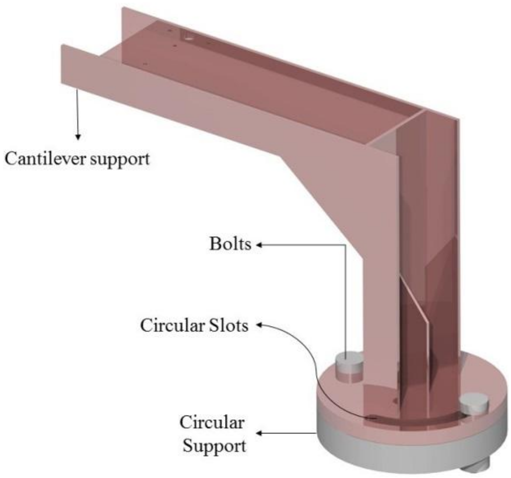

Fig. 5: Rotatable Cantilever arm

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Fig. 5 shows the modified design which enables rotation of the cantilever arm. Such a design provides extra space for pouring the raw material into the bottom plate and also makes the cantilever assembly portable. The bolts are unfastened and the cantilever arm is rotated along the axis of the circular base manually and is locked in position using the same bolts. Also, the cantilever beam can be made out of LC 75 instead of LC 100.

III. Results and Discussions

A. Permissible maximum deflection

For structural beams, maximum allowable deflection limits are specified. The ratio L/f where 'L' is the length/span of the beam while 'f' is the factor, gives the maximum allowable deflection. The factor 'f' is dependent on the application of the beam. The maximum final deflection should not normally exceed span/250 due to all loads including the effects of temperatures, creep and shrinkage and measured from the as-cast level of the supports of floors, roof and all other horizontal members [10]. Hence the maximum allowable deflection for the cantilever arm taken is shown in equation 1.

$$L/f = 335mm/250 = 1.34\ mm \ldots\ldots \text{ Equation (1)}$$

B. Initial Design

The maximum deflection was observed to be 0.61mm which is less than the designed permissible deflection and the maximum stress was observed to be 27.522 MPa which is much less than the yield stress limit of the chosen material which is 250 MPa. The equivalent stress variation and the deformation in the assembly can be seen in Fig. 3 and Fig. 4 respectively.

C. Modified Design

Fig. 6 showed that a maximum deformation of 1.15mm was obtained for a force of 750 N, three times our specified force of 250 N. The maximum stress at this load obtained was 164.25 MPa (Fig. 7), which is still below 250 MPa, thus proving the reliability of the design for higher load applications. Also, LC 75 has a mass of 5.7 kg/m compared to the initial design which utilized the LC 100 which has a mass of 7.9 kg/m, without significant change in performance, leading to weight savings.

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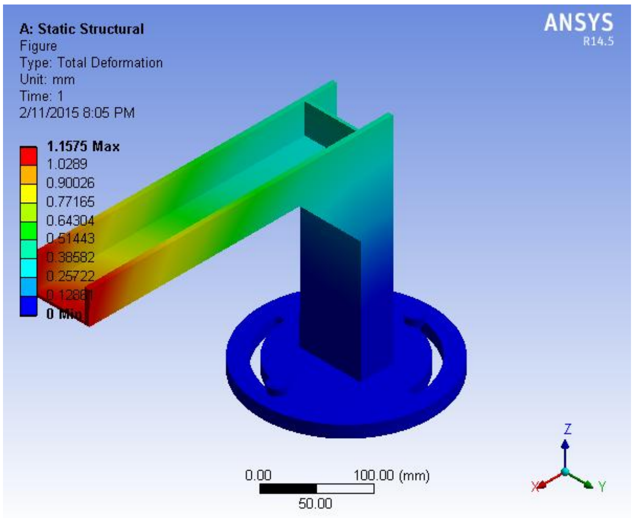

Fig. 6: Total Deformation of Modified Design

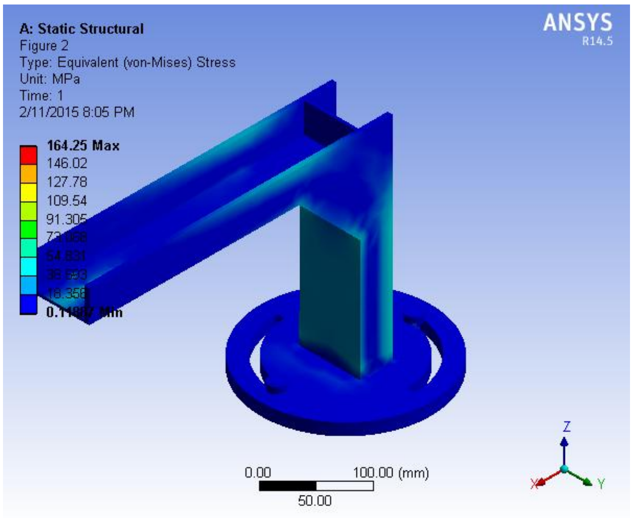

Fig. 7: Stress Distribution of Modified design

IV. Conclusion

With the increasing demand for composites in every field of engineering, academic research has increased for altering properties to match the challenging needs. The design optimization of the pneumatic press was carried out successfully to aid in the ease of handling the composite and produce better specimens. With more work space, worker constraints are reduced, provisions for larger composite dimensions are made and recommendations for lesser lead time are generated. Analysis showed that the induced stresses and deformations are well within the permissible limits. Different setups can be similarly designed to prepare larger size composite panels, by using larger beams and plates.

V. Scope for future work

The assembly shown in Fig. 8 introduces an assembly which can be used to manufacture composite panels of variable dimensions. This assembly requires bottom plate, receiver plate and pressure plates of the size of the specimen required. Different sized bottom plates can be fixed to the work table using the support plates which are free to traverse along their respective plain slots provided. The receiver plate is provided with a hook underneath which can be pulled and hooked to the table initially before pouring of the raw material. The spring assembly helps to provide uniform pressure during compaction and after unhooking, the assembly helps to eject the receiver plate after compaction. The spring specifications can be calculated by fixing few parameters such as free length and outer diameter of the coil. Considering 4 springs in total, for a sample force of 250 N, free length of 50 mm and outer diameter as 30 mm, the spring constant is found to be 0.670 N/mm.

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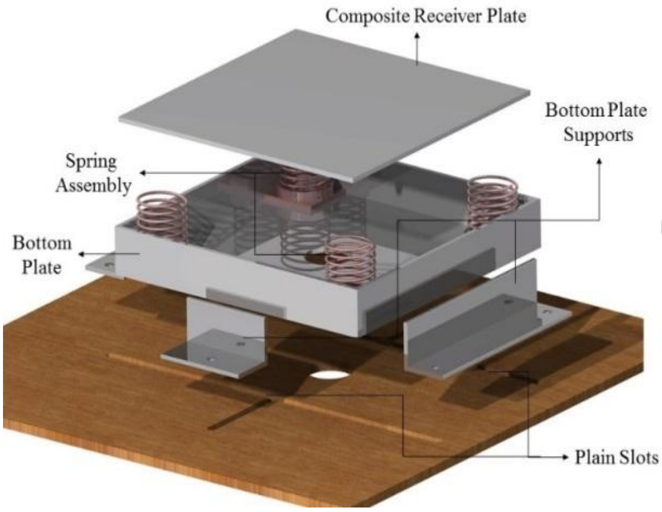

Fig. 8: Variable sizes with spring assembly

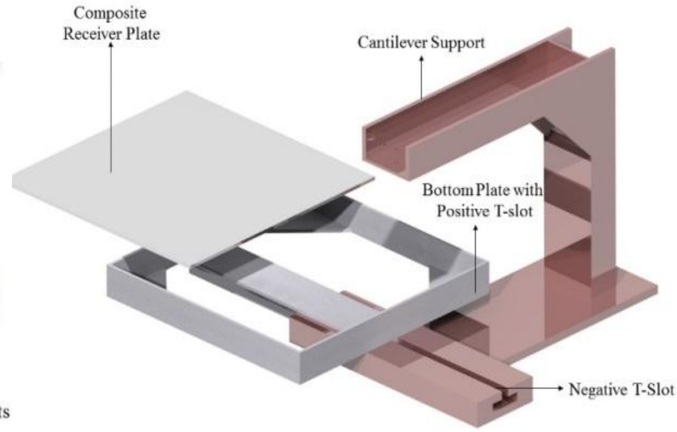

Fig. 9: Sliding T-Slot assembly

Fig. 9 shows a design where the whole setup can be carried and used wherever required. It consists of the cantilever arm of similar design as with dimensions as per IS LC 75. The other parts are the composite receiver plate which freely fits into the bottom plate with positive T-slot. The bottom plate then slides into the negative T-slot which if required, can be made an integral part of the cantilever arm by welding. Instead of T-slots dove-tail joint can also be used. The composite is poured into the sliding plate assembly. It is then conveniently slid into the T-slot provided below the cantilever or the upper plate. After applying the pressure for the required time, the bottom plate is removed from the slot and placed for curing. Post curing, the composite can be easily removed by inverting the plate and pushing the composite receiver plate.

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