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The Effect of Clamping Restrain on the Prediction of Drape Simulation Software Tool

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Abstract**—**To investigates the effect of fiberglass clamping process improvement on drape simulation prediction. This has great effect on the mould and the fiber during manufacturing process. This also, improves the fiber strain, the quality of the fiber orientation in the area of folding and wrinkles formation during the press-forming process. Drape simulation software tool was used to digitalize the process, noting the formation problems on the contour sensitive part. This was compared with the real life clamping processes using single and double frame set-ups to observe the effects. Also, restrains are introduced by using clips, and the G-clamps with predetermine revolution to; restrain the fabric deformation during the forming process.The incorporation of clamping and fabric restrain deformation improved on the prediction of the simulation tool. Therefore, for effective forming process, incorporation of clamping process into the drape simulation process will assist in the development of fiberglass application in manufacturing process.

Keywords**—**clamping, fiberglass, drape simulation, press forming.

I. Introduction

THE Clamping of fabric is one of the most important processes in contour sensitive part manufacturing. During this process, deformation varies from different points across the surface of the fabric depending on the clamping position, restrains and how simple or complex is, the contour sensitive part to be formed. The need to study and understand these effects in relation to the prediction of drape simulation software tool, will be an additional development in the field of research of reinforced 8H satin weave fiberglass materials study.

These clamping effects, combined with demand for proper production procedures, have led to an increasing industrial interest in product structural characterization. The type of clamping for press-formed fiberglass thermoset composite is quite different from the prepeg thermoplastic composite.

Therefore, the effects of this process need to be incorporated into the drape simulation software tools to improve on the development of fiberglass application as a lightweight replacement for metal and its alloys.

The Drape Simulation Software Tool

Material draping simulation software tool is becoming an inevitable tool in many structural components developments. This tool indicates the feasibility of materials structural forms and gives the real life deformation pattern of composite fabric applications in the growing industrial and manufacturing industries of today's market. This tool also provides important information, such as the distribution of yarn, orientation, the deforming angles of materials and the fiber volume fraction or thickness of the fabric stack [1]. This information allow the digital prediction of structure before the real life forming process, so as to correct in advanced most problem that can be encounter during the contour sensitive part production processing.

Material Clamping Process

Contour sensitive parts production process needs the development and incorporation of effective clamping and restrains process. This need to be incorporated into the software tool development in both the manufacturing and industrial sector, because it has effects on the structure produced after most production process, especially in the fiberglass applications in the manufacturing sector. In this article, the effect of clamping positions on the drape simulation software prediction was observed.

The process shows the need for the incorporation of clamping process in the already developed software tools and for the development in the fiberglass research study and application.

II. Review of previous works

Many literatures study has being conducted by researchers to develop on fiberglass fabrics application in production processes. Wang et al, [1] study the draping of woven fabric preforms and prepregs for the production of polymer composite components. In their findings, the drape simulations predictions using pin-jointed net model, which include the draped pattern, undraped flat ply shape, and maximum shear angle, agree well with the test results. Also, the simulation was able to provide information about the optimal draping pattern and indicate where interplay shear needs to occur in draping forming. These results are inconsistent with the results reported [2-3], in their previous findings on material tests and analysis, in which the yarn slippage is considered to relate to the magnitude of the shear angle only.

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Willems et al, [4] illustrated the application of 2D digital image correlation [DIC] technique in assessing the macro-scale textile deformations during biaxial tensile and shear tests in order to verify, the loading homogeneity and the correspondence between the textile and rig deformation. They concluded that optical measurements are mandatory for reliable assessment of textile deformation. This can be effectively applied in textile characterization, to study the homogeneity of loading and the correspondence between rig and textile deformation. The textile shear deformation for a weave in a particular configuration is not significantly affected by the tensile state.

Long et al, [5] developed a constituent-based predictive approach in modeling the rheology of viscous textile composites. This is used to predict the shear force against the shear angle for viscous textile composite sheets based on the uniaxial continuum theory for ideal fiber-reinforced fluids, but also applicable to woven textile composites. The kinematics leads to significant energy dissipation due to viscous shearing between tow crossovers. Micro-mechanical models were used to give both qualitatively and quantitatively accurate force versus shear angle predictions for both glass/polypropylene thermoplastic and carbon/epoxy thermosetting textile composites. The model gives accurate predictions and provides a means of calculating the forming rheology of textile composites without recourse to either the textile composite characterization experiments or complicated micro-scale finite element simulations.

Skordos et al, [6] introduced a simplified finite element rate-dependent model of forming and wrinkling of pre-impregnated woven composites, incorporating the effects of wrinkling and strain rate-dependence. The model convergence was tested and its validity was checked against experimental results from the forming of pre-impregnated woven carbon hemispheres. It was found that the model reproduces successfully, experimental measurements of shear and wrinkling with a relative error of approximately 4%, while solution times are kept below 60s on a conventional PC. These features allow potential iterative use of the model within a process optimization scheme. The sensitivity of the model and its outcome to process parameters such as blank holder force and forming speed, were also investigated in their work.

Lomov et al, [7] applied the full-field strain measurements in the studies of textile deformability during composite processing. Their finding concluded that optical full-field strain techniques are the preferable technique of assuring correct deformation measurements during tensile or shear tests of textile materials. The result also provided a verifying tool for the local fiber orientations determination and shear angles, for assessing the validity of drape simulation software predictions tool.

Savci et al, [8] proposed a method of investigating the deformation of weft-knit preforms for advanced composite structures, using simulation formability of dry preforms in relation to their physical and mechanical properties. The full milano structure results showed that the plain loop length and tensile properties enabled a good prediction of simulated formability. The study also investigated the effects of different knit structures on the deformation of weft-knit preforms. The results of this finding indicated that irrespective of structure, the loop length and tensile properties determine the simulated formability of weft-knit preforms. The results have clear implications for composite fabrication via deep drawing processes and subsequent resin infusion processing of fabric materials.

Lin et al, [9] in their study, observed the predictive modeling for optimization of textile composite forming processes in the area of wrinkling formation. The prediction of this defect is of major importance for the design and optimization of textile composite structures. Their result on hybrid finite element (FE) model incorporates a fully predictive multi-scale energy model, which determines the shear resistance of the textile composite sheet.

In addition, the effects of varying the normal force distribution across the edges of the blank and blank size, together with the effect of changes in the forming temperature on the final fiber pattern and wrinkling behaviour were also investigated. Predictions are evaluated against press-formed components. The results from the simulation and the experiments have good correlation, and shows that wrinkling can be minimized by optimizing the force distribution around the edge of the manufacturing tool and by careful choice of forming temperature.

In this article, the drape simulation software tool prediction was compared with the clamping and restrain on fiberglass contour sensitive part press-forming process. The report shows the need for the incorporation of the clamping process into the development of the software development. This is to aid the manufacturing process of both the thermoplastic and thermoset fiberglass composite high volume part production process.

III. METHODOLOGY

- The Single Frame with Varying Clamp Position

During the manufacturing process, it was observed that the usual four (4) points clipping of the fabric material during various forming process, sometimes, does not yield the desired result in the area of folding and wrinkles formation in the contour sensitive part. Therefore, a single and double frame structure was design using supper wood with cross section of 460mm X 460mm. This was clamped firmly onto the male mould during the experimental fabric layups to avoid movement during the press-forming process as shown in Figure 1. The fabric was secured lightly in 8 regions on the frame during the process as shown in Figure 2. Adhesive tape is used to introduce less restrain during manual press-forming process.

The structure produced from the process is as shown in the Figure 3. It shows wrinkles and folding projecting in some regions. This is as a result of fabric clamping on the frame with less restrains.

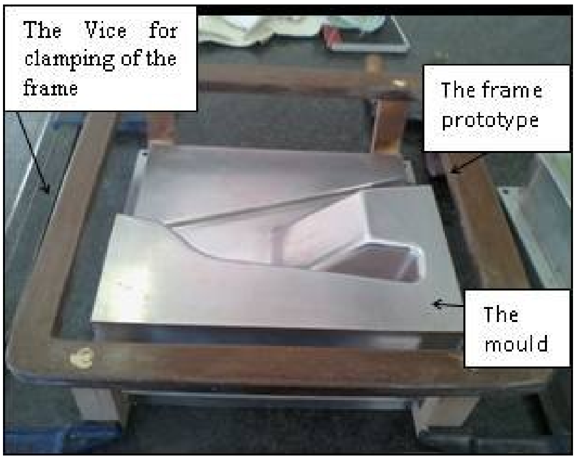

Fig. 1 The frame structure coupled onto the mould.

Fig. 2 Impregnated fabric with less restrain on the mould.

This does not reflect in the drape simulation process. From the experimental hand layup process above, the process needs further work on material clamping method; therefore eight (8) point clipping was introduced to give more restrains on the fabric on the frame. The structure produced gives improvement in the less complex area of the structure, but the folding and wrinkles are projected inward at the complex area as shown in Figure 4. With the observation above, the clamping position of the fabric clipping is increased to twelve (12) positions to further improve on the material clamping process. The result of the restrain shows an inprovement in the folding area as shown in Figure 5. From the outcome of the press-formed process above, it was observed that the clamping positions also have effects on the material during the forming process.

This improvement is as a result of restrain in the fabric movement during the process. These effects (fabric calmping) need to be incorporated into the drape simulation prediction because, the press-forming force and pressure are not enough to guide the simulation prediction of real life process.

- Introduction of Second Frame and Ten (10) Point Clamping Process.

Fig. 3 Structure produced.

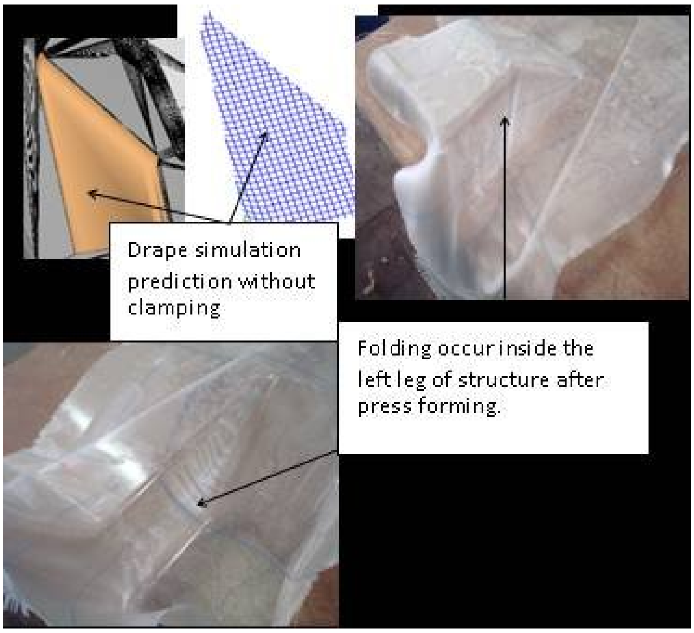

Fig. 4 Folding detected in the structure.

The process of single frame clamping gives good structure clamping result. But as the number of plies increases, the tendency of wet fabric sliping and the inconsistence sagging movement of the material before press-forming is inevitable. To avoid voids formation, folding and wrinkles during the process, a second frame was introduced inorder to keep the wet fabric in a secured and firmly position during press-forming of the structure. The result is as shown in Figure 6. The double frame clamping process gives good strcutural product when compared to the single frame clamping.

The prospect of automation process incorporation in most manufacturing sector, with the possibility of sliping of the fabric on the single frame need the fabric to be further restrained due to manufacturing processes. This restrain will adequately constrain and align the fabric in the desired orientation for automated press-forming process.

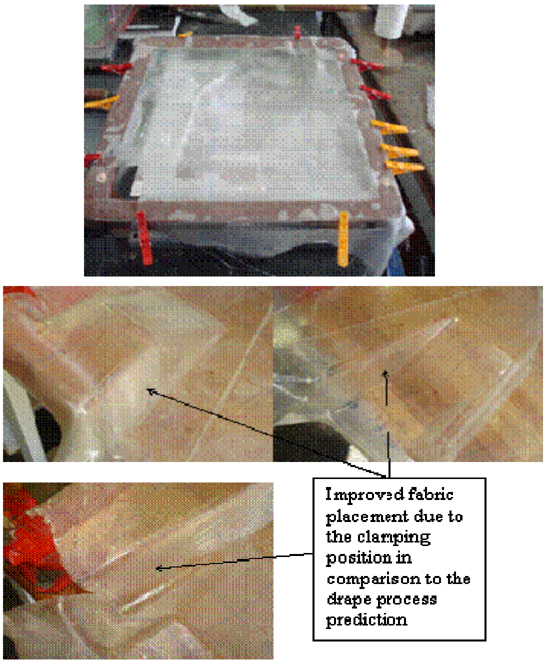

Fig. 5 Additional clamping position to improve on the folding detected.

Fig. 6 Four (4) plies fabric clamped and press-formed.

But adequate care must be taken during the G-clamp restrain grip on the frame because;

1) Thight grip will introduce unacceptable strain on the material and this might also cause forceful mold closure, that will have great impact on both the material and the mold during the process.
2) Predetermine grip with certain number of revolutional turn on the G-clamp grip will produce the desired result. For this process, the clamping holding revolution was counted from 55 turn outward/inward to grip firmly, but additional 2 revolutional turn outwards gives the free fabric movement desired in this press-forming process.
3) Loosened grip will introduce variational movement in the numbers of plies and can introduce material slippage, voids formation, folding and wrinkles in the structure produced.

IV. Conclusion

The restrain introduced by the clamping process improved on the outcome of the contour sensistive part produced. The observation from the process shows the effect and improvement in the predetermined real life clamping process in comparison to the insight provided by the drape software tool prediction. For effective application of drape software tools in the manufacturing process, the incorporation of clamping constraint with the effects of the restrains on the material will further improve the development of these processes in the field of 8H satin weave composite material application in structural products. The forming load and pressure are not enough to determine the material behaviour for real life press-forming process. The effect of clamping should also be incorporated into the simulation process.

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