Journal of Mechanical Engineering Research Vol. 2(7), pp. 149-156, December 2010
Available online at http://www.academicjournals.org/jmer
ISSN 2141 - 2383 ©2010 Academic Journals

Full Length Research Paper

The need for the incorporation of boundary condition prediction in real life layups using Drape simulation software tool

T. A. Adegbola*, I. Aghachi and R. Sadiku

Department of Mechanical Engineering, Tshwane University of Technology, Pretoria, South Africa.

Accepted 7 December, 2010

The focus on the contour sensitive part mating boundary conditions development, using software in the fabric deformation during the hand layup and automation of press-forming process is important in the development of composite materials. During the real life layup production processes, the fabric directional changes produced wrinkles and voids in the part produced. This directional changes are not really feasible as predicted for real life production process by the Drape simulation, where the process can be stopped and fabric direction changed to avoid the wrinkles. In this study, the fabric was pulled and adjusted before it was finally cured during the hand layup to conform to the shape of the contour sensitive part, but during the press forming process the mould closure prevent this pulling. This is not accounted for in the simulation process of the part. Therefore, there is the need for further research into the analysis of these mating boundaries conditions in real life with the prospect of automation process. This changes in boundary conditions as the material been deformed assumes the shape of the mould constitutes major challenges for the contour sensitive part production processes. This still need further development for its effective application in the composite material development.

Key words: Mating boundary, Drape-simulation, press forming, real-life process.

INTRODUCTION

Simulation of the processes of contour sensitive part before the commencement of production, is now gaining fast and advance input into different areas of applications in the field of manufacturing in today's market. This is also required in the area of high volume parts production and mould manufacturing processes instead of the trial and error technique.

This software contributes significantly to the advance technological material development problem associated with these materials in terms of complex area analysis, complexities in the geometrical structures and structural manufacturability. All these and many more are becoming a major challenge in the industries. Therefore, it is inevitable to introduce a digitalization process to observe, monitor and correct all these shortcomings before parts are produced.

The drape software tool used for this result was a freebee using finite element mesh analysis in the prediction of the fabric behavior. This gave insight into the problems encounter in the materials production processes prior to the commencement of manufacturing. These problems were adjusted and improved upon by using the insight gained in the software prediction in real life production processes.

The mating boundary conditions of Drape simulation application in real life layup, remains a challenge for researchers in the field of composite materials. This is largely due to the interrelated effects of assumptions incorporated into the software program. Although, these have proved adequate for evaluating physical simulation analysis process, but are inadequate to guide the whole

*Corresponding author. E-mail: talktotaoreed@yahoo.co.uk. Tel: +27767466454.

Table 1. Material properties.

Weave	Warp count	Weft count	Warp yarn	Fill yarn	Weight (g/m^2)	Thickness (mm)	Strength warp
8H satin	377	168	ECG 150 1/2	150 1/2	302	0.22	350

process of real life contour sensitive part development.

Simona et al. (2004), studied the fused panel modelling using a numerical simulation of drape. In their finding the end form of product depends on the qualities of the build material and its construction requirements. Also, their results of numerical analysis obtained show the significance of additional development in research area regarding the computer simulation of the product behaviour.

Cerda et al. (2003) considered the gravity-induced draping of a 3D object with a naturally flat, isotropic elastic sheet. They observed that as the size of the sheet increases, the appearance of new folded structures complexity increased, due to the competition between elasticity and gravity. Also in their analyses of some of the simpler 3D structures when considering their shape, response and stability, show that these structures can easily switch between numbers of meta-stable configurations. For more complex draperies, scaling laws were derived for the appearance and disappearance of new length scales. The results are inconsistent with observations of drapes and complement large-scale computations of draping, thereby providing benchmarks for simulation processes.

Skordos et al. (2006) introduced multi-objective optimisation into the woven of composite draping using genetic algorithms. Their finding presents draping optimisation scheme based on the integration of a commercial kinematic Drape simulation code and a genetic algorithm. The kinematic model allows a fast solution to the drape model which reproduces successfully the distribution of shear over the component surface, while the genetic algorithm drives the optimisation. The efficiency of the methodology was evaluated based on the results of the scheme applied to the draping of a composite pilot helmet.

Vanclooster et al. (2008), in their study, presented a comparison between two different modelling approaches commonly used in the simulation of draping woven composite fabric. The first one being a kinematic mapping approach, while the second the mechanical model approach, considers elastic constitutive behaviour of the fabric as the probable realistic approach. Both approaches are compared with experimental process. They concluded that the mapping approach severely fails in predicting the fibre reorientation that occurs during forming. The main sources of these faulty predictions are the unrealistic initial conditions and not taking the fabric draping behaviour into account. In addition, the mechanical simulation approach gives a fairly good prediction of the fibre reorientation and seems the most promising technique in having good draping simulations.

Researchers are also using a variety of methods to examine the impact of fabric mechanical properties on drape using drape meters or drape testers operated principles. In this area, Collier (1991) in his finding, related fabric drape value to fabric shearing and bending measurements, while Hu and Chan (1998) related drape coefficient to bending and shear properties, but found that mean deviation of friction coefficient and tensile linearity were also important in the process application.

Chen and Govindaraj (1996) utilized a square rather than a circular surface for their work on drape and concluded that, although many fabrics may share the same drape coefficient, the actual shape of the drape is unique. They also found drape to be influenced by a variety of parameters including Young's modulus in the warp and weft directions, shear modulus and thickness. Yang and Matsudaira (1998) demonstrated that fabric mechanical properties, which include bending rigidity, shearing rigidity, shearing hysteresis and weight per unit area influenced the shape of draped fabric, depth of weaves, and number of nodes greatly influenced the fabric parameters. It is clear from their work that drape is a complex characteristic process.

METHODOLOGY

The material properties are shown in Table 1. The procedure was section into two; Drape simulation process and the experimental real life layup (hand layup and press forming processes).

Drape simulation

The drape software used in this process is a freebee simulation tool that gives general overview of the part showing the problem areas that need improving on before the real life layup. The processes are as follow:

(1) The input of material properties into the drape software
(2) The selection of colour ranges for the fabric shear deformation in the tool. This ranges shows good fabric orientation, wrinkle formation and fabric folding within the range of material properties.
(3) The point of first contact on the mould was then selected because, this affect the fabric movement on the mould during the layup process.
(4) The fabric shear direction was then selected (± 0/90 and 0/45°) this is in-line with the in-feed of the fabric on the mould and the type of fabric weave was then selected for the process. The shear referred to is the shearing movement of the fabric as it is assuming the shape on the mould.
(5) The simulation was allowed to run and the sequence of Drape simulation process, the problem area predicted and result are as shown in Figures 1a, b and c.

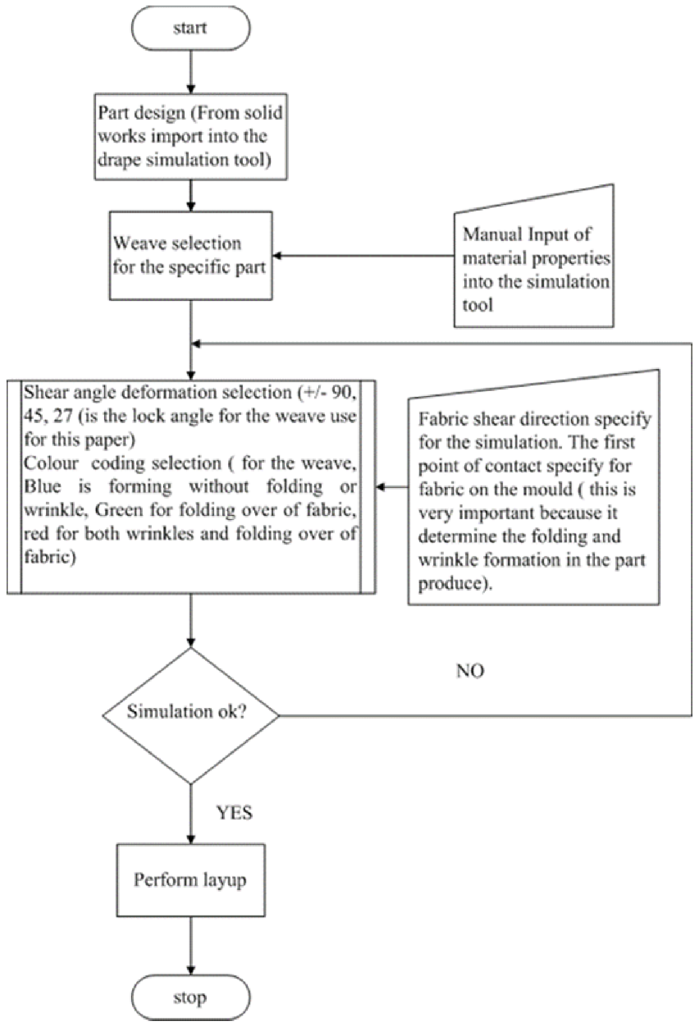

Figure 1a. The simulation process.

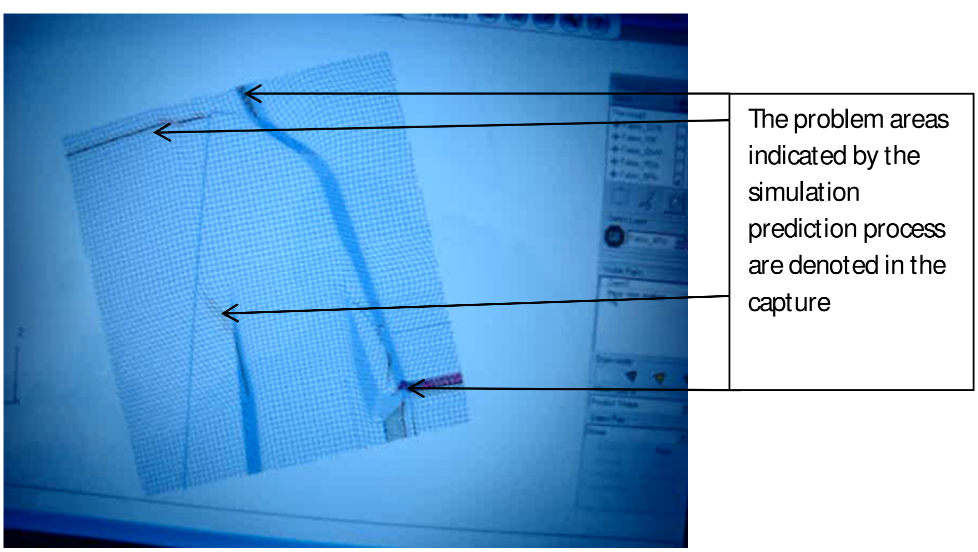

Figure 1b. The simulation prediction showing problem area.

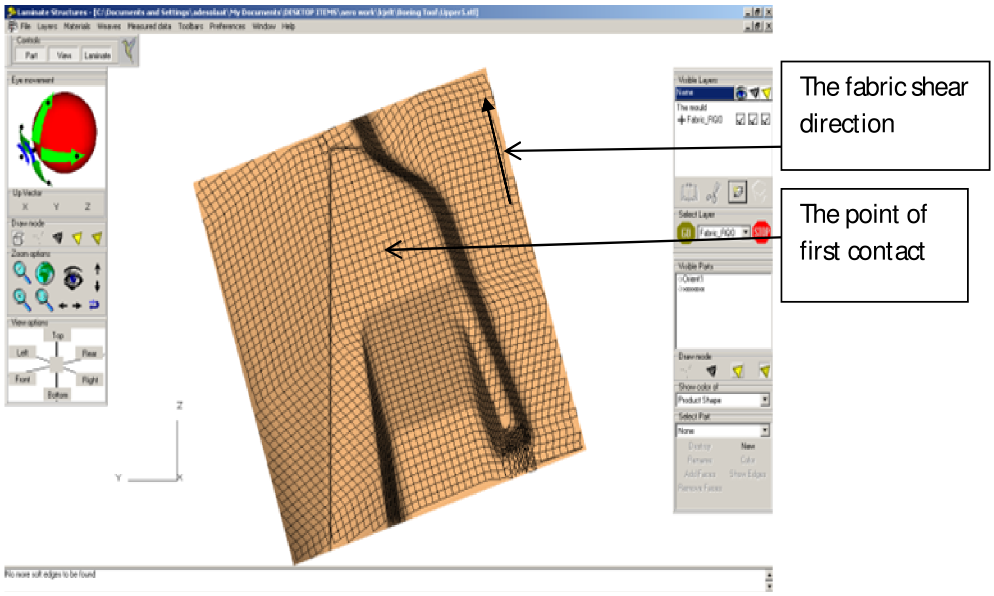

Figure 1c. Drape simultion process.

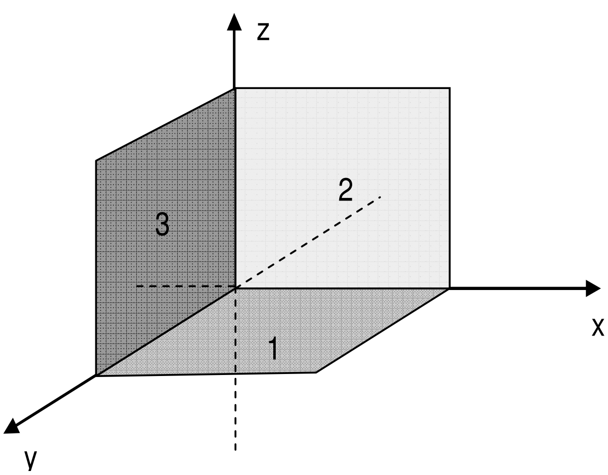

Figure 2. Part sub-surfaces.

The experimental process steps for both the hand layup and press forming are as follows:

(1) The material was prepared to size following the simulation prediction
(2) The resin and hardener was applied in the right proportion required for the process. Note the effect of this was not considered in this process.
(3) The fabric shear direction was position at 0/90 and 0/45° following the observation from Drape simulation in Figure 1.
(4) For the real life layup processes, the fabric was restrained on the mould at 0/90 and 0/45°. The position variation was limited during press forming due to the fixture of the press tool, but unlimited for the hand layup processes.
(5) The mould closure for press forming was also in 0/90 and 0/45° direction in relation to the shear direction specified for the fabric.
(6) To further support the process findings, the fabric was also shear to the maximum lock angle of 27° during the layup to observe the effect on the boundary condition during the process.

The experimental real life layups was then demould and compared with the simulation result to observe the need for the boundary condition incorporation into the tool.

RESULTS AND DISCUSSION

The tool predicts accurately and provides effective solution to the problem of fabric weaves directional changes, giving proper and better part formation in the simulation process. The weave directions were changed in many different ways in drape and different results were generated. This process prediction was applied to the fabric in real life layup. It was observed that it is less difficult to follow the simulation using the hand layup process but more complicated during press-forming operations according to the finding of Lin et al. (2007). In addition, it is of crucial important to understand that fabric responds differently to boundary condition on the mould, this is due to changes in the tow architecture during deformation. This depend on the in-plane tension and stiffness in the fabric, this is supported by the findings of (Lim et al., 1999; Boisse et al., 2001; Yu et al., 2005/2006; Hancock et al., 2005) related research into composite forming simulation process.

In addition for this process, the part surface under consideration was section into three planes: XY-plane, XZ-plane,YZ-plane and vice versa for Y and Z plane as shown in Figure 2. These sub-surface planes are regions where the mating boundary conditions on part surface have effects, due to consideration of the complexity of the

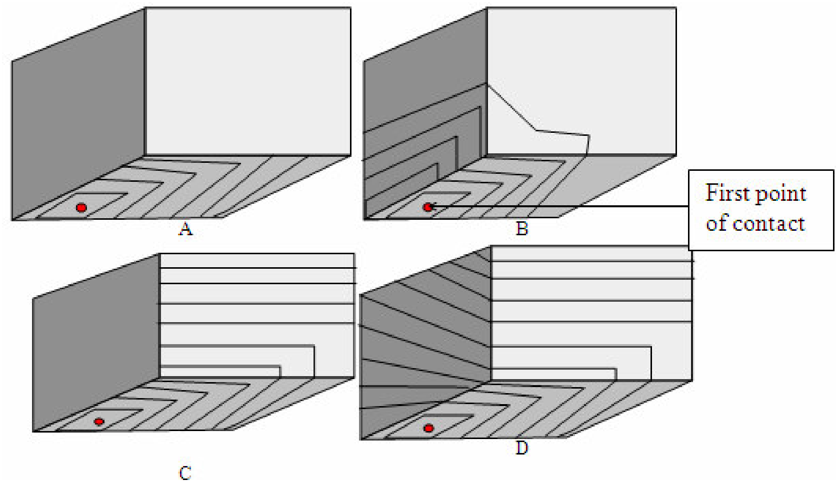

Figure 3a-d. Drape process.

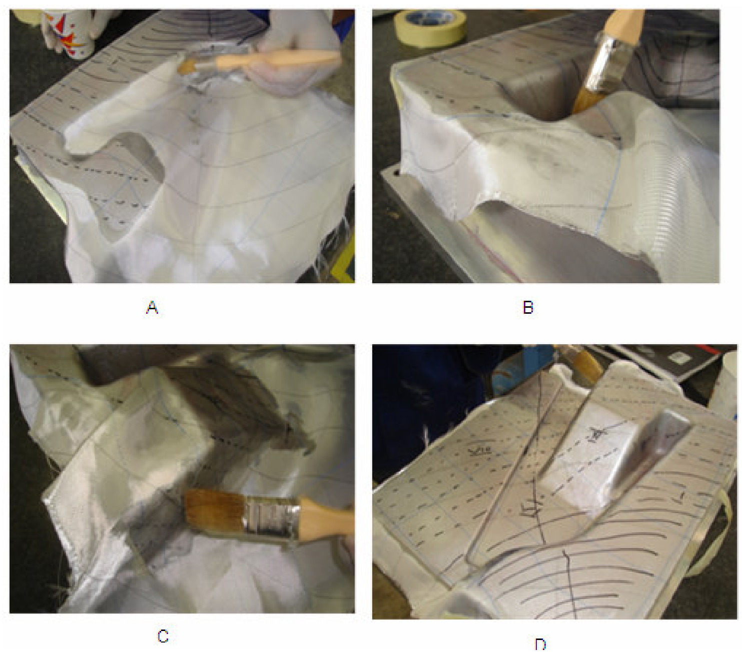

Figure 4a-d. Process of hand layup.

real life layup boundary condition on the surface prediction, simulation approach are only use in approximating the fabric composite behaviour according to Robertson et al. (1981), Long et al. (1994) and Van West et al. (1997). In the Drape simulation process, the assumption such as fabric inextensibility which neglect bending and shear stiffness (Lin et al., 2007), made at the boundary regions are in contrary to the real life process.

The observation shows drape program covering the entire part surface starting from the first point of contact and working outward in a rectangular motion as shown in Figures 3a to d. During the process, drape will simultaneously put squares on all sub-surface 1, 2 and 3. This is due to the different assumptions incorporated for boundary conditions in the simulation program process. But in the hand lay-up and press-form processes, the operator will not work simultaneously on all surfaces at once as shown in Figures 4a-d, but will first cover sub-surface 1, then sub-surface 2, and finally sub-surface 3; until the layup is completed.

For the press forming process, the mould was closed as shown in Figure 5, this closure makes it difficult to observe the movement of the fabric at the mating

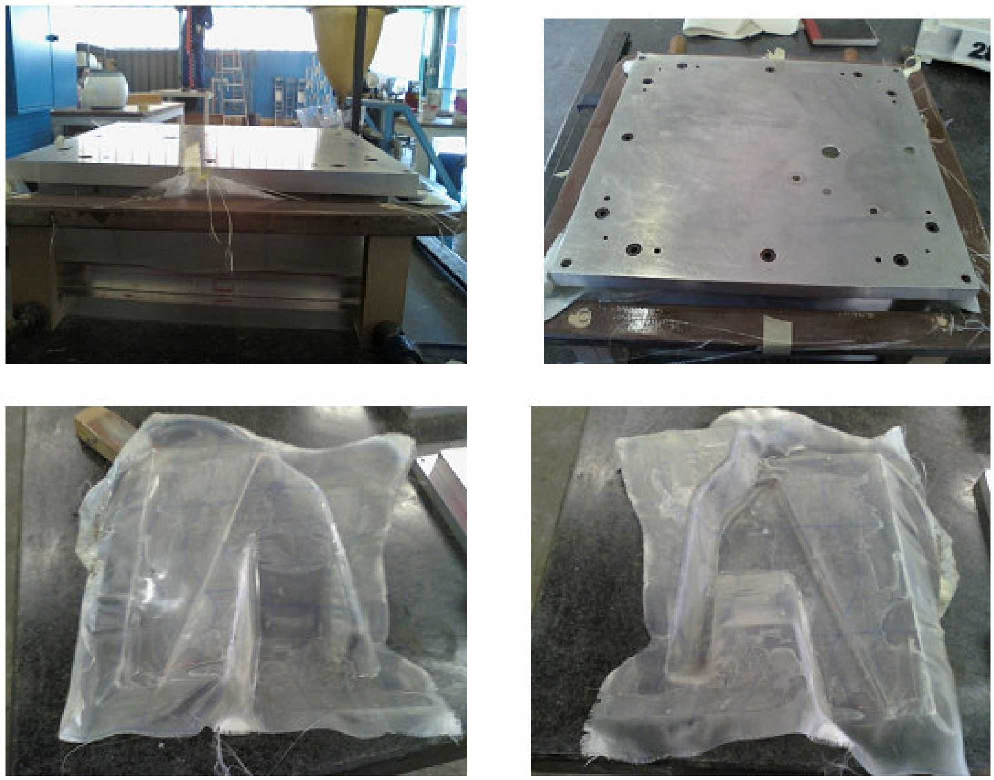

Figure 5. Press forming process.

boundaries. This difference in the operator hand layup and press-forming processes, results in differences between the Drape simulation boundary condition feasibility and applications in real life production process.

In addition, different sub-surfaces can be selected in drape and these are covered step-by- step during the process. By combining the photographs of these individually draped sub-surfaces at the end of the simulation process, in order to get a digital representation of the entire surface, is somehow not really feasible during the layup process due to the processing condition of the fabric.

Also, the pictorial representation in Figures 6a-c shows that for the mating boundaries, the sub-surfaces gets to a point where three sub-surfaces require multiple starting points. These conditions cannot be assumed in real life layups and in this work, the fabric was manually pulled to compensate for this condition before it completely cured, to conform to the shape of the contour sensitive part at these regions. This manual pulling has effect on the fabric during process and therefore, ways to improve these conditions require developing for material software application.

This observation still needs further development for simulation application to be effective in the area of hand layups and press forming automation process where the mating boundaries are sometimes impossible to reach during the forming process. The wrinkles and folding formations in the contour sensitive part production are due to these mating boundaries. These effects can be adjusted using thermoset composite material. However, it is a complicated issue during the compact thermoplastic forming process, where the fabrics are difficult to reach or adjust.

Conclusion

The Drape simulation process gave good fabric weave and direction orientation, however, its assessment in evaluating meeting contour sensitive part boundary conditions, has shortcoming in analyzing the problems encountered in real life production processes. This is due to the assumption made during the development of the tool, which cannot be overlooked in the real life production processes. For feasible application, the development of this area in real life and automation forming process, still needs to be well investigated for composite materials. This will aid the fast production process development of material using Drape simulation tool.

In addition, manual pulling of fabric before it cures completely is applicable to material with small size. However, with larger size material, the development of

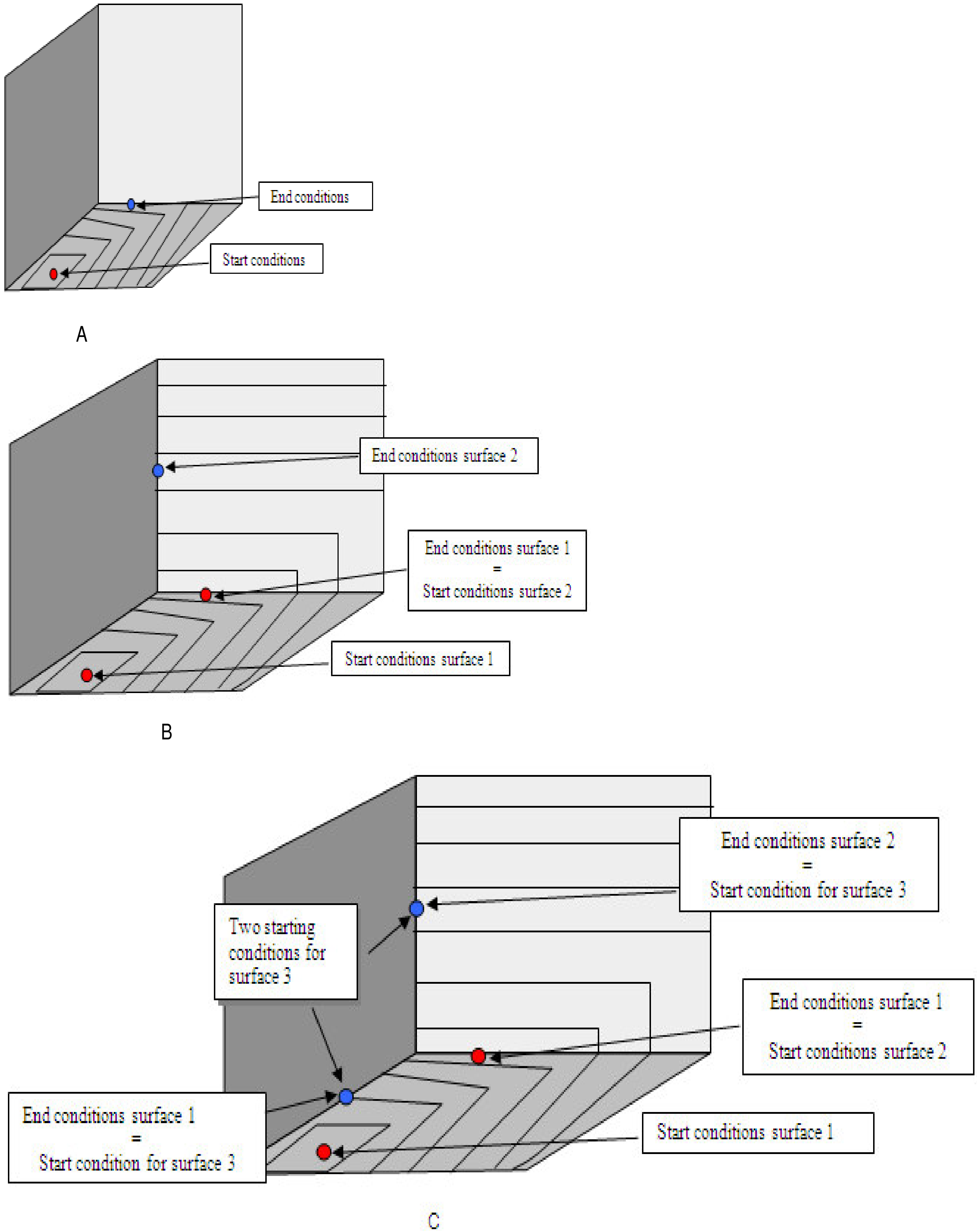

Figure 6a-c. The mating boundary conditions.

simulation application is inevitable in order to protect the structure and reduce the material stress and strain deformation in its application.

ACKNOWLEDGEMENT

The authors acknowledge the Department of Mechanical Engineering, Tshwane University of Technology and Aerosud Innovation and Training, South Africa.

REFERENCES

Boisse P, Gasser A, Hivet G (2001). Analyses of fabric tensile behaviour: determination of the biaxial tension–strain surfaces and their use in forming simulations. Composites A, 32: 1395-414.

Cerda E, Mahadevana L, Pasini JM (2004). The elements of draping Division of Engineering and Applied Sciences, Harvard University, 29, Oxford Street, Cambridge, MA 02138. www.pnas.org.

Chen B, Govindaraj M (1996). “A Parametric Study of Fabric Drape”, Textile Res. J., 66(1): 17-24.

Collier B (1991). “Measurement of Fabric Drape and Its Relation to Fabric Mechanical Properties and Subjective Evaluation”, Clothing and Textiles Res. J., 10(1): 46-52

Hancock SG, Potter KD (2005). Inverse drape modeling – An investigation of the set of shapes that can be formed from continuous aligned woven fibre reinforcements. Composites A, 36: 947-53.

Hu J, Chan Y (1998). “Effect of Fabric Mechanical Properties on Drape”. Textile Res., J., 68(1): 57-64

Lim TC, Ramakrishna S, Shang HM (1999). Axisymmetrical sheet forming of knitted fabric composite by combined stretch forming and deep drawing. Composites B, 30: 495-502.

Lin H, Wang H, Long A, Clifford MJ, Harrison P (2007). Predictive model for optimization of textile composite forming, J. compos. Sc. Tech., 67: 3242-3252. www.elsevier.com/locate/compscitech.

Long AC, Rudd CD (1994). A simulation of reinforcement deformation during the production of performs for liquid moulding processes. J. Eng. Manuf. Proc. IMechE B, 208: 269-278.

Robertson RE, Hsiue ES, Sickafus EN, Yeh GSY (1981). Fibre rearrangements during the moulding of continuous fibre composites, I. Flat cloth to hemisphere. Poly Compos, 2(3):126-131.

Simona J, Jelka G (2004). Modelling the Fused Panel for a Numerical Simulation of Drape Faculty of Mechanical Engineering Department of Textiles Institute of Textile and Garment Manufacture Processes Smetanova 17, SI-2000 Maribor, Slovenia, J. Fibres Text. Eur., 15(1): 45.

Skordos AA, Sutcliffe MPF, Klintworth JW, Adolfsson P (2006). Multi-Objective optimisation of woven composite draping using genetic algorithms.

Van West BP, Luby SC (1997). Fabric Draping Simulation in composites manufacturing part i and ii. J Adv. Mater. 29-41443000 Leuven. Int. J. mater., www.mtm.kuleuven.be/.

Vanclooster K, Lomov SV, Verpoest I (2008). Simulation and validating the draping of woven fibber reinforced polymers K.U. Leuven Department of metallurgy and materials Engineering-Kasteelpark Arenberg 443000 Leuven. Int. J. Mater., www.mtm.kuleuven.be

Yang M, Matsudaira M (1998). “Measurement of Drape Coefficients of Fabrics and Description of Those Hanging Shapes, Part 3: The Effect of Fabric Parameters on Drape Shapes”, J. Text. Machinery Soc. Japan, 51(9): 182-191.

Yu WR, Harrison P, Long AC (2005). Finite element forming simulation for non-crimp fabrics using a non-orthogonal constitutive equation. Composites A, 36: 1079-1093.

Yu XB, Cartwright B, McGuckin D, Ye L, Mai YW (2006). Intra-ply shear locking in finite element analyses of woven fabric forming processes. Composites A, 37: 790-803.