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Forming characteristics and surface damages of stitched multi-layered para-aramid fabrics with various stitching parameters for soft body armour design

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Abstract
In this study, effects of different stitching parameters on formability behaviour of multi-layerd para-armide panels were investigated. Different stitching pattern namely, Uni-axial longitudinal,Bi-axial straight, Uni-axial-diagonal, Bi-axial-diagonal, Edge stitch and Unstitched were used for binding different layers. Stitch length and gap parameters were also considered while formability using different values. Diamond quilted stitched with less stitch gap and short stitch length shows severe surface wrinkling and stitch thread breakage, whereas unstitched layers show a better deformability without wrinkling and stitch thread breakage. Similarly, diamond quilted stitched shows a very less drawing-in values both in warp and weft directions. As stitch density increases, the drawing-in measurement value reduced due the formation of more rigid layer to resist the deformation. Unstitch and diamond quilted preform possess the highest and least deformation recovery percentage respectivly. Moreover, deformation recovery percentage of the layers become very less as the stich gap and stitch length reduced.

Keywords: 2D para-aramid fabrics; Forming behaviour of dry multi-layered fabrics; Stitching process; Soft body armour.

1. Introduction

For last few decades, three-dimensional (3D) materials have been used to substitute two-dimensional (2D) materials due to their better inter-ply stability. However, still a significant number of industries have used the most common 2D plain weave preform for many technical applications. Plain weave is one of commonly used two dimensional weave pattern for soft body armour design which consists of warp yarn (0° or x-direction yarns) that interlaces over the weft yarn (90° or y-direction yarns) [1] by applying different binding systems i.e. stitching. Stitching is not only improving the inter-layer strength but also provides mechanical connection of the multi-layer so as to avoid the preform shifting [2]. In contary, the stitching process in soft body armours might have also drawbacks due to its time consuming and costly step in manufacturing and also reduce armour flexibility to users resulting in comfort issues. Beside using 2D fabrics in flat form, various technical application also needs the 2D fabrics which can be mould into 3D shapes. For example, in design and manufacturing of female soft body armour components, the material should have not only greater properties in terms of dynamic absorptions, strength-to-weight ratio and modulus but also formability of the material is one of the most important characteristic of textile mechanical performance to fit the three-dimensional body shape [3]. Formability, also known as “drapability” or “mouldability”, is the ability of a planar textile structure to be directly deformed to fit a three-dimensional surface without the formation of wrinkles, kinks or tears [4]. It is also referred to shear deformations at macro scale when shearing angle between warp and weft yarns are changed at crossover points [5]. Mostly three-dimensional (3D) material shapes can possibly produced by eliminating the cutting of 2D planar textile fabrics to fit its dimensional shapes in the manufacturing process using proper material formability. This process is not only increases the productivity of the material fabrication, but also enhances the mechanical properties