FINITE ELEMENT ANALYSIS OF DOUBLE-LAP COMPOSITE T-JOINTS

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Abstract: *Pro/ENGINEER 3D CAD modeling system has been used in the optimization process and design of firefighter water tanks and joints. Following variables has been taken into consideration: the length between composite T-joint baffles and composite T-joint width-to-thickness ratio. In the built up of finite element analysis file, composite T-joint clamping distance, pulling force constraint, clamping constraints, bonded interface between sidewall and connection laminate as well as the mesh definition are presented. More stages in the optimization process are required. More efficient composite T-joints clamping methods have to be designed restraining only the displacement of the double-lap connection laminate on the z-axis.*
Keywords: *composite T-joint, baffle, finite element analysis, double-lap joint, width-to-thickness ratio*

1. INTRODUCTION

In the last decades, there has been a revolution using computer-aided design (CAD) in the development of new products, in first place for 3D design, using 3D CAD info as input for computer-aided manufacturing (CAM). Today's design software programs (Pro-Engineer, Catia, Unigraphics, etc.) goes a lot further than the initial CAD/CAM. Today's software makes it possible to simulate and virtually fine-tune products so their behavior in real environment can be accurately predicted. Using those new tools, helps us to avoid 'over dimensioned' products, having a positive influence on environment, lead-time, and general quality. This paper aims to optimize layered double-lap composite T-joints (CTJs) used to stiffen the firefighter water tank walls and to restrain the water flow inside these tanks. Modelling and simulation of failure mechanisms and damage behavior of CTJs subjected to various loadings using the finite element analysis are presented in references [1-9]. Design approaches and optimization methods have been used to improve the structural properties of these joints [10-13]. Strength and stiffness of all composite T-joint (CTJ) components (sidewall, baffle and connection laminate) have been determined in three-point bending tests [14]. Forces and pressures that act inside a full, filled firefighter water tank during driving have been measured, providing a first view of the tank behavior. Especially, the composite T-joint (CTJ) baffles used to increase the stiffness of the tank walls and to restrain the flow of water are for great importance. The baffles' design concept is similar to bulkheads in ships to reduce deformation of flat sidewalls, bottom, front and endplates. A homogenization method and some averaging methods to predict the elastic properties of multiphase pre-impregnated composite materials like Sheet Molding Compounds (SMCs) have been presented in reference [15]. The upper and lower limits of the homogenized coefficients for a 27% fibers volume fraction SMC have been computed. An interesting paper presents hysteresis behaviors of three-phase randomly oriented glass fiber-ceramic particles-reinforced polyester resin composite material subjected to static cyclic tension-compression loadings. Various cyclic tests with different test speeds, load limits and number of cycles have been accomplished on a Lloyd Instruments LS100Plus materials testing machine with STGA/50/50 E85454 extensometer [16]. The most important results regarding mechanical properties of three-phase chopped strand mat-Al_2O_3 particles-SYNOLITE 8388 P2 polyester resin laminates subjected to short time static cyclic tension-compression loadings are presented in reference [17]. Distributions of 10 cycles' tension-compression loadings at various test speeds and cycle limits have been determined on a Lloyd Instruments LS100 Plus materials testing machine. Simulations regarding the elastic properties of glass, carbon and Kevlar49 fiber-reinforced composite laminates based on epoxy resin and subjected to off-axis loading system have been presented in paper [18]. Behavior simulations of various polymer matrix composite laminates subjected to three and four-point bending using the finite element method have been carried out. The models have been designed and analyzed with MSC Patran and MSC Nastran and three types of composite laminates have been subjected to four-point bend tests using the resistive stress analysis [19, 20]. Basic mechanical properties have been experimentally determined on twelve layers glass fabric-reinforced polyester resin specimens subjected to tensile loads on weft direction until break [21]. A research paper presents the most important mechanical properties determined in a simple tensile test on a 0.4 mm thickness 2/2 carbon twill weave fabric impregnated with epoxy resin, used as skins for an advanced ultralight sandwich composite structure with expanded polystyrene as core [22]. Mechanical properties of glass fiber-reinforced HDPE and LDPE as well as carbon fiber-reinforced epoxy resin have been determined experimentally using three-point bend tests [23]. Stratimat 300 glass fibers with 300 g/m^2 specific weight has been used to reinforce Heliopol 9431ATYX_LSE resin in hand lay-up process [24]. Numerical simulations have been carried out on Torray T700 carbon fibers-reinforced composite laminate based on Huntsman XB3585 epoxy resin and subjected to off-axis loading systems to determine its most important elastic properties and compared to experimental data [25]. An experimental analysis of an advanced composite U-beam pultruded profile based on isophtalic polyester resin reinforced with unidirectional glass fibers and overlay veil has been carried out to determine its most important mechanical properties [26]. To increase the overall stiffness of a composite laminate is usual to use a polyester mat embedded as core in thin structures. This procedure can increase the structure`s stiffness without increasing the thickness of a laminate [27].

2. FINITE ELEMENT ANALYSIS TOOLBOX

Pro/ENGINEER 3D CAD modeling system has been used in the optimization process and design of firefighter water tanks and joints. Following variables has been taken into consideration: the length between CTJ baffles (Fig. 1) and CTJ width-to thickness ratio (Figs. 2 and 3). In the built up FEA file, CTJ clamping distance, pulling force constraint, clamping constraints, bonded interface between sidewall and connection laminate as well as the mesh definition are presented in Figs. 4-8.

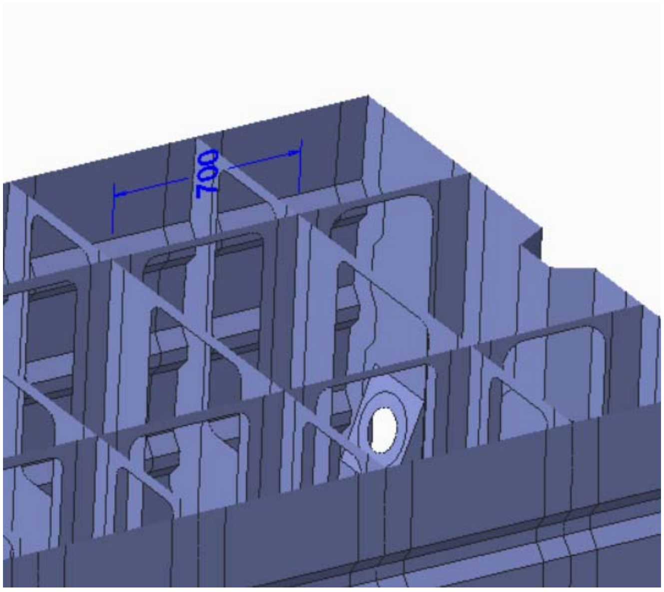

Figure 1: Length between CTJ baffles

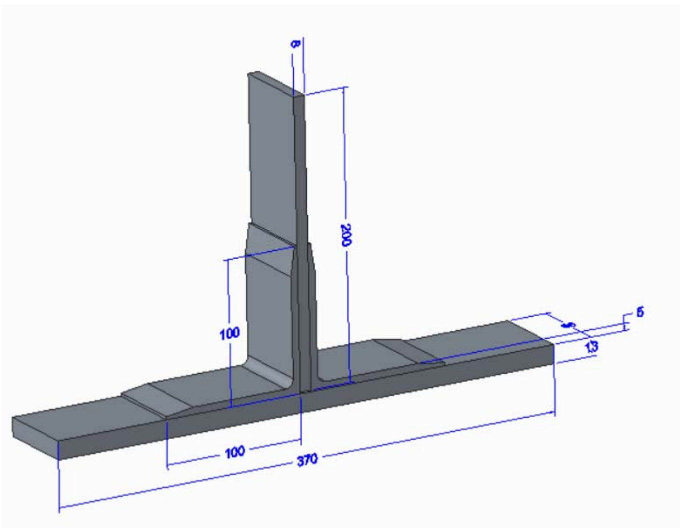

Figure 2: CTJ with 3.33 width-to-thickness ratio

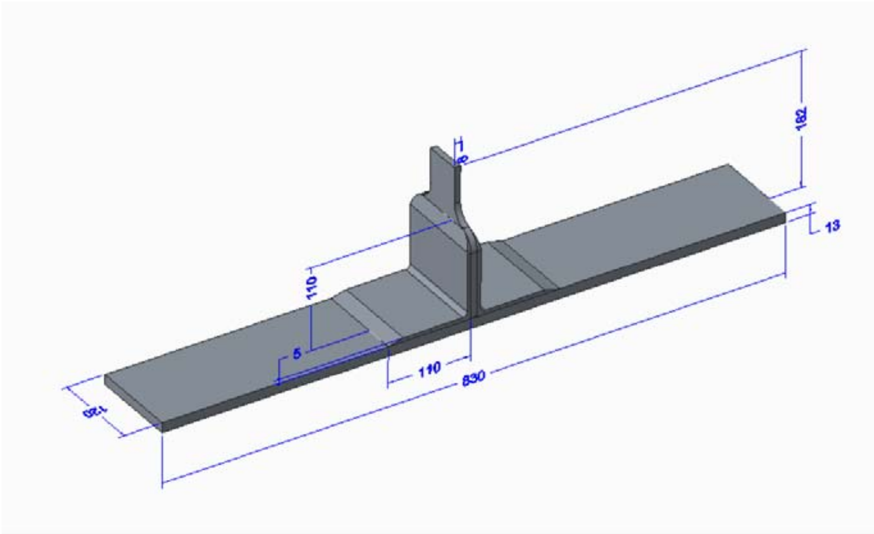

Figure 3: CTJ with 6.66 width-to-thickness ratio

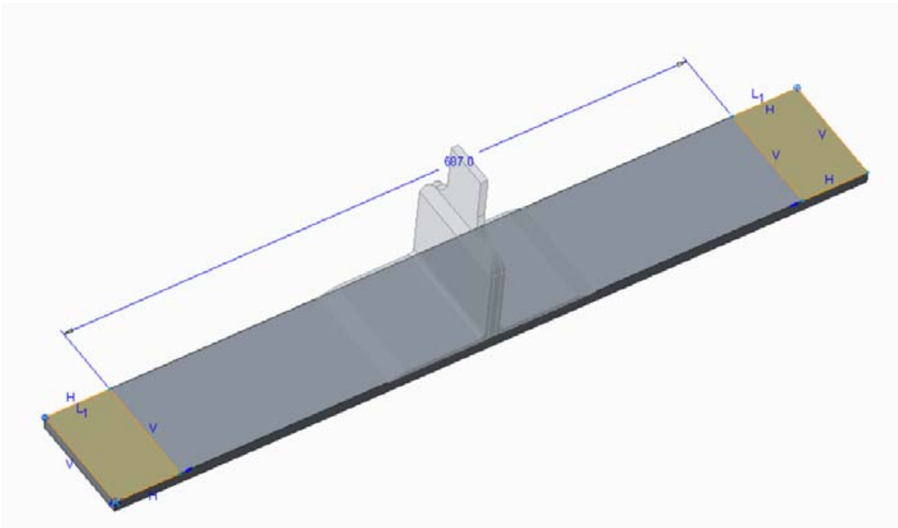

Figure 4: CTJ clamping distance

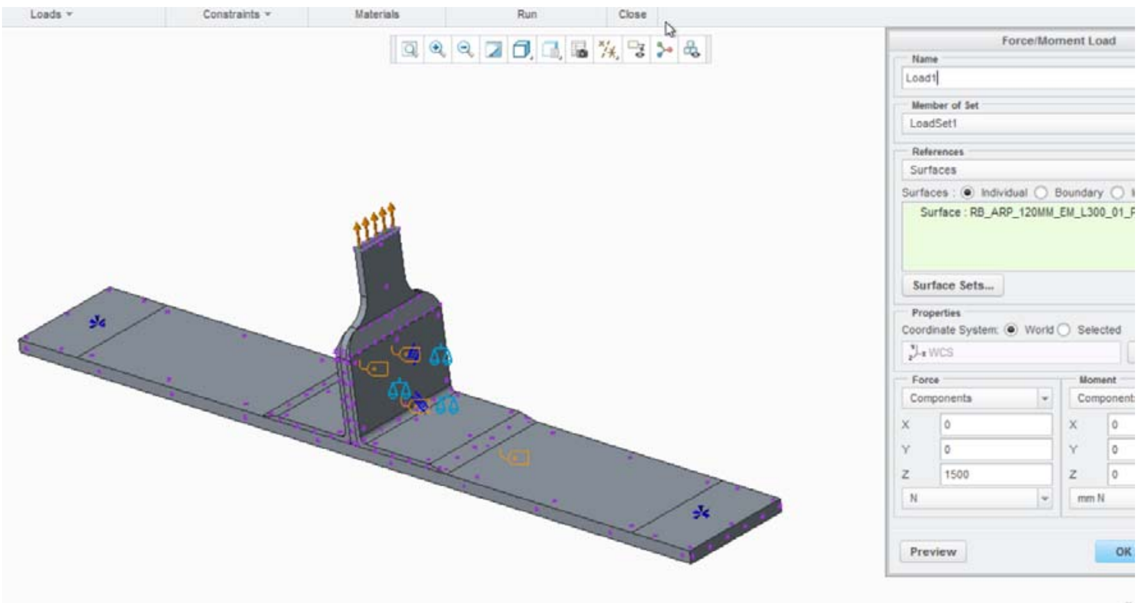

Figure 5: CTJ pulling force constraint

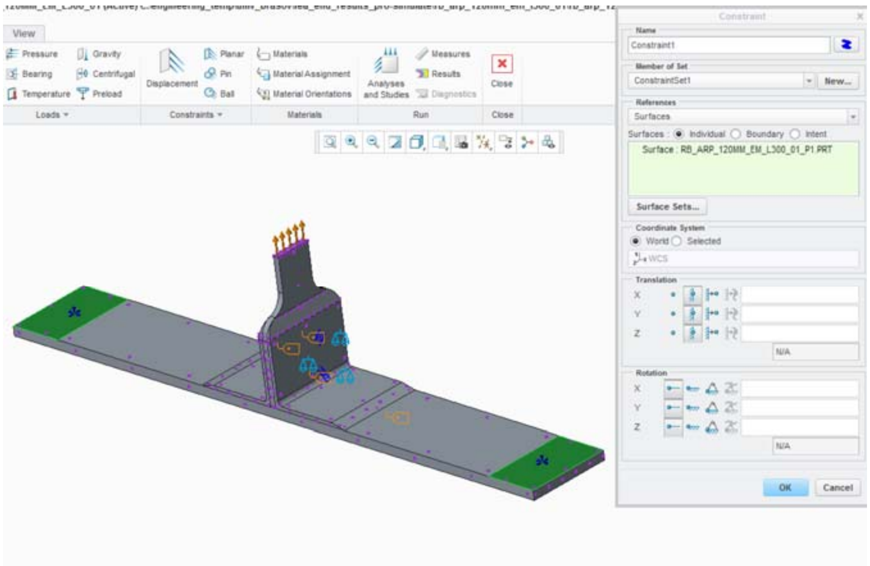

Figure 6: Fixed xyz clamping constraints

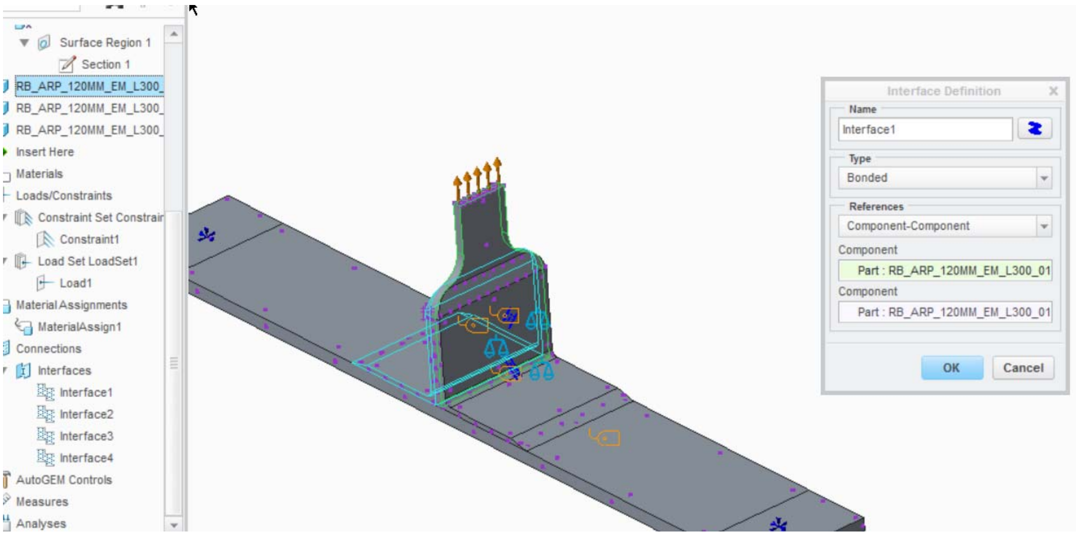

Figure 7: Bonded interface for connection laminate

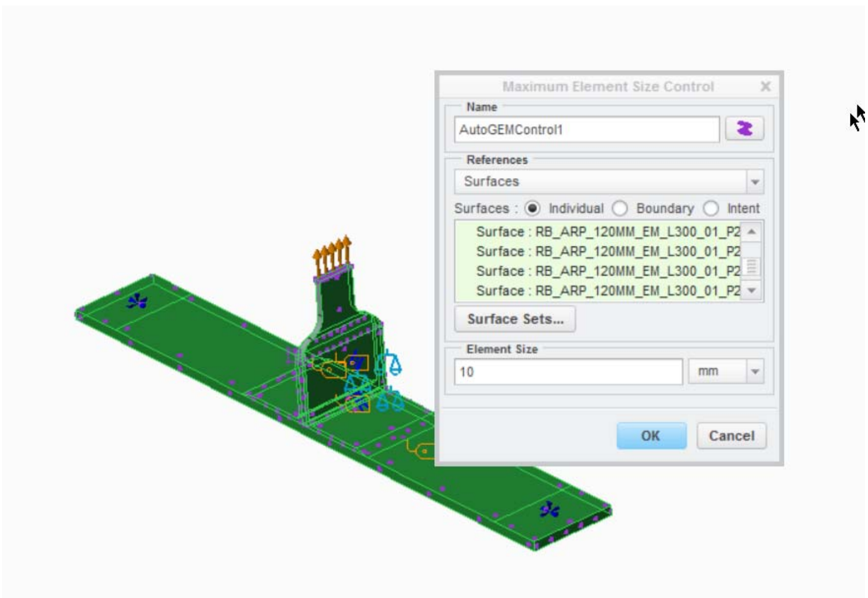

Figure 8: Mesh definition: 10 mm 3D mesh tri/quadri

3. RESULTS

Finite element analysis has been carried out on two CTJ samples with 3.33 and 6.66 width-to-thickness ratios to validate the experimental set-up. The results are presented in Figs. 9 and 10.

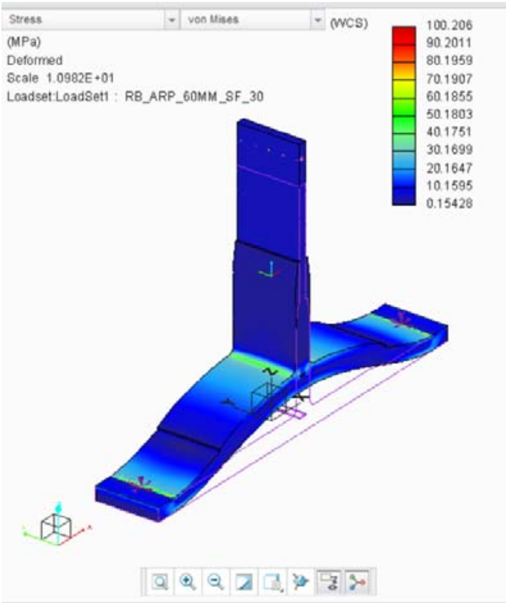

Figure 9: Stress at failure on CTJ sample with 3.33 width-to-thickness ratio and 300 mm clamping length

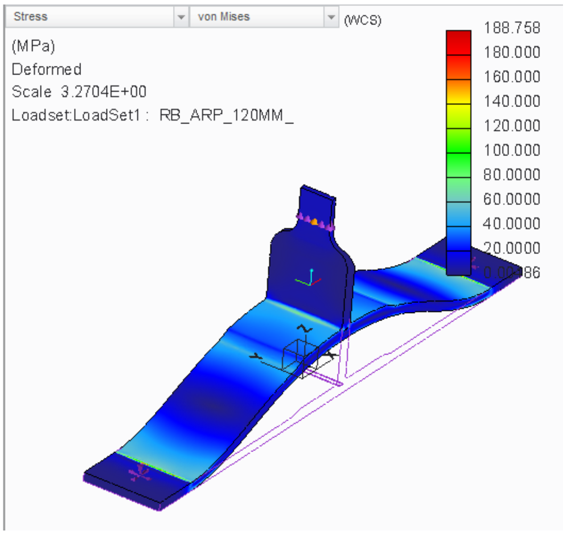

Figure 10: Stress at failure on CTJ sample with 6.66 width-to-thickness ratio and 700 mm clamping length

4. CONCLUSION

More stages to refine our final computing system are required in the optimization process of firefighter water tanks. To attain this end more tests have to be done especially using more efficient methods to clamp the CTJs, restraining their displacement only on their thickness direction.

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