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DETERMINATION OF THERMAL SHEAR STRESSES ON TERMOPLASTIC COMPOSITE ADHERENTS JOINED HYBRID TYPE

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Abstract

This paper aims to determine of thermal shear stresses on thermoplastic adherents which are joined by hybrid type. It is designed both adhesive and two parallel pins. Both plotting and solving of this problem were done using ANSYS software. Therefore solutions were performed with finite element methods (FEM). Modeling of hybrid joint was established as three dimensional. Thermal stresses were caused to apply uniform thermal loads on designed structure. Determined results pointed out that thermal shear stresses were strictly affected of increasing uniform thermal loads. Briefly, their values were increased by increasing of thermal loadings.
Keywords: FEM, ANSYS, Shear stress, Thermal Stress, Hybrid joint

HİBRİD TİP BAĞLANTI UYGULANMIŞ TERMOPLASTİK KOMPOZİT PLAKALARDAKİ ISIL KAYMA GERİLMELERİNİN BELİRLENMESİ

Özet

Bu çalışmanın amacı hibrid tip bağlantı uygulanmış termoplastik kompozit plakalardaki ısıl kayma gerilmelerinin belirlenmesidir. Hibrid bağlantı yapıştırıcı ve iki paralel pim uygulaması şeklinde tasarlanmıştır. Problemin çizimi ve çözümü ANSYS yazılımı kullanılarak gerçekleştirilmiştir. Bu yüzden çözümlerde sonlu elemanlar metodu kullanılmıştır. Hibrid bağlantının modellenmesi üç boyutlu olarak yapılmıştır. Tasarlanan yapıdaki ısıl gerilmeler uygulanan uniform sıcaklık yükleri nedeniyle meydana gelmiştir. Elde edilen sonuçlar, ısıl gerilmelerin uniform sıcaklık artışına çok önemli oranda bağlı olduğunu göstermiştir. Kısaca, ısıl kayma gerilmeleri, sıcaklık yükündeki artışa bağlı olarak artmıştır.
Anahtar Kelimeler: FEM, ANSYS, Kayma gerilmesi, Isıl gerilme, Hibrid bağlantı

1 Introduction

Historically and even today in most of the world, mankind has relied on anisotropic and composite materials for the majority of its structural engineering [1]. A foremost advantage of using various form of reinforcing fibers in designing structural parts is that this composite system can be tailored to specific needs [2]. Fiberglass is a familiar example, in which glass fibers are embedded within a polymeric material [3]. Additionally, reinforced thermoplastics have become very commonly used owing to the fact that they are easy to use and mould as well as have certain mechanical characteristics and size stability [4].

A transient thermal analysis of an adhesively bonded and laser-spot welded joint was performed based on a thermal model developed for the laser-spot welding of multi-layered sheets using a pulsed Nd:YAG laser by Apalak et al [5]. Sen [6] estimated the elasto-plastic thermal and residual stresses in a thermoplastic composite disc which was reinforced as rectilinear under uniform temperature effect. Rastogi et al. [7] studied on thermal stresses in aluminum-to-composite, symmetric, double-lap joints using FEM. The joint configuration considered aluminum adherent in combination with four different unidirectional laminated composite adherents subjected to uniform temperature loading.

That's why mechanically fastened joints are commonly used in composite structures [8]. They present a number of characteristics that make them well suited for joining composite laminates. For example, mechanically fastened joints are relatively low-cost to produce and can be disassembled [9]. Sen and Sayman [10] studied on the effects of the selected geometrical parameters such as the edge distance-to-hole diameter ratio (E/D), plate width-to-hole diameter ratio (W/D) on the failure response of bolted-joint aluminum glass-epoxy sandwich composite plates. Ataş et al. [15] obtained failure load and failure modes of laminated glass-polyester composite plates with two parallel circular holes. A traction force was performed by two rigid pins. The performances of pin loaded composite plates were investigated both experimentally and numerically for different geometries and fiber orientations. Pakdil et al. [14] analyzed effect of preload moments on failure behavior of glass-epoxy laminated composite which was single bolted-joints with bolt/hole clearance.

In this study, thermal shear stresses on a hybrid joint which was designed for thermoplastic composite adherents were analyzed, numerically.

2 Hybrid Joint

Hybrid joint is presented in Fig. 1. As seen from this figure, two thermoplastic composite adherents are joined both a adhesive layer and two parallel pins named as hybrid joint. A uniform temperature (T_o) was performed on whole modeled structure as 35, 45, 55, 65 and 75 °C.

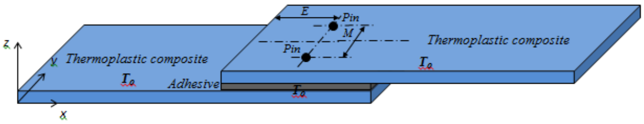


Figure 1. Hybrid joint type with adhesive and two pins.

Owing to symmetry condition, the half model was designed as seen in Fig 2. This model provided to decrease both node and element numbers on modeled structure. Therefore solution time was shortened to compare with whole model.

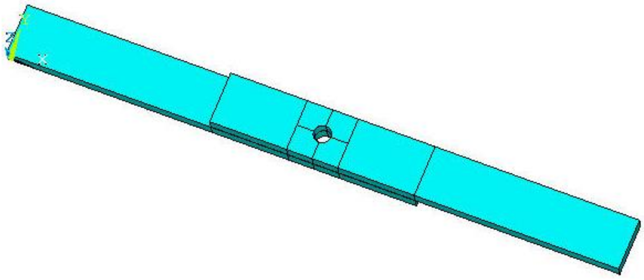


Figure 2. Half solid model of hybrid joint.

The mesh structure of half hybrid joint was plotted in Fig. 3. After the meshing process, node and element numbers were 14250 and 10800, respectively. Detailed drawings of mesh structure were also presented in Fig. 3. It is clearly seen that mapped mesh was made on whole model included through pin hole zone.

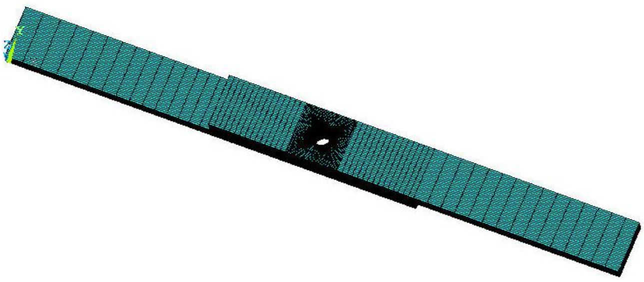
Table 1. Mechanical properties of thermoplastic composite.

E_1 (MPa)	E_2 (MPa)	G_{12} (MPa)	ν_{12}	α_1 (1/°C)	α_2 (1/°C)
41000	1200	420	0.25	12.6 E-6	130 E-6

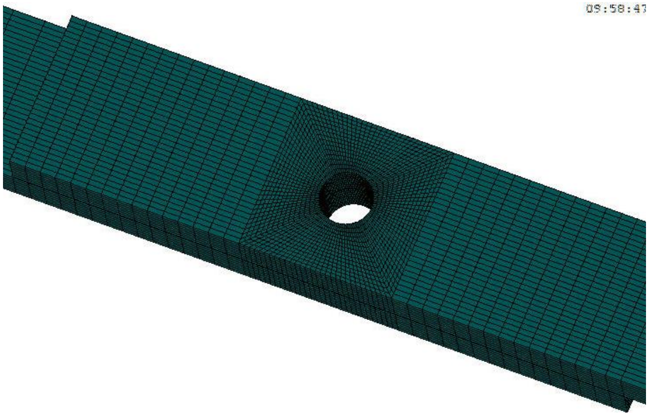
The mechanical properties of thermoplastic composite material are given in Table 1[13]. Additionaly, mechanical properties of adhesive are listed in Table 2 [5]. It is a kind of epoxy resin.

Table 2. Mechanical properties of adhesive.

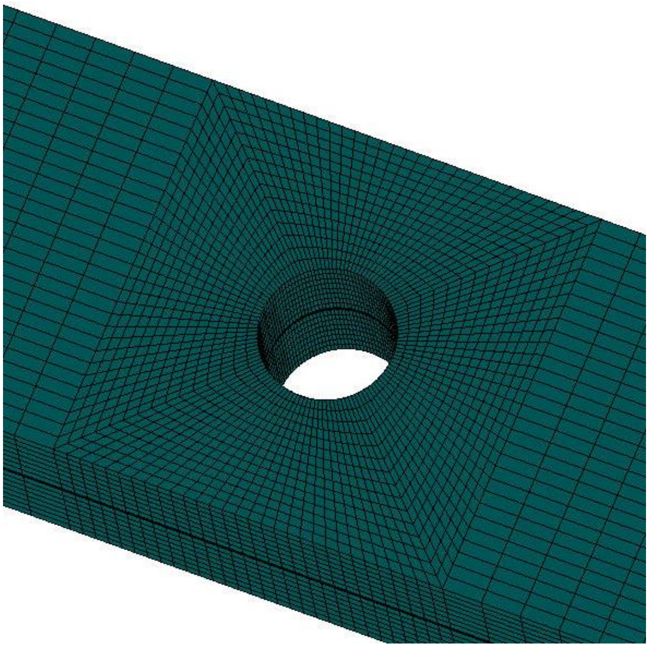
	E (MPa)	ν	α (1/°C)	ρ (kg/m³)
Epoxy	3300	0.30	43.3	1264



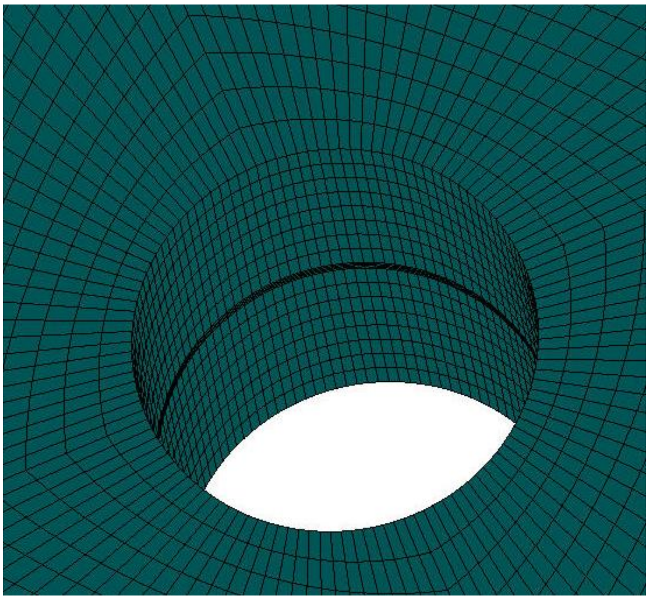
a) Full mesh



b) Detail mesh through adhesive zone



c) Detail mesh through adhesive zone

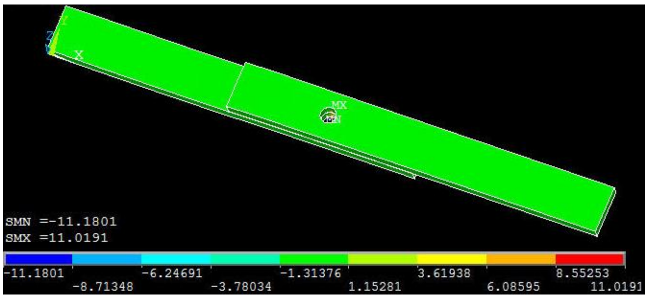


d) Detail mesh through pin zone

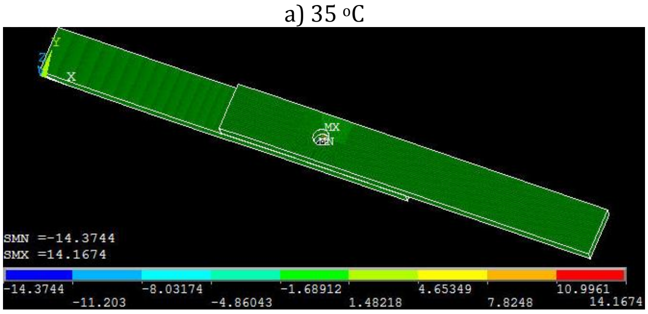
Figure 3. Mesh on half model of hybrid joint.

3 Results and Discussion

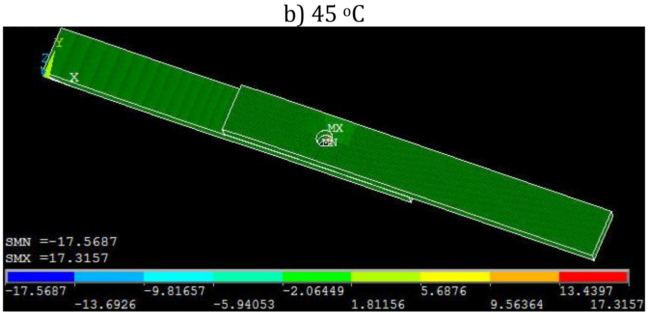
Distributions of τ_{xy}, τ_{yz} and τ_{xz} thermal shear stresses are shown in Fig. 4, 5 and 6, respectively.



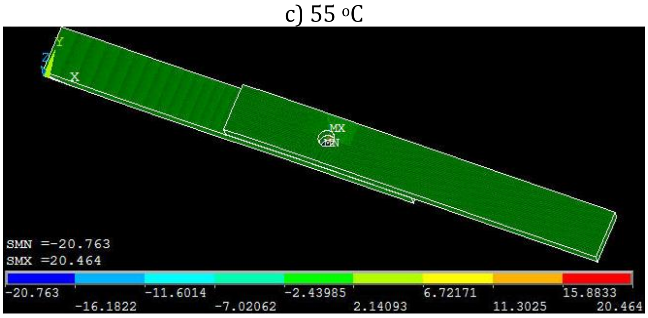
a) 35 °C



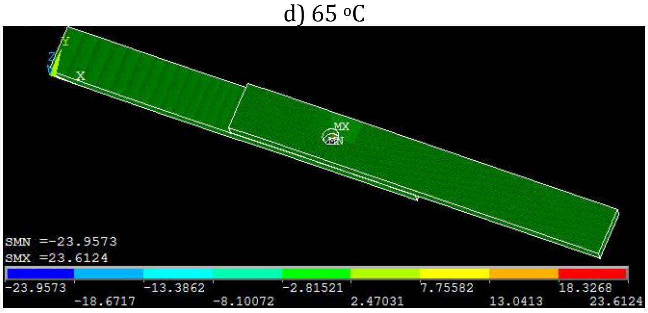
b) 45 °C



c) 55 °C



d) 65 °C

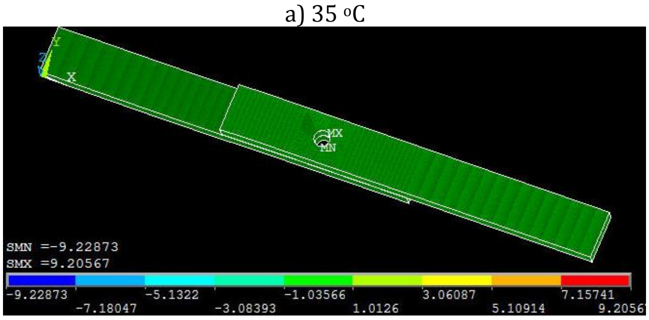


e) 75 °C

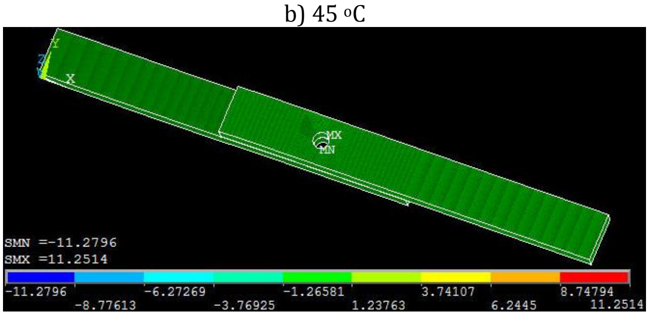
Figure 4. Distributions of τ_{xy} shear stresses.

Firstly, these figures points out that thermal shear stresses are increased by increasing of uniform temperature loadings. In other words magnitudes of thermal shear stresses are affected from changing of thermal loads.

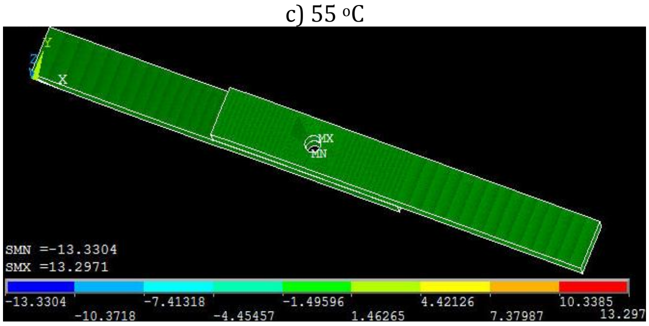
a) 35 °C



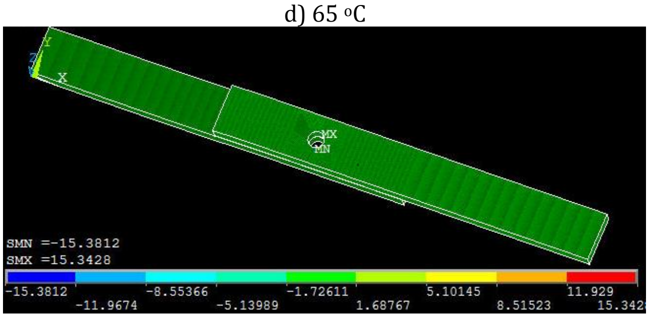
b) 45 °C



c) 55 °C



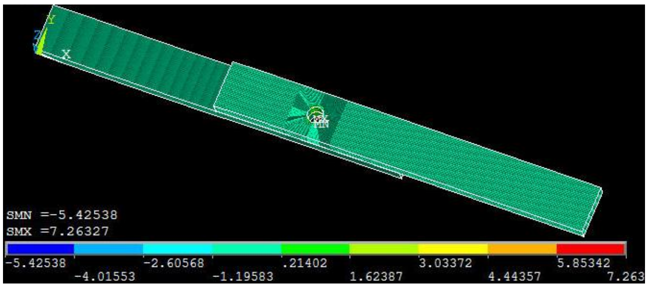
d) 65 °C



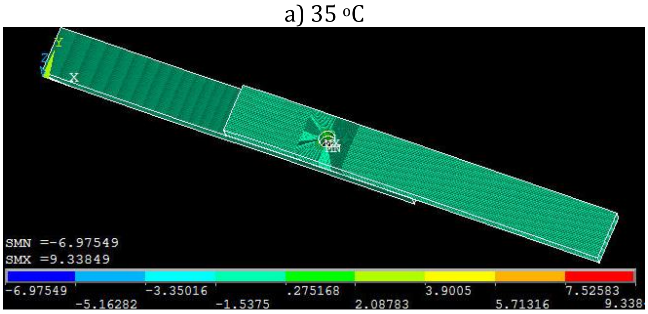
e) 75 °C

Figure 5. Distributions of τ_{yz} shear stresses.

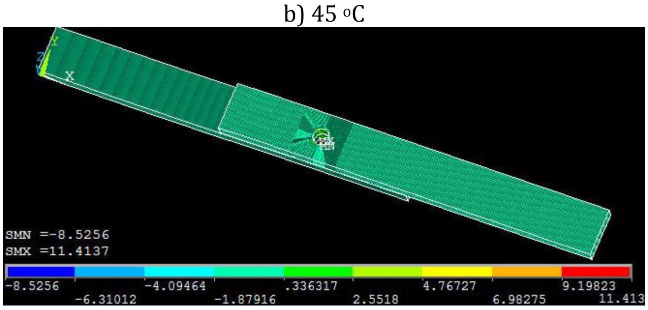
According to Fig. 5 and 6, τ_{yz} and τ_{xz} thermal shear stresses cannot be neglected level. Their values are seen lower from τ_{xy} but they have high values. It is understood that three dimensional modeling and solution of present hybrid joint study are important for this result.



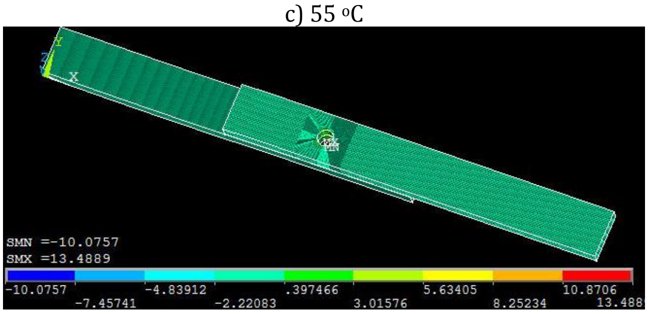
a) 35 °C



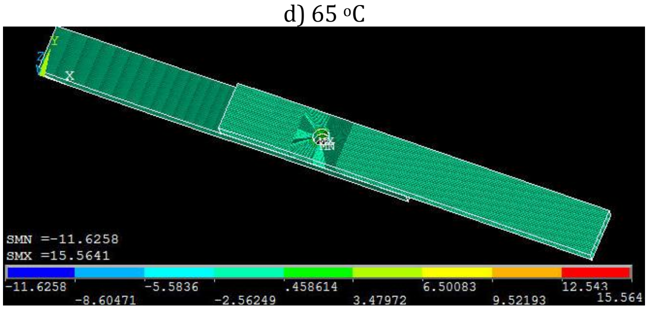
b) 45 °C



c) 55 °C



d) 65 °C



e) 75 °C

Figure 6. Distributions of τ_{xz} shear stresses.

The highest thermal shear stresses are calculated at 75 °C uniform thermal loadings, whereas the lowest values are computed at 35 °C uniform thermal loads.

The magnitudes of thermal shear stresses are not increased linearly related to linear increasing of uniform thermal loads. Since upper and lower adherents of hybrid jointed model are thermoplastic composite. It is an orthotropic material and its mechanical properties are listed in Table 1, previously.

As mentioned above modeling of hybrid joint was done as half part due to symmetry condition. Therefore, one pin hole is seen in figures. It is seen that pin hole cause stress concentrations where is around itself. The maximum stresses were also obtained near the pin hole.

4 Conclusion

According to present numerical analyses results of three dimensional hybrid joint problem for thermoplastic composite plates, some important remarks can be concluded as;

1- Thermal shear stresses increased by increasing uniform thermal loadings.

2- Parallel pin holes cause thermal shear stress concentrations.

3- The uppermost values of thermal shear stresses are obtained around pin holes.

4- Thermal shear stresses are not increased with linear rising of uniform thermal loading because of composite material which has anisotropic properties.

5- Three dimensional present solutions are seen very important, since magnitudes of τ_{yz} and τ_{xz} thermal shear stresses very high. They are not negligible levels.

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