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Numerical modelling of the mechanical behavior of hybrid joint obtained by spot welding and bonding

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A R T I C L E I N F O

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A B S T R A C T

Hybrid joints can be obtained using two or more techniques to attach two materials. This technique was well discussed, in the last two decades, for the use of different welding process. The development of new structural adhesives improved the use of adhesive bonding in the manufacturing sector to join assemblies, specialty aerospace and automotive industries. Compared to the common welding methods, adhesive bonding has many advantages such as simplified process, favorable fatigue properties, and the ability to join dissimilar metals. Weld bonding as a hybrid welding method combines welding and adhesive bonding to join metals. This work presents a numerical model based on the finite element method to assess the mechanical response of spot weld and hybrid joints composed by the combination of spot welding and bonding. The numerical model considers constitutive and geometric nonlinearities and is used to study the stress distribution and failure of the spot welding and weld bonding joints. A cohesive zone model is used to represent the adhesive bonding behavior. Numerical results are developed to assess the joints capability of the supporting loading and the stiffness joints. Experimental data obtained from previous works is used to calibrate the numerical model.

1. Introduction

Fricke et al. [1] reported that to manufacture multi-material hybrid parts for the automotive industry, mechanical joining processes like riveting are well established. However, adhesive bonding is increasingly being used in the car body to realize lightweight structures with high crash performance using a multi-material design. They also concluded that the synergetic combination of the specific advantages of both joining techniques in form of hybrid joints results in joint improvements of manufacturing, crash, and durability performance.

Hybrid joints obtained by a combination of two simple techniques, e.g. by spot welding and adhesive, are relatively modern joints developed especially for application in aerospace industry [2]. This contribution describes the modelling and testing of structural elements by application of an angle bar and spot welding techniques with the introduction of adhesive layers between adherends. Numerical modelling of the mechanical response using the Finite Element Analysis requires a description of 3 different damage processes: (1) plastic degradation of the spot welded points, (2) plastic deterioration of the joined parts around the regions of spot points and (3) degradation of the adhesive layer. According Golewski et al. [3], the variable thickness creates chamfer defined by a geometric parameter which has a very positive influence on the mechanical response of the joint.

The most difficult task in the numerical modelling of the joint deformation process is the description of progressive damage behavior of joined parts and the adhesive. Up to now most papers deal with a modelling of single lap hybrid joints without consideration of the damage processes which develop in many parts of the joint subjected to mechanical loading. And the results revealed premature adhesive layer debonding, while the maximum load was governed by the spot weld [4].

Bartczak el al [5] used a hybrid joint of car body and concluded that

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Table 1
Mechanical properties of IF steel.

Yield strength (MPa)	Ultimate tensile stress (MPa)	Elongation (%)	Hardness (HRB)	Roughness (μm)
182	296	43	37	0.8–0.7

Table 2
Adhesive mechanical properties.

Property	Syntho-Subsea™LV Epoxy
Flexural strength (MPa)	31.4
Tensile strength (MPa)	41
Compressive strength (MPa)	50.9
Flexural Modulus (MPa)	980
Shear strength (MPa)	12.3

this joint has the advantages of both the adhesively bonded and spot-welded joint. The application of such a joint: reduces the stress concentration in the spot-weld, and balances the entire structural effort, increases the strength and the energy absorption, results in an increased structural stiffness, improves the tightness and the corrosion resistance of spot welded joints, and improves the vibration suppression feature.

According to Boutar et al. [6], structural adhesives are more frequently used in manufacturing processes as they provide numerous advantages when compared with the traditional joint systems, such as corrosion resistance, weight reduction, and elimination of stress concentration due to the fastener mounting hole. Other benefits include improved stiffness, rigidity, impact behavior and energy absorption, less vibration, sound deadening, and higher static and fatigue strength [7]. Costa et al. [8], studied the mechanical behavior of spot welding-adhesives joints, found that exist an improvement in the shear strength and stiffness with the use of hybrid joints, despite the degradation of the adhesive and possible contamination of the nugget.

Adhesive joints are increasingly being used due to their improved mechanical performance and a better understanding of the mechanics of failure [9]. To predict the joint strength, one must have the stress distribution and a suitable failure criterion. The stress distribution can be obtained by a Finite Element Analysis (FEA) or a closed-form model. For complex geometries and elaborate material models, a FEA is preferable, e.g. [9,10,7].

Budhea et al. [10] observed that the analysis of adhesively bonded joints can be carried out by analytical methods and finite element methods (FEM). Analytical methods analyses the joints easily, fast and with high accuracy, but certain assumptions are necessary for complex joints and that might limit the accuracy of the results. On the other hand, the FEM has the capability to analyze complex geometries and complex material models, only the computing time is the constraint. In the following subsections, recent developments in analytical methods and FEMs are discussed.

The performance of adhesively bonded joints depends on many parameters such as composite bonding methods, surface preparation, material parameters (adhesive and adherend properties), geometrical parameters (adhesive thickness, overlap length, stacking sequence, ply angle, fillet etc.).

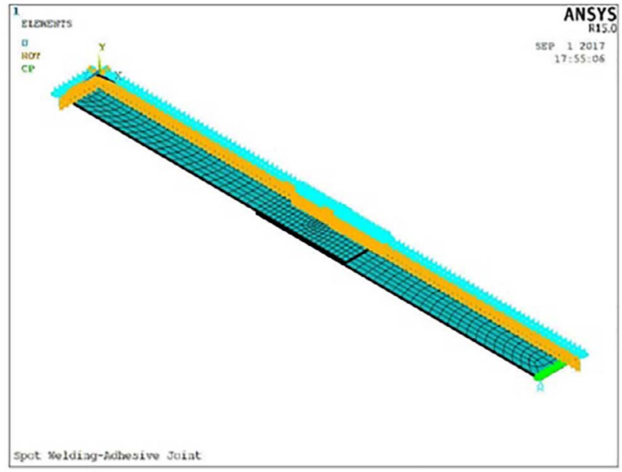


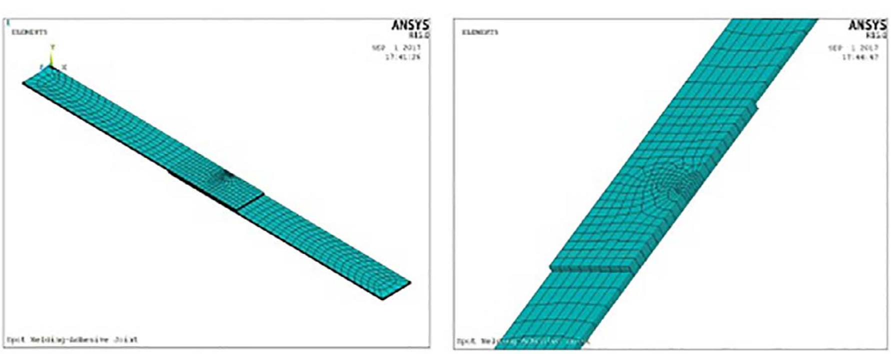
Fig. 2. Finite element model. Boundary conditions and prescribed loading.

Table 3
Model Parameters for the IF steel.

Parameter	Value
Elastic modulus (GPa)	200
Poisson ratio (–)	0.29
Yield stress (MPa)	190
Hardening parameter (GPa)	0.75

Table 4
Model Parameters for the adhesive.

Parameter	Value
Maximum normal contact stress (MPa)	30
Contact gap at the completion of debonding (mm)	4.2×10^{-3}
Maximum equivalent tangential contact stress (MPa)	0.5
Tangential slip at the completion of debonding (mm)	1



(a) (b)

Fig. 1. Finite element model: (a) mesh and (b) detail of the joint region.