

Analysis of Single Lap Adhesive Joints between Magnesium and Other Structural Automotive Materials

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P. K. Mallick and Shardul Bhambure
Univ. of Michigan-Dearborn

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ABSTRACT

This paper will present the results of 3-D finite element analyses of single lap adhesive joints between magnesium and three other automotive materials, namely steel, aluminum and SRIM composites. The modulus of magnesium is lower than that of either steel or aluminum, but is higher than that of SRIM. Thus, this study aims at determining the effect of the difference in substrate modulus on the deformation, stress and strain distributions and maximum stresses in adhesive joints of magnesium with the other three materials. In addition, the effect of adhesive modulus is also explored.

INTRODUCTION

The need for lightweighting to improve fuel economy is leading the automotive industry to consider various alternative materials, such as advanced high strength steels, aluminum alloys, magnesium alloys and fiber reinforced composites, for body and chassis components and structures. Over the last two decades, there have been many focused projects in which each of the individual groups of materials has been used to develop lightweight vehicles or vehicle components. Examples of these projects are ultra light steel auto body (ULSAB), aluminum-intensive vehicles, composite front end and magnesium engine block. While all these projects have produced significant results in lightweighting technology and many of the materials and manufacturing technologies developed in these projects are being adopted in production vehicles, future lightweight vehicles will most likely be constructed using a combination of these materials. One key question in using multiple materials is how these materials will be joined. Currently, with steel as the principal material of construction, resistance spot welding is the most common joining techniques used in the automotive industry

(Figure 1). Since resistance spot welding and other welding techniques are either not suitable or are not fully developed, adhesive joining, either by itself or in combination with mechanical joining, will play a major role in vehicles in which multiple materials with dissimilar physical and mechanical characteristics will be assembled and joined to build the structure [3].

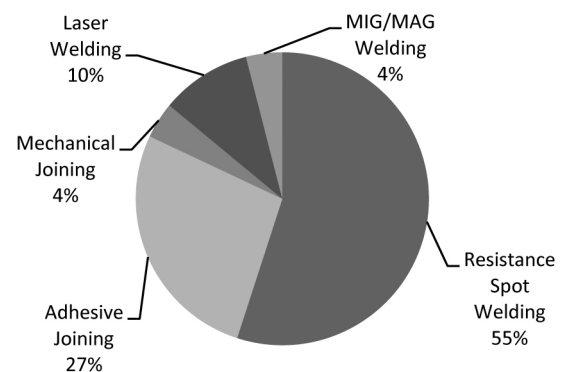


Figure 1. Joining techniques used in the automotive industry [1-2]

The objective of this study was to determine stress distributions and maximum stresses in single lap joints between similar and dissimilar materials considered for automotive applications. The materials selected were steel, aluminum, magnesium and SRIM composite. SRIM is a randomly oriented short E-glass fiber composite dispersed in a polyurethane matrix and has a modulus lower than that of magnesium. A linear elastic three-dimensional stress analysis was performed using a commercial finite element code. With joints between similar materials, the substrate on each side of the joint was the same, i.e., steel, aluminum, magnesium or

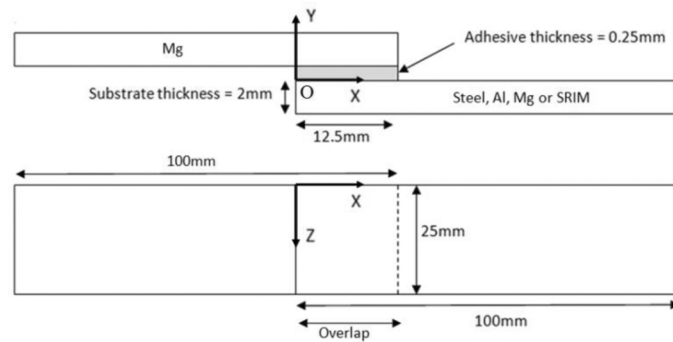


Figure 2. Front and top views of the single lap joint

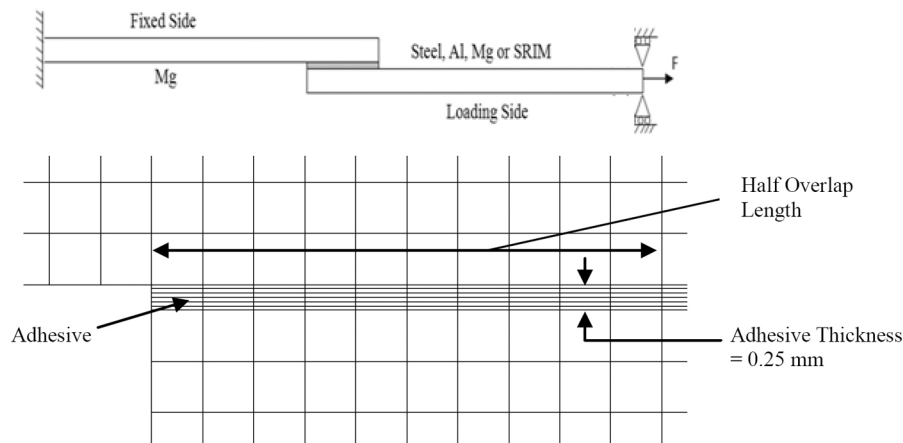


Figure 3. Boundary conditions (top) and mesh pattern around the adhesive (bottom)

SRIM composite. With joints containing dissimilar materials, the substrate material on one side of the joint was magnesium, while the substrate on the other side was varied between steel, aluminum and SRIM. Since these materials have significantly different modulus values, it was possible to determine the effects of substrate modulus on the deformations and maximum stresses in single lap joints. The effect of adhesive modulus on maximum stresses was also considered.

FINITE ELEMENT MODEL

The specimen dimensions used for the single lap joints are shown schematically in [Figure 2](#). The length and width dimensions of the substrate are 100 mm and 25 mm, respectively. Both substrates have a uniform thickness of 2 mm. The length of the overlap is 12.5 mm and the adhesive thickness is assumed to be 0.25 mm.

A three-dimensional linear elastic finite element stress analysis of the lap joint was conducted using Radioss, a commercially available finite element solver. For the analysis, the lap joint was fixed at one end and loaded at the other end with an axial force F as shown in [Figure 3](#). The loading side, which was the bottom substrate, is free to

translate in the X direction. The axial force, F , was assumed to be 100 N in magnitude and it was distributed equally among all nodes at the loading end. The material on the fixed side was magnesium, whereas the material on the loading side was steel, aluminum, magnesium or SRIM composite. The adhesive was assumed to be an epoxy with a linear elastic stress-strain diagram.

The location of the origin and the co-ordinate axis directions are defined in [Figure 2](#). A 3D fine mesh was used around the overlap region and a relatively coarse mesh was used toward the ends of the joint. All the elements used for the adhesive and substrates were eight noded solid elements. The adhesive thickness was divided into six layers of elements; element dimensions in the adhesive were $0.5 \text{ mm} \times 0.5 \text{ mm} \times 0.041 \text{ mm}$ (thickness). The substrate thickness was divided into four layers so that the element thickness in the substrate was 0.5 mm.

MATERIAL PROPERTIES

The material properties used in the analysis are shown in [Table 1](#). The different combinations of materials used for the analysis are listed in [Table 2](#). For combination of dissimilar materials, magnesium was used as the substrate on the fixed