

A Fatigue Life Prediction Method of Laser Assisted Self-Piercing Rivet Joint for Magnesium Alloys

Hong Tae Kang
University of Michigan

Abolhassan Khosrovaneh
GM

Xuming Su
Ford Motor Co.

Yung-Li Lee and Mingchao Guo
FCA US LLC

Chonghua Jiang
AET Integration Inc.

Zhen Li
University of Michigan

ABSTRACT

Due to magnesium alloy's poor weldability, other joining techniques such as laser assisted self-piercing rivet (LSPR) are used for joining magnesium alloys. This research investigates the fatigue performance of LSPR for magnesium alloys including AZ31 and AM60. Tensile-shear and coach peel specimens for AZ31 and AM60 were fabricated and tested for understanding joint fatigue performance. A structural stress - life (S-N) method was used to develop the fatigue parameters from load-life test results. In order to validate this approach, test results from multijoint specimens were compared with the predicted fatigue results of these specimens using the structural stress method. The fatigue results predicted using the structural stress method correlate well with the test results.

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INTRODUCTION

The application of magnesium alloys in vehicle structures is of interest for effecting vehicle weight reduction. One of the challenges of using magnesium alloys in vehicle structures is joining the magnesium alloy either to other magnesium alloys and/or other materials.

The self-piercing rivet (SPR) is a method for joining sheet steels and aluminum alloys. This method is very similar to traditional riveting but without a pre-drilling procedure. The SPR is a mechanical joint that mainly used to join ductile materials. However, magnesium alloys are generally very brittle and cannot be joined using traditional SPR processes. Thus, laser assisted SPR (LSPR) joining techniques are considered for joints involving magnesium alloys. Joining in this method requires no drilling but rather is performed by first preheating the sheet stack and then punching a tubular rivet through the stack

that includes magnesium alloys. While being driven, the tubular rivet flares out on the bottom side of the stack to form mechanical interlocks with each sheet in the stack.

Jiang and co-workers [1] reported fatigue performance of LSPR joints of magnesium alloys including AZ31, AM60, and AM30. Their study utilized test results to establish structural stress versus life curves for LSPR joints. It also included coach peel test results for magnesium alloy AZ31. To construct a structural stress versus life curve, it is assumed that the basic mechanics of the LSPR joint is similar to that of an electrical resistance spot weld joint [2].

In this study, Rupp's spot weld analysis approach [2, 3, 4] is used to calculate the structural stress for LSPR joints. In the finite element analysis, the LSPR joint is presented with two different element types: CBAR and area contact method (ACM) for the joint (or sub-structural) half coach peel (CP) and tensile shear (TS).

geometry specimens were cut from front shock tower structures [9] and tested at various load amplitudes to validate whether the structural stress approach works for LSPR joints. The fatigue test results of the sub-structural specimens were also compared with fatigue prediction results using the structural stress method.

MATERIALS, PROCEDURES AND RESULTS OF LSPR FATIGUE TESTING

AZ31 to AZ31 LSPR tensile-shear and coach peel specimens were manufactured in order to characterize joint fatigue performance. Only tensile-shear specimens were fabricated for the AZ31 to AM60 stack-up. Specimen dimensions and geometry for both tensile-shear and coach peel configurations are shown in Figures 1 and 2, respectively. Sheet thickness for all magnesium alloys was 2.0 mm.

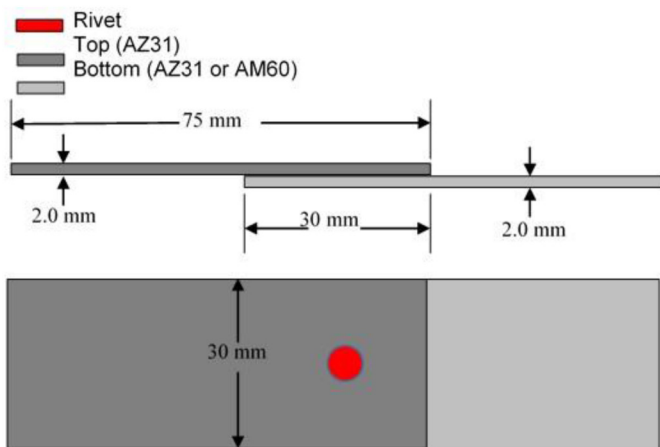


Figure 1. Tensile-shear specimen geometry.

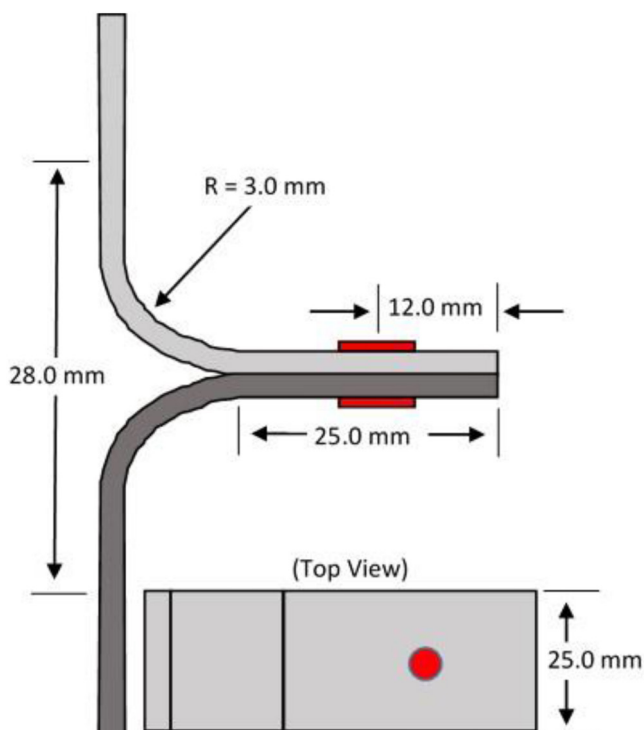


Figure 2. Coach peel specimen geometry.

Quasi-static tests were first conducted to estimate initial fatigue load ranges. The ultimate strength was determined by averaging results from three specimens. The ultimate strength of AZ31-AZ31 and AZ31-AM60 tensile-shear specimens was 5500N and 4750N, respectively. The ultimate strength of the coach peel AZ31-AZ31 specimens was 810N. In all cases, quasi-statically loaded specimens exhibited rivet pull-out failure, as shown in Figure 3.

Fatigue tests were conducted at five load levels and targeted failures in a range between 1,000 and 1,000,000 cycles. In this study, failure was defined as full specimen separation. A load ratio (R) of 0.1 and a frequency of 50 Hz were used in all tests. Most specimens, including coach peel, failed in the top sheet base material. It is noteworthy to mention that two specimens failed in the bottom sheet, and a few specimens exhibited rivet pull-out failures at relatively high load ranges (with peak loads exceeding 80% of the ultimate strength of the specimen). Figure 4 shows that the specimen failed at the top sheet and the bottom sheet. Fatigue test (load-life) results are shown in Figure 5 includes all fatigue failure modes.

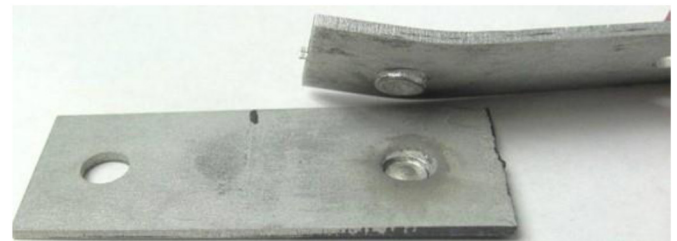


Figure 3. Rivet pull-out failure mode.

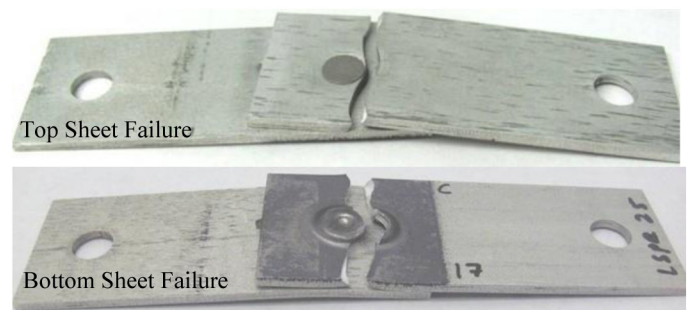


Figure 4. Typical failure modes observed in magnesium alloy LSPR joints.

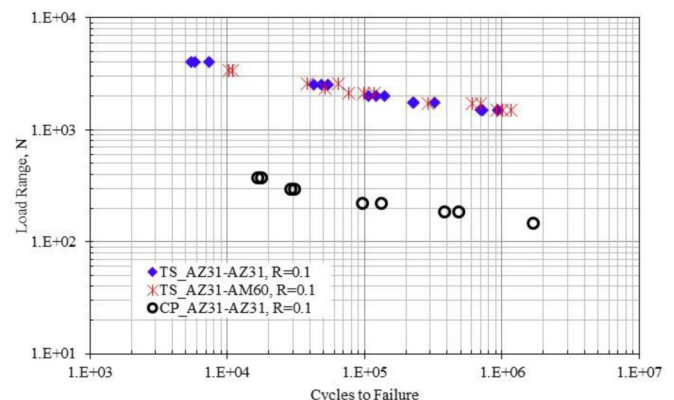


Figure 5. Load range versus cycles to failure diagram for all specimens.