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

Hong-Tae Kang\textsuperscript{1}, A.K. Khosrovaneh\textsuperscript{2}, Xuming Su\textsuperscript{3}, Mike Guo\textsuperscript{4}, Cindy Jiang\textsuperscript{5}, Yung-Li Lee\textsuperscript{4}, and Zhen Li\textsuperscript{1}

\textsuperscript{1}The University of Michigan- Dearborn
\textsuperscript{2}General Motors, LLC.
\textsuperscript{3}Ford Motor Company
\textsuperscript{4}Fiat Chrysler Automotive
\textsuperscript{5}AET Integration, LLC.
Fatigue Analysis and Testing Lab in UM-Dearborn

- Fatigue Testing
  - Various Joints: Spot, SPR, FSLW, GMAW, Adhesive, Solder
  - TMF
  - Round Bar Specimen, 4-point Bending

- FEA based Fatigue life analysis
  - S-N
  - E-N
  - Structural Stress Approaches
Challenge/project scope

A/31 - Sheet
AM60 - Cast
AM30 - extruded

CP Specimen
TS Specimen
Fatigue Testing: Coupon

- Rivet
- Top (AZ31)
- Bottom (AZ31 or AM60)

Dimensions:
- 75 mm
- 2.0 mm
- 30 mm

Failure modes:
- Top Sheet Failure
- Bottom Sheet Failure

Graph:
- Load Range, N
- Cycles to Failure

Data points:
- TS_AZ31-AZ31, R=0.1
- TS_AZ31-AM60, R=0.1
- CP_AZ31-AZ31, R=0.1

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Structural Stress Approach
Structural Stress Approach

\[ \sigma_{\text{sheel1}} = -\sigma_{\text{max}}(FX1) \cos \theta - \sigma_{\text{max}}(FY1) \sin \theta + \sigma(FZ1) + \sigma_{\text{max}}(MX1) \sin \theta - \sigma_{\text{max}}(MY1) \cos \theta \]

where

\[ \sigma_{\text{max}}(FX1) = \frac{FX1}{\Pi ds_1} \times SFFXY \times d^{DEFXY} \times s_1^{TEFXY} \]

\[ \sigma_{\text{max}}(FY1) = \frac{FY1}{\Pi ds_1} \times SFFXY \times d^{DEFXY} \times s_1^{TEFXY} \]

(Contributions from the shear forces. Note that these are adjusted by an empirical factor, \( SFFXY \times d^{DEFXY} \times s_1^{TEFXY} \) which adjusts the contributions of the shear forces relative to those of the axial force and bending moments, and allows a size effect in terms of weld diameter and sheet thickness to be taken into account.)

\[ \sigma(FZ1) = \frac{1.744 \times FZ1}{s_1^2} \times SFFZ \times d^{DEFZ} \times s_1^{TEFZ} \quad \text{if } FZ1 > 0 \quad \text{or} \quad 0 \quad \text{if } FZ1 \leq 0 \]
Structural Stress Approach

(Contributions from the axial force; note that only the contribution from tensile loads is considered. Note also the empirical factor in the same form as before.)

\[
\sigma_{\text{max}} (MX1) = \frac{1.872 \cdot MX1}{ds_1^2} \times SFMXY \times d^{DEMXY} \times s_1^{TEMXY}
\]

\[
\sigma_{\text{max}} (MY1) = \frac{1.872 \cdot MY1}{ds_1^2} \times SFMXY \times d^{DEMXY} \times s_1^{TEMXY}
\]

(Contribution from the bending moment, again including an empirical factor.)

A similar set of equations is used for the stresses in sheet 2.
Structural Stress Approach

![Diagram of structural stress approach]

Graph showing structural stress range vs. cycle to failure for different conditions:
- CP_AZ31 to AZ31
- LP_AZ31 to AZ31
- LP_AZ31 to AM50

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Fatigue Testing: Sub-Structural Specimens

*Specimen design and fatigue testing were conducted by AET Integration
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Predicted Life vs. Experimental Life

![Graph showing predicted life vs. experimental life with different markers for Half-Coach Peel-CBAR, Half-Coach Peel-ACM, TS-Specimen-CBAR, and TS-Specimen-ACM.](image)
• Tensile shear and coach peel specimens were fabricated and tested to characterize the fatigue performance of magnesium LSPR joints.

• Based on the observation of the failure modes of the joints, it was assumed that the mechanics at the LSPR joint was similar to that of the electrical resistance spot weld joint.

• Therefore, the same structural stress parameter equations as used in spot welded joints were used to analyze Mg LSPR joints.

• The structural stress parameters were then used to predict the fatigue life of sub-structural (or component-like) specimens. Results of fatigue tests of sub-structural specimens and the prediction results were also compared.
Summary/Conclusions

From this study, the following conclusions may be made:

• While the test results (load range vs. Life) of Magnesium LSPR TS and CP specimens are quite different, these differences are minimized once the data is presented as structural stress range versus life.

• In the high cycle fatigue regime, the failures in magnesium alloy LSPR appears as an “eyebrow” crack very similar to that observed in the fatigue of electrical resistance spot welds.

• Structural stress equations and methodology developed for electrical resistance spot weld are applicable to magnesium LSPR joints.
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Thank you!