International Journal of Fatigue 80 (2015) 58–68

Contents lists available at ScienceDirect

International Journal of Fatigue

journal homepage: www.elsevier.com/locate/ijfatigue

Fatigue strength evaluation of self-piercing riveted Al-5052 joints under different specimen configurations

Se-Hyung Kang [a], Ho-Kyung Kim [b,*]

[a] Graduate School, Seoul National University of Science and Technology, Seoul 139-743, Republic of Korea
[b] Dept. of Mechanical and Automotive Engineering, Seoul National University of Science and Technology, Seoul 139-743, Republic of Korea

ARTICLE INFO

Article history:
Received 21 January 2015
Received in revised form 7 May 2015
Accepted 10 May 2015
Available online 5 June 2015

Keywords:
SPR joints
Fatigue lifetime
Coach-peel
Tensile–shear
Equivalent stress intensity factor

ABSTRACT

In this study, static and fatigue tests were conducted using coach-peel, cross-tension and tensile–shear specimens with Al-5052 plates for evaluation of the fatigue strength of the SPR joints. For the coach-peel, cross-tension and tensile–shear geometries, the ratios of the fatigue endurance limit to static strength were 11%, 14% and 34%, respectively, assuming fatigue cycles of 10^6 for an infinite lifetime. The equivalent stress intensity factor range can properly predict the current experimental fatigue lifetime. Fatigue crack initiation occurred due to fretting damage between the upper and lower sheets and between the rivet and these sheets.

1. Introduction

One of the main objectives in the automotive industry currently is to reduce the weights of automobiles. To achieve this goal, a new joining technology as a replacement for spot welding in lightweight metals, such as aluminum and magnesium alloys, is required in the automotive industry. Riveting methods are often considered as substitutes for spot welding. Among the several types of riveting methods available, the self-piercing riveting (henceforth SPR) process is gaining in popularity due to its many advantages. SPR does not require a pre-drilled hole, and this method can be used to join a wide range of materials, including combinations of similar or dissimilar materials.

SPR is essentially a cold-forming joining process. During the SPR process, a semi-tubular rivet is pressed by a punch into the sheets. The rivet pierces the upper sheet and flares into the bottom sheet under the influence of an upset die. A mechanical interlock is formed between the two sheets, which is key to the structural strength of the joints.

The fatigue strength of the SPR joints has been investigated by a number of authors for a number of materials [1–6]. For example, Mori et al. [2] examined the static and fatigue strengths of spot-welded and self-piercing rivet joints in aluminum alloy sheets under tensile–shear and cross-tension configurations. They observed that while the static strength of the self-piercing rivet joint was about 1.5 times as large as that of the spot-welded joints, the fatigue strength was increased by about three times in the tensile–shear configuration. He et al. [3] investigated the strength, stiffness, impact resistance, failure modes and failure mechanisms of SPR joints with similar and dissimilar metal sheets consisting of an aluminum alloy and a copper alloy. They reported that the fatigue strength of SPR joints was largely affected by the properties of the sheets and that both the static and fatigue strength of SPR joints increased with an enhancement of the joint stiffness. Xing et al. [4] investigated the static and fatigue strength of multiple-rivet SPR joints. They reported that these levels are influenced by the rivet number and rivet distribution pattern. Franco et al. [5] investigated the possibility of joining aluminum alloys and carbon fiber composites using SPR. They reported large values of the fatigue resistance of SPR joints, even for load amplitudes close to the maximum static resistance of the joint and a fairly large range of fatigue strengths. Su et al. [6] investigated the fatigue behavior of SPR and clinch joints in tensile–shear specimens of aluminum sheets. They reported that the experimental fatigue lives of these joints can be estimated using structural stress solutions.

However, fatigue lifetime data of a SPR joint is normally reported as a function of the applied load range [7–9]. The reported fatigue strength data are not high enough to apply the other types of specimens due to the obscurity of the various factors that govern

---

* Corresponding author. Tel.: +82 02 970 6348; fax: +82 02 979 7032.
E-mail address: kimhk@seoultech.ac.kr (H.-K. Kim).

http://dx.doi.org/10.1016/j.ijfatigue.2015.05.003
0142-1123/

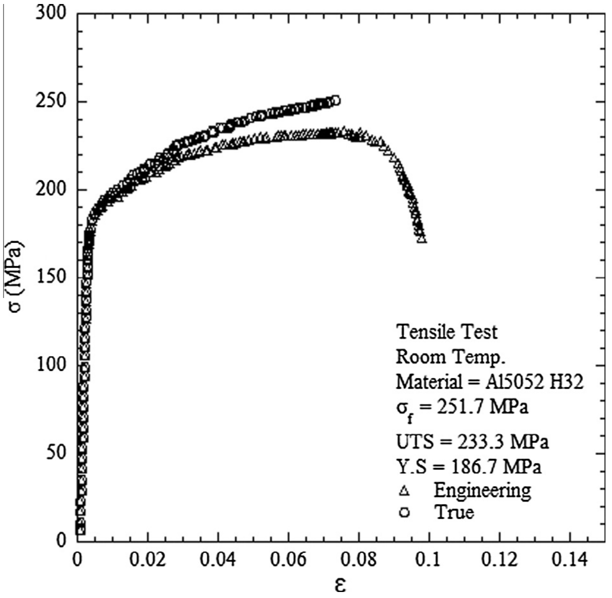

Fig. 1. Stress–strain curves of the Al5052-H32 alloy.

Table 1
Mechanical properties of the Al5052-H32.

Material	σ_u (MPa)	σ_y (MPa)	E (GPa)	Elong. (%)
Al5052-H32	251.7	186.7	78.3	10

their fatigue strengths. The fatigue lifetime of a SPR joint specimen is generally dependent on the load magnitude, the loading type, the dimensions and configuration of the specimen, the sheet material, and other factors. Even with the same rivet diameter, sheet material, and sheet thickness, the load range amplitude representing the fatigue strength can differ from one specimen type to another due to different loading types. Therefore, the fatigue strength data for the SPR joints under several types of loading are needed in order to design a structure with SPR joints. To solve this problem, it is desirable to adopt general structural parameters, such as the stress, strain, and multiaxial fatigue criteria, to assess the fatigue lifetimes of these joints. Thus far, there has not been any report on appropriate fatigue strength parameters to correlate the fatigue lifetimes of SPR joints with different specimen configurations.

Therefore, in this study, fatigue tests under constant amplitude loads are conducted using coach-peel, cross-tension and tensile–shear specimens of Al-5052 aluminum alloy sheets to evaluate the fatigue strength of SPR joints under different specimen configurations. The experimental fatigue lifetimes of SPR joint specimens are also estimated using fatigue strength parameters. Finally, appropriate parameters for evaluating the fatigue lifetimes of three types of specimens are proposed.

2. Experimental procedure

2.1. Specimen preparation and fatigue test

Al5052-H32 aluminum alloy sheets with a thickness of 1.5 mm were joined by SPR. Tensile tests on the sheet material were conducted in order to obtain the tensile stress–strain curve for a FEM structural analysis. The tensile specimen was machined to a uniform gage length and width of 70 mm and 12.5 mm, respectively. Fig. 1 shows the engineering stress–strain curve for the Al5052-H32 alloy. The mechanical properties of the material are summarized in Table 1.

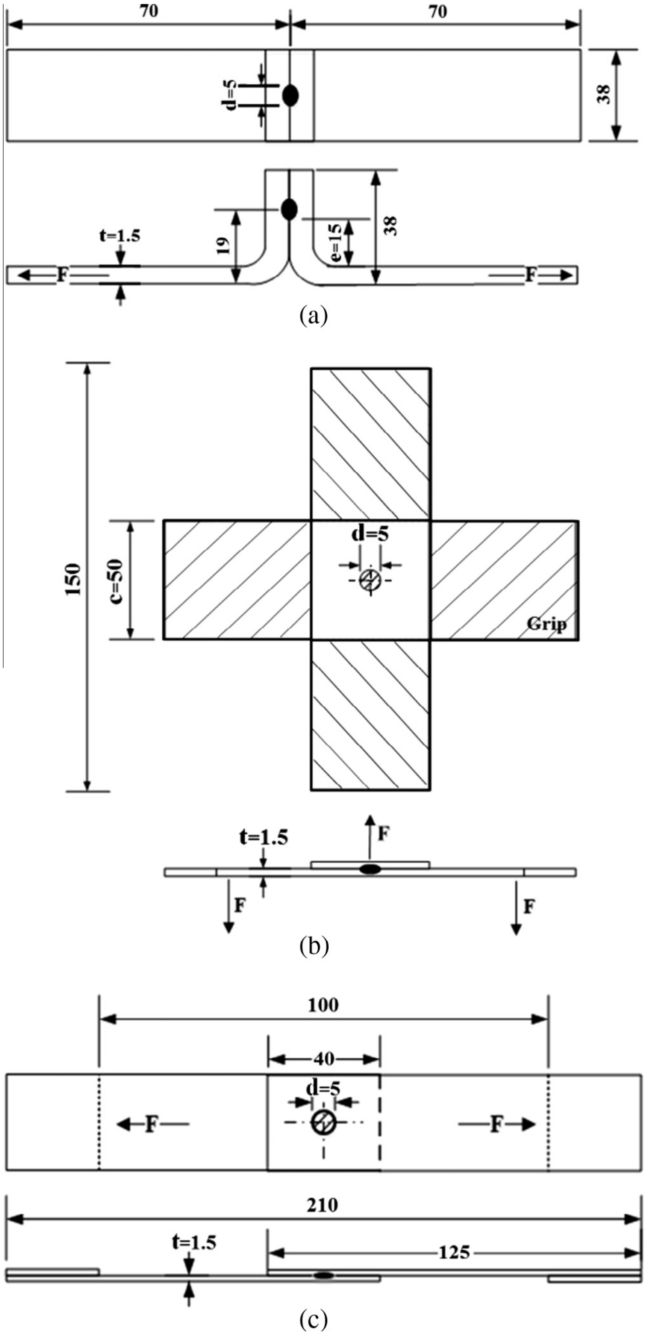

Fig. 2. Geometries of three types of SPR specimens: (a) coach-peel, (b) cross-tension and (c) tensile–shear.

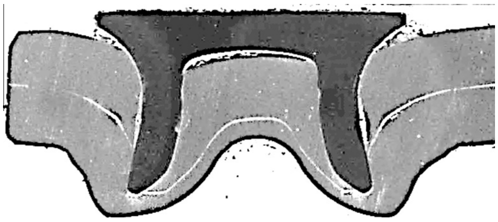

Fig. 3. Cross-section of the SPR joint after riveting.