UDC 539.4

The Ultimate Tensile Strength of Coach Peel Self-Piercing Riveting Joints

X. He[1] and B. Xing[2]

Kunming University of Science and Technology, Kunming, People's Republic of China

[1] hhxxcc@yahoo.co.uk

[2] xbb0808@163.com

УДК 539.4

Анализ прочности узлов сопряжений листовых материалов, соединенных самопробивными заклепками, при статическом растяжении

Кс. Хи, Б. Ксинг

Университет науки и технологии, Куньмин, КНР

Широкое использование легких листовых материалов обусловливает актуальность применения технологии самопробивных заклепок для их соединения. Исследуется статическая прочность узлов сопряжения листовых материалов, соединяемых с помощью самопробивных заклепок. В процессе пробивания и фиксирования заклепок используется автоматизированная технология оценки качества соединения в режиме реального времени. Сигналы с датчиков усиливаются и передаются в систему измерения, обработки и хранения данных. В ходе статических испытаний на растяжение узлов сопряжения различных листовых материалов с помощью самопробивных заклепок проводились измерения пределов их статической прочности и деформации до разрушения. Выполнен вероятностный анализ полученных экспериментальных результатов на основании гипотезы их нормального распределения.

Ключевые слова: самопробивная заклепка, узел сопряжения листовых материалов, деформация, прочность при растяжении.

Introduction. As a result of the trend towards lightweight construction in manufacturing, self-pierce riveting (SPR) is widely used in different industrial fields in recent years [1, 2]. There have been a number of published results on the static and fatigue properties of the SPR joints in the past few years. Wood et al. [3] investigated the performance of self-piercing riveted joints in aluminum sheet (A5754) at typical automotive crash speeds. A finite element (FE) model of the fixture and test measurement system was developed to ensure a near optimal design. Durandet et al. [4] studied the laser-assisted SPR (LSPR) of AZ31 magnesium alloy strips. A simple but effective thermal analysis of LSPR was presented that enabled both the absorption of the laser radiation and heat transfer between plies to be determined. Mucha [5] has carried out comparison analysis within the FE numerical experiment range to cover the effect of various riveting process parameters on the rivet deformation.

In spite of the fact that the coach peel self-pierce riveted (CPSPR) joints have been widely used in manufacturing practice, literature on study of CPSPR joints remains limited. Porcaro et al. generated an accurate 3D numerical model for CPSPR joint, subjected to various loading conditions [6]. An algorithm was generated in order to transfer all the information from the 2D numerical model of the riveting process to the 3D numerical model of the joint. Booth et al. [7] compared the ultimate tensile strength and fatigue behavior of CPSPR joints with those of resistance spot weld joints for a variety of material and thickness combinations. In present study, the ultimate tensile strengths of CPSPR joints are investigated experimentally for different material combinations. The online window technique was introduced in the SPR processes for evaluating the quality of joints. Signals obtained from sensors were amplified and transferred to the data acquisition system which measured, processed and saved the signals. Monotonic tensile tests were carried out to measure the ultimate tensile strengths for CPSPR joints with different material combinations. Deformation and failure of the joints under monotonic tensile loading were studied. The normal hypothesis tests were performed to examine the rationality of the test data.

Configuration, **Material Properties of CPSPR Joints**. As shown in Fig. 1, the CPSPR joints investigated in the present work were comprised of two L-shaped sheets with a single rivet joining them together. The rivets are made of high strength steel and are of dimensions 6 mm long × 5.3 mm diameter. The L-shaped sheets are made of 5052 aluminum alloy and 45 steel and are of 2 mm thickness. In order to make it easy to describe the different CPSPR joints, the following nomenclature is used:

AA joint: CPSPR joint comprises two aluminum alloy sheets;

AS joint: CPSPR joint comprises one aluminum alloy sheet and one 45 steel sheet.

For the AS joints, the 45 steel sheet was arranged at the rivet head side.

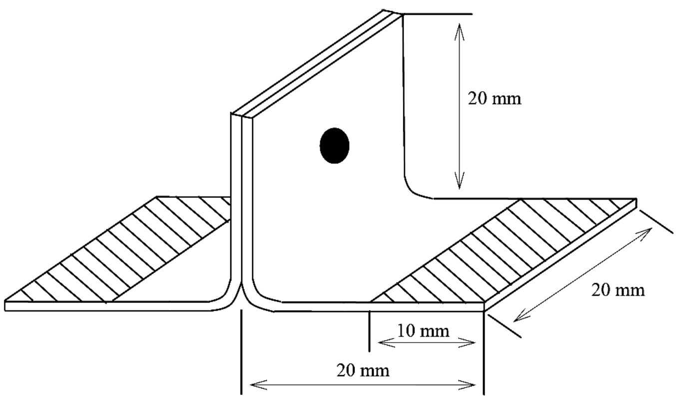
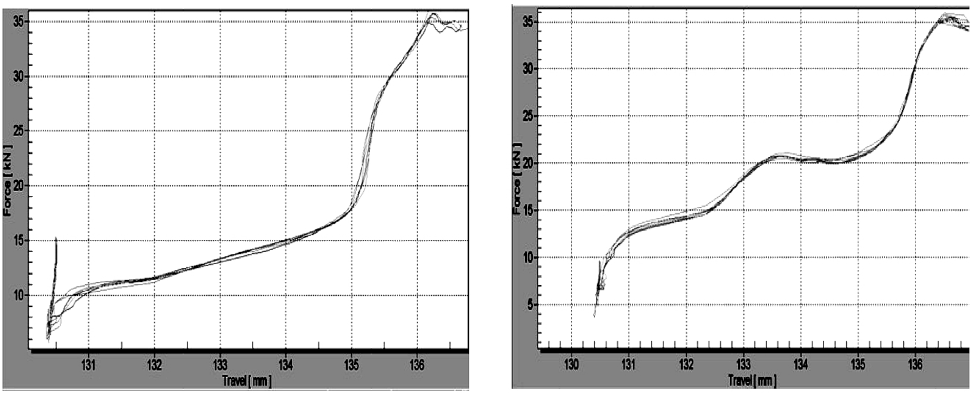


Fig. 1. Geometry of the CPSPR joints.

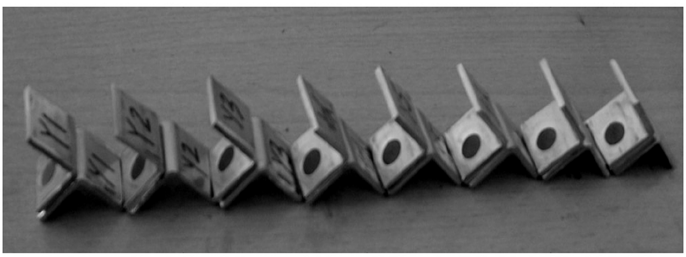
SPR Process Online Monitoring. SPR processes were carried out by a RIVSET MTF self-pierce rivet machine with a built-in window monitoring system. The process window monitoring of SPR joint is carried out by measuring actual SPR setting force through a force sensor and punch travel through a position sensor. The SPR setting force reflects the deformation force on the sheet materials and the punch travel indicated the geometric change of the sheets during SPR process. Signals obtained from sensors are amplified and transferred to the data acquisition system which measures, processes and saves the signals. A computer is used to save the measured data and generate the force–travel curves. All CPSPR joints were made with constant pre-clamp (5 kN) and setting (40 kN) load.

Before the monitoring process, a reference force–travel curve must be established under the standard work conditions which were based on a range of experiments. The CPSPR joint could be supposed to be of good quality under these conditions. It is obviously that under the same work conditions, the monitoring force–travel curves should be very close to the reference one and have nearly the same pattern. The corresponding CPSPR joints would have similar good quality. Figures 2 and 3 show the CPSPR joints and force–travel curves separately.



AA joints AS joints

Fig. 2. Force–travel curves of AA and AS joints.



AA joints

AS joints

Fig. 3. AA and AS joints.

Monotonic Tensile Tests. Deformation and failure of the AA and AS joints under monotonic tensile loading were studied in this section. A servohydraulic testing machine with hydraulic grips was used for conducting the monotonic tensile tests. All tests were performed by using displacement control. The upper end of the joints was fixed and a quasi-static downward displacement was applied to the lower end. The displacement rate of 5 mm/min was applied for all tests. Continuous records of the applied displacement–load curves were obtained during each test. Figure 4 shows the monotonic tensile process. It is clear that joint rotation occurs during tensile tests.

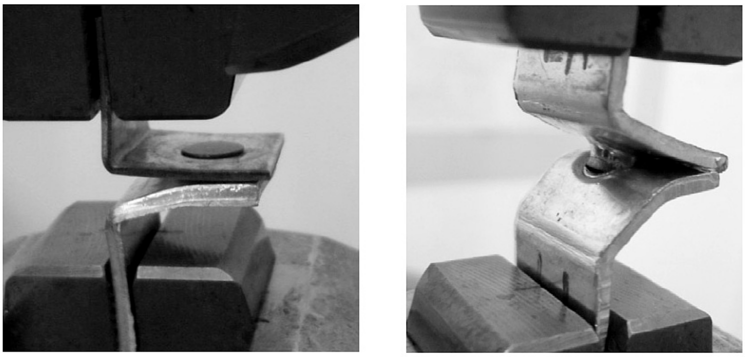
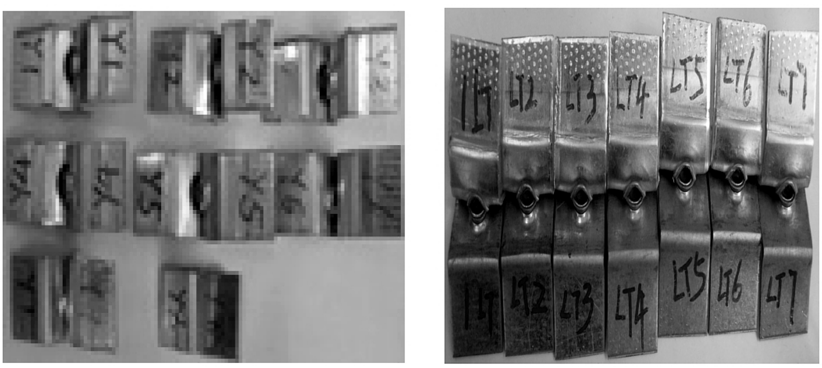


Fig. 4. Monotonic tensile process of CPSPR joint.

Experimental Results. Figure 5 shows failed AA and AS joints. It can be seen from Fig. 5 that the failure mode was plate failure forming at the contact location between the rivet bottom and the lower sheet. In the test, plastic deformation around contact location developed to such a large level that the rivet was pulled out from the lower sheet.



AA joints AS joints

Fig. 5. Failed AA and AS joints.

The force–displacement curves of AA and AS joints are shown in Fig. 6. To examine the rationality of the test data, the normal hypothesis tests were performed using MATLAB 7.0. The results show that the maximum tensile strength of AA and AS joints follow normal distributions. The mean values (μ) and standard

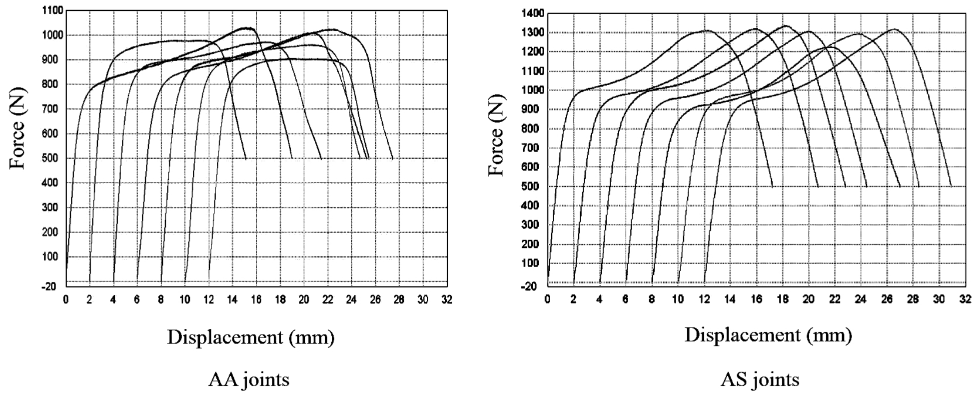


Fig. 6. Force–displacement curves of AA and AS joints.

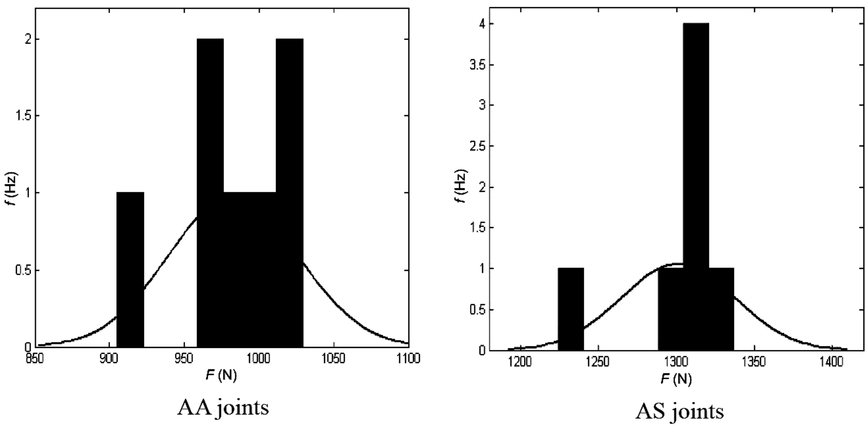


Fig. 7. Maximum tensile strengths normal probability density distributions.

deviations (σ) have the following numerical values: $\mu_{AA} = 982.68$ N, $\sigma_{AA} = 43.27$ N, $\mu_{AS} = 1301$ N, and $\sigma_{AS} = 36.19$ N. All test data fitting the region estimated by the degree of confidence of 95%. The maximum tensile strengths normal probability density distributions of the AA and AS joints are showed in Fig. 7. It can be seen that the tensile strength of AS joint is higher than that of the AA joint, as expected.

Summary. SPR is a new high-speed mechanical fastening technique which is suitable for point-joining the advanced lightweight sheet materials. The ultimate tensile strength of coach peel self-pierce riveted joints is investigated in this study. The online window technique was introduced in the CPSPR processes for evaluating the quality of CPSPR joints. Signals obtained from sensors were amplified and transferred to the data acquisition system which measures, processes and saves the signals. Ultimate tensile tests were carried out to measure the ultimate tensile strengths for CPSPR joints with different material combinations. Deformation and failure of the AA and AS joints under monotonic tensile loading were studied. The normal hypothesis tests were performed to examine the rationality of the test data.

Acknowledgment. This study is partially supported by National Science Foundation of China (Grant No. 50965009).

Р е з ю м е

Широке використання легких листових матеріалів зумовлює ріст актуальності застосування технології самопробивних заклепок для їх з’єднання. Досліджується статична міцність вузлів сполучення листових матеріалів, що з’єднуються за допомогою самопробивних заклепок. У процесі пробивання і фіксування заклепок використовується автоматизована технологія оцінки якості з’єднання у режимі реального часу. Сигнали з датчиків підсилюються і передаються в систему вимірювання, обробки і зберігання даних. У ході статичних випробувань на розтяг вузлів сполучення різних листових матеріалів за допомогою самопробивних заклепок проводили вимірювання границь їх статичної міцності і деформації до руйнування. Виконано імовірнісний аналіз отриманих експериментальних результатів на основі гіпотези їх нормального розподілу.

1. X. He, F. Gu, and A. Ball, “Recent development in finite element analysis of self-piercing riveted joints,” *Int. J. Adv. Manuf. Technol.*, **58**, 643–649 (2012).
2. X. He, I. Pearson, and K. Young, “Self-pierce riveting for sheet materials: state of the art,” *J. Mater. Process. Technol*., **199**, 27–36 (2008).
3. P. Wood, C. Schley, M. Williams, and A. Rusinek, “A model to describe the high rate performance of self-piercing riveted joints in sheet aluminium,” *Mater. Design*, **32**, 2246–2259 (2011).
4. Y. Durandet, R. Deam, A. Beer, et al., “Laser assisted self-pierce riveting of AZ31 magnesium alloy strips,” *Mater. Design*, **31**, S13–S16 (2010).
5. J. Mucha, “A study of quality parameters and behavior of self-piercing riveted aluminium sheets with different joining conditions,” *Strojniški Vestnik/J. Mech. Eng.*, **57**, 323–333 (2011).
6. R. Porcaro, A. G. Hanssen, M. Langseth, A. Aalberg, “The behaviour of a self-piercing riveted connection under quasi-static loading conditions,” *Int. J. Solids Struct.*, **43**, 5110–5131 (2006).
7. G. S. Booth, C. A. Oliver, S. A. Westgate, et al., *Self-Piercing Riveted Joints and Resistance Spot Welded Joints in Steel and Aluminum*, SAE Technical Paper No. 2000-01-2681 (2000).

Received 06. 11. 2012