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Mechanical properties of extensible die clinched joints in titanium sheet materials

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ABSTRACT

The mechanical properties of extensible die clinched joints in titanium sheet materials were investigated in this paper. Tensile–shear tests were carried out to characterize the mechanical properties of different clinched joints made of the similar titanium sheets and the dissimilar metal sheets combinations. The normal hypothesis tests were performed to examine the rationality of the test data. The load-bearing capacity, energy absorption and failure modes of different titanium sheets clinched joints were studied. Results showed that almost all titanium sheets clinched joints failed in the neck fracture mode. Results also showed that the load-bearing capacity and energy absorption of clinch joints with titanium as upper sheets are higher than that of the clinched joints with titanium as lower sheets.

1. Introduction

The overall weight of a vehicle has a great impact on fuel consumption and the amounts of vehicle emissions. This has resulted in an increasing need to design lightweight structures and use lightweight materials in the manufacture of vehicle bodies. Some of these lightweight materials are difficult or impossible to weld with conventional spot welding and so considerable effort has gone into developing new joining processes suitable for use with lightweight materials [1–4].

Clinching has also been developed rapidly into a new branch of mechanical joining techniques [5–7]. The use of clinching is of great interest to many industrial sectors including aerospace and automotive. This, together with increasing use of lightweight materials which normally are difficult or impossible to weld, has produced a significant increase in the use of clinching technology in engineering structures and components in recent years [8–11].

The strength of the clinching has been compared with other joining techniques, such as self-pierce riveting (SPR) and spot-welding by researchers (e.g., [12,13]). Although the static strength of clinched joints is lower than that of other joints, but the fatigue strength of clinched joints is comparable to that of other joints and the strength of the clinched joints is more consistent with a significantly lower variation across a range of samples [12]. Fig. 1 compares the fatigue behavior of different joining techniques [13].

In industrial applications of the clinched structures, knowledge of the mechanical characteristics of clinched joints is very important. The static and dynamic behavior of clinched joints has been the subject of a great amount of numerical and experimental studies. An investigation on clinching mechanism has been conducted by Gao and Budde [14]. Some elementary terms were used to establish a basic theory for analyzing the clinching mechanism. The influence of the clinching process parameters on the join-ability of high-strength steel was studied by Mucha [15] using finite element (FE) method. The results showed that some parameters, such as die radius, die depth and die groove shape were mainly affected on the join-ability. Markowski et al. [16] presented the results of FE analysis for clinching joint machine's C-frame. Several versions of frame geometry were accounted for when analyzing the straining of material, including the mass reduction. The purpose of this FE simulation was to determine the effect of mass reducing material recess on the structure rigidity. The suitability and economics of clinching processes were studied by Varis [17,18].

The sheet metal may normally be pressed or stamped prior to mechanical clinching. The pre-strain from the pressing or stamping may have an influence on the quality of the clinched joints. A recent study was conducted to understand the effect of pre-straining aluminum on the static strength of the clinched aluminum-to-steel joint [19]. The section parameters (i.e., undercut, neck thickness, and bottom thickness) and joint strength were measured. It was found that the work hardening resulting from pre-straining decreased the ductility of aluminum AA6111-T4 and induced some

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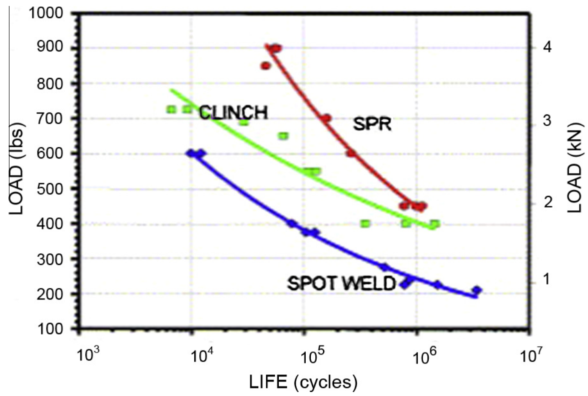

Fig. 1. Fatigue behavior comparison of clinching, spot-weld and SPR joints [13].

Table 1
Chemical compositions of sheet materials (%).

Material	Fe	C	N	H	O	Ti
TA1	0.08	0.01	0.014	0.001	0.09	Rest
Material	Si	Cu	Mg	Zn	Mn	Al
Al5052	0.25	0.1	2.2	0.1	0.1	Rest
Material	Zn	Fe	Pb	P	Cu	
H62	36.8	0.15	0.08	0.01	Rest	

Table 2
Mechanical properties of sheet materials.

Material	Young's Modulus (GPa)	Tensile strength (MPa)	Yield strength (MPa)	Elongation (%)
TA1	98.5	402.5	396.8	33
H62	110	424.5	340.3	30
AA5052	69.5	229.9	211.5	12

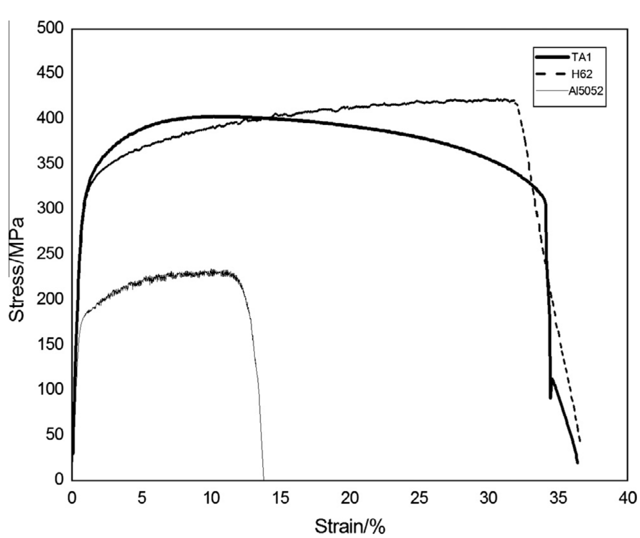

Fig. 2. Stress–strain curves for sheet materials.

ductile damage on the clinched aluminum workpieces. A 5% pre-strain on AA6111-T4 caused a significant decrease (about 20%) in joint strength.

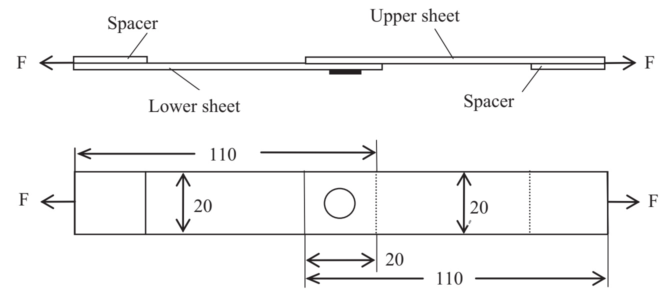

Fig. 3. Configuration and boundary condition of a single lap clinched joint (dimensions in mm).

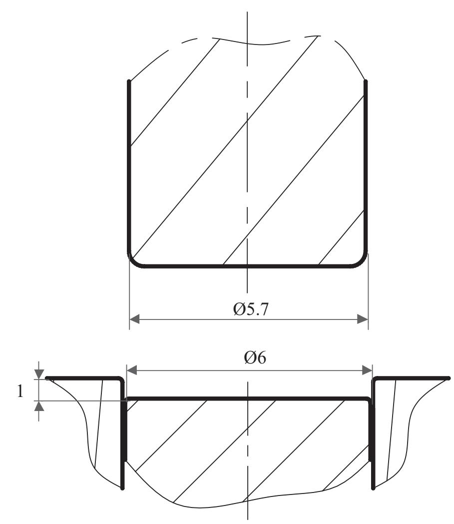

Fig. 4. Geometries of extensible die.

A die-less clinching process has been proposed by Neugebauer et al. [20]. Using the die-less clinching, it is possible to produce a one-sided flat connection, which is not producible with any other joining technology. Additionally it is possible to enlarge the application potential of mechanical joining technologies as for example semi-finished parts made of magnesium can be partially heated and directly joined without an increase in process time or a reduction in the process stability. The tool's costs, the necessary tolerances and the tool wear are significantly reduced.

A new clinching technology using additional rivets (ClinchRivet) has been proposed by Mucha et al. [21,22]. The capabilities of S350 GD sheet metal joining using the ClinchRivet technique were presented. The joint strength researches based on the uniaxial shearing test of the overlay joints for steel sheet of 1 mm thickness, which is used in the light gauge steel profiles in the wireframe structures of residential and commercial buildings. The results achieved for joints arranged in parallel and perpendicular to the load for specified joint spacing were discussed. The assessment of joint effectiveness were performed for both homogenous double joints and for various combinations of these joints.

The results of experimental researches on effect of clinching joint's load direction change on its characteristics and the maximum shearing force value have been presented. The single-folded clinched joints made of aluminum sheet AW1050A were the subject of researches [23]. Properly prepared specimens of rectangle clinched joints with material notch were shear tested on the tensile testing machine UTS 100. The extreme joint destruction were analyzed for the layout angle 0° and 90°. The separation mechanism were described for all angle values 0°, 30°, 45° and 90°. The total separation work by joint shearing was also mentioned.