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Method for repairing of adhesive-bonded steel

H.J. Yang [a], Y.S. Zhang [a,*], X.M. Lai [a], J. Shen [a], X. Zhao [a], P.C. Wang [b]

[a] Shanghai Key Lab for Digital Autobody Engineering, School of Mechanical Engineering, Shanghai JiaoTong University, Shanghai, China
[b] R&D Center, General Motors Corporation, Warren, MI 48090, USA

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ABSTRACT

With an increase in the use of advanced high strength steels in vehicle architectures, materials joining issues (e.g., performance and manufacturability) have become increasingly important. Among the various joining methods, adhesive bonding is increasingly used in automobile manufacturing. Successful implementation of adhesive bonding for vehicle welding application requires not only the knowledge of issues related to processing and design but also a practical method to repair the bonded joints.

In this study, a plug stud welding (PSW) process is proposed to repair the bonded steels. The process is as follows: (a) punching a hole at the first metal sheet; (b) inserting slug into hole; (c) and (d) passing electrical arc through slug of sufficient intensity to promote melting at the interface between the first and second metal sheets and slug, thereby (e) securing the metal workpiece. The repaired bonded DP780 steel samples were fabricated and tested. Test results were compared with that of conventional resistance spot welds. The results show that repaired bonded steels had comparable tensile and fatigue strengths to conventional spot welds. These results suggest that plug stud welding process is feasible for repairing the adhesive-bonded steels in vehicle assembly plants and collision body shops.

1. Introduction

With an increase in the use of advanced high strength steels in vehicle architectures [1–4], materials joining issues have become increasingly important. Among the various joining methods, adhesive bonding is increasingly used in automobile manufacturing [5,6]. It has the ability to join different materials and thin sheets with even load transfer and good fatigue performance [7–9]. Successful implementation of adhesive bonding to improve structural crashworthiness and reduce vehicle weight requires not only the knowledge of issues (e.g., manufacturability and performance) related to processing and design but also a practical method to repair the bonded joints.

From a joint repair standpoint, adhesive bonding, unlike resistance welding, is not too forgiving. Once the structures with poor adhesive bonds are assembled, they are often difficult to repair. With increasing use of adhesives in the body shop as well as in aftermarket repair, OEMs are compelled to develop the repair techniques to ensure quality and durable repairs in the vehicle body shop and aftermarket. Thus, the objective of this study is to provide a practical and efficient method of repairing discrepant adhesive-bonded joints.

In this study, a plug stud welding (PSW), shown in Fig. 1, is developed to repair adhesive-bonded steels. An outline of the remainder of the study follows. Following a description of the PSW process, experimental procedure that includes the material properties, sample fabrication, testing apparatus, and mechanical testing is presented. This is followed by the experimental results and cross-section examinations of the repaired samples. Finally, we discuss the effects of various process and geometrical variables on the static strength of repaired adhesive-bonded steel joints.

2. Plug stud welding process

Fig. 1 shows the schematic of the plug stud welding (PSW) process. As shown, the process is as follows: (a) punching a hole at the first metal sheet; (b) inserting slug into hole; (c) and (d) passing electrical arc through slug of sufficient intensity to promote melting at the interface between the first and second metal sheets, and slug, thereby (e) securing the metal workpiece.

As shown in Fig. 1, the hole extends through the first metal sheet. The hole is sufficiently configured to receive a slug. A slug formed from metal and has a shaft. As the shaft of the slug is inserted into the hole, an electric current is fired. An arc is formed as the slug is pulled away from the hole. The current is supplied to the slug at a level or intensity sufficient to result in arc heating and localized melting between the slug and the workpieces. This localized melting forms a weld, thereby welding the slug to the workpieces. Additionally, the head portion is welded to the first metallic member providing an added measure of resistance to separation of the workpieces.

* Corresponding author. Tel.: +86 21 34206288; fax: +86 21 34204542.
E-mail address: zhangyansong@sjtu.edu.cn (Y.S. Zhang).

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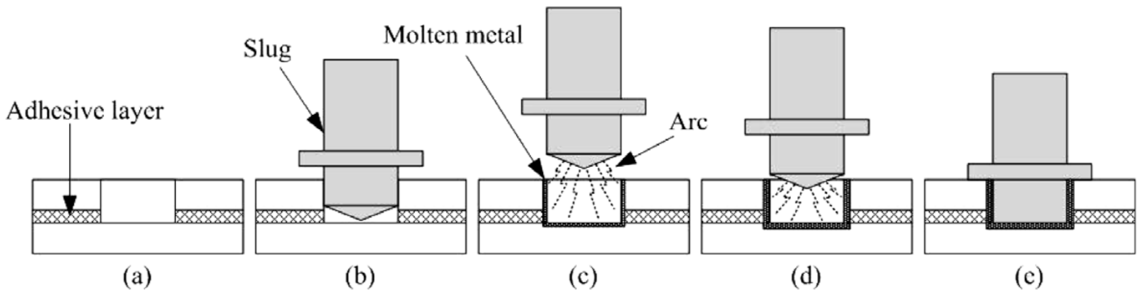

Fig. 1. Schematic of plug stud welding process.

3. Experimental procedure

3.1. Materials

1.0 mm thick high strength steel DP780 and low carbon steel H08A were used for base metal and slug materials, respectively. A proprietary crash-toughened epoxy, Henkel 5087 manufactured by Henkel Inc. was used in this study. The mechanical properties of the base metal, slug and adhesive are shown in Table 1 and Fig. 2, respectively.

3.2. Slug

Fig. 3 shows the schematics of the stud used in this study. As shown, two types of stud were used: commercial stud and special flanged stud. The stud diameter (d) and flange length (L) are 10 mm and 2 mm, respectively.

3.3. Sample fabrication

The lap-shear specimen configuration, shown in Fig. 4 was selected in this study. The specimens were fabricated from 38 × 127 mm steel sheets. The repair of adhesive-bonded specimens were prepared as follows: (1) applying the adhesive with a bondline thickness of 0.2–0.4 mm, through a hand-held injection gun, on one of the two contact surfaces; (2) curing specimens in the oven for 30 min at 180 °C per manufacturer's recommended procedures; (3) drilling a hole at the center of the cured adhesive and metal sheet; (4) turning the drilled workpiece upside down and lay it over on top of the metal sheet with an overlap distance of 15 mm; (5) positioning them with a fixture; and (6) plug arc welding the specimens. All finished specimens are examined for the presence of any discrepancies.

3.4. Optimum process development

In order to study how the process variables (i.e., stud geometry, shielding gas and arc lift) affect the static strength of the joints, samples made with a bondline thickness of 0.25 mm were repaired with a flanged stud. Quasi-static testing of repaired specimens was conducted at room temperature. Table 2 shows the optimum process variables for stud plug welding of bonded 1.0 mm thick DP780 steel. For the purpose of comparison, the process variables for resistance spot-welded DP780 steel are also listed in Table 2.

Table 1
Mechanical properties of base metal and slug.

	Yield strength, MPa	Ultimate tensile strength, MPa	Fracture elongation, %
Slug (H08A)	175	295	35
Base metal (DP780)	491	793	20.4

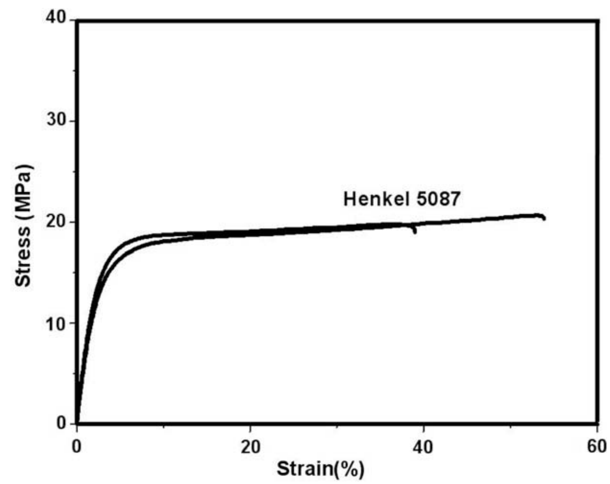

Fig. 2. Tensile stress–strain properties of Henkel 5087 adhesive.

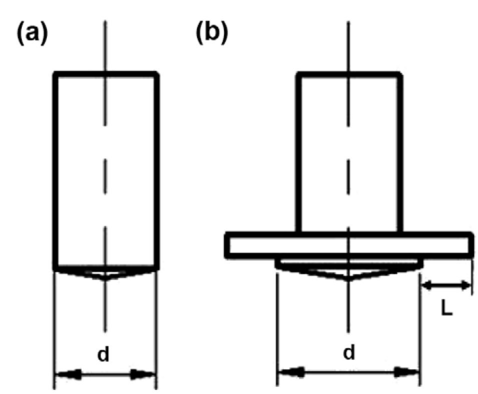

Fig. 3. Schematic of the stud (a) commercial stud and (b) flanged stud.

3.5. Static test

Quasi-static tests were performed by loading each specimen to failure in a tensile tester. To minimize bending stresses inherent in the testing of lap-shear specimens, filler plates were attached to both ends of the sample using masking tape to accommodate the sample offset. Load vs. displacement curves were obtained as the specimens were loaded at a stroke rate of 2 mm/min. Three replicates were performed, and the average peak loads were reported. Post-failure analysis was performed with optical microscope to study the failure mechanisms.