Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 23 (2014) 24 – 28

www.elsevier.com/locate/procedia

Conference on Assembly Technologies and Systems

Effects of increased tool velocity on mechanical joining of steel and aluminum sheet metals

Mathias Jäckel, Christian Kraus*, Thomas Kropp

Fraunhofer IWU, Nöthnitzer Straße 44, 01187 Dresden, Germany

* Corresponding author. Tel.: +49-351-4772-2420; fax: +49-351-4772-2403. *E-mail address:* christian.kraus@iwu.fraunhofer.de

Abstract

The paper shows possibilities for improving the joining process of self-pierce riveting with solid rivets (SPR-SR) by increasing tool velocity. The focus is put on the joining process of high-strength steel sheets with aluminum sheets. Proper and reliable joining of these material combinations is a major challenge for mechanical joining techniques. In the conventional joining process, with common tool velocities well below 1 m/s, different problems during the joining process caused by the high strength of the steel sheets can occur. These problems can be reduced significantly by increasing tool velocity.

Selection and peer-review under responsibility of the International Scientific Committee of 5th CATS 2014 in the person of the Conference Chair Prof. Dr. Matthias Putz matthias.putz@iwu.fraunhofer.de

Keywords: mechanical joining; self-pierce riveting

1. Introduction

The project aims to enhance the process limits of self-pierce riveting with solid rivets of high-strength steel sheets with aluminum sheets by using high speed joining and showing its potential for elementary and hybrid joining.

For several years, research in various fields for usable effects by increasing the tool velocity has been done by different research facilities. Main subjects of the investigations are the plastic strain rate and temperature-dependent material properties in the joining process [1,2] as well as the inertial effects in the global structure [3,4]. In the literature, the term "high speed joining" is mainly used to describe processes with a tool velocity range of about 5 m/s to 100 m/s. In the following investigations, elevated tool velocities of about 5 to 10 m/s are applied, while tool velocities in conventional joining applications in mechanical joining are well below 1 m/s.

2. Process conditions and test setup

2.1. Joining with self-piercing solid rivets

Through joining with self-piercing solid rivets permanent connections of sheet metal parts without pre-manufactured holes can be produced [5]. The piercing process is performed by a cylindrical solid rivet, and a two-sided accessibility to the workpieces is required. With this process two or more workpieces can be joined. The piercing capability of the material and a deformability of the die-side material are important. Because of the combination of interlock and force closure, SPR connections have a significantly higher service life than thermal joined connections particularly at oscillating load [6].

In the beginning of the process, the workpieces are fixed between die and blank holder (Fig. 1, I.). Afterwards, resulting from the movement of the punch, the rivet pierces a hole into the components and is subsequently pressed into the workpieces until the countersunk head of the rivet is installed flush with the surface of the upper piece of the sheet metal (Fig. 1, II.). In the third step of the riveting process,

Selection and peer-review under responsibility of the International Scientific Committee of 5th CATS 2014 in the person of the Conference Chair Prof. Dr. Matthias Putz matthias.putz@iwu.fraunhofer.de

doi:10.1016/j.procir.2014.10.062

workpieces and rivet are jointly pressed against the die at a high level of force to indent the die into the lower sheet metal. This presses the material volume of the die-side sheet metal into the shaft groove of the rivet, which then creates interlocking (Fig. 1, III.).

A high level of ductility and a low level of material strength are beneficial for forming the die-side sheet metal into the rivet shaft groove. Hence, the aluminum sheets are preferably arranged on the die-side in case of steel-aluminum joints. The setting velocity is well below 1 m/s with the conventional SPR-SR process.

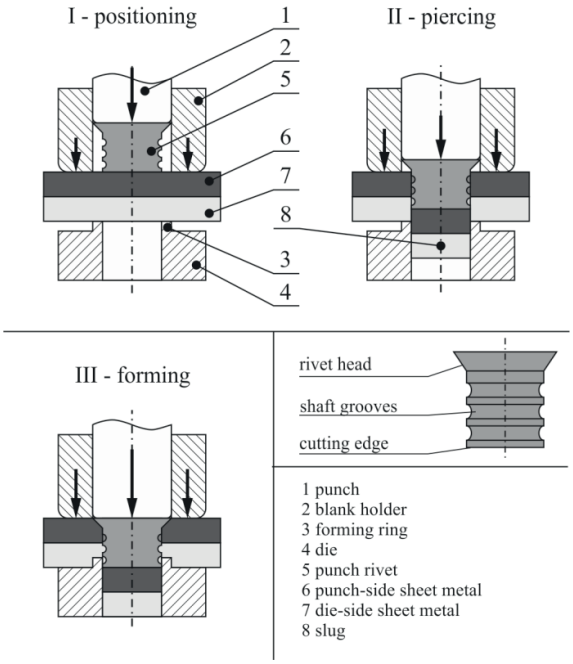

Fig. 1. Process steps – SPR-SR (schematic).

2.2. Limitations in joining of high-strength steels with aluminum sheets

In the first step of the process, the sheets to be connected are pierced by the rivet as described, whereby the rivet functions as a punch. The necessary cutting force is transmitted on the projection of the die on the lower piece of sheet metal. This is the reason why there might be an indentation of the elevation on the die in the die-side sheet metal even before piercing the holes in the components, if there is a high level of piercing force caused by a high level of material strength in the steel sheet. Consequently, there is no possibility in the third process step to press a sufficiently large material volume into the rivet groove. This might be the cause for poor quality of the joint as there is insufficient interlock between rivet and die-side sheet.

Furthermore, small circular blanks, so called slugs, are separated from the workpieces in the piercing process. These slugs are discharged through the hole in the die. Sometimes, the upper slug has a larger diameter than the hole in the die, due to an improper piercing process of the high-strength steel sheets (Fig. 2, I). The projecting burr is then sheared off on the cutting edge of the die while discharging these parts (Fig. 2, II) and is formed into the area of the rivet shaft groove in the further process routine (Fig. 2, III).

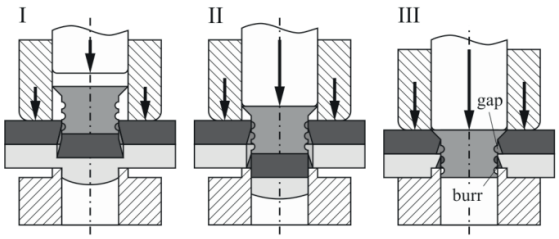

Fig. 2. Formation of burr in SPR-SR (schematic).

The process described produces joints at an unacceptable level of quality. Finally, the partially conic sheared edge can produce an undesired gap between the rivet and the punch-side sheet metal. This gap can impair the strength properties and corrosion resistance of the rivet connection.

2.3. Test setup for piercing and joining experiments

The results presented in this article were produced with a high speed joining machine using a pneumatic actuator (Fig. 3). The structure of the machine is based on a four-column frame. The drive consists of an impact cylinder and an impact weight, which is mounted on the piston rod of the cylinder. The impact weight impacts on the guided punch, which pierces the rivet into the sheets.

This joining machine reaches impact speeds between the impact weight and the punch up to 15 m/s. However, the impact speed can be regulated by a precision pressure regulator system. The upper part of the machine can be lifted and lowered for inserting the joining elements or workpieces and for the replacement of the punches by pneumatic cylinders.

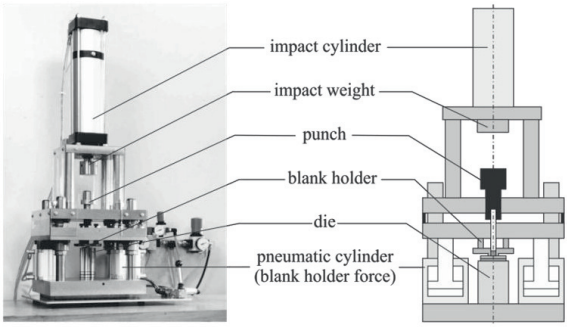

Fig. 3. Structure of the pneumatic high speed joining machine.

As described in section 2.2, there are some problems when joining high and ultra-high-strength steels with SPR-SR process caused by the material behavior during the cutting of the sheets. To analyze the piercing step in SPR-SR process