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Fatigue Behaviour of Aluminium Tube Crimp Connections Applying the Electromagnetic Pulse Technology

K. Lipp[a] *, R. Schaefer[b], D. Horwatitsch[c]

[a]*Fraunhofer LBF, Bartningstr. 47, 64289 Darmstadt, Germany*
[b]*PSTproducts GmbH, Junkerstr. 1, 63755 Alzenau, Germany*
[c]*LKR Leichtmetallkompetenzzentrum Ranshofen GmbH, Lamprechtshausenerstr. 61, 5282 Ranshofen-Braunau, Austria*

Abstract

During a still running European Project the feasibility of vehicle light weighting technologies for the manufacturing of light urban electric vehicles with new standards of mechanical performance will be demonstrated. One of the innovative technologies of the project, the Electromagnetic Pulse Technology (EMPT), which is a high speed crimping method, will be applied for joining of particular structural parts of the body, especially to join different lightweight materials such as Al- or Mg-tubes and Al- and Mg-cast or forged nodes.
Current heat-intensive joining processes are faced with a number of drawbacks and “cold” classical adhesive techniques require cost-intensive preparation methods plus long curing times and show design uncertainties in terms of mechanical strength. Hence, joining of dissimilar materials is presently not widely used.
The Electromagnetic Pulse Technology (EMPT) is an innovative approach for joining particular structural parts, where different lightweight materials can be joined without any significant heat input by a fast process. Therefore, this technology is determined as a high efficiency joining process from the quality and the energetic point of view, with virtually no loss of energy in form of heat.
Presently, no design relevant characteristic values of such joints, neither endurable stress amplitudes (fatigue) nor stiffness behaviour of the connection during cyclic loading, are available. Hence, the reliability of such EMPT joints has to be validated with regard to fatigue and stiffness behaviour in order to guarantee a durable connection under typical service loading conditions.
This paper will present first fatigue testing results for aluminium tube joints of EN AW-6082-T6 with a diameter of 40mm. Within this investigation the endurable strength and stiffness behaviour of EMPT joints will be determined in order to validate the performance of the Electromagnetic Pulse Technology for reliable applications under cyclic loading for e. g. urban electric vehicles.

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Keywords: Aluminium; Fatigue; Crimp joint; stiffness; EMPT

1. Introduction

The project URBAN-EV aims to demonstrate the feasibility of light weighting technologies for the manufacturing of light urban electric vehicles with new standards of mechanical performance and occupant safety. The target is placed in a two seats car, with a targeted final weight of maximum 450 Kg (excluding rechargeable energy storage system).In order to achieve this goal, the URBAN-EV consortium will design, manufacture and demonstrate new lighter architectures with enhanced engineering reliability for the principal systems of the vehicle such as chassis and body in white. Most of the applied materials will be light

* Corresponding author. Tel.: +49-6151-705243; fax: +49-6151-705214.
E-mail address: klaus.lipp@lbf.fraunhofer.de

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alloys and low cost, high integrity polymeric composites, which will be combined using an advanced multi-material design approach.

Current heat-intensive joining processes (arc welding, uncontrolled resistance spot welding) are faced with a number of disadvantages, such as need for using gases and filter wire, the generation of a heat affected zone, usually rich in brittle intermetallics as far as metals are concerned, and a relatively low productivity. On the other hand, "cold" classical adhesive techniques require cost-intensive preparation methods plus long curing times, and show uncertainties in terms of mechanical strength. Mechanical fastening, in turn, is inherently faced with the stress concentration around the joint and will be increased by joining dissimilar materials (especially when metals are concerned). In consequence heat-intensive methods will be reduced to the minimum extent possible within the URBAN-EV project.

Hence, the Electromagnetic Pulse Technology (EMPT) will be applied for joining of the particular structural parts of the body. The reliability of the EMPT joints has to be validated with regard to stiffness and fatigue behavior in order to guarantee a durable connection under service conditions. Despite multiple and various applications applying the EMPT joining technique were approved by end users, no design relevant data are available due to confidentiality reasons.

Therefore, a coupon test program has been defined in order to generate fundamental data on manufacturability, stiffness, strength and fatigue of EMPT joints. The present paper presents first results under constant amplitude axial loading.

2. 2 Electro Magnetic Puls Technology

The electromagnetic pulse technology (EMPT) basically consists in deforming one of the components to be joined by means of the induction of high electrical currents in it, Figure 1 [1]. The deformed component then replicates the shape of the counter-part, creating a strong link just by a crimpling effect [2, 3]. In special chances, particularly in sheet metal joining, the technology can be tailored in order to have an additional 'welding effect'. EMPT is suited to join tubular profiles of any cross sectional area (not necessarily circular) as well as sheets.

The technology is of purely cold nature (the assembly, once formed can seemingly gripped by hand), which totally eliminates the problems associated to heat affected areas (stress concentration, material inhomogeneity, distortion). EMPT doesn't require any auxiliary material, such as gases or filler wires; it is clean (no fumes and residues are generated) and fast (the weld is produced in microseconds). On the other hand, the contactless character of the process allows to create a more uniform crimpling pressure with constant quality and no tool marks inherent to mechanical processes. The EMPT technology is especially suited for dissimilar materials joining (metal to metal or polymeric based material to metal), as it involves no chemical or metallurgical transformation.

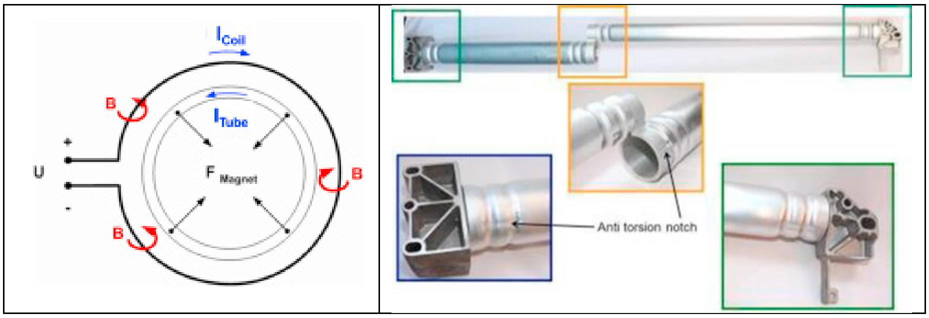

Figure 1: left: process fundamentals: by means of a high coil current pulse (Icoil), a high magnetic pulse (B) is generated, which induces electric current in the part (tube) causes a deformation by means of magnetic forces; right: examples applying EMPT technology

3. Design, materials and manufacturing of the coupons

The coupon test program has been defined applying geometry, quality and choice of materials similar to the vehicle design. The test samples need to be manufactured at the lab facility of PSTproducts in Alzenau/Germany. Respective materials have to be provided according to the design specification by LKR/AIT in Austria. Upfront the testing program the joint design and joint strength as well as the related crimping parameters were simulated in computer model and calculated by means of a Finite Element Analyzes (FEA) model. Then based on the simulation investigation of the FEA the test environment for the crimping procedure was defined.