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Joining of tubes by internal mechanical locking

L.M. Alves, C.M.A. Silva, P.A.F. Martins*

IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

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ABSTRACT

This paper presents an innovative plastic deformation process for connecting two tubes by their ends. The connection is done by internal mechanical locking at room temperature and is capable of ensuring uniformity of the outer diameters of the two tubes to be joined. The range of applicability is complementary to mechanical joining based on fasteners or plastic deformation by crimping or local instability, which are known to compromise the overall appearance and aesthetics of the resulting applications and products. The presentation identifies the major process parameters and investigates their influence on the deformation mechanics and joining feasibility. The force requirements to produce the new type of joint and to detach the tubes by application of tensile loading are also analysed by means of experimentation and finite element modelling. Selected examples give support to the presentation.

1. Introduction

The selection of a joining process to connect two tubes by their ends results from the interaction between technological and economic requirements. The technological requirements include (i) the functional constraints associated to the working conditions, (ii) the spatial constrains related to the size, weight and geometry and (iii) the technical constraints imposed by the material type, operating temperature and environmental conditions. The economic requirements include the availability, ease of implementation, cost and production rate.

The currently available joining processes that satisfy the above mentioned requirements at least partially, may be classified into three main categories: (i) welding and brazing (ASM, 2011), (ii) adhesive bonding (Albiez et al., 2012) and (iii) mechanical joining based on fasteners (Parmley, 1996) or plastic deformation (Mori et al., 2013). Fig. 1 presents a summary of the most well-known types of end-to-end tube joints belonging to the above three main categories.

In a previous paper, Alves et al. (2014) performed a comprehensive analysis of the advantages and disadvantages of the three different categories of joining processes that are commonly used to connect two tubes by their ends. Their conclusions are summarized in Table 1 and stimulated the development of the new mechanical joint that is shown in Fig. 2a.

The working principle of the joint shown in Fig. 2a is based on a locking mechanism built upon the development and simultaneous propagation of plastic instability waves in the two tubes to be joined. As seen, and in contrast to existing mechanical joints based on fasteners (Fig. 1c – left), the joint proposed by Alves et al. (2014) is simple, effective, and accomplished without the need of adding materials and connecting elements. The joint also presents advantages against alternative solutions based on plastically formed joints produced by electromagnetic forming (Psyk et al., 2011; refer to Fig. 1c – right) derived from the availability and cost of the equipment, and from its material range of applicability.

Thus, because mechanical joints are generally based on fasteners it may be concluded that they generally suffer from non-uniformity appearance (size and volume). This problem is most of the times ignored in case of applications in air-conditioning, refrigeration, heat-exchangers, supply lines and pipelines to convey fluids from one location to another because the critical requirement is to ensure that the inner diameter of the tube joint is identical to that of the tubes in order to prevent changes in flow and pressure drops.

However, there are applications belonging to architecture, engineering and building construction in which the outer appearance and aesthetics of tubular frames is more important than the uniformity of its inner diameters. This is the case, for example, of tubular frames in direct contact with human hands such as tubular stair handrails, tubular frames of gymnastic equipment and children's playgrounds, among other applications. In practical terms, this means that the functional and spatial constraints of the joints applied in architecture, engineering and building construction may change in such a way that the utilization of a mechanical joint

* Corresponding author.
E-mail addresses: luisalves@ist.utl.pt (L.M. Alves), carlos.alves.silva@ist.utl.pt (C.M.A. Silva), pmartins@ist.utl.pt (P.A.F. Martins).

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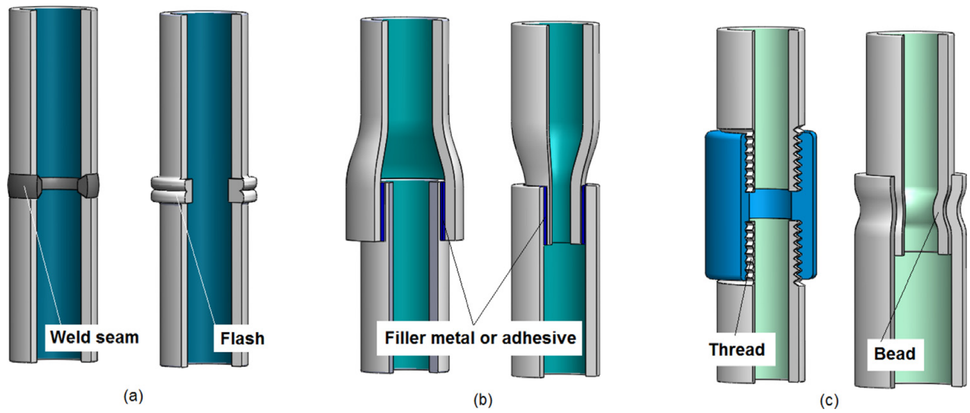

Fig. 1. Different types of joints utilized to connect two tubes by their ends: (a) welded joints, (b) brazed and adhesive bonded joints and (c) mechanical fastened and plastically formed joints.

Table 1
A brief comparison of the three different categories of processes utilized in the end-to-end joining of tubes.

	Welded or Brazed	Adhesive Bonded	Mechanical
Simplicity			
Availability	⇕	⇩	⇧
Assembly and disassembly	⇩	⇕	⇧
Durability			
Temperature	⇧	⇩	⇧
Environmental conditions	⇕	⇩	⇧
Uniformity			
Appearance/Geometry	⇕	⇧	⇩
Tightness	⇧	⇧	⇕
Applicability			
Dissimilar materials	⇩	⇧	⇧
Production rate and cost	⇕	⇩	⇧

Note: The arrows indicate tendencies to high (⇧), intermediate (⇕) and low (⇩).

Fig. 2. Connection of two tubes by their ends by means of innovative mechanical joints produced by forming.
(a) 'External' joint based on a locking mechanism that is formed by the development and propagation of plastic instability waves (Alves et al., 2014);
(b) 'Internal' (hidden) joint based on a locking mechanism that will be presented in this paper.