Polymer joining techniques - a state of the art review

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ADVANCED JOINING PROCESSES UNIT

Introduction

The automotive, electronics and medical industries have expanded the use of equipment made with engineering polymers, using advanced joining techniques to allow for complex designs, high rigidity and low cost [1]. In this way, a review work has carried out to highlight and understand the main experimental and numerical research work carried on the main structural joining techniques of engineering polymers, reporting the relative advantages of each technique and the most important future trends.

Engineering polymers and their uses

The main industrial applications of engineering polymers are for structural purposes and load bearing purposes (Table 1). The allow for high strength/weight ratio when applied with fibres, the manufacture of complex parts and can offer special thermal properties.

Table 1 – Main areas and specific application of polymers.

Main areas[1]	Specific application
Aerospace	Airframe structures
Automotive	Headlights, panels, chassis
Biomedicine	Prosthetics
Packaging and food sustainability	Food and drug packaging
Others	Eletronics, ballistic protection and others

According to Fink [2], when it comes to structural joining processes the main polymeric substrates are Epoxy, Polyurethane, Polyethylene, Acrylic, Polyamide 6 and Polybutylene Terephthalate and others.

Polymer joining techniques

The techniques used for joining polymers are diverse. They are usually classified according to their operation principle [3]:

- Thermal;
- Friction;
- Electromagnetic.

For structural joints, Figure 1 illustrates the main processes which currently find extensive industrial use.

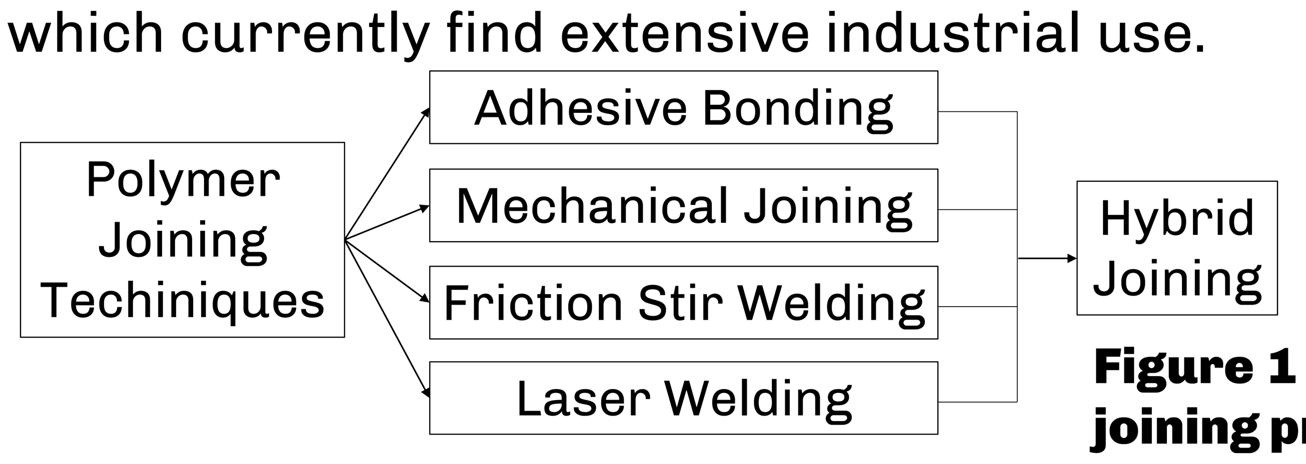

Figure 1 – Main polymer joining processes.

Adhesive Bonding

The adhesive bonding technique (Figure 2) is a highly flexible and powerful technique, which has recently gained importance due to advances in chemical synthesis of adhesives, surface preparation and joint modelling [1].

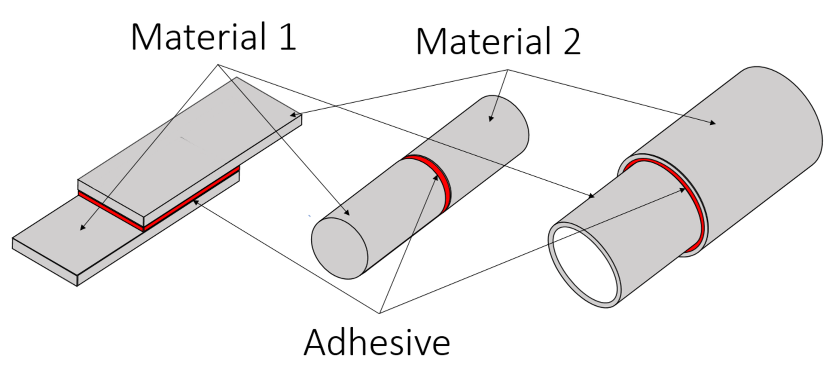

Figure 2 – Adhesive joints in single lap shear joint (SLJ), tube butt joint and tube lap shear joint.

Mechanical Joining

Mechanical joining (Fig. 3) of polymers can be attained with the interlocking via plastic deformation or the use of fasteners to induce a closing force. It creates significant stress concentration of the soft polymer material, but it is a very inexpensive and practical process [4].

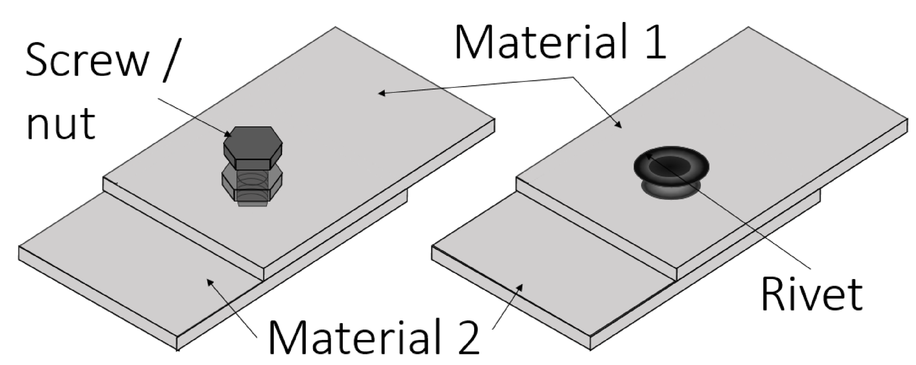

Figure 3 – Mechanical joints (general). By fastener and rivet-mounted SLJ.

Friction Stir Welding

The friction stir welding of polymers (FSW) (Fig. 4) is performed by plastic deformation of heat softened material, achieved with the use of a rotating pin and joint. Although complex to implement and limited to flat surfaces, it is flexible enough to join dissimilar materials [5].

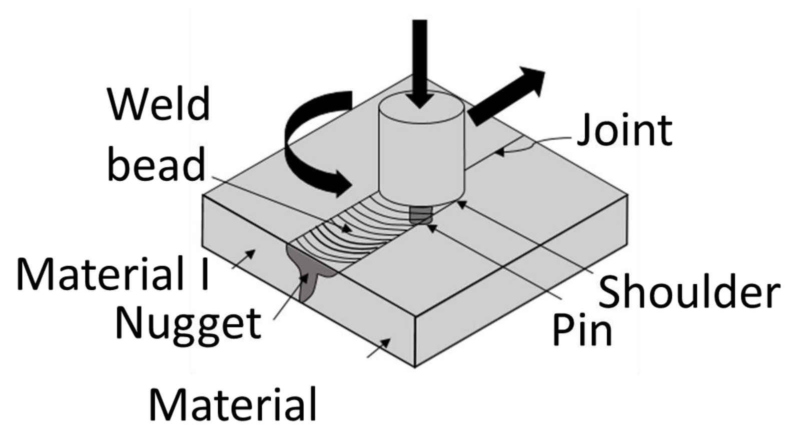

Figure 4 –Friction stir welding process.

Laser Welding

Laser welding (Fig. 5) is based on a continuous or pulsed beam of light with a wavelength in the order of nanometers in which on contact with the medium it excites the atoms generating heat, melting the material.

- Similar materials (absorbent mode) (Fig. 5a);
- Dissimilar materials (transparent + absorbent) (Fig. 5b);
- Similar materials (transparent + absorbent coating) (Fig 5c);

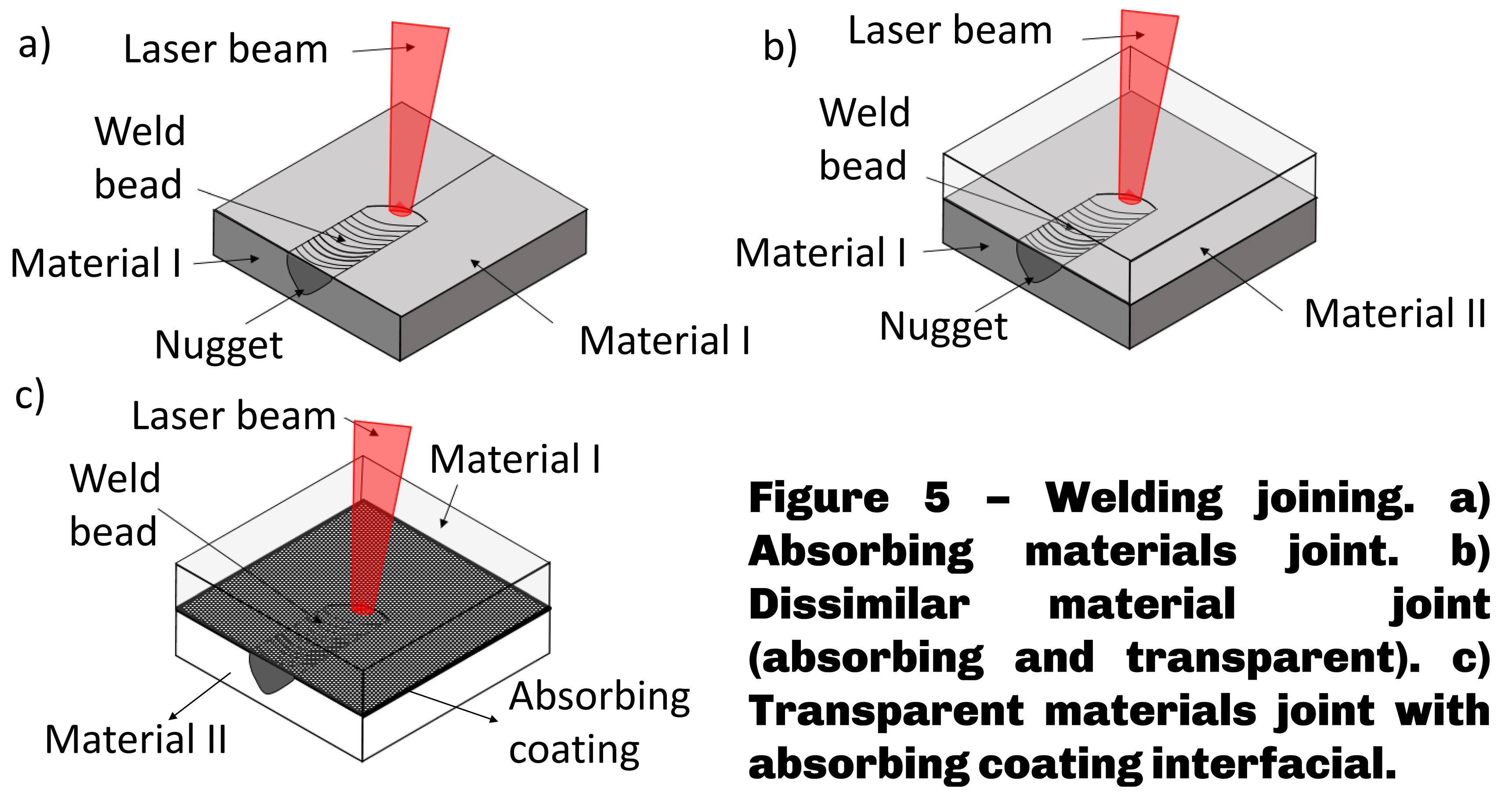

Figure 5 – Welding joining. a) Absorbing materials joint. b) Dissimilar material joint (absorbing and transparent). c) Transparent materials joint with absorbing coating interfacial.

Hybrid joining techniques

The techniques of adhesive bonding, mechanical joining, friction welding and laser welding are all suitable for these applications, with different relative advantages and suitability for specific applications. However, current research trends focus on the design of hybrid joints, which improve performance due to process synergy. These include:

- Laser assisted adhesive bonding, optimising the curing of the adhesive and increasing the joint strength;
- Use of FSW laser-assisted bonding in pre- and post-heating of the material, reducing the power or optimising the efficiency of the joint;
- The use of laser welding in mechanical fixation assistance, aiming at joint tightness;
- Optimization of hybrid joining processes in polymers and other materials.

References

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