BONDING OF THERMOPLASTIC MATERIAL – A LITERATURE REVIEW

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Abstract - *The paper provides a general information related to Fusion bonding or welding of Thermoplastic materials along with various processes carried out for bonding. The various welding techniques and the corresponding manufacturing methodologies, the required equipment, the effects of processing parameters on weld performance and quality, In many welding process techniques are applying we can join thermoplastics material Joining of thermoplastic composites is an important step in the manufacturing of aerospace thermoplastic composite structures. Joining of thermoplastic composites can be categorized into mechanical fastening, adhesive bonding, solvent bonding, co-consolidation, and fusion bonding or welding. Fusion bonding or welding has great potential for the joining, assembly, and repair of thermoplastic composite components. The process of fusion-bonding involves heating and melting the polymer on the bond surfaces of the components. The bonding formation for the carbon fibre reinforced composites is mainly through the polymer-polymer interface healing which involved carbon fibre as reinforcement.*

Key Words: Fusion bonding, Welding processes, Thermoplastics, Carbon fibre reinforced plastic, Testing procedures.

1. INTRODUCTION

THERMOPLASTIC MATERIAL

Polymer composites are composed of a polymer matrix material (thermoplastic or thermosets) with organic or inorganic fillers (Figure) like mineral pigments, short fibers, long fibers, continuous fibers, paper or fabrics to enhance the mechanical properties for special applications. Particles like mineral powder, wood flour or carbon black are used to increase the stiffness of the matrix material. The fatigue strength of the matrix material usually will be not increased, but is sometimes decreased.

Continuous fibers from glass, carbon or aramid will influence the mechanical properties of the polymer compound by the adjustable orientation of the fibers. Besides increasing fatigue strength and stiffness the temperature-dependent expansion of the compound can also be decreased.

Polymer compounds with thermoplastic matrix usually can be melted by thermal processes like welding, but not polymer compounds with thermoset matrix. [wiley 2011]

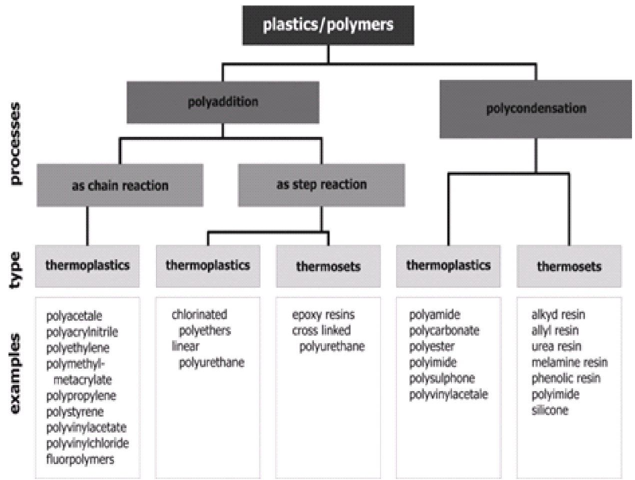

Figure 1: Process for generating Plastics and Examples [2011 Wiley-VCH Velar et al.]

1.1 WHAT IS CFRP ?

Carbon fiber reinforced polymer (CFRP) is one of the most important materials for structural applications, particularly in aviation industries owing to its high strength to weight ratio. CFRP contains extremely thin carbon fibers (CFs) of about 0.005- 0.010 mm in diameter in polymeric matrices leading to light weight composite structures. At a microscopic scaled level, carbon atoms of fibers are bonded together parallel to the fiber axis, and thus give rise to the unidirectional alignment, which in turn contributes to superior tensile strength along with light-weight structures and low thermal-expansion.

In most real-life applications, CFRP requires joining with metal frames to form complete structures, which play an important role in hybrid design. Hybrid design is an emerging process of joining composites and metals with desirable and unique material characteristics such as higher strength and stiffness, resistance to physical damage due to cracks, resistance to radiation damage, design versatility etc. [Johnson, 2014].

2. BONDING OF THERMOPLASTIC MATERIAL

Due to the high strength and specific stiffness, density and small thermal expansion coefficient, and good dimensional stability, composite material especially carbon fiber reinforced polymer (CFRP) composite becomes one of the most important construction materials in civil aircraft engineering [1]. On the other hand, compared to the metal, CFRP composite displays poor impact resistance and low strength between surface layers and substrate which lead to the difficulty in assembly connection of the structure and high technical requirements.[2]There are many processes are welded to thermoplastics material.

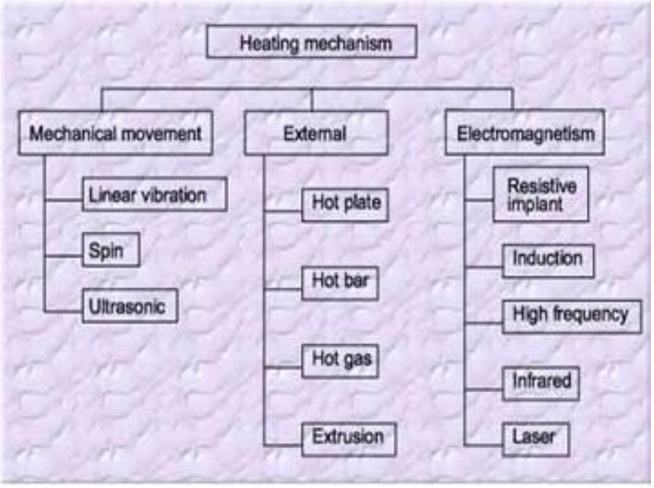

Figure 2: Welding processes for thermoplastics.

1. Stud Welding- An alternative to staking is ultrasonic stud welding. This process can be used to join plastic parts of similar material at single or multiple localized attachment points. Thus, the technique is useful in applications that do not require a continuous weld. Stud welding can be used when resin selection, size, or part complexity prevent the use of other techniques. A variation of the shear joint is used in stud welding.

2. Insertion- Insertion is the assembly process of embedding a metal component in a thermoplastic part. A hole is pre-molded into the thermoplastic part slightly smaller than the O.D. of the insert it is to receive. As ultrasonic energy is applied to the insert, frictional heat is generated due to the insert vibrating against the plastic. The plastic melts, permitting the insert to be driven into place. The insert is surrounded by molten plastic, which flows around the knurls, flutes, and undercuts on the O.D. of the insert. Total process time is usually less than one second.

3. Swaging and Forming - Swaging is the process of capturing another component of an assembly by melting and reforming a ridge of plastic (usually the outside wall). It is a method of assembling two materials without creating a molecular bond. The material that is swaged is always thermoplastic. The material of part that is captured is typically a dissimilar material, such as glass. Forming is the process of physically changing the shape of a plastic part.

4. Spot Welding - Ultrasonic spot welding joins two like thermoplastic components at localized points with no pre-formed hole or energy director. It produces a strong weld and lends itself to large parts, sheets of extruded or cast thermoplastic, and parts with complicated geometry and/or hard-to- reach surfaces. Spot welding is often used on vacuum-formed parts, such as blister (clamshell) packaging. Most thermoplastics can be spot welded. In spot welding, a specially designed spot welding tip melts through the top thermoplastic layer and part way into the second layer. The weld occurs at the interface between the two sheets.

5. Hot Plate Welding - Hot plate welding is one of the simplest welding techniques making it highly reliable and common place in industry. The process works by bringing the faying surfaces to be joined in contact with a heated tool. The tool can have relatively complex geometries to allow the welding of complex interfaces. In addition, the tool is often coated with a non-stick material (often PTFE, product name: Teflon) to act as a release agent. In the initial phase (matching phase), pressure is applied to promote squeeze flow of the faying surfaces to assure that the faying surfaces are well defined and all part irregularities are removed. Once sufficient matching displacement is achieved, the pressure is removed by mechanical stops or pressure regulators, so that a relatively thick melt layer is developed. After a pre-selected heating time, the parts are retracted from the tool, the tool is quickly displaced away from the parts and the parts are brought together to allow the two molten interfaces to weld.

6. Laser/IR Welding - While laser welding of plastics has been reported as far back at the late 1960, it has only become popular in the last decade, primarily due to the significant reduction in cost for laser energy. The current market prices for lasers is less than 10 $/W, compared to 1000 $/W just a decade ago. There are two basic modes of IR/laser-welding

1. Surface-heating.

2. Through Transmission Infrared (TTIR) welding.

While much less common surface heating can be used to weld subassemblies. Surface heating is very similar to heated tool (plate) welding as shown in Fig. The surfaces of the components to be joined are heated by direct IR/laser exposure for a sufficient length of time to produce a molten layer, usually for 2 to 10 s. Once the surface is fully melted, the IR/laser tool is withdrawn from between the parts, the parts are forged together, and the melt is allowed to solidify. The heating source must be continuous thus either the laser/IR source must be achieved through continuous illumination or high speed scanning. That is to say, because surface heating relies on residual heat and melting at the faying surfaces, slow-speed scanning is not possible.

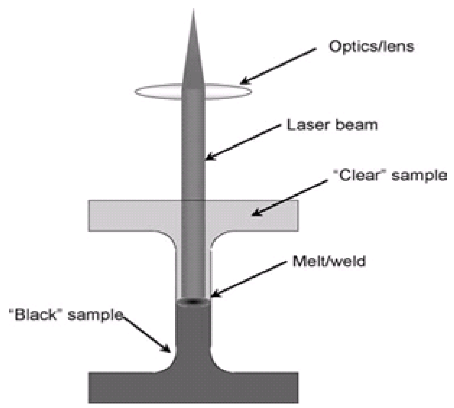

Figure 3: TTIR welding of plastics

3. CRITICAL ANALYSIS

1. Tensile-tests

The tensile test is probably the most common method used to determine weld quality. There are several variations on the tensile test that may be applied, depending on factors such as the quality of the weld and the form of the material to be tested.

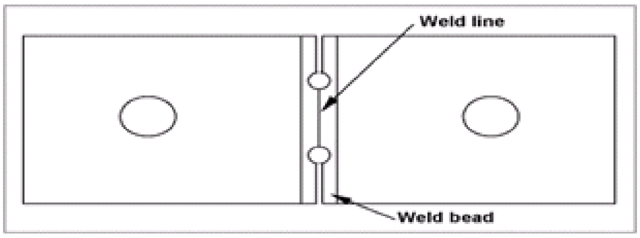

Figure 4: Tensile welded joints(BS EN 12814-2)

2. Peel-test

Peel tests for materials that are joined using some form of overlap joint, such as EF joints, are described in BS EN 12814-4. The specimen is pulled perpendicular to the weld until complete separation occurs. Analysis of the fracture surfaces provides qualitative information about the joint integrity. Ductile yielding, with signs of stress whitening and drawn material between the wires indicates a good quality weld. Smooth fracture surfaces indicate a weak brittle failure, characteristic of a poor quality weld.

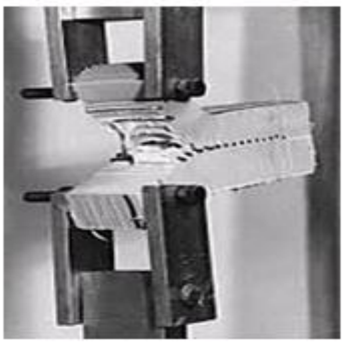

Figure 5: Peel Test test BS EN 12814-4

3. Hydrostatic-pressure-tests

Hydrostatic pressure tests can be used to determine the time to failure of plastic pipes under constant internal pressure, following test methods such as ASTM D1598 and ISO 1167. Data obtained for a range of internal pressures, giving a pipe lives over two or more logarithmic decades, can be analysed using regression methods.it should Noted that although these tests can be applied to welded pipes, since the circumferential stress in this test is twice the axial stress, failure will normally occur in the parent pipe away from the weld. This may not be the case for in-service welded pipes, which may fail at the weld, due to a combination of internal pressure and external loading. Consequently, this test method is not recommended to determine the long-term performance of welded joints in plastic pipes.

4. REVIEW METHODOLOGY

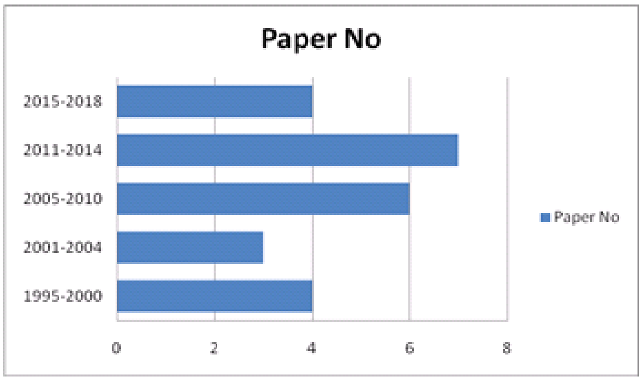

Figure 6: Year wise research paper

In this review methodology there are most thermoplastics material paper in year 2011-14 published to many journals. Then, second number in year 2005-10 most useful thermoplastic paper are read to different journals and many authors are study for different thermoplastics material. In review methodology there are many paper are published to international journal of engineering research and technology (IJERT) in year 2001-2004.

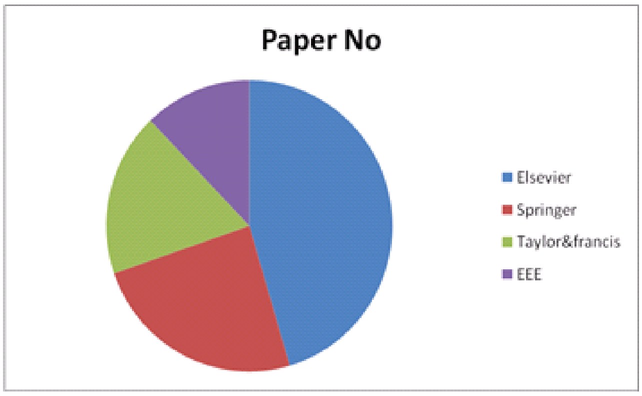

Figure 7: Journal name and paper no of each journal.

5. DISCUSSION

In study of literature review there are many paper of different journals in the show to figure of review methodology to classified journal wise.

The Fernandez Villages are most study to carbon fiber and polyphenylene sulfide (CF/PPS) thermoplastic material in Taylor & Francis journals. Fernandez Villages are used to Ultrasonic welding process to joining of CF/PPS thermoplastic material to study for A comparative evaluation between flat and traditional energy directors (ED).

In the literature review, Frank balle are study to Carbon fiber reinforce polymer (CFRP) material joining to other thermoplastics material and metal joining with CFRP material using different joining method like spot welding, Ultrasonic welding etc. Frank balle was study of The non heat treatable aluminum wrought alloy (AA5754) was ultrasonically welded onto the carbon fiber reinforced thermoplastic composite made of polyamide 66(CF-PA66) Elsevier- journals 3.

Avraham benatar, Raman V. eswaran et al. are used to in the near-field Ultrasonic welding of amorphous (acrylonitrile-butadiene-styrene and polystyrene) and semicrystalline (polyethylene and polypropylene) polymers. High frequency ultrasonic wave propagation and attenuation measurements were made in order to estimate the dynamic mechanical module of the polymers. 4. M.Hou, L.Ye, et al. are Study of Carbon Fiber Fabric Reinforced Polyetherimide (CF Fabric/PEI) Composite Material using to Resistance Welding. An optimum processing window was proposed for the resistance welding of CF Fabric/PEI composite.

6. CONCLUSION

In literature review this paper there are study of Ultrasonic welding of thermoplastic material.

There are using of many different types of techniques to welding of thermoplastic material like spot welding, hot plate welding, friction welding, laser/IR welding, extrusion weldin-etc.

It can be used for adhesive bonding techniques to easily welded to thermoplastic to metal joining.

There are welding of thermoplastic material they can used many test for thermoplastic material like Tensile test, Izod impact test, peel test, Hydrostatic pressure tests, flexural test, energy test etc.

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