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Recent Trend in Joining of Metal to Polymer- A Review

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Abstract - The metal-polymer hybrid system is widely used in automobile and aviation sector due to its lightweight characteristics. Besides, it has many advantages such as noise reduction and damping. Inclusion of these system improve the fuel economy, which eventually results in dramatic reduction of carbon footprint. One of the important metal-polymer hybrid system is sandwich panels. These are used as structural members by the transportation industries. Joining of polymers to metals is always a challenge because of their large property difference. Traditional joining methods are not recommended practice in sandwich sheet joining. Till now, many attempts are made to join polymers to metals. This paper highlights various difficulties and defects in joining of polymer to metals. Moreover, effect of process variables is also discussed in detail. The main objective of this review is to find out an efficient process for joining of metal-polymer composite and to establish a systematic approach of improving the quality of joints in sandwich sheets.

Key Words: Metal-polymer hybrids, Sandwich sheets, Joining, Welding.

1. INTRODUCTION

From the beginning of human civilization, joining of different materials has been practicing throughout the globe. Since then, many developments have been witnessed in joining technology. In this journey, joining of a large variety of materials has been attempted. These include joining of similar materials such as metal to metal, polymer to polymer etc. in broad sense. Later, joining of dissimilar material evolved due to introduction of metal-polymer hybrid system. The metal-polymer hybrid system has been recognized as light weight system in automobile and aviation industries. It is mainly used as the outer body parts of the automobiles. Joining of polymer to metal is always problematic due to large difference in their properties. Previously many researchers have attempted to join plastic to metal and polymer metal hybrid system.

2. Joining of Metal to plastic

The joining of metal to plastic is attempted by many researchers in the past. Katayama and Kawahito, (2008) have developed a laser direct joining process to make joints between a 304 stainless steel plate and a polyethylene terephthalate (PET) in lap configuration. Several tests are conducted to check the quality of the made joint. Acceptable joint strength is achieved and a strong joint between metal and plastic at atomic level is seen in the Transmission Electron Microscope (TEM) images [1]. Balle et al. (2007) have attempted to join carbon fiber-reinforced polymer (CFRP) to aluminium by ultrasonic spot welding. The joint produced has shown promising properties evident by tensile test. The fractography also shows development of good bonding between metallic material and the carbon fibers [2]. However, the process is only applicable for joining of small parts because ultrasonic welding is suitable for spot joining. Amancio, (2007) has attempted friction riveting technique for joining of metal to polymer. In this process, the joining between polymer and metal is achieved by a metallic rivet. The bonding is caused by mechanical interference between polymer and metal [3]. Filho and Santos, (2009) have highlighted various reasons of difficulties in joining of metal to plastic. One of the reason the low solubility of polymer in the metal. Further, the heat required to melt the polymer is much lesser than that of the metal. It is also reported that there are other techniques of joining the metal-polymer such as mechanical fastening, riveting, adhesive bonding are other joining methods [4]. However, these processes need additional process and materials. For instance, the mechanical fastening requires the requirement of additional consumable materials and surface preparation of parts are the drawbacks of these processes. The metal to polymer joining procedures attempted by other researchers is summarized in Table 1.

Table -1: Various joining methods of metal to polymers

Authors	Joining method adopted
Liu et al. (2014) [5]	Friction lap welding
Wang et al. (2021) [6]	Injection molding
Mongan et al. (2021) [7]	Ultrasonic welding
Kah et al. (2014) [8]	Mechanical fastening, Adhesive joining

3. Joining of Metal – Plastic hybrid system

After developing many procedures to join metal to plastic, several attempts are made for joining of metal-polymer hybrid systems as well. In this context, Rana et. al. (2021) has applied Friction Stir Spot Welding (FSSW) of sandwich sheets made of AA5052-H32 skins and HDPE core. The effect of dwell time is studied in this article and a thorough investigation is done to check the quality of the joint. It is found that at some optimum range of dwell time, better joint strength is achieved by larger bond width and finer microstructure [9]. Salonitis et al. (2010) have investigated the leaser welding of metal-polymer sandwich sheets in butt configuration by using finite element modelling. Since the thickness of the sandwich sheets are relatively larger, sufficient heat is required to join the upper and lower sheets. It is observed that while trying to join upper and lower skin of the sandwich sheets, the polymer layer gets degraded due to localized evaporation. This degradation of polymer layer results in loss of damping properties of the sandwich sheets. In order to avoid it, the laser welding with lower heat input is attempted both sides [10]. The comparative diagram of single-

side and both-side approach is schematically shown in Figure 1.

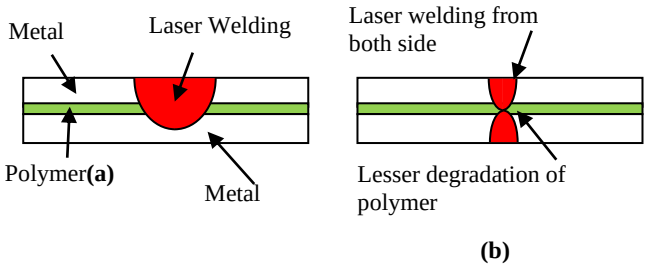

Fig -1: Laser welding of sandwich sheets: (a) single side approach, (b) double-side approach

Pickin et al. (2007) attempted to join polymer core sandwich sheets known as Hylite by self-pierce riveting (SPR). The SPR is an effective way to join two or more sheets in lap configuration. In this process, a mechanical interlock is produced between overlapping sheets by forcing a tubular rivet into it and deformed within an upsetting die. Successful joints have been produced with considerable mechanical strength. It is observed that during SPR, the rivet tries to comes out of the sheet due to spring-back in the polymer and metallic sheets. This results in the formation of a cavity beneath the rivet tail, which is known as substrate defect. Further, larger deformation beneath the rivet head occurs due to interlocking between the upper and lower sheets. This further results in non-uniform deformation in the upper metallic sheet [11].

4. CONCLUSIONS

The metal-polymer joining is different than the joining of metal-metal or polymer-polymer, because there is a large difference in the properties of metal and powder. Large number of research work have been carried out till now to develop and effective method to join metal to polymer or metal polymer hybrid systems. In this context, the joining method used are ultrasonic welding, laser welding, adhesive bonding, mechanical fastening, self-pierced riveting, friction stir welding, etc. Some of these are successfully adopted in industries and more extensive investigation is needed to establish a robust joining technique for metal-polymer system.

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BIOGRAPHIES

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