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FABRICATION OF ALUMINUM MATRIX COMPOSITES FOR AUTOMOTIVE INDUSTRY VIA FRICTION STIR PROCESSING TECHNIQUE – A REVIEW

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Abstract: Materials with strong corrosion resistance, superior wear resistance, and high strength-to-weight ratios are significant in the automobile sector. Aluminum, nickel, titanium, magnesium, and their alloys are the most commonly used materials in this branch of industry, depending on the desired qualities. Aluminum and its alloys have been significant during the production of MMCs. Aluminum matrix composite (AMC) has a wide range of applications in automobile industries, including mechanical parts such as pistons, engine cylinders, disc and drum brakes, engine connecting rods, and Cardan shafts. Friction Stir Processing (FSP) has become a popular method for creating surface composites on a variety of materials. Friction Stir Processing (FSP) is a unique approach evolved from the friction stir welding process, in which reinforcing particles are dispersed using a tool through a groove or hole in the matrix material. This paper attempts to review the current status of FSP position as a technology for surface modification and production of aluminum alloy surface composites in the automobile industry.

Key words: Friction Stir Processing (FSP), Aluminum matrix composite (AMC), automotive industry

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1 INTRODUCTION

Friction stir processing is a novel solid-state surface modification method used in surface engineering to develop composite surface layers and modify the microstructure and properties of engineered materials. FSW (friction stir welding) technology, which was developed by The Welding Institute (TWI) [3], is the source of FSP, which was created by Mishra et al. [1,2], and is based on the same principles as FSW. In the FSP method, the material is plasticized as a result of the heat produced by the friction of a unique, non-consumable tool against the surface of the altered material. The tool heats up the sample, which causes the plasticized material to move. During the FSP process, the combined actions of heat and pressure lead to changes in the microstructure and morphology of the phases [4–6]. The resulting microstructural effects in FSP technology depend not only on the shape and size of the tool but also on the rotating speed, travel speed, and tool tilt angle [7–9].

The automobile industry has always struggled with two of the biggest problems: how to make cars lighter while also enhancing passenger safety. The first goal is crucial for enhancing vehicle performance, including acceleration, top speed, and fuel consumption. In case of a collision, the latter is essential to protect passengers. It is typically challenging to develop a product while simultaneously taking into account both of these factors. Aluminum is one of the materials that provide adequate strength while being lightweight.

2 FRICTION STIR PROCESSING (FSP) CONCEPT

FSP has two main sides in the workpiece: The Advancing Side and Retreating Side [7,8]. In FSP, the side of the workpiece that is moving forward is the side in which the tool's traverse and rotation directions are identical. The retreating side, on the other hand, has distinct traverse and rotation directions. In FSP Tool with a pin and Tool without a pin are used. Clamping is used to secure the workpiece to the backing plates. Previously defined rotating speed is then applied to the tool, which is then lowered into the workpiece until the shoulder makes contact with the surface. Heat is produced by friction, which is created when the tool's shoulder makes contact with the workpiece [7-9]. As a result of friction, heat is generated in FSP, which helps the material move more easily from the advancing side to the retreating side of the workpiece. FSP produced heat is below the melting temperature of the workpiece and this state is known as the solid-state process [10]. The previously defined traverse speed is provided to tool after plunging, enabling it to move in the transverse direction [11,12]. By combining the reinforcement and the workpiece, this rotating and traversing motion creates surface composites. However, because of the swirling motion of the polished surface, FSP also aids in grain refinement, recrystallized grain structure, and intense plasticity of the workpiece [13]. The FSP working principle is shown in Fig. 1.

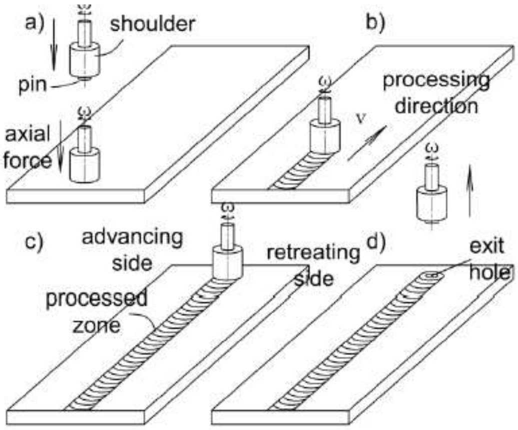

Figure 1. *FSP working principle [14]*

3 AUTOMOTIVE APPLICATIONS OF FSP

Materials with great corrosion resistance, good wear resistance, and high strength-to-weight ratios are crucial in the automobile industry. Aluminum, nickel, titanium, magnesium, and their alloys are primarily used in this industry based on the required qualities. Automotive parts built of Aluminum Matrix Composites (AMCs), which are produced by FSP, include engine cylinders, pistons, disc and drum brakes, engine connecting rods, and Cardan shafts.

3.1 Composites reinforced with Al_2O_3

Some proven applications of Al_2O_3 reinforced aluminium based composite in manufacturing industries are shown in Table 1. The impacts of friction stir processing (FSP) and friction stir vibration processing (FSVP) on the mechanical, wear, and corrosion parameters of the Al6061/SiO2 surface composite were studied by Barati, Abbasi, and Abedini (2019) [15]. SiO2 nanoparticles were used as the second phase particles in surface composites developed utilizing the FSP and FSVP procedures on the Al6061 alloy surface. The treated specimens' mechanical, wear, and corrosion characteristics were investigated. The experiments demonstrated that FSVP specimens had greater strength, ductility, and wear resistance than FSP specimens.

In a 2019 study, Titus Thankachan, Prakash, and Kavimani examined the effect of hybrid reinforcement particles on the microstructural, mechanical, and tribological characteristics of friction stir processed copper surface composites. According to the results, there was an increase in mechanical characteristics as particle dispersion increased. Due to the hardness and self-lubricating properties of the dispersed ceramic particles, an enormous increase in wear resistance was observed in regard to the increase in hybrid particle dispersion [16].

TiB_2 and B_4C ceramic reinforcement particles were added to the AA7005 alloy, which improved its ballistic resistance [17]. The surface composite was found to have a ballistic mass efficiency factor that was 1.6 times greater than the base alloy. Balakrishnan et al. produced cast aluminum matrix composites made of AA6061 and Al3Fe and then applied the friction stir technology. After FSP, the dislocation density significantly increased. Tensile strength and ductility were improved as a result of the microstructural modifications [18].

Table 1. *Some proven applications of Al_2O_3 reinforced aluminium based composite*

Manufacturer	Components
Toyota	Piston rings
Dupont	Connecting rods
Chrysler	Connecting rods
Honda	Engine blocks

3.2 Pistons

An explicit investigation is made into how FSP affects the microstructure, hardness, and mechanical characteristics of a piston alloy [19]. The as-cast eutectic LM13 aluminum alloy surface in the paper [20] was converted to a hypereutectic Al-Si alloy utilizing 5 µm Si particles via FSP, in an effort to better understand how tool geometry and process parameters affect particle distribution, microstructure, hardness, and strength. Adetunla and Akinlabi produced AMC's using multiple passes of friction stir processing (FSP) in order to enhance their corrosion performance and mechanical qualities. Ti-6Al-4V was chosen as the reinforcing particle while 7075 Al alloy was used as the matrix [21].

Fig.2 *Friction stir processed piston [22]*

4 CONCLUSIONS

A versatile method for creating matrix composites is FSP. The distinctive characteristics of this technique are the grain refinement attained by FSP and the solid state aspect of processing. The matrix composites have higher wear and corrosion resistance as well as high hardness. Ceramic particles and metallic particles are among the reinforcements that FSP has successfully introduced into metallic matrix. The manufacturing of matrix composites using FSP is a relatively new approach that provides easy particle dispersion. A literature review of aluminum matrix composites fabrication for automotive industry and the current state of understanding of FSP are discussed in this in this paper.

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