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Investigations on AWJ cutting process of hybrid aluminium 7075 metal matrix composites using nozzle oscillation technique

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ABSTRACT

Difficult-to-machine materials like composites, super alloys and ceramics are cut by Abrasive water jet cutting (AWJC). However, the failure of the jet to cut through the work piece is a major issue particularly in thicker materials. The jet's inability to produce longer smooth cut surface, minimum surface roughness and minimum kerf taper are the major challenges the researchers are trying to find solutions. This paper addresses the three issues in cutting of aluminum 7075 hybrid metal matrix composites. The hybrid composite is developed by incorporating two reinforcements (B_4C and TiC) into Aluminum matrix. Cutting experiments were carried out on Pure AL7075, AL7075 + (2.5%B4C + 2.5%TiC), AL7075 + (5%B4C + 5%TiC) AL7075 + (7.5%B4C + 7.5%TiC). The surface generated, smooth cut region and kerf taper were analyzed on the all composite machined using AWJC machine.

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1. Introduction

AWJC is one of the state of the art machining process progressively employed in different engineering applications such as in automobile, aerospace and construction industry. This advanced machining technology induces no thermal effects, causes minimal stresses on the work piece, is less sensitive to material properties and does not produce chatter as experienced in conventional machining process [1]. AWJC removes material by erosive action of abrasive particles by the action of high pressure abrasive water jet slurry on the work surface [2]. The material removal process for pure ductile and brittle materials in AWJC is observed to show similar mechanisms as in the conventional removal process. One of the common feature of cuts made with beam-cutting techniques such as jets, lasers or plasmas is striation formation [3,4]. When the thickness of the work piece is less than the depth of the smooth zone, desirable surface finish can be attained. In spite of the importance of minimization or elimination of this striation formation phenomenon, so far the striation formation mechanism is still not very well stated. It have been reported that formation of striations is a result of external disturbances such as machine vibrations [3]. The general cut surface generated by abrasive water jet (AWJ) cutting comprises of an upper smooth zone which is free from striations and its primary surface anomaly is roughness, and a lower rough zone where the wavy striations are the dominant characteristic features [5]. The change of material removal process from one mode to another is attributed to be the reason of striation or waviness [6]. Kantha babu and chetty [7] have studied the effect of recycled abrasives in performance of the machined surfaces. Recycled abrasives decreases kerf taper, refining the parallelism of cut surface. From the literature study, it was found that the machining studies focusing cutting of the hybrid composite materials not been performed earlier.

This investigation studies the effect of machining of hybrid composite materials by AWJC and also tries to predict the performance characteristic of Cutting of aluminium composite materials while altering the input parameters.

2. Materials and methods

Influence of Reinforcement into aluminium Matrix composites on cut quality were experimentally investigated. The materials

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used in this investigation were commercial Al-7075 aluminium as matrix and Titanium carbide (TiC) and boron carbide (B_4C) as reinforcements. The most extensively used abrasive in AWJC is garnet GMA 80 garnet. So it was selected as the reference standard abrasive for this investigation. The hybrid composite is developed by incorporating two reinforcements (B4C and TiC) into Aluminum matrix. Cutting experiments were carried out on Pure AL7075, AL7075+ (2.5%B4C + 2.5%TiC), AL7075+ (5%B4C + 5%TiC) AL7075+ (7.5%B4C + 7.5%TiC). They were developed by a stir casting route. The composites were shaped in the form of rectangular block of 15 × 40 × 100 mm. The chemical composition of the 7075 Al alloy matrix was (wt%): 1.6 Cu, 2.6 Mg, 0.11Si, 0.21 Cr, 5.4 Zn, and balance Al. Fig. 1 shows the schematic of Abrasive water jet cutting. Experiments were performed in which the oscillation angle and the nozzle traverse speed were changed within practical ranges. In these investigation, the oscillation angle was varied from 2 to 8° while the oscillation frequency was maintained at 4 cycles/s. The traverse speeds used for processing the materials were in the range from 60 to 180 mm/min. The position of the nozzle is maintained perpendicular to the work piece surface. The other parameters used were: Nozzle diameter: 1.2 mm; Abrasive mass flow rate: 0.40 kg/min; Water-jet pressure: 350 Mpa; Standoff distance: 2 mm. stylus type equipment was used to get the Surface roughness values for each of the surfaces at four points from the top edge of the cut-wall.

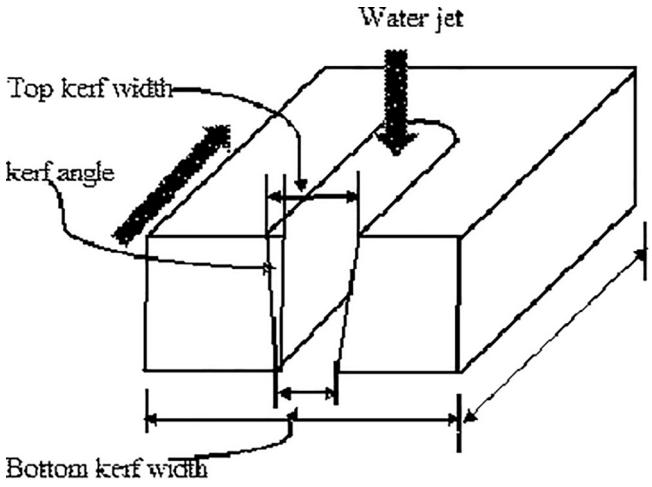

Fig. 1. Schematic of Abrasive water jet cutting.

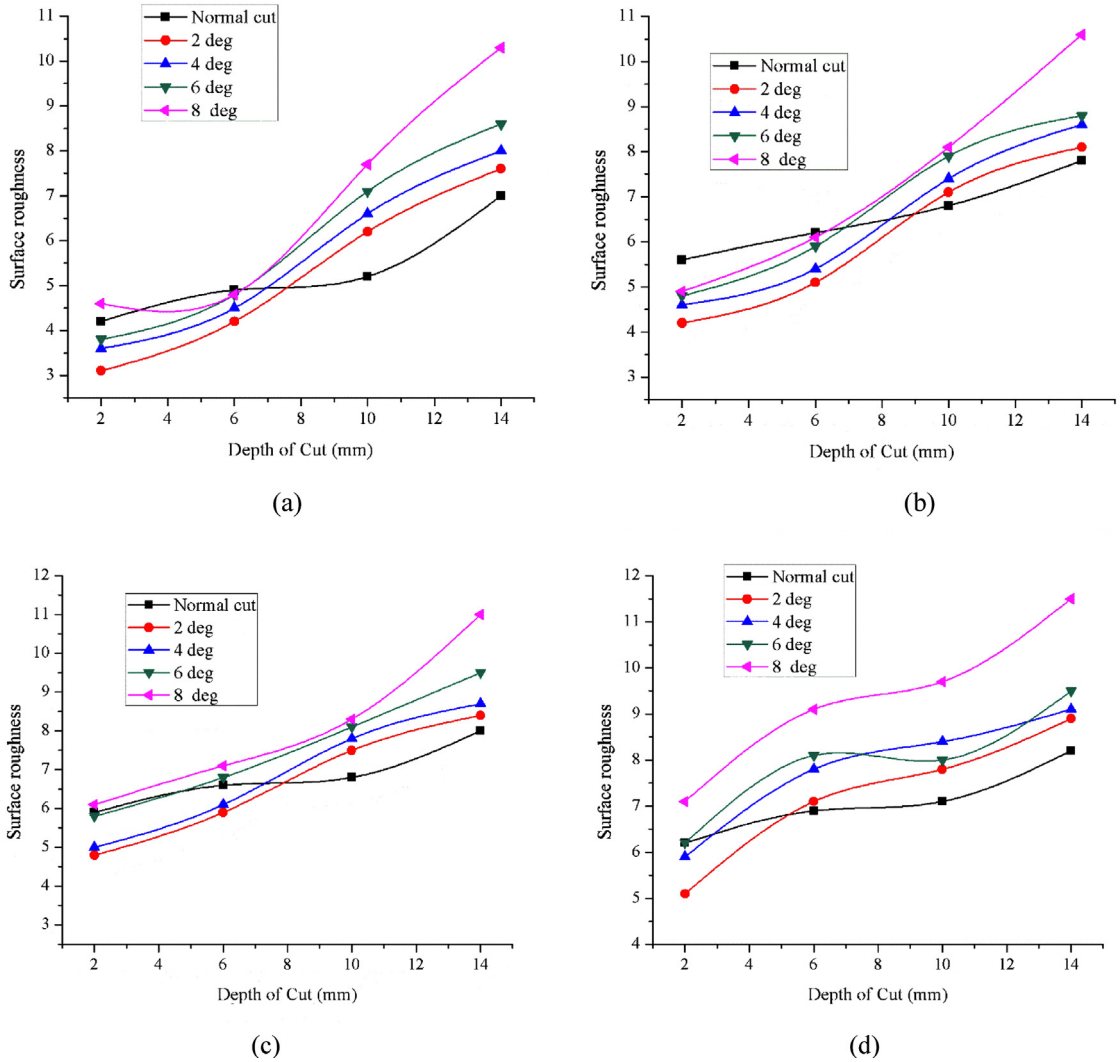

Fig. 2. Surface roughness of different composites cut in AWJC (a) AL7075 (b) AL7075+(2.5%B4C + 2.5%TIC) (C) AL7075+(0.5%B4C + 5%TIC) (d) AL7075+(7.5%B4C + 7.5%TIC).

3. Results and discussion

3.1. Surface roughness

The Surface roughness for the aluminum metal matrix composites treated at traverse speeds of 60 mm/min are presented in Fig. 2 for normal cut and head oscillation cutting method. The oscillation frequencies followed with these traverse speeds was 4 cycles/s. The results indicate that the surface qualities for materials cut using the head oscillation technique were significantly better than that of surfaces generated by the traditional or normal AWJ cutting technique. At the lower head oscillation angle, the average value of Ra for the samples cut with 60 m/min traverse speed was about 15% lower than that using the normal AWJ technology, while this improvement indicates increase when the Ra was observed further down along the cut-wall. When the surface roughness increases as measured downwards as expected due to inability of the jet to remove materials along its path of travel. The incorporation of more particle into the matrix poses problem to the jet for easy removal of material. Due to this, jet is not able to remove materials completely leaving imperfections on the surface of bottom portion of the cut.

3.2. Kerf taper

The effect oscillation angle on kerf taper angle produced is shown in Fig. 2(a to d). It displays the influence of traverse speed on the kerf taper angle. It is observed from the Figure that the kerf taper angle slightly increased with the increase of the oscillation angle from 2 deg to 8 deg because the outer rim of the diverged jet still has sufficient energy to remove material. The test also predicts that the kerf taper is reduced at low traverse speed of 60 mm/min. The kerf taper has the increasing trend when the traverse speed increased to 180 mm/min. The increase of traverse speed offers less cutting force and reduces the penetration ability of the jet. The Fig. 2(b-d) show the effect of the reinforcement in abrasive water jet cutting of aluminum hybrid composites. Due to the incorporation of the reinforcement, the strength of the composite becomes higher. The jet removes small portion of the material and the kerf taper is also less when the reinforcement is added more.

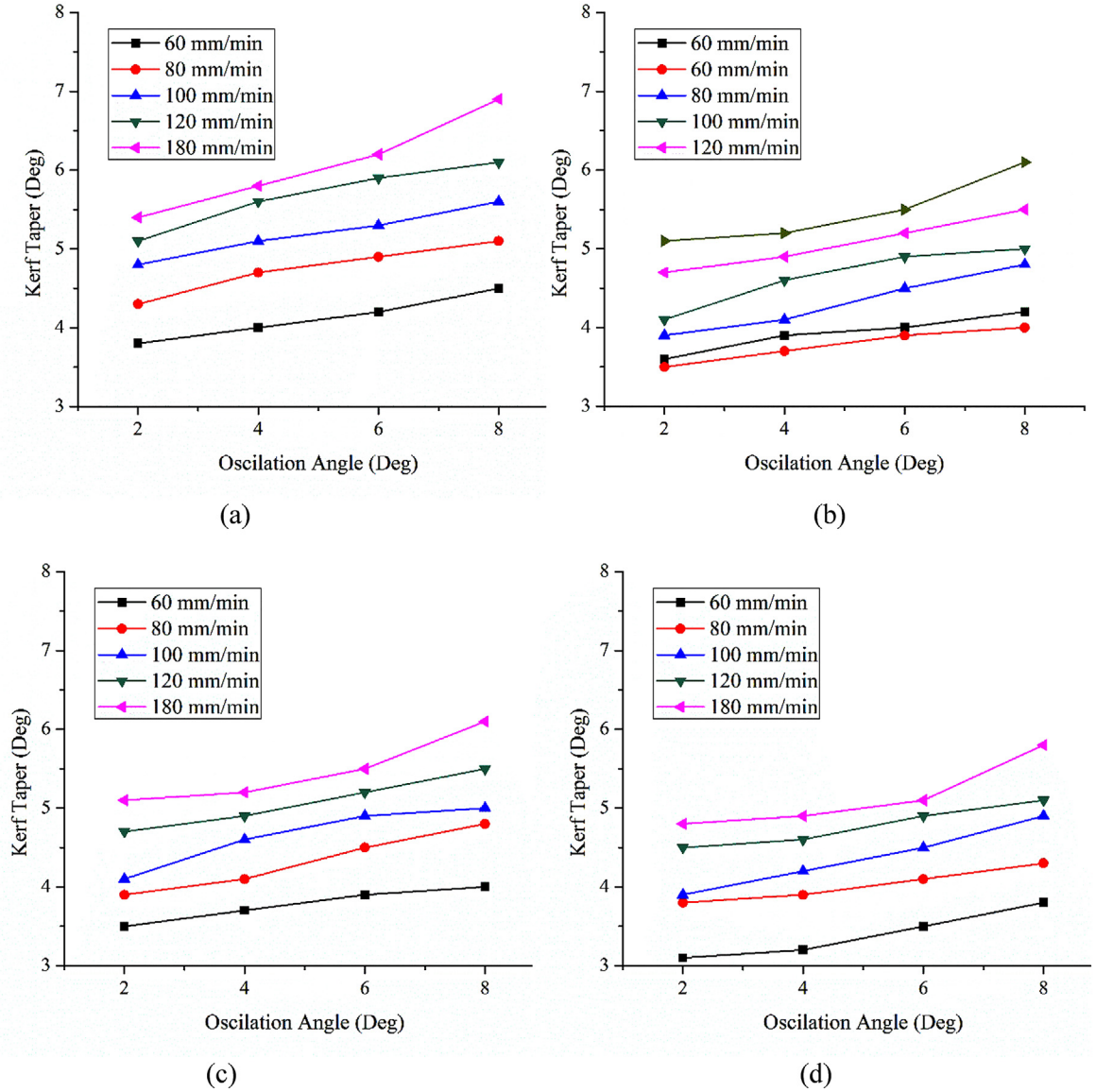

Fig. 3. Kerf Taper of different composites cut in AWJC (a) AL7075 (b) AL7075+(2.5%B4C + 2.5%TIC) (C) AL7075+(0.5%B4C + 5%TIC) (d) AL7075+(7.5%B4C + 7.5%TIC).

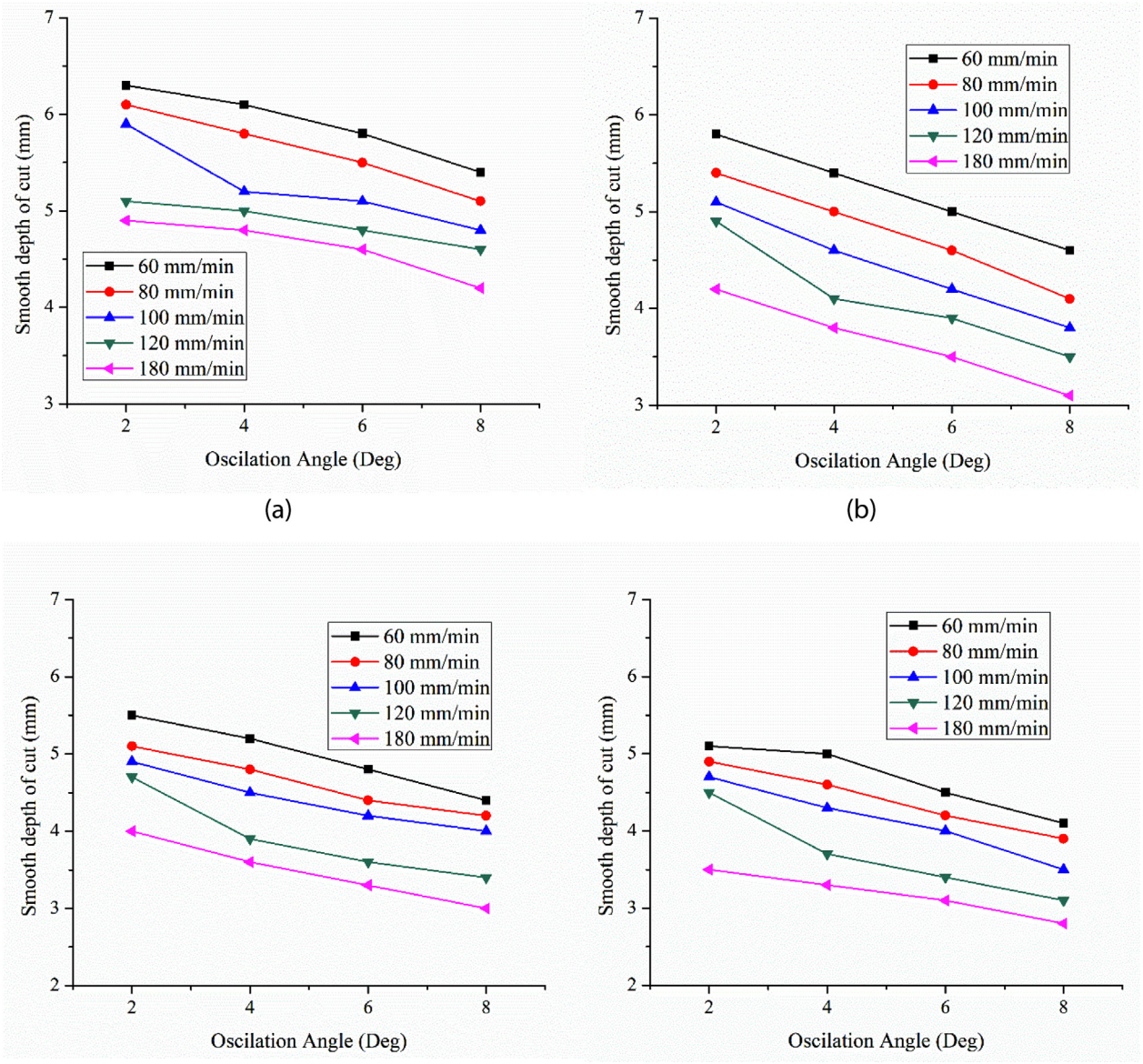

Fig. 4. Smooth depth of cut of different composites cut in AWJC (a) AL7075 (b) AL7075+(2.5%B4C + 2.5%TIC) (C) AL7075+(0.5%B4C + 5%TIC) (d) AL7075+(7.5%B4C + 7.5%TIC).

$$\theta = tan^{-1}\left(\frac{W_{top} - W_{bottom}}{h}\right)$$

3.3. Smooth depth of cut

The two important features of AWJC are depth of cut and Smooth depth of cut. The depth of cut indicates the capacity of the jet penetration in the target material. Engineering applications always warrant large smooth depth of cut for its effective functioning. In this investigation the depth of smooth cut region was observed from the entry of the jet down to where clear striations are seen. It was observed that depth of cut gets decreased steadily as the traverse speed is increased as per expectation. It was also revealed that total depth of cut and smooth depth of cut increase with decrease in oscillation angle. The Fig. 3(a–d) shows the smooth depth of cut of different samples. The increase of reinforcement into the matrix reduces the total depth of cut. This is due to the reason that the jet energy reduces while penetrating into the target material as it goes in to deeper. Since the jet energy diminishes during removal of material its penetration capacity is also getting decreased (Fig. 4).

4. Conclusion

This paper reports the findings of research on head oscillating method in AWJC OF aluminum hybrid composites. Tests performed on aluminium hybrid composites indicate improved performance of cut surface in terms of quality compared to non-head oscillation method.

The results can be summarize as follows:

- While the normal cut produces the Ra value 4.2 μm in aluminum 7075, the 2° oscillation generates the Ra value 3.1 μm.
- While the normal cut produces the Ra value 6.2 μm in aluminum 7075 with 15% of reinforcement addition, the 2° oscillation generates the Ra value 8.2 μm.
- As measured from top surface to down the surface roughness increases
- While The kerf taper reduces by 15% in case of 2° oscillation in aluminium 7075 cutting, it was 10% reduction in 15% reinforcement combination.
- Smooth depth of cut region was getting reduced while increasing the jet oscillation angle.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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