3D Visualization and Topographical Analysis in Turning of Hybrid MMC By CNC Lathe SPRINT 16TC Made of BATLIBOI

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3D Visualization and Topographical Analysis in Turning of Hybrid MMC By CNC Lathe SPRINT 16TC Made of BATLIBOI

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Abstract: The performance evaluations of any manufacturing materials are significantly affected by their quality of surface as well as mechanical and metallurgical properties. MMCs are preferable material for the automobile and aircraft industries due to its excellent properties such as lightweight, high strength to weight ratio and high wear resistance. However, the presence of hard reinforcement particles in the matrix alloy makes it difficult to machine, which leads to the microstructural variation and extent of the subsurface damage. In the present study, three different rotational speed (varies from 200 rpm to 600 rpm) is used to turn the surface of previously in-house made hybrid MMC A359/2%B_4C/2%Al_2O_3 on CNC lathe SPRINT 16TC made by BATLIBOI. An attempt is made to examine the 3D surface visualization and generate the surface roughness report by Micro-Prof FRT optical profilometer, surface topographical by Olympus Lext OLS 3100 laser confocal microscope for surface characterization. The results reveal the smooth machined surface with surface roughness ranges between 1.5 µm to 2.9 µm. The topographical images revealed a flat surface full of repetitive cutting marks parallel to each other and along the direction of cutting. There are no significant topographical differences are varying rotational speed.

Keywords: Aluminum alloy A359; Metal matrix composite; 3D Surface visualization; Surface topography; CNC turning

1. Introduction

In Today's world, metal matrix composites (MMCs) are one of a suitable choice of material for most of the engineering application [1-4)]. The tremendous properties like lightweight, anti-corrosion and improved mechanical and thermal properties increase its demand in the manufacturing industries [5-8)]. However, the behaviour under machinability is also an important way of characterization of MMCs. These are hard to cut materials possess high hardness [9-11)]. Due to high hardness and the presence of hard ceramic particle which is abrasive proves poor results in the machining of MMCs generating high tool wear [12-13)]. Hence the study still searches for better machining method for such materials. The common types of machining operations such as cutting, milling, drilling and turning can be applied on MMCs [14-15)]. In turning operation, conventional turning is widely used for most of the MMCs. The conventional turning of MMCs includes the turning via simple lathe or CNC lathe [16)]. The cutting operation includes the physical contact of the tool with the rotating workpiece, and the removal of material is done in the form of continuous or discontinuous chips [17-18)]. The mechanism of cutting is shown in Figure 1. There are several challenges involves in turning of MMCs like accuracy in dimensions, improved machining results like better surface finishing and high metal removal rate (MRR), improved surface characterization properties, high tool life as well as low-cost [19-20)]. Most of the tool materials like high-speed steels and ceramics cannot be effectively applied for the machining of such hard MMCs because of the rapid wear due to the presence of hard reinforcement particles [21)]. However, coated carbides tools can withstand the tool to wear for a short time of machining [22-23)]. Most of the authors have reported that polycrystalline diamond (PCD) tools can be applied for the MMCs because of the capability of valuable tool life [24)]. It is to be noted that PCD is harder than SiC, B4C or Al_2O_3 and it possesses a non-chemically reactive tendency with work material but the main disadvantage of PCD tool is its high cost due to the diamond particle bonded [25].

In the machining operation, the quality of the machined surface plays an important role in deciding the suitable machining process for a particular material. In the present study, three different rotational speed (varies from 200 rpm to 600 rpm) is used to turn the surface of previously in-house made hybrid MMC A359/2%B_4C/2%Al_2O_3 on CNC lathe SPRINT 16TC made by BATLIBOI. An attempt is made to examine the 3D surface visualization and generate the surface roughness report by Micro-Prof FRT optical profilometer, surface topographical by Olympus Lext OLS 3100 laser confocal microscope for surface characterization.

2. Experimental Details

The material selected for the study purpose is previously in-house developed hybrid metal matrix composite A359/2%B4C/2%Al2O3 produced by electromagnetic stir casting process. After testing the mechanical properties of the samples are given in Table 1.

Table 1. Basic mechanical properties of the tested hybrid MMCs.

Sample	Strength (MPa)	Hardness (HRC)	Toughness (J/m2)
A359/2%B_4C /2%Al_2O_3	112.6	52.5	10.6

The experimental work is performed on CNC lathe SPRINT 16TC made by BATLIBOI (Figure 2). Rotational speed was selected as a variable parameter in the range of 200 rpm to 600 rpm. The reason behind the selection of this range is obtained from the pilot runs. The rotational speed out of the range (lower than 200 rpm and higher than 600 rpm) was significantly affected the surface topography of the machined surface and it increases the surface defects like tool marks, chattering etc. So that in the present work, the rotational speed of the workpiece was kept 200 rpm, 400 rpm and 600 rpm for turning processes. The effect of rotational speed on surface characterization is also observed. The other process parameters of the machining process are fixed. Table 2 shows the technological conditions of turning in CNC lathe. The experiments are conducted at a given set of rotational speed, and three separate surfaces are created for each type of experimental run. The diameter of the workpiece samples was taken 20 mm.

The elements of surface integrity such as roughness parameters (Ra, Rq, Rz), 3D surface visualization, surface topography, are discussed to understand the behaviour of the machined surface.

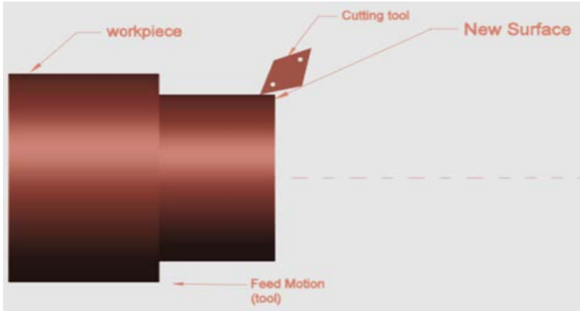


Figure 1. Cutting mechanisms in turning on CNC lathe

3. Result and Discussion

The turning process at three different speeds was successfully performed on the hybrid MMC workpiece. Figure 3 shows the surface created by turning processes. In visual observation, the surface texture of CNC lathe samples is shiny and free from defects like porosity and voids. Tool marks in the form of cutting lines, but no specific pattern is observed. These cutting lines are found significantly low when increasing the rotational speed.

Table 2. Technological conditions of turning operation

Parameters	Values
Number of rotation (rpm)	200, 400, 600
Workpiece diameter (mm)	20
Depth of cut (mm)	0.2
Feed rate (mm/rev)	0.050
Coolant type	SAE20W40
Tool insert	Coated Carbide
Tool type	TNMG (Kyocera)

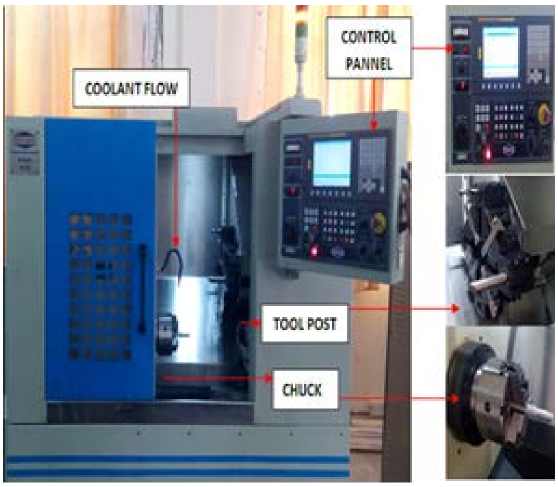


Figure 2. Sprint 16 TC CNC lathe machine

The surface roughness report was generated for each turned surface using an optical profilometer. ISO 4287 standard has been applied to measure the roughness parameters along ten parallel lines on the circumferential surface of the cylindrical workpiece. The specifications of optical profilometer are as follows: Noise filter cut-off A similar pattern has been observed for other roughness parameters (Rq and Rz). The lowest range (1.5µm to 2.9 µm) of average surface finish (Ra) has been observed in the turning process. Improved surface finishing at higher rotational speed is attributed to the reduction in built-up edge (BUE) formation of cutting insert.

Micro proof FRT optical profilometer is also used to capture the surfaces produced by the turning process. Figure 4 shows the 2D and 3D visualization of the machined surface created by CNC lathe at a given set of rotational speeds.

At a glance, it is challenging to differentiate all three surfaces which are similar in appearance. However, some of the observations are found on which they differ to each other. Images show the perfectly rolled surface and free from defects like porosity, voids or cracks. The surface texture shows the repetitive tool marks in the direction of feed and along the cutting direction. At the lower rotational speed (Figure 4 (a)), the tool marks are observed approximately parallel to each other. However, the small scale of the micro-pores appears on the surface. It is attributed to the effect of high thermal energy and mechanical stresses per unit time per unit area of the circumferential length due to which the formation of the larger built-up edge of tool insert is found during turning. At this stage, the tendency of dislodgment of reinforcement particles from the machined surface is increased and creates small-scale voids and porosity. At the medium range of rotational speed (400 rpm) shown in Figure 4 (b).

It is observed the undulation on the surface, and tools

8 µm, evaluation length 7.5 mm, sampling length 2.5 mm, cut-off wavelength 2.5 µm and the number of cut-offs 3. Three parameters of roughness Ra, Rq, and Rz are measured, and their values are given in Table 3. It is observed from the values that a better surface finishing can be found at an increasing trend of rotational speed.

marks are slightly inclined. However, due to high contact stresses and heat, the surface porosity decreases. At higher rotational speed the formation of the built-up edge is reduced which makes the smooth surface as shown in Figure 4 (c).

Surface topography of all the machined surfaces is studied by images captured by OLYMPUS Lext OLS 3100 laser confocal microscope. Figure 5 shows the 2D and 3D surface topographical images of CNC lathe machined surfaces. The images revealed a flat surface full of repetitive cutting marks parallel to each other and along the direction of cutting. There are no significant topographical differences are varying rotational speed. At each set of rotational speed, approximately similar surface with few peaks and valleys are observed.

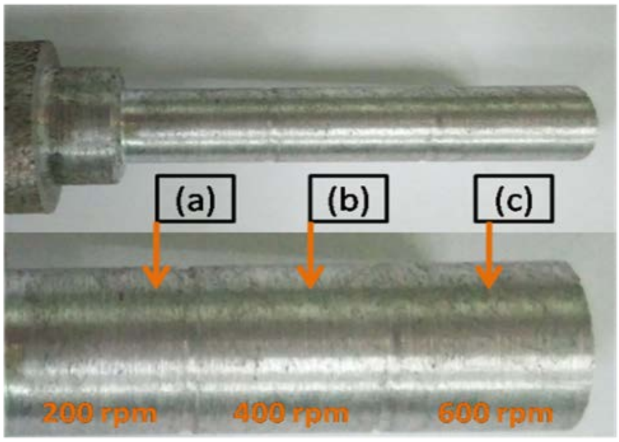
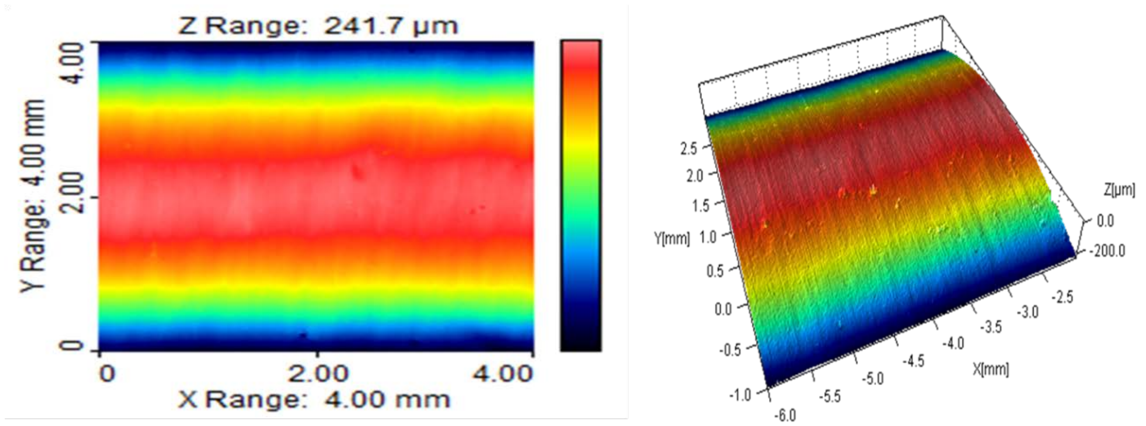


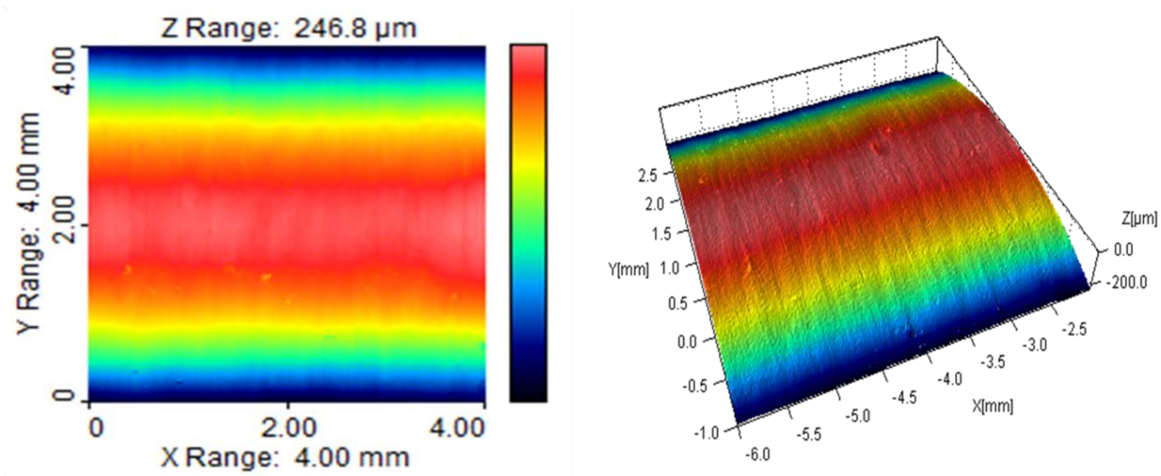
Figure 3. Machined samples of CNC lathe

Table 3. Surface Roughness report

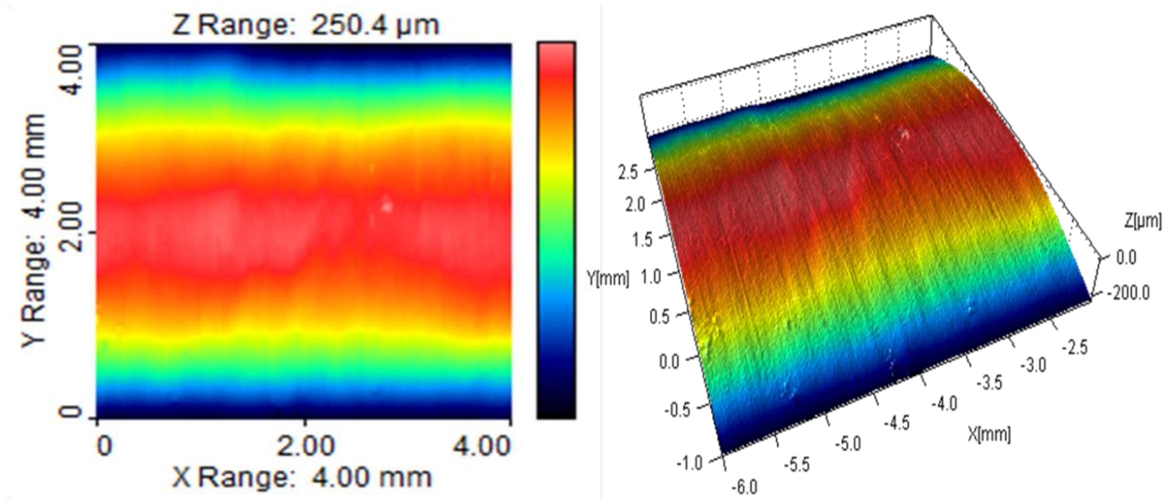
	Rotational speed →	200 rpm			400 rpm			600 rpm		
	Reading numbers ↓	Ra	Rq	Rz	Ra	Rq	Rz	Ra	Rq	Rz
CNC Lathe	1	2.463	2.958	14.671	1.870	2.342	13.638	1.602	1.991	11.428
	2	2.240	2.894	17.184	1.873	2.301	12.925	1.645	2.090	13.641
	3	2.432	3.242	19.357	1.524	1.948	12.368	1.577	1.973	13.282
	4	2.619	3.394	22.213	1.856	2.232	12.474	1.510	1.887	12.491
	5	2.658	3.332	17.406	1.906	2.276	11.527	1.530	1.922	12.034
	6	3.011	3.632	17.807	2.023	2.604	15.206	1.723	2.118	10.670
	7	2.755	3.458	18.334	2.262	2.822	17.049	1.633	2.034	12.162
	8	2.693	3.481	20.387	2.267	2.806	14.652	1.637	2.012	10.818
	9	2.964	3.699	22.391	2.122	2.660	13.904	1.538	1.919	11.132
	10	2.869	4.614	30.524	2.277	2.985	16.183	1.644	2.077	15.296
	Avg	2.6704	3.4704	20.0274	1.998	2.4976	13.9926	1.603	2.0023	12.2954



(a)

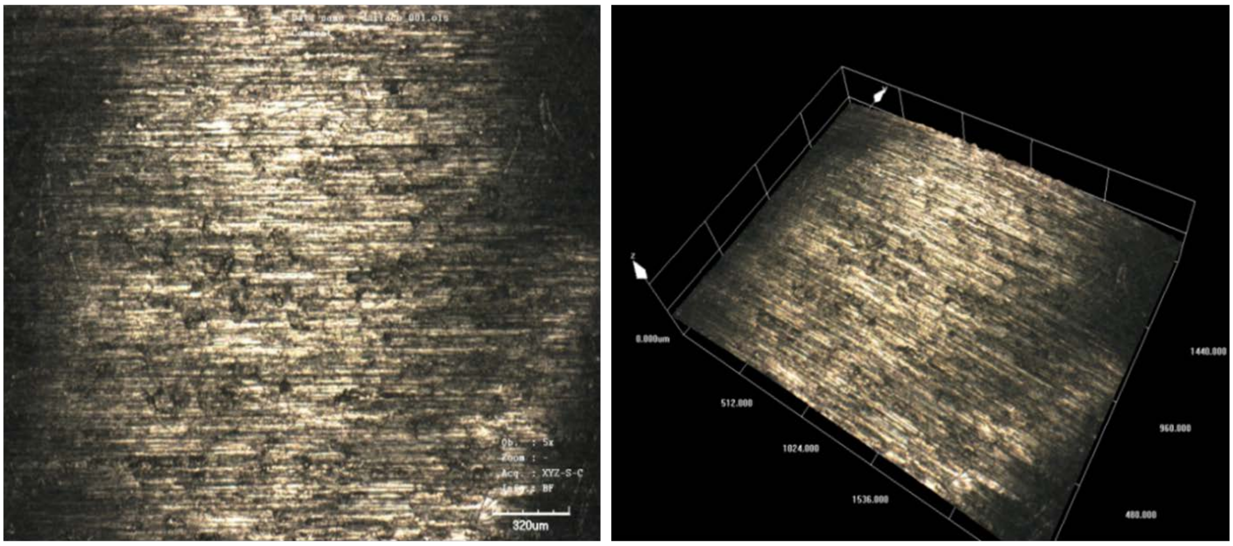


(b)

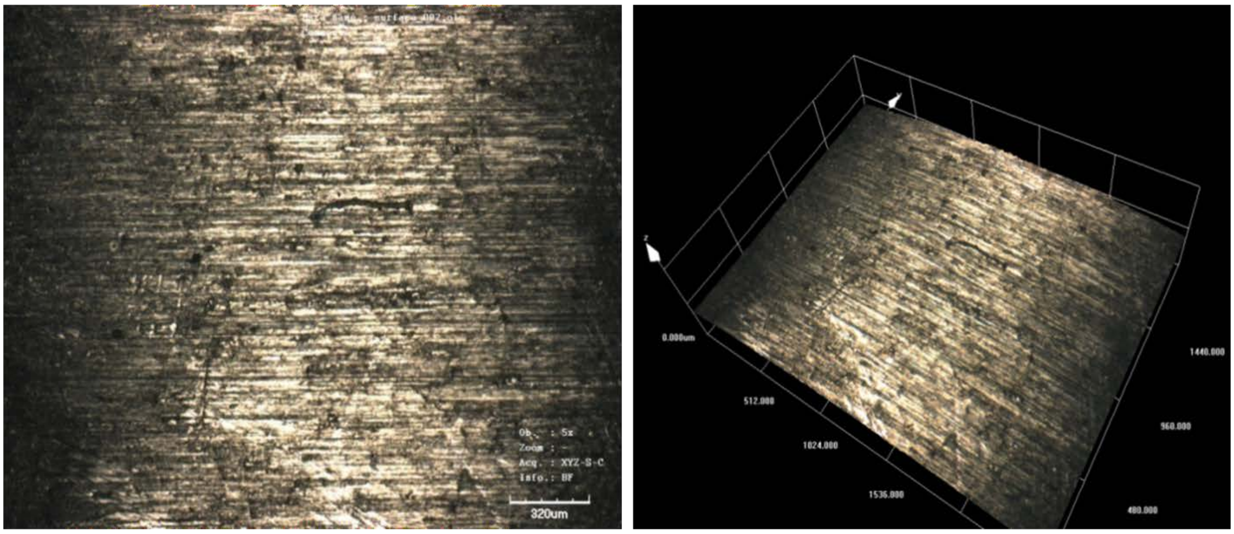


(c)

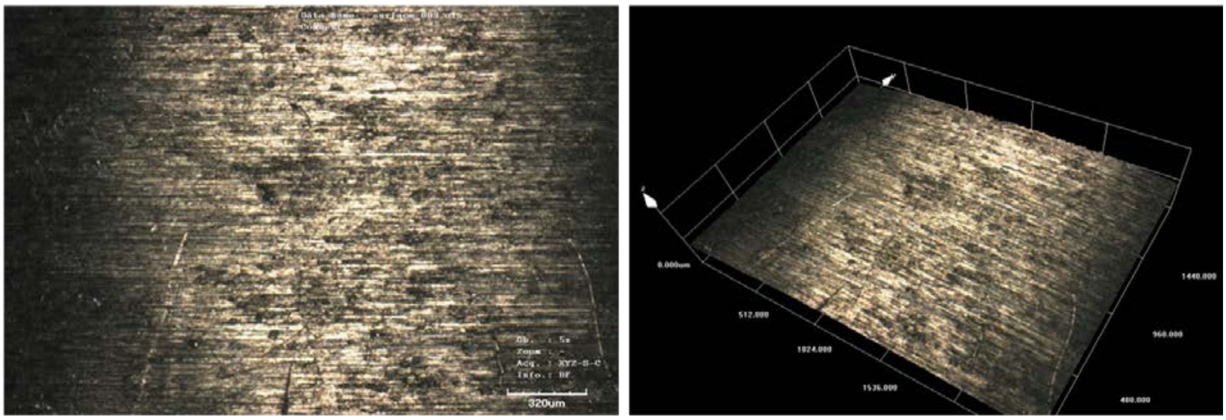
Figure 4. Surface visualisation produced by CNC lathe at (a) 200 rpm (b) 400 rpm (c) 600 rpm



(a)



(b)



(C)

Figure 5. Surface topography by CNC Lathe surfaces (a) 200 rpm, (b) 400 rpm, (c) 600 rpm

4. Conclusion

The present work highlights the outcome of turning operation on A359/2%B_4C/2%Al_2O_3 by CNC lathe (SPRINT 16TC BATLIBOI). The study includes the measurement of surface roughness parameters namely Ra, Rq and Rz and the topographical study of the turned surface by 3D surface visualization images and topographical images. Based on observations the following conclusion has suggested:

1. The range of surface roughness value lies between 1.5 µm to 2.9 µm during the turning operation at varying rotational speed from 200 rpm to 600 rpm. The Improved surface finishing at higher rotational speed is observed which is attributed to the reduction in built-up edge (BUE) formation of cutting insert.
2. 3D surface images show the perfectly rolled and free from defects like porosity, voids or cracks. The surface texture shows the repetitive tool marks in the direction of feed and along the cutting direction. 2D and 3D surface topographical images revealed a flat surface full of repetitive cutting marks parallel to each other and along the direction of cutting. There are no significant topographical differences are varying rotational speed.
3. At the lower rotational speed, the tool marks are observed approximately parallel to each other, while at higher rotational speed the formation of the built-up edge is reduced which makes the smooth surface. The small scale of the micropores appears on the surface. It is attributed to the effect of high thermal energy and mechanical stresses per unit time per unit area of the circumferential length. At this stage, the tendency of dislodgment of reinforcement particles from the machined surface is increased and creates small-scale voids and porosity.

Declaration of conflicting interest

The author(s) declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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