JCARME
ISSN: 2228-7922
Journal of Computational and Applied Research in Mechanical Engineering
Vol. x, No. x, xxxx
jcarme.sru.ac.ir

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Mechanism of surface generation in grinding of AA6061-TiB_2/ZrB_2 in-situ composites

Nomenclature

Al_2O_3 - Aluminium Oxide.
CBN - Cubic Boron Nitride.
KBF_4 - Potassium Hexa fluroborate
K_2TiF_6 - Potassium Hexa flurotitanate.
K_2ZrF_6 - Potassium hexa flurozirconate.
TiB_2- Titanium Diboride
ZrB_2- Zirconium Diboride

Abstract

In-situ composites are gained the attention of worldwide researchers in the interest of its greater mechanical properties at the lower reinforcement ratio. Controlling the surface quality of the component is a paramount task in grinding process in order to withstand the creep and fatigue load at service conditions. The current effort is intended to examine the mechanism of surface generation in grinding of AA6061-TiB_2/ZrB_2 in-situ composites under different reinforcement ratio, grinding parameters and wheel materials. The analysis of results indicates that the grinding of unreinforced alloy is complicated than the composites. Diamond wheel yields superior performance by generating lesser surface roughness and subsurface hardness at all grinding conditions. Among the various grinding parameters, grinding speed and grinding depth are more sensitive than other parameters. This experimental investigation helps to control the surface roughness and subsurface at various grinding conditions.

Keywords:

In-situ composites, grinding, grinding parameters, surface roughness, subsurface hardness, mechanism.

1. Introduction

Aluminum matrix composites are drawn the attention of many scientists due to high strength-to-weight ratio, excellent elevated strength, better tribological properties and corrosion fighting ability when compared to monolithic alloys (Bains et al., 2016; Dwivedi et al.,2016). Aerospace, automotive, space and defense sector are consistently seeking the weight reduction and enforced to apply the aluminum matrix composites (Surappa,2003; Myalski and Posmyk,2016). Aluminum matrix composites manufactured by in-situ route encompasses smaller size reinforcements, fine particles, homogeneously distributed reinforcements, uncontaminated matrix-reinforcement interface, improved interfacial strength and thermodynamically stable in nature

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(Gao et al., 2016). The above listed positive aspects make them to attain the extraordinary mechanical properties at room and elevated temperature. TiB_2 and ZrB_2 ceramics possess numerous diverged properties including high melting temperature, exceptional corrosion resistance, extreme thermal conductivity, fabulous oxidation resistance, strength, fracture toughness and admirable creep resistance (Li et al., 2016 ; Amirsardari et al.,2016). These reinforcements are chemically stable and acts as grain refiner(Yang et al.,2107).Adding an additional reinforcement into matrix helps to attain the advantages of the both ceramics. Hence, TiB_2 and ZrB_2 ceramics are selected as reinforcements for manufacturing composites. The application of aluminum matrix composite is restricted to aerospace, space and defense applications where the cost of machining is not bothered.However, the commercial applications of the aluminum matrix composites are not appreciated due to uneconomic machining of them (Nicholls et al., 2016). Surface roughness and sub surface performance is an unavoidable requirement in machining process, as it is deemed a manifestation of product quality (Ferreira et al.,2016).Grinding is an inescapable process in manufacturing industry and it is used for final finishing of manufactured component (Deng et al., 2017; Wan et al., 2016). Further, this process is well advised for machining harder and arduous to cut materials (Linke, 2015; Yin et al., 2016). The cutting grit gets worn out at short intervals. However, the worn-out grit has either re-sharpened or cut away at some stage in grinding process (Mandal et al., 2015; Mahata et al., 2014).This re-sharpening ability of grinding wheel makes them to machine harder materials than the grit (Kadivar et al., 2017). During grinding, more specific energy is used up for material removal thereby greater temperature is generated at the grinding zone in turn creates the adverse effect like surface alteration, surface defects and residual stress on the grounded surface (Huang et al., 2016). Cylindrical grinding is a machining process, which is widely recognized for finishing the components with high degree surface roughness and to obtain the desired tolerances (Zahedi and Azarhoushang, 2017).The real time application of the component made by the composites requires a good surface condition. Deviations in the surface condition are highly influenced by fatigue and creep (Pal et al., 2012; Song et al., 2017). Grindability studies on aluminum matrix composites are widely reported in the literatures. Ronald et al., (2009) interrogated the consequence of the wheel bond material on grindability of aluminum matrix composites. Electro plated wheel and resin bonded wheel are selected for the experimental work. Grinding force, surface roughness, acoustic emission and temperature are studied as responses. The investigation result indicates that, the resin bonded wheel yield better performance than the electroplated wheel. Thiagarajan et al.,(2011) conducted an experimental investigation on the grindability of Al/SiC composites using cylindrical grinding. The effect of grinding operating parameters including wheel speed, work piece speed, feed rate, grinding depth and SiC content on the grinding force, surface roughness and grinding temperature are examined. The result obtained from the experimental work indicates that, the fine surface roughness and damage free surfaces are obtained at lower grinding depth, greater wheel and work piece speed. Huang and Yu,(2017) presented an experimental investigation of grinding of Al-SiC composites under dry, wet, cryogenic and ELID grinding conditions. Result analysis showed that wet grinding offered lesser grinding force than the dry grinding. Huang et al., (2015) studied chip forming mechanism and shape of chip in grinding of Al-SiC composites with diamond grinding wheel. They observed different forms of chips namely: matrix chips, reinforcement chips and matrix-reinforcement chips. More voume of matrix- reinforcement are collected with the shape of chunky and saw toothed. Lin etal., (2016) intended to establish the grindability issues of the AA-7050-6%TiB_2 in-situ composite produced by K_2TiF_6-KBF_4 reaction system. The influence of the grinding operating parameters and grinding wheel materials on grinding force, surface roughness, grinding temperature and subsurface hardness are investigated. This study resulted that the, grinding parameters and wheel materials are offered noteworthy influence on the grinding performance. The material removal mechanism of the grinding process was being as ductile mode and there is no indication of pull out or fractured particles on the generated surface. Due to very limited attention of grindability issues of in-situ aluminum matrix composites in the literatures, the wide spread application of the composites in industries are constrained. The composite materials are fabricated by embedding the sub micron size TiB_2 and ZrB_2 at high interfacial strength via in-situ reaction. Mechanism of surface generation in grinding of AA6061-TiB_2/ZrB_2 in-situ composites under different reinforcement ratio, grinding parameters and wheel materials requires some understanding for attaining the economic machining rate without negotiating the surface quality. Therefore, an effort has been made to establish the mechanism of surface generation in grinding of the AA6061-TiB_2/ZrB_2 in-situ composites.

2. Materials and Method

AA6061-TiB_2/ZrB_2 in-situ composites with 0%, 2.5%, 5% and 7.5% reinforcement ratio are used for experimental work. These composites are made by reacting K_2TiF_6, KBF_4 and K_2ZrF_6 salts. The detailed procedures for synthesizing the composites are presented in our previous work (Mahamani et al., 2015). Composite samples are solutionized at 505°C for 1 hour followed by aged at 170° C for 6 hour to get homogenization. Microstructure and XRD sketch of the composite sample is presented in the Figures 1 and 2 . Small size (1-2µm) reinforcement particles, clean interface between particle and matrix, and homogeneous dispersion of the particle are seen in microstructure. Al, TiB_2 and ZrB_2 phases are detected in the XRD pattern. The dimension of the work piece is Φ30x300mm. Grinding experiments are conducted by using horizontal spindle cylindrical grinding machine (Heavy duty machine, Indian make). The photographic view of experimental setup is illustrated in Figure 3. Al_2O_3, SiC, CBN and Diamond grinding wheels are employed for the experimental work. The surface roughness values are measured by using Mituyoya surface roughness tester (Cutoff length is 5mm and the evaluation length is 10mm from the machined edge). Micro hardness of subsurface measured by using MH 06 model micro vicker hardness tester with 500 gm load. Scanning electron microscopic studies are conducted using scanning electron microscope (JEOL6360 LV Model, Karunya University, India). The grinding wheel parameters and ranges of the and grinding parameters are like wheel speed, work speed, grinding depth and feed rate are tabulated in the Table 1.

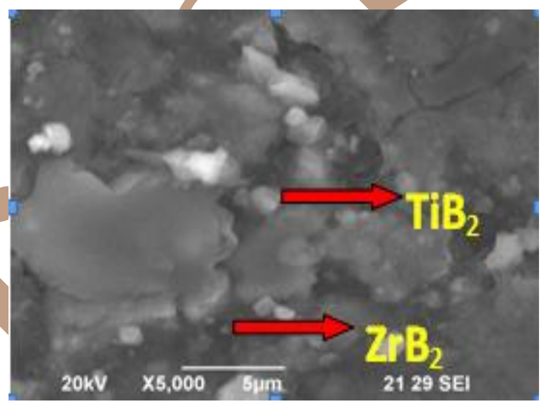


Fig. 1. SEM image of 5 % composite sample.

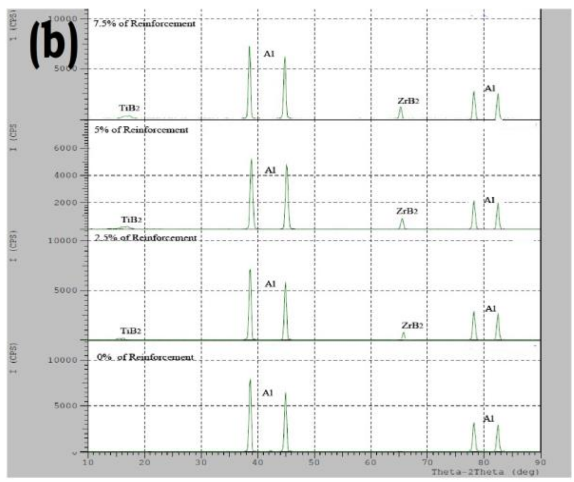


Fig. 2 XRD pattern of unreinforced alloy and composites

Fig.3.Photographic view of the experimental setup

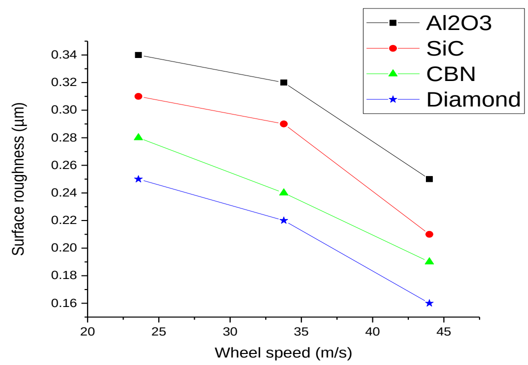
Table 1. Parameters and their levels

Parameters	Units	Levels		
		Level 1	Level 2	Level 3
Wheel speed	m/s	23.5	33.7	43.9
Work speed	m/min	6	12	26
Grinding depth	µm	10	20	30
Feed rate	m/min	0.06	0.09	0.17
Grinding wheel	Resin bonded Diamond, grain size of 80/100, φ300x 25mm.			
	Resin bonded CBN, grain size of 80/100, φ300 x 25mm.			
	Vitrified- bonded Al_2O_3, grain size of 80/100, φ300 x 25mm.			
	Vitrified bonded SiC , grain size of 80/100, φ300 x 25mm.			

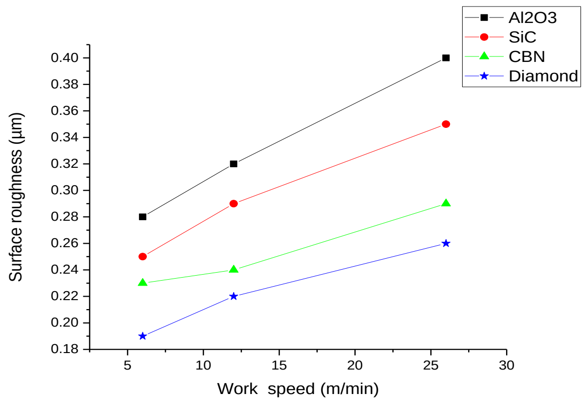
3. Result and discussion

3.1 Surface Roughness

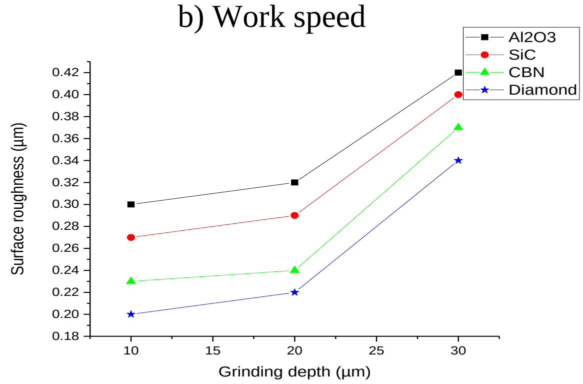
The effect of wheel speed on surface roughness as a function of wheel materials are presented in the Figure 4a. This investigation is carried out by fixing the work speed as 12m/min, grinding depth 20µm,feed rate 0.09m/min and 5% reinforcement ratio. It is seen from the Figure 4a the diamond wheel outperformed than other wheels in terms of generating very low surface roughness. Al_2O_3 wheel generating higher surface roughness for the given experimental conditions. The surface roughness generated by CBN and SiC wheels is lying between diamond and Al_2O_3wheels. The knoop hardness number of TiB_2 is 3370, ZrB_2 is 1550, SiC is 2480, $Al_2O_3$is 2100, CBN is 4500 and diamond is 7000. TiB_2 ceramic has more hardness than SiC and Al_2O_3 and these ceramic phases cause more wear on $Al_2O_3$and SiC due to rubbing action. As the wheel speed increases the rubbing action on work piece also increased. $Al_2O_3$and SiC wheels are subjected to the severe wear. Worn out grinding wheel extend the surface roughness of the grounded surface. The effect of clogging is more on the worn out wheel (Chockalingam et al., 2012). Hence, the existence of clogging effects also a reason for more surface roughness when using $Al_2O_3$and SiC wheels. Excessive hardness pertaining to the CBN and diamond wheel causes minimal wear. It is also seen from the Figure 3a the enhancement in wheel speed decreases the surface roughness for all wheels. It may be attributed that the enhancement in wheel speed reduce the undeformed chip thickness and reduce the contact area between wheel abrasives and work piece (Ilio and Paoletti, 2000). The influence on work speed on surface roughness under a variety of wheel materials are displayed in the Figure 4b. This study is conducted by keeping the grinding parameters as wheel speed as 33.7m/s, grinding depth 20µm,feed rate 0.09m/min and 5% reinforced composites. The Figure 4b depicts that, the enhancement in work speed maximize the surface roughness for all grinding wheels. At higher work speed, the tangential and normal component of grinding force on surface is maximum (Li et al., 2016). Thickness of undeformed chip is maximized; this phenomenon enhances the surface roughness. It is obvious from the Figure 3b the surfaces generated by diamond and CBN wheels are low surface roughness than $Al_2O_3$and SiC wheels. The extreme wear resistance of diamond and CBN wheel materials during grinding process offers lower surface roughness. Variation of surface roughness when increasing the grinding depth under different wheel materials are illustrated in the Figure 4c.This investigation is carried out by holding other parameters as wheel speed 33.7m/s, work speed as 12m/min, feed rate 0.09m/min and 5% reinforced composites. It is clear from the Figure 4c the increase in depth of grinding hike the surface roughness despite the consequences of the grinding wheel. The frictions between the work piece and wheel grain as well as the undeformed chip thickness are relatively more when increasing the grinding depth. This mechanism allows more material removal rate, in turn increase the surface roughness. The effect of grinding depth offer very limited impact on the diamond and CBN wheel. Excessive friction at higher grinding depth form cavities on Al_2O_3 and SiC grinding wheel. The deposition of melted chip in the cavities detoriate the surface roughness. Influence of rate of feed on surface roughness under a variety of grinding wheels and parameters as wheel speed as 33.7 m/s, work speed as 12m/min, grinding depth 20µm is shown in Figure 4d. The Figure 4d clearly brings out that, the enhancement in feed rate increase the surface roughness. This trend is common for all wheels, which are considered for the experimental work. These experiments are also conducted by keeping the wheel speed, work speed, grinding depth and volume content of composite as constant. Increase in feed rate maximizes grinding force alongside the axis of the job rotation and uncut chip thickness and material removal rate. Larger material removal rate maximize the surface roughness. As mentioned earlier, the TiB_2 and ZrB_2 are harder ceramics than Al_2O_3 and SiC and softer than CBN and diamond. Hence Al_2O_3 and SiC wheels allows more particle pulling whereas diamond and CBN allows cutting off the particles(Cheung et al., 2002). Hence, the surfaces generated by diamond and CBN wheels are low surface roughness than other wheelsThe influence of reinforcement ratio on surface roughness under various wheel materials is represented in the Figure 4e. This experimentation conducted keeping grinding parameters as wheel speed 33.7 m/s work speed as 12m/min, grinding depth 20µm,feed rate 0.09m/min. The Figure 4e depicts that the unreinforced alloy has more surface roughness irrespective to wheel materials. It may be attributed that the low hardness unreinforced alloy is exposed to high temperature environment during grinding. The ductility of the alloy further increased and goes to partial melting. The fused chips are attaching with the grinding wheel and cause clogging effect. The deposited chips fasten with the surface and increase the surface roughness. Further, the part of clogged chips with grinding wheel also deposited on grounded surface and thereby increases surface roughness. It is understandable from the Figure 4e the 2.5 % reinforced composites have lower surface roughness than 7.5% reinforced composites. A hike in reinforcement ratio, increase the number of particles with in unit area of composites. Presence of excessive volume fractions of particle increases the surface roughness irrespective of grinding condition and grinding wheel materials. It is also observed from the Figure 4e, the surface generated by the diamond and CBN wheels are smoother than the Al_2O_3 and SiC. Diamond and CBN are considered as super ceramics and possess more hardness and wear resistance. These properties enable the cutting through mechanism while grinding and thereby reduce surface roughness. The clogging effect of on diamond and CBN are very negligible due to high wear resistance. In contrary, the Al_2O_3 and SiC are having poor wear resistance. This property allows higher wear rate of the wheel and enhance the clogging effect. The lower hardness wheel permits more particles pulling than cutting through mechanism. Increased particle pulling effect cause poor surface roughness.



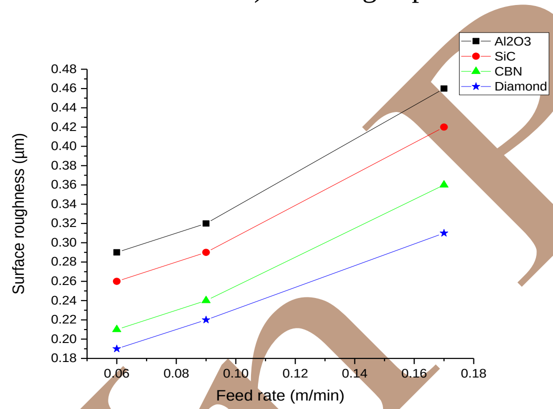
a)Wheel speed



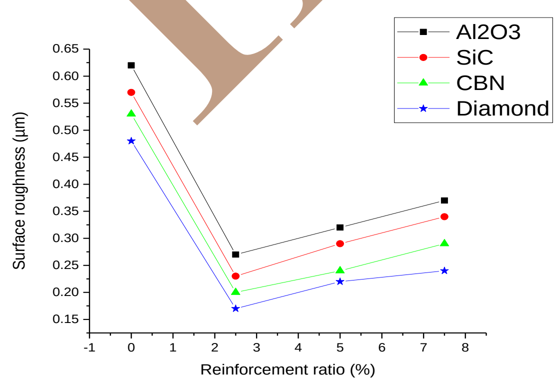
b) Work speed



c) Grinding depth



d) Feed rate

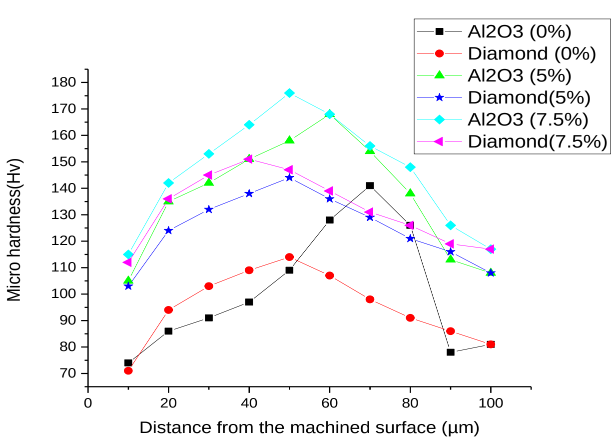


e) Reinforcement ratio

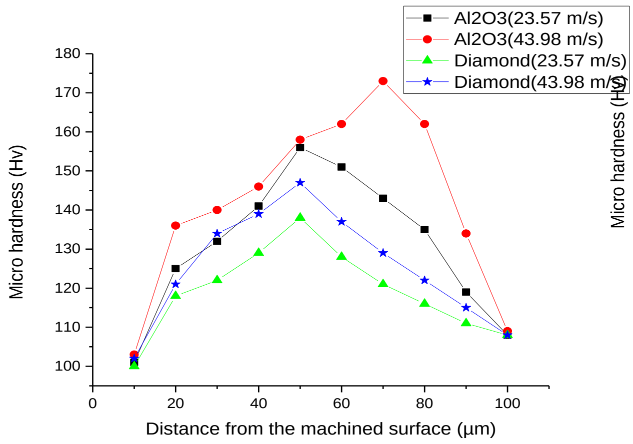
Fig. 4: Effect of wheel speed, workspeed, grinding depth, feed rate and reinforcement ratio on surface roughness.

3.2 Subsurface hardness

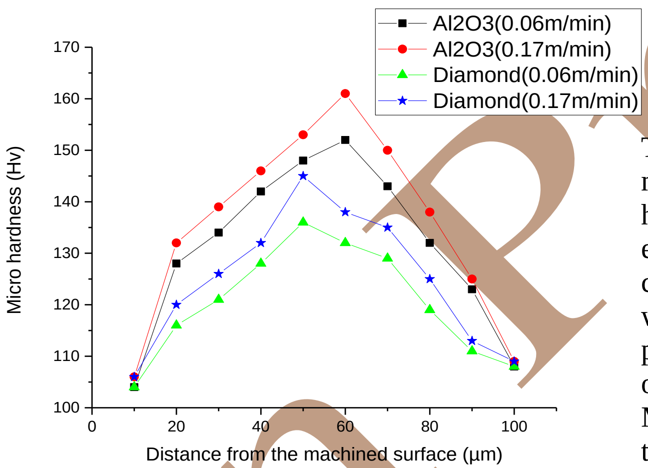
Al_2O_3 wheel is low cost. Smooth surface can be generated by selecting the appropriate grinding parameters. Diamond wheel is costlier than Al_2O_3. Higher degree surface roughness can be obtained by using diamond wheel and the wheel damage during grinding is very minimal. Hence, Al_2O_3 and diamond wheels are selected for the sub surface hardness analysis. The Figure 5a indicates that the micro hardness analysis on the subsurface under different reinforcement ratio of the composites. Influence of and reinforcements ratio on subsurface hardness is studied by selecting the 0%, 5% and 7.5% reinforced composites by fixing the wheel speed as 33.7 m/s work speed as 12m/min, grinding depth as 20µm and feed rate as 0.09m/min. It is clear from the Figure 5a the subsurface hardness of unreinforced aluminum alloy grounded with Al_2O_3 wheel has higher deviation from the base hardness of unreinforced alloy. As we discussed earlier, under similar grinding condition the Al_2O_3 wheel cause poor surface roughness due to lower heat dissipation rate, higher worn out and more clogging effect. These mechanism offer more loads and bring more heat to the work piece. The unreinforced aluminum alloy undergoes partial melting and ductility of the materials is increased. Excessive load and higher ductility facilities more plastic deformation in turn the subsurface hardness is relatively high. At the same grinding condition unreinforced alloy grounded by using diamond wheel has lower subsurface hardness. It may be attributed that, the good lubrication, heat dissipation, and minimal clogging effect reduce the subsurface hardness. The Figure 5a clearly brings out that the comparison of sub surface hardness developed by Al_2O_3 and diamond wheels. Al_2O_3 wheel offers more subsurface hardness than diamond wheel. Increase in reinforcement ratio reduce the grain size of the composites and allow minimum plastic deformation. The subsurface hardness developed by Al_2O_3 grinding wheel on 7.5 reinforced composites has higher hardness at all points of measurements. Hardness of 7.5% reinforced composite is high and influence of the grinding wheel offer less plastic deformation, ultimately the subsurface hardness generated by Al_2O_3 wheel is more. On the other hand the subsurface hardness generated by diamond wheel is less than the subsurface hardness generated by Al_2O_3wheel under same composites and grinding condition. It may be attributed that the lubrication exhibited by the diamond wheel on the surface and thereby heat generation is minimized. This mechanism limits the plastic deformation and reduces the hardness. Similar observations also made for the 5% reinforced composites. Figure 5a also shows that, the increase in reinforcement ratio increase subsurface hardness. However, the plastic deformation phenomenon is decreased when increasing the reinforcement ratio. Possession of higher hardness at higher reinforcement ratio dominates the mechanism of plastic deformation. This phenomenon allows more subsurface hardness. The influence of wheel speed on subsurface hardness under similar grinding condition and reinforcement ratio are presented in the Figure 5b. Influence of wheel speed on subsurface hardness is studied by selecting the wheel speed of 23.5m/s and 43.9 m/s by fixing the work speed as 12m/min, grinding depth as 20µm and feed rate as 0.09m/min. It is evident from the Figure 5b the subsurface hardness generated by Al_2O_3 wheel is higher than diamond wheel. The Figure 5b also depicts that the increase in wheel speed maximize the subsurface hardness irrespective of wheel materials. It is due to the higher dissipation of heat on grinding interface at higher wheel speed. Excessive plastic deformation on the ground surface maximizes the subsurface hardness. Influence of feed rate on subsurface hardness under different grinding wheels is illustrated in the Figure 5c. Influence of feed rate on subsurface hardness is studied by selecting the feed rate of 0.06m/min and 0.12m/min by fixing the wheel speed as 33.7 m/s, work speed as 12m/min, as grinding depth as 20µm. The subsurface hardness generated by $Al_2O_3$is higher than diamond wheels. It is also observed from the Figure 5c the increase in feed rate maximize the subsurface hardness. It may be attributed that, the higher feed rate enhance cutting effort and maximize the cutting force.[22] Higher cutting force exhibits more plastic deformation in turn maximizes subsurface hardness. Figure 4d represents the effect of depth of grinding on subsurface hardness under various grinding wheels. Influence of grinding depth on subsurface hardness is studied by selecting the grinding depth of 10µm and 30µm by fixing the wheel speed 33.7m/s, work speed as 12m/min and feed rate as 0.09m/min. Subsurface hardness generated by Al_2O_3 is more when compared to diamond wheels. It is also found from the Figure 5d increase in grinding depth increase the subsurface hardness. Higher grinding depth maximizes the grinding force normal to the surface and increases the plastically deformed region. The compressive load on the surface enhances the subsurface hardness. The effect of work speed on subsurface hardness as function of grinding wheel material is displayed in the Figure 5e. Influence of work speed on subsurface hardness is studied by selecting the work speed of 6m/min and 26m/min by fixing the wheel speed as 33.7m/s, grinding depth 20µm and feed rate as 0.09m/min. It is seen from the Figure 5e, and diamond wheels are superior than Al_2O_3 wheels by exhibiting lower subsurface hardness. The Figure 5e also depicts that the increase in work speed maximize the sub surface hardness. At higher work speed, the normal and tangential component of grinding force is more and thereby the depth of plastic zone is increased. Wide plastic zone maximizes the subsurface hardness.



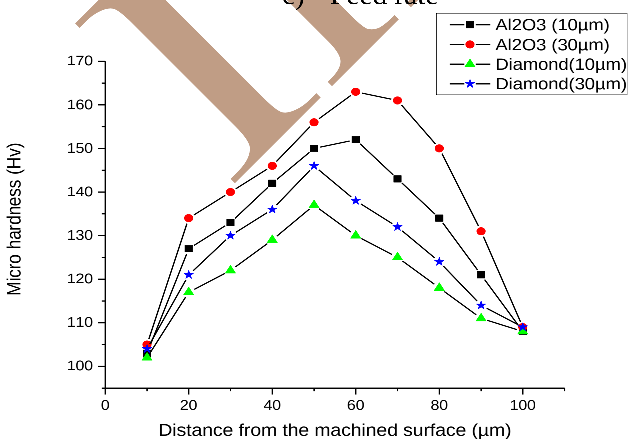
a) Reinforcement ratio



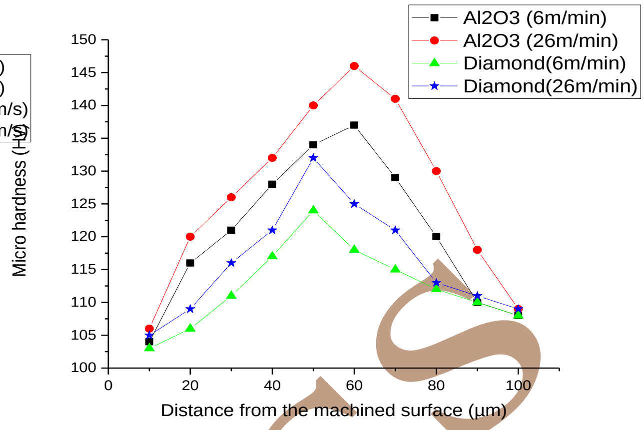
b) Wheel speed



c) Feed rate



d) Grinding depth



e) Work speed

Fig. 5 : Effect of reinforcement ratio, wheel speed , grinding depth, feed rate and workspeed on subsurface hardness.

Mechanism of surface generation

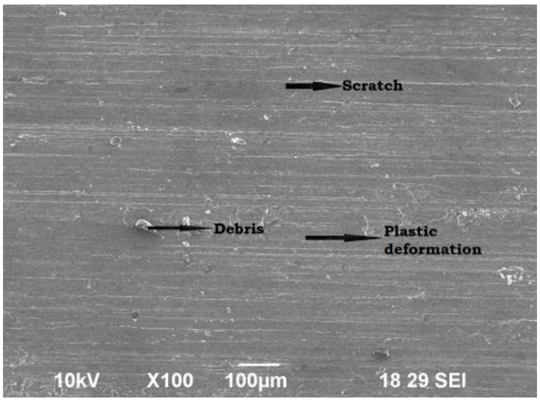
To understand the surface generation mechanism in grinding of in-situ composites helps to employ the grinding process for economic machining rate without compromising the surface quality. The grit-work piece interaction under various processes parameters and grinding wheels plays vital role on chip formation and surface generation. Major part of mechanical energy drawn from the grinding condition is converted as heat and minor part of energy spent for surface generation (Brinksmeir et al.,2016). Grinding processes has three stages namely: sliding, plowing and cutting (Li et al., 2017). In the sliding phase, the grit penetration depth is extremely limited and results the work piece is subjected to elastic deformation. The penetration depth is enhanced when the shifting from sliding to plowing phase and allows ridge formation without material removal. Whenever, the penetration depth reaches the critical value, the chip formation phase initiated. Grit and work piece interaction determines the cutting processes, tribological characteristics, material pile up, work piece deformation and thermo-mechanical system. Number of grains per unit

wheel volume and undeformed chip thickness are major component of surface generation mechanism (Pandit and Sathyanarayanan, 1982). A raise in wheel speed decline the undeformed chip thickness, chip length, volume of chip, plowing force, shearing force, specific plowing energy, specific shearing energy and grit- chip contact length (Linke, 2015). However, friction force and specific total energy are growing up by enhancing the wheel speed. A hike in work speed and feed rate step up the undeformed chip thickness, chip length, chip volume, plowing force and shearing force. On the other hand, friction force and specific total energy is drop off when rising the work speed and feed rate. An increment in grinding depth enlarges the uncut chip thickness, length of chips, volume of chips, plowing force. Nevertheless, the friction force and specific to the grinding energy is declining by enhancing the grinding depth (Linke et al 2017). A swell in wheel speed diminish the number of grains in grinding contact zone whereas an increment in work speed, feed rate and grinding depth enhance the number of grain in grinding contact zone. At higher wheel speed the thickness of undeformed chip is lessened. This mechanism brings more number of sliding grains and reduces the number of plowing and cutting grains (Jiang et al 2013). Grinding depth has greater influence to bring number grain in to contact zone than wheel speed, work speed and feed rate. A raise in wheel speed reduce the penetration depth whereas a hike of work speed, feed rate and grinding depth enhance the penetration depth. However the grinding depthis more influential grinding parameter on penetration depth than the wheel speed, work speed and feed rate (Agarwal and Rao, 2012).
The thermal expansion of work piece due to grinding zone temperature is not reversible when the work piece reaches the room temperature. Higher thermal expansion and lower shrinkage of work piece under the grinding action provokes the residual stress on the grounded surface. Deposition of compressive residual stress on grounded surface is advantageous for service condition whereas the tensile residual stress brings on fatigue failure (Salositis, 2014). Residual stress with compressive nature is facilitated at higher specific energy grinding conditions. Higher wheel speed, lower wheel speed, feed rate and grinding depth are favorable condition to produce the residual stress with compressive nature. Excessive wheel speed brings more grinding zone temperature and softens the work piece whereas lower level of other grinding operating parameters apply mechanical load to the grounded surface. However, grounded components may be finished with lower wheel speed and grinding depth. This action enhances the compressive residual stress additionally (Heinzel and Bleil, 2007). Higher wheel speed along with greater grinding depth is more favourable condition for thermally induced tensile residual stress. Setti et al., (2017) correlated these phases with Johnson's Indentation theory. The mode of deformation of indentation is elastic, elastic-plastic and purely plastic nature. These modes of deformation are coinciding with sliding, plowing and cutting zones of grinding. If mean contact pressure of the grit is less than 1.1 times of yield strength of the work piece, that zone comes under elastic deformation. If mean contact pressure of grit is lies between the 1.1 to 2.97 times of yield strength of the work piece, that region is termed as elastic-plastic deformation zone whereas if mean contact pressure of grit is greater than the 2.97 times of yield strength of the work piece that zone belong to purely plastic deformation zone. Increment in reinforcement ratio, enhance the yield strength of the composites. For constant grinding, the enhancement in reinforcement ratio raises the mean contact pressure requirement of grit for attaining the purely plastic deformation zone along with chip formation in grinding process. Further, insufficient contact pressure of grit facilitates sliding and plowing thereby diminishes the cutting action. The composite material has three regions namely: matrix, reinforcement and matrix – reinforcement interface. Mean contact pressure necessity for initiating the chip formation of matrix region is fewer than the matrix – reinforcement interface region. Grit and reinforcement interaction requires more mean contact pressure than the previously mentioned regions. The mechanism of surface

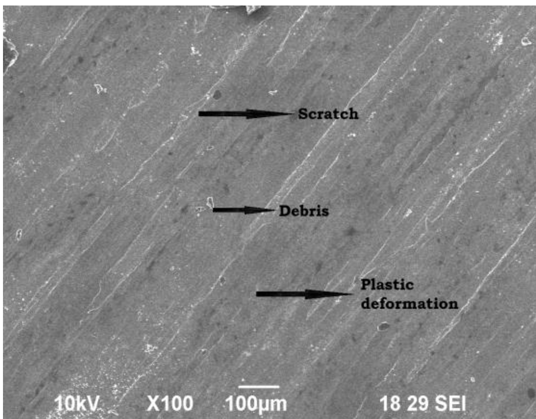
generation at reinforcement region is either particle fracture or particle pulling (Liu et al., 2018). Diamond and CBN grits are having higher wear resistance. At greater power grinding condition, these super abrasives are retained its shape with minimal wear against the TiB_2 and ZrB_2 ceramics and assist for better surface quality. In contrast, Al_2O_3 and SiC grits have poor wear resistance against the and ZrB_2 ceramics and subjected to more wear. The worn out grit has larger negative rake angle with dual cutting edge and smaller protrusion height. This mechanism brings more sliding action thus spoils the grounded surface and induce the residual stress formation.

3.3. Surface texture analysis

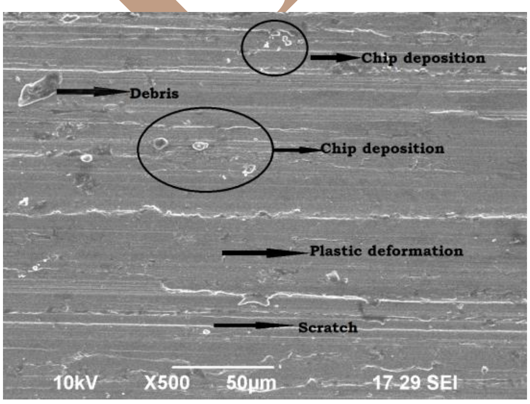
Scanning electron microscopic images of the surface generated by the grinding parameters ie wheel speed 33.77 m/s, work speed as 12 m/min , grinding depth20µm , feed rate 0.09 m/min on 5% reinforced composite using diamond and Al_2O_3 wheel are presented in the Figures 6a and 6b . It is found from the Figures 6a and 6b, the surface generated by diamond wheel is smoother than Al_2O_3 wheel. Figure 6a has small scratches, ridges, debris, plastic deformation marks on the grounded surface. It may be ascribed that, the diamond wheel offer good lubrication, heat conductivity, wear resistance and low clogging effect (Hung et al., 1996).These abilities generate minimal heat at the interface and reduce the load which is subjected to the ground surface. Figure 6b has excessive debris deposition, thick ridges, deep grooves on the generated surface. Consequence of grinding load and temperature the Al_2O_3 grit will lose its shape and the cutting edge is dulled. Worn out grit enhance the sliding and plowing action in turn forms the deep grooves and thick ridges. The Figures 6c and 6d clearly brings out the effect of reinforcements on the surface roughness when grinding with Al_2O_3 wheel with wheel speed 33.77 m/s, work speed as 12 m/min , grinding depth20µm , feed rate 0.09 m/min on 5% reinforced composites . Figure 6c indicates that the surface generated on the unreinforced alloy and the generated surface has deep grooves with excessive plastic deformation and the deposition of clogged chips. Low hardness pertaining to the unreinforced alloy allows more wheel clogging effect and severe plastic deformation. Severe deformation due to excessive plowing action and the deposition of clogged chips spolils the surface. In contrast, the Figure 6d shows that, the surface generated on 5% reinforced composite has minimal scratches and minimum plastic deformation. It is due to the reduced grain size of composite, when increasing the reinforcement ratio. Hence, the hardness and plastic deformation is minimized due to the existence of sub micron size reinforcement in the composites. Figure 6e shows that the surface generated by wheel speed 43.9 m/s work speed as 12 m/min , grinding depth20µm , feed rate 0.09 m/min on 5% reinforced composite. It is exposed from the Figure 6e the surface is roughness is appeared smooth. At higher wheel speed the uncut chip thickness is minimum. Hence, the depth of penetration contact is reduced and thereby surface is appeared very smooth. The Figure 6f depicts the surface produced by wheel speed 33.77 m/s , work speed as 12 m/min , grinding depth20µm , feed rate 0.17m/min on 5% reinforced composite. Influence of higher feed rate on the surface roughness is displayed in the Figure 6f. Increase in feed rate brings more cutting edges to grinding zone and the load on the grit is increased. This effect removes the particles from composite and form voids on the grounded surface. Further, the influence of plowing action also observed in the Figure 6f. The surface generated by the wheel speed of 33.77 m/s , work speed of 26 m/min , grinding depth of 20µm, feed rate of 0.09m/min on 5% reinforced composite is illustrated in the Figure 6g. At higher work speed induce the smearing effect, ridge and groove formation on the grounded surface. This indications are responsible for excessive sliding and plowing action of the grits. Figure 6h exhibits that the grounded surface generated at the wheel speed of 33.77 m/s , work speed of 12 m/min , grinding depth of 30µm, feed rate of 0.09m/min on 5% reinforced composite. Clogging effect, uneven surface and smearing are noticed in the Figure 6h. Greater area of contact and cutting action results excessive surface roughness. Further, the Figure 6h clearly brings out that the influence of grinding depth on surface roughness than other grinding parameters. Ridge and groove formation on the grounded surface indicates that the mode of surface generation is ductile.



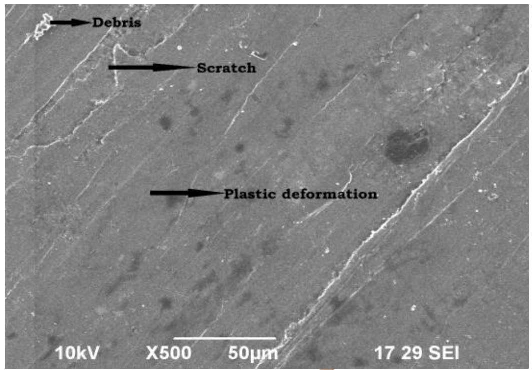
a) Diamond wheel



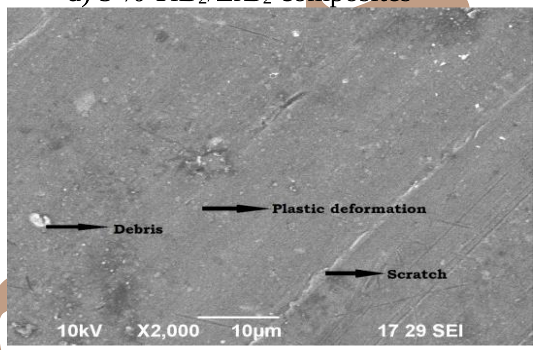
b) Al_2O_3 wheel



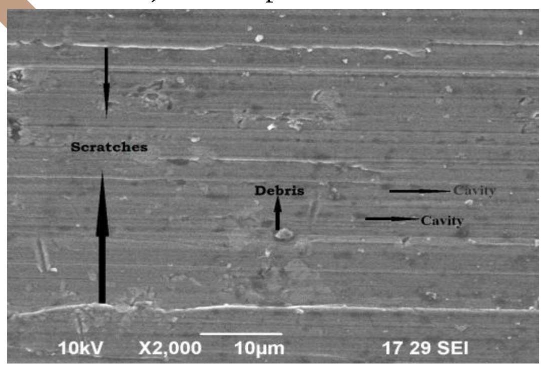
c) Unreinforced alloy



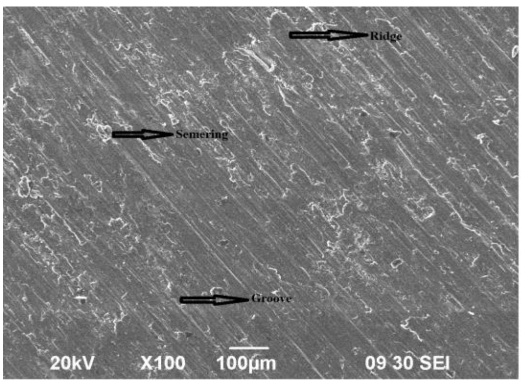
d) 5 % TiB_2/ZrB_2 composites



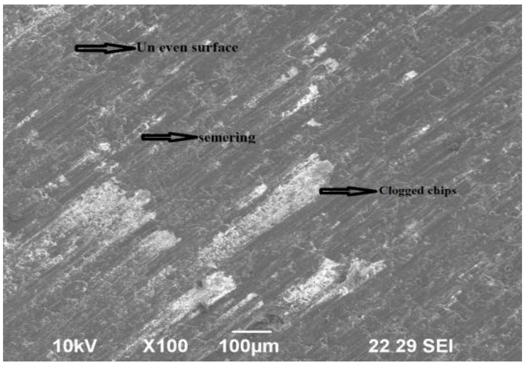
e)Wheel speed



f) Feed rate



g) Work speed



h) Grinding depth

Fig. 6 SEM images of Grounded surface

4. Conclusion

The mechanism of surface generation in gri nding of AA6061-TiB_2/ZrB_2 in-situ composites under different reinforcement ratio, grinding parameters and wheel materials are investigated and following conclusions are drawn. An enhancement in wheel speed reduces the surface roughness and raises the subsurface hardness. A raise in work speed enhances the surface roughness and subsurface hardness. A hike grinding depth enhances the surface roughness and subsurface hardness. Increment in feed rate hikes the surface roughness and subsurface hardness. An enhancement in reinforcement ratio raises the surface roughness and subsurface hardness. However, the unreinforced alloy has poor grindability due to clogging effect due to excessive plowing action. Diamond wheel is superior to Al_2O_3 wheels in terms generating low surface roughness and subsurface hardness. Surface and subsurface performance of the CBN wheel and SiC wheels are lying in between the diamond and Al_2O_3 wheels. Surface defects like ridge, groove, smearing, void, fused chip deposition are observed at various grinding conditions. However, ridge and groove formation are observed at all grinding conditions. Hence, the mechanism of surface generation is originated by ductile mode. Understanding of surface generation mechanism in grinding of in-situ composites helps to employ the grinding process for economic machining rate without negotiating the surface quality.

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