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Original Article

Fabrication and machining performance of ceramic cutting tool based on the Al_2O_3-ZrO_2-Cr_2O_3 compositions

T Norfauzi[a,b], AB Hadzley[a,*], UAA Azlan[b], AA Afuza[a], MM Faiz[a], MF Naim[a]

[a] Advanced Manufacturing Centre, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal Melaka 76100, Malaysia
[b] Department of Manufacturing Engineering Technology, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal Melaka 76100, Malaysia

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ABSTRACT

This study presents the cutting tool development of zirconia toughened alumina (ZTA) with chromia addition. The process used for its development is solid-state, in which the powders of Alumina (Al_2O_3), Zirconia (ZrO_2) and Chromia (Cr_2O_3) were processed by a ball mill, compacted under a Cold Isostatic Press (CIP) and sintered at a constant temperature of 1400 °C with 9 h soaking time. The initial study investigated the effect of Polyethylene glycol (PEG) as a binder, CIP and hardness of Al_2O_3-ZrO_2 mixtures. The percentage composition between Al_2O_3 and ZrO_2 was varied to choose the best for the highest mechanical performances determined by the density, porosity and properties analysis. The cutting tool that possessed the highest hardness and bending strength was selected the Al_2O_3-ZrO_2 mixture was mixed 0.6 wt% Cr_2O_3 for machining trials within the cutting speed of 200–350 m/min and constant feed rate and depth of cut of 0.150 mm/rev and 0.5 mm, respectively. The results of the ZTA mixed with Cr_2O_3 and combined with the ratio 80-20-0.6 wt% showed that the addition of 0.6 wt% PEG and a CIP pressure at 300 MPa and 60 s dwell time resulted maximum hardness and bending strength of 71.03 HRc and 856.02 MPa, respectively. The fabricated cutting tool was capable to reach 225 s tool life when machining AISI 1045 at a lower cutting speed of 200 m/min and higher feed rate of 0.150 mm/rev.

1. Introduction

ZTA is composed of the primary elements of Al_2O_3 and mixed with a lower percentage of ZrO_2. Inside ZTA, Al_2O_3 is the dominant main structure that provides consolidated high hardness when compacted and sintered at adequate temperature and soaking time. When mixed with ZrO_2, particles of ZrO_2 can reportedly infiltrate between the structures of Al_2O_3 to inhibit the grain growth, thereby reinforcing the integrity of the surrounding matrix and yielding very high fracture toughness [1–3]. The ZTA cutting tool has the features required in the machining process, where the cutting tool is known for its wear resistance and high hardness [4–6]. Therefore, ZTA has been applied widely in the field that requires refractoriness

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* *Corresponding author.*
E-mail: hadzley@utem.edu.my (A. Hadzley).

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such as cutting tools, large-scale machinery, aerospace, electronics industry, and energy structure [7,8]. To manufacture ceramic-based ZTA, the ball milling operation can be an efficient process to crush smaller powders into a homogenous mixture [9]. Subsequent to powder mixing, the use of CIP in ceramic compaction is one of the best methods to tie each grain well and strongly by compressing the powders using water or air [10]. This technique enables the production of ceramic with complicated shapes, is lower in cost, has a cheaper facility, and requires less energy [11]. During the CIP process, powders are filled into an elastic mould before being sealed and placed in a pressure chamber. The filled elastic mould is then pressed with high pressure in the surrounding direction. Homogeneous compaction of the ceramic body can be achieved by controlling the pressure as well as dwell time [8,12].

Properties of ZTA can be improved with the addition of tertiary phases or filler materials. The introduction of Cr_2O_3 as a filler material for ZTA is one of the alternatives as Al_2O_3 and Cr_2O_3 are sesquioxides and have the same corundum crystal structure [13,14]. When sintering together within a temperature beyond 1000 °C, the high delusion rate of Cr ions will form an isovalent solid solution through the surface of the Al_2O_3. This controls the shape and grain size of the Al_2O_3. The hardness and the elastic modulus could be increased through crack bridging by the interlocked grains, which in the end contributes to high refractoriness and chemical stability of the ZTA- Cr_2O_3 mixture [2].

The introduction of ZTA as a cutting tool was introduced by Azhar et al. [13] and suggested that when 0.6 wt% Cr_2O_3 was added into ZTA, the grain size was increased in the form of plate-like shapes to improve the fracture toughness. When machining was performed with stainless steel 316 L, the wear area of ZTA with the addition of Cr_2O_3 was reduced up to 26.70%. Manshor et al. [14] studied the improvement of a cutting tool with the addition of Cr_2O_3 into TiO_2 (ZTA–TiO_2) ceramic composite. The authors indicated that by adding Cr_2O_3, the grains became larger and bimodal in size distribution. Such bimodal grains yield intergranular crack resistance to enhance the fracture toughness of ceramic structure. Furthermore, Singh et al. [15] fabricated ZTA doped with Cr_2O_3. The author recorded increases in hardness and fracture toughness when Cr_2O_3 was added up to 0.8 wt%. When machining was performed using AISI 4340, the tool life of the developed insert was slightly better than pure ZTA cutting tool.

The above-mentioned studies proved that Al_2O_3 is suitable to be applied as a cutting tool. While the studies focused more on the mechanical and microstructure improvements, the study of failure modes or wear mechanism of ZTA- Cr_2O_3 cutting tools have considerably less attention. In the present study, the wear performance of the ZTA cutting tool prepared by mixing Cr_2O_3 was investigated. The specific composition of Al_2O_3-ZrO_2 was fabricated with the addition of Cr_2O_3. To obtain bodies with full density, PEG binder was blended into the mixtures and CIP was employed to press the powders. The powders were then sintered at an elevated temperature and controlled soaking time. Mechanical properties, such as bending strength, hardness, and density, were measured to relate the variations of PEG binders, CIP pressure, and Al_2O_3-ZrO_2 compositions. The selected cutting tool with maximum hardness and bending strength was tested to machine AISI 1045. Tool wear and wear mechanisms were examined to evaluate the effects of the cutting speed on the newly fabricated cutting tool. This study is a continual update from previous research [16].

2. Experimental procedures

2.1. *Development of ceramic cutting tool*

The initial stage of cutting tool development started with mould preparation. Mould was developed according to the specifications of RNGN 120600 with a size of 12 mm diameter and 6 mm thickness. 90 wt% Al_2O_3 and 10 wt% ZrO_2 were blended with the addition of PEG and each composition was mixed and ground by a ball mill for 12 h. The blended ceramic powders were poured into the mould and compacted with a manual press machine of 5 tonnes to form a green body, in which the green body was a mixture of ceramic which has been compacted before it was sintered or burned. The green body was then further compacted inside a Cold Isostatic Press (CIP) within a variety of pressures and dwell time. The compacted powders were subsequently sintered at a constant 1400 °C and 9 h soaking time.

To study the mechanical properties of the samples, the density of the sintered bodies was evaluated using a Densitometer. Density tests were performed through the Archimedes principle of the sintered specimen through calculations based on Eq. 1. Archimedes principle was used in the experimental procedures to determine the mass and density [17]. Another evaluation for mechanical properties was hardness test by the Rockwell Hardness Tester. The test was conducted to obtain the reference value representing the strength of the ceramic cutting tool.

$$\text{Density} = \text{mass/volume} \tag{1}$$

i Mass was measured in gramme (g)
ii Volume was measured in units of length cubed (cm^3)
iii Unit for density is g/cm^3

As the maximum density and hardness were obtained, the respected formulation and parameter were selected for further improvement by varying the mixture of Al_2O_3-ZrO_2 at ratios of 75 wt% -25 wt%, 80 wt% -20 wt%, 85 wt% -15 wt%, 90 wt% -10 wt%, and 95 wt% -5 wt%. At this stage, 0.6 wt% Cr_2O_3 was added according to the suggestions by Refs. [13]. For each sample, density, hardness, and bending strength were evaluated. Fig. 1(a) shows of cutting tools that have been developed according to the size of RNGN 120600 clamped on a CRDN252543 tool holder and Fig. 1(b) shows the example of machining trials for the fabricated cutting tool.

2.2. *Machinability evaluation*

The cutting tool that possessed maximum hardness and bending strength was selected for machining trials. The performance of cutting tools was evaluated by machining AISI 1045 at 50 mm diameter and length of 210 mm. Experiments

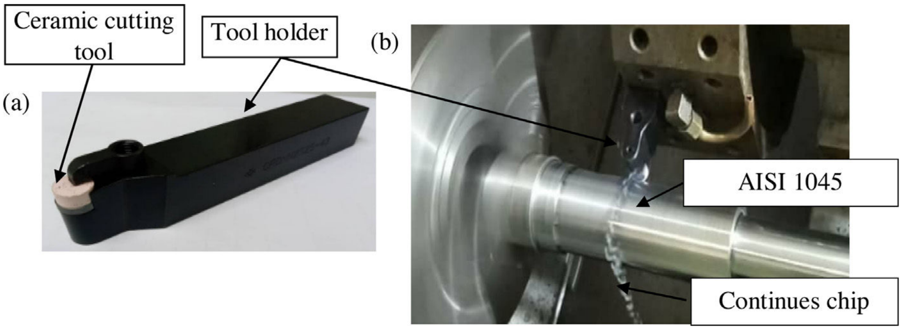

Fig. 1 – Machine tool (a) tool holder with ceramic cutting tool and (b) machining trial for the fabricated cutting tool.

were performed in a dry condition with the cutting speed varied at 200–350 m/min, while the feed rate and depth of cut were kept constant at 0.150 mm/rev and 0.5 mm, respectively. A variety of cutting speed was used to obtain the suitable parameter corresponding to ZTA mixed with the Cr_2O_3 cutting tool. Flank wear of cutting tools was measured using a toolmaker microscope to reach 0.3 mm according to ISO 3685. The toolmaker microscope was used to measure wear while Scanning Electron Microscope (SEM) was employed to analyze the wear mechanism on the failed cutting tool.

3. Results and discussion

3.1. Parameter development

The development process was carried out with basic and optimal composition of Al_2O_3- ZrO_2. The composition of the ceramic powder used in the study was 90 wt% Al_2O_3 and 10 wt% ZrO_2 due to the minimum composition and following a previous study by Norfauzi et al. [16], who found the ratio of 90 wt% Al_2O_3 and 10 wt% ZrO_2 was the best mixing percentage to obtain a long tool life of ceramic cutting tools. In the first phase of the cutting tool development, identification was done on the appropriate binder percentage, which covered 0.6 wt% up to 1.25 wt%. Furthermore, CIP was performed to produce a solid green body that can improve machining reliability. All experiments were sintered at 1400 °C and 9 h soaking time.

3.1.1. Binder

Early stages of cutting tool development focused on the effective selection of PEG binder during powder compaction. The tests were important to determine the appropriate percentage selections as an input for the next process of the cutting tool development. Fig. 2 shows the effect of PEG binder concentrations on the relative density of 90 wt% Al_2O_3 -10 wt% ZrO_2 cutting tool. Considering 3.987 g/cm^3 as an effective density, the plot also shows that the relative density decreased as the binder increased from 0.6 wt% to 1.0 wt%. The highest density of 92.60% (3.692 g/cm^3) was recorded when 0.6 wt% binder was added to Al_2O_3-ZrO_2 powder. For the binder contents of 0.75 wt% and 1.0 wt%, the relative density for each of these decreased to 90.64% (3.614 g/cm^3) and 90.30% (3.604 g/cm^3), respectively. The graph rose sharply when the binder mixture was increased to 1.25 wt%, where relative density increased to 92.07% (3.671 g/cm^3).

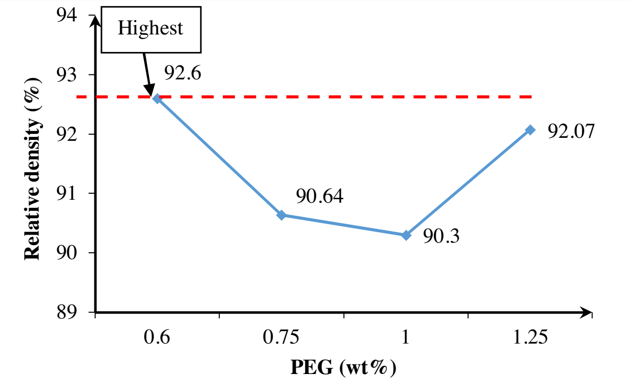

Fig. 2 – Effect of PEG binder concentrations on relative density of 90 wt% Al_2O_3-10 wt% ZrO_2 composition.

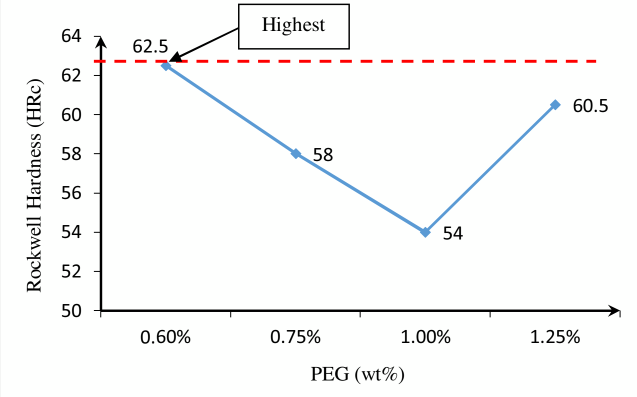

Fig. 3 – Effect of PEG binder concentrations on hardness of 90 wt% Al_2O_3-10 wt% ZrO_2 composition.

Fig. 3 shows the effect of PEG binder concentrations on the hardness of 90 wt%Al_2O_3-10 wt% ZrO_2 cutting tool. Consistent with the relative density, the highest hardness value of 62.5 HRc was recorded when 0.6 wt% PEG binder was added to the powder mixture. The hardness substantially decreased to 58 HRc and 54 HRc when 0.75% and 1.0% of PEG binders were added, respectively. However, when the percentage of PEG increased to 1.25 wt%, the graph shows an increase in the hardness value to 60.5 HRc.

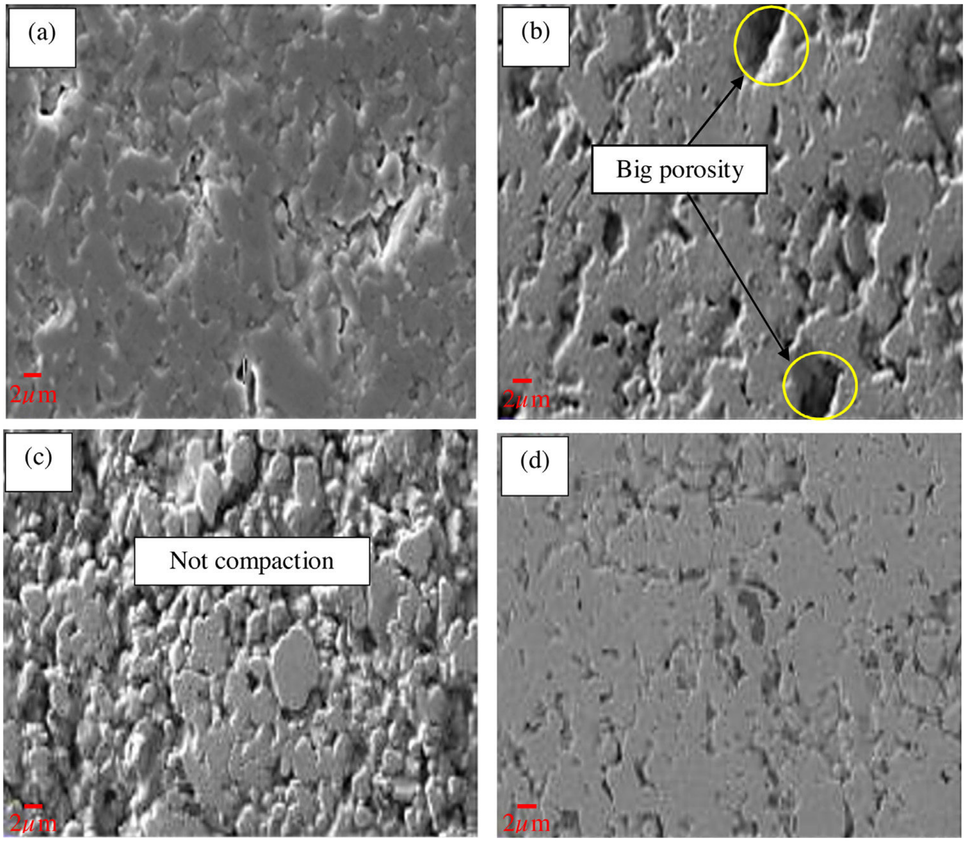

Fig. 4 – Microstructure from top surface with 2 μm scaled 5.1 wt%, (b) 0.75 wt%, (c) 1.0 wt% and (d) 1.25 wt%.

The plots in Figs. 2 and 3 show that the influence of binder is very volatile where the percentage of binder content does not guarantee the increase in density and hardness among others due to the agglomeration and the percentage of the binder itself. Agglomeration occurs because the grain and the percentage of binders do not mix, and match evenly and indirectly cannot achieve the density and hardness of ceramic cutting tools [18–19]. High density and hardness were dominated by 0.6 wt% binder, where the results showed a decrease of hardness and density with the increase of binder percentage. This is because binders can be eliminated during the sintering process, resulting in porosities that could occur between the ceramic grains. The degradation of density when the percentage of binders increased probably due to a mixture of the binder with ceramic powder tends to agglomerate.

However, a significant increase occurred when the binder percentage increased to 1.25 wt% compared to 0.75 wt% and 1.00 wt%. Theoretically, from previous studies made by Azhar et al. [13], the increase in binder content increases the sample density, however the use of Cr_2O_3 results in a reduction in density due to evaporation and condensation during the sintering process. Inconsistency of density and hardness due to evaporation during the sintering process, where the Cr_2O_3 that bind with Al_2O_3 and ZrO_2 by binder material will dissolve as well as deposited to the surface of cutting tool and causing of an erratic result acquired. The suitability of the binder percentage plays an important role in producing high density and hardness when added the Cr_2O_3 powder. It occurs due to forms an isovalent solid solution of both are sesquioxides and have similar corundum crystal structure between ions of Al^{+3} and Cr^{+3} [13]. This can be seen in Fig. 4 from the microstructural observation for samples with varying amounts of binders from 0.60 to 1.25 wt %. The addition of binder at 0.6 wt% and 1.25 wt% presented fine particles compaction with less porosity as shown in Fig. 4(a) and 4(d). Meanwhile, significant porosity along the Al_2O_3- ZrO_2 structure appeared when 0.75 wt% and 1.00 wt% binders were added into the compositions as shown in Fig. 4(b) and 4(c).

3.1.2. *CIP*

Fig. 5 shows the effect of CIP pressure on the relative density of Al_2O_3- ZrO_2 cutting tool with a ratio of 90–10 wt%. The results showed that the use of CIP with 300 MPa pressure and 60 s dwell time resulted in the highest relative density of 95.8%. Compared to 400 MPa pressure with 60 s dwell time, the relative density of Al_2O_3- ZrO_2 only achieved 94.7%. In general, samples that were pressed with CIP obviously contributed significant densification as compared with the non-CIP process [20]. During the CIP process, the powders were compacted from all directions to improve densification by eliminating the air bubbles and decreasing the porosity of the green body. At a certain level, higher compaction was unable to improve the compaction process. Instead, when high pressure was applied, the overload pressure could invoke the slipping of grain in the green body structure, resulting in dislocation between

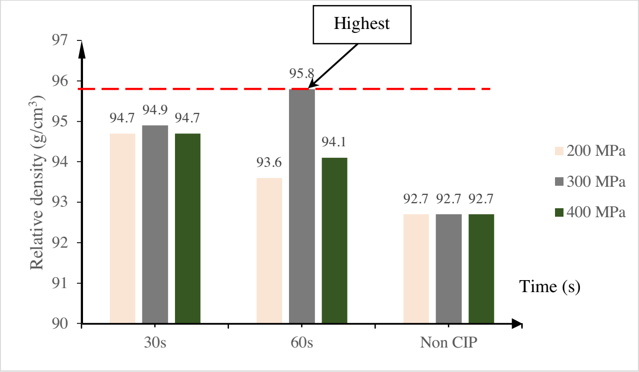

Fig. 5 – Effect of CIP pressure on relative density of 90 wt% Al_2O_3- cutting tool with ratio -10 wt% ZrO_2.

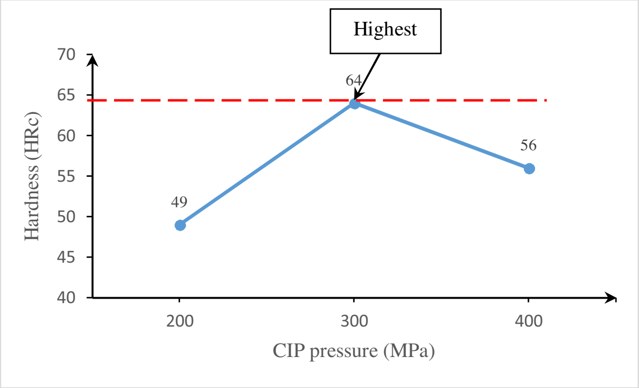

Fig. 6 – Effect HRc on CIP pressure at 60 s dwell time.

Table 1 – Compositions of Al_2O_3-ZrO_2 mixed with constant 0.6 wt% Cr_2O_3.

Type	Al_2O_3 (wt%)	ZrO_2 (wt%)
A	75	25
B	80	20
C	85	15
D	90	10
E	95	5

grain boundaries. As a result, the compaction process did not take place where porosity or microcracks remained between the grain boundaries. When sintering, such porosity trapped between the dislocated grains could reduce the density of the Al_2O_3- ZrO_2. In addition, the porosity and grains dislocation could induce stress concentration that could facilitate deformation during hardness indentation. This is shown in Fig. 6 when a sample pressed with 400 MPa contributed only 56 HRc in hardness as compared to 64 HRc achieved by 300 MPa CIP pressure.

3.2. *Mechanical behaviour*

Percentage composition of Al_2O_3- ZrO_2 mixed with 0.6 wt% Cr_2O_3 to fabricate the cutting tool as seen in Table 1 was investigated to identify the mechanical behavior of ceramic cutting tools that were robust and suitable for machining purposes.

The development of cutting tools was a continuation of the parameters obtained from the binder and CIP tests.

3.2.1. *Density*

Fig. 7 shows the effect of percentages between Al_2O_3 and ZrO_2 by adding Cr_2O_3 composition on the density of the fabricated cutting tool. It shows that the density of the cutting tool increased as the ZrO_2 content increased since the density of ZrO_2 is higher than the density of Al_2O_3. In terms of density improvement, the addition of 20 wt% ZrO_2 into 80 wt% Al_2O_3 consumed up to 3.40% density improvement, which is from 93.6% to 97%. This shows that the addition of 20 wt% ZrO_2 contributed a significant increase in densification during powder mixture and sintering of ceramic bodies.

3.2.2. *Hardness*

Fig. 8 shows the effect of Al_2O_3-ZrO_2 composition on HRc. For the initial stage, HRc was selected as the predominant output. Consistent with density, the highest hardness was recorded at 71.03 HRc when the composition of 80–20 wt% was used. This was followed by 85–15 wt% and 75–25 wt%. The results are consistent with Smuk et al. [21], where the addition of 20 wt% ZrO_2 on Al_2O_3 matrix exhibited better mechanical properties, as can be seen in Fig. 10 which portrays the highest hardness on composition B.

3.2.3. *Bending strength*

Fig. 9 shows the effect of ZTA compositions on bending strength with the addition of a constant 0.6 wt% Cr_2O_3. The results show that the cutting tool fabricated with the mixing percentage of 80–20–0.6 wt% exhibited the highest bending strength of 856.02 MPa. This shows that this mixing percentage was able to withstand load during machining and bending strength or alternatively known as a rupture modulus, which is a load test applied to the ceramic cutting tools to determine the level of strength. Bending strength is important to represent the capability of cutting tool to resist load during a material engagement with workpiece material. This is to avoid catastrophic failure as the cutting tool is in contact with the workpiece.

3.2.4. *Microstructure*

The microstructures were observed to identify and support the data obtained from the study of the mechanical behavior of various percentages of Al_2O_3-ZrO_2 mixed with 0.6 wt% Cr_2O_3. The sintered sample microstructure was examined by using the SEM with a magnification of 5000X at 1 μm. With the composition of 80 wt% Al_2O_3 and 20 wt% ZrO_2 as shown in Fig. 10(d), the porosity of the surface of the cutting tool was further reduced compared with Fig. 10(a) at 95 wt% Al_2O_3 – 5 wt% ZrO_2; Fig. 10(b) at 90 wt% Al_2O_3 – 10 wt% ZrO_2; and Fig. 10(c) at 85 wt% Al_2O_3 – 15 wt% ZrO_2. An increase in the percentage of ZrO_2 helped strengthen the bonds, assisted by the evaporating Cr_2O_3 when sintered where the grains covered the space between the grain necks on the surface of the cutting tool. The percentage composition of Al_2O_3-ZrO_2 was appropriate and sufficient to add Cr_2O_3, which helped accelerate the expanding of the grain. However, for Fig. 10(e) at 75 wt% Al_2O_3 – 25 wt% ZrO_2, when the ZrO_2 content was increased to 25 wt%, the surface morphology shows the

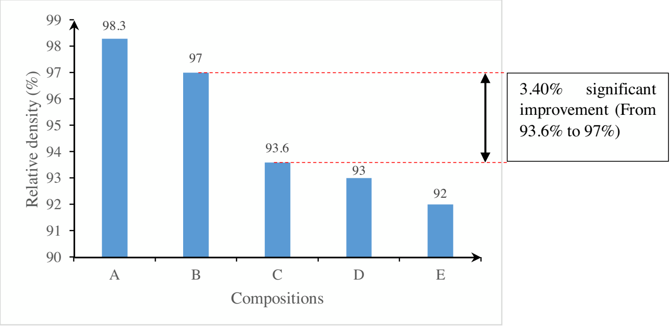

Fig. 7 – Density on various compositions of Al_2O_3-ZrO_2 mixed with Cr_2O_3.

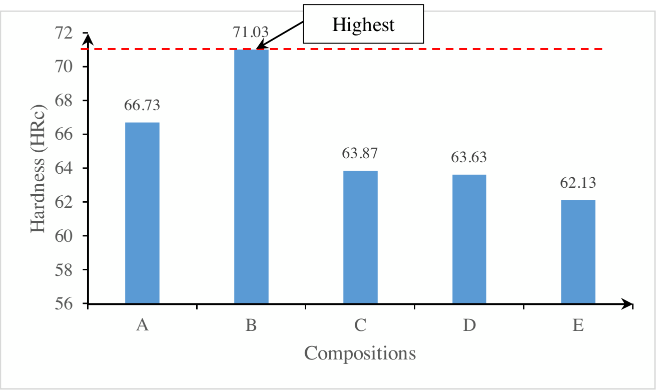

Fig. 8 – Hardness on various compositions of Al_2O_3-ZrO_2 mixed with Cr_2O_3.

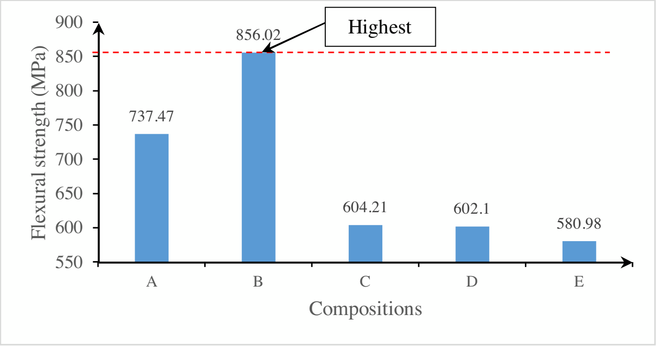

Fig. 9 – Bending strength test on various compositions.

deteriorating reaction of the grains through the appearance of microstructure by increasing the porosity space between the grains. According to Smuk et al. [21], the addition of ZrO_2, which is at 20% mass can maintain a uniform distribution in the structure, although ZrO_2 causes segregation. However, Mondal et al. [22] emphasised the content of ZrO_2 between 10–15% volume to produce a strong ceramic cutting tool that has better fracture toughness and abrasion resistance than pure Al_2O_3. Based on observation, the addition of ZrO_2 turned out to minimize the percentage of porosity in the cutting tool, and the ideal percentage of ZrO_2 is 20 wt%, which can improve the mechanical behaviour of the cutting tool.

3.2.5. *XRD analysis*

A typical XRD at 80 wt% Al_2O_3-20 wt% ZrO_2 and mixed with 0.6 wt% Cr_2O_3 has been described in Fig. 11 and it proved the existence of Cr_2O_3 on the ZTA cutting tools. Cr_2O_3 can be seen in some places, but at a small percentage and is limited compared with Al_2O_3 and ZrO_2. The Al_2O_3 used was α-Al_2O_3; it is a stable element compared to γ-Al_2O_3. α-Al_2O_3 is widely used as one of the refractory materials of the oxide group because

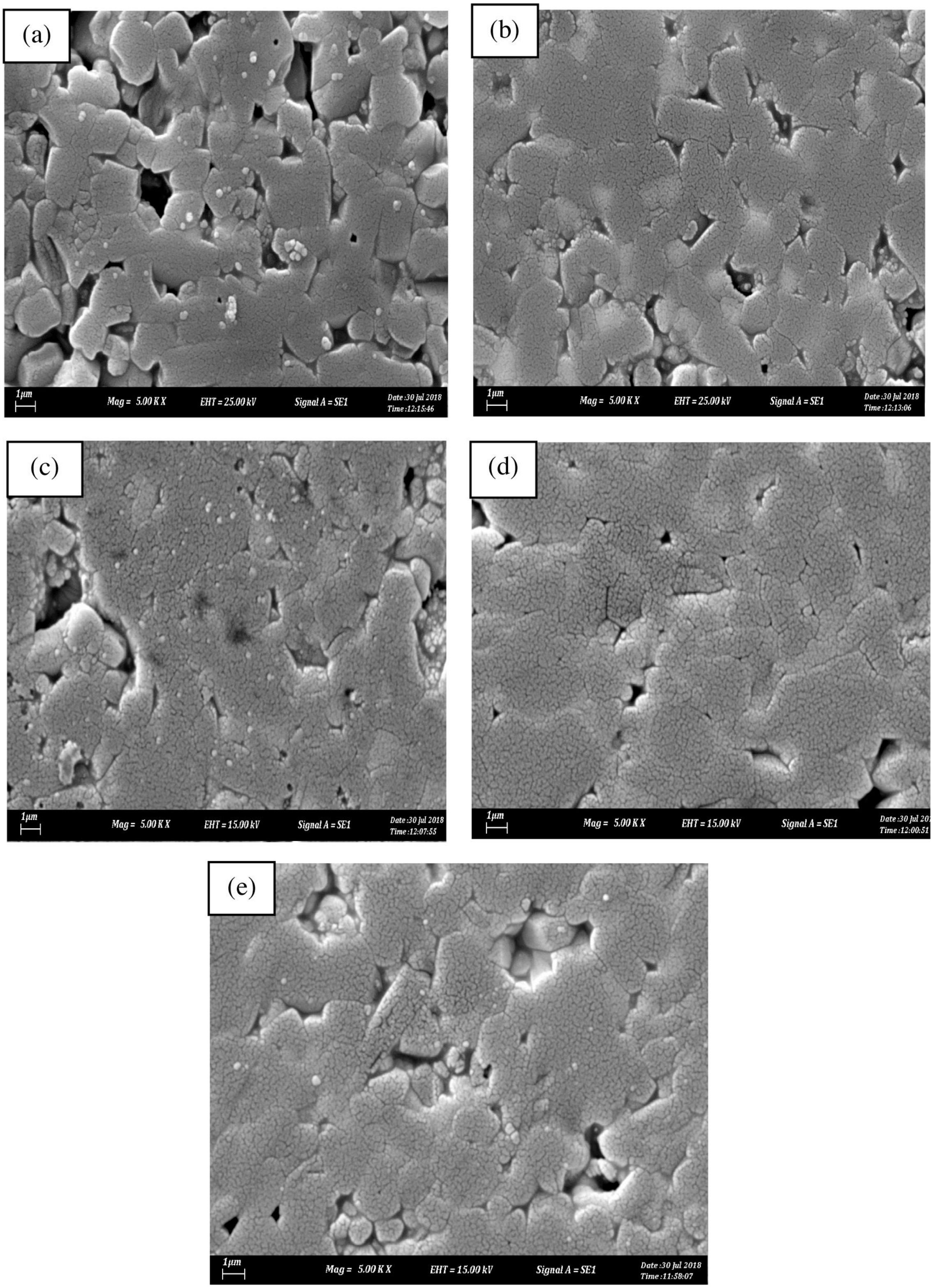

Fig. 10 – Microstructure comparison of top surface views of Al_2O_3-ZrO_2 mixed with Cr_2O_3 with 1 μm scaled.

it has excellent physical, mechanical, and thermal materials [24]. The most stable phase of Al_2O_3 is the α-Al_2O_3 phase, in the thermal treatment process obtained through the transformation process and clearly suitable for cutting tool development. Meanwhile, the ZrO_2 identified in this test was in a tetragonal phase, and this phase is most stable than cubic and monoclinic phases. The ZrO_2 identified was classified as a tetragonal and t-ZrO_2 ceramic powder which is very stable, because when

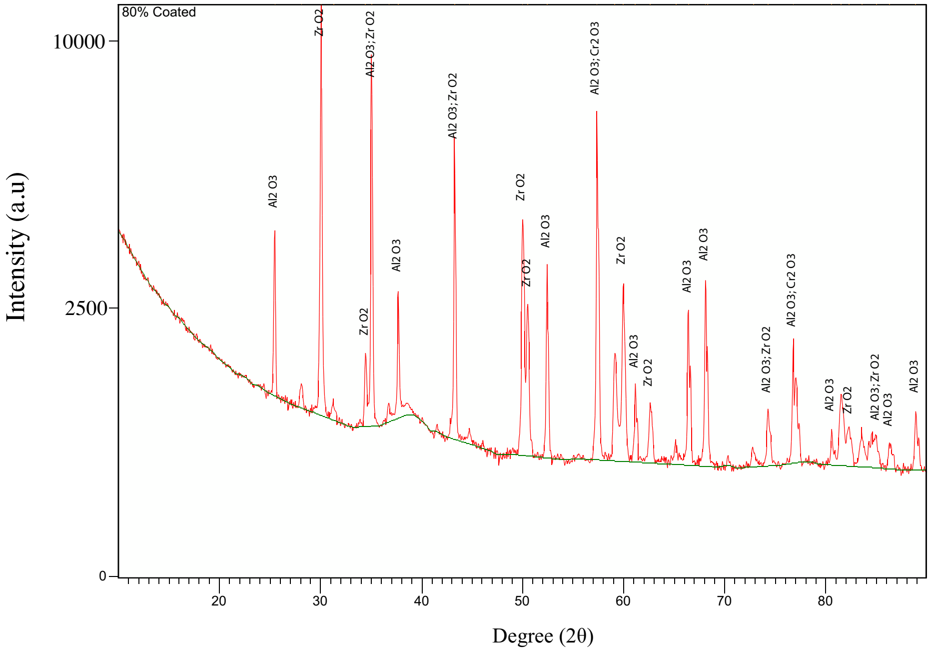

Fig. 11 – XRD patterns of 80 wt% Al_2O_3-20 wt% ZrO_2 mixed with 0.6 wt% Cr_2O_3.

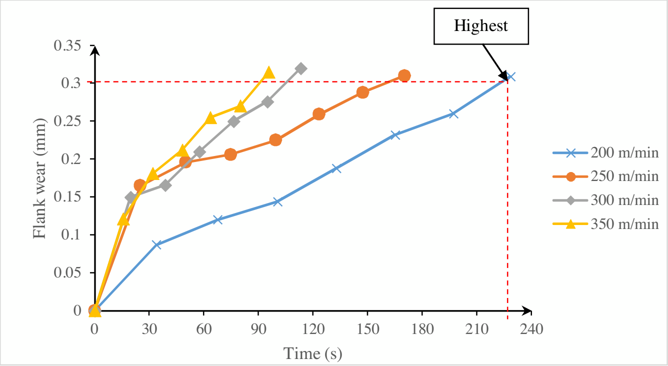

Fig. 12 – Wear performance of fabricated cutting tools at different cutting speed and constant feed rate of 0.150 mm/rev.

some properties of ZrO_2 are at the tetragonal phase, it can be metastable [25].

3.3. *Machining performance*

Fig. 12 shows the effect of cutting speed on tool wear for the fabricated Al_2O_3-ZrO_2-Cr_2O_3 cutting tool with a composition of 80–20-0.6 wt%. The plot clearly indicated that tool life increased as the cutting speed decreased. The fabricated cutting tool demonstrated its ability when performed at a lower cutting speed of 200 m/min and high feed rate 0.150 mm/rev. At the early stages of machining, (around 30 s), tool wear, *Vb* increased tremendously almost to 0.1 mm. As the machining prolonged, machining with 200 m/min demonstrated a stable wear rate with average progressing time until 225 s to reach 0.3 mm and time recorded 230 s equal to wear of 0.309 mm. Meanwhile, machining with cutting speed of above 300 m/min demonstrated tremendous failure to reach 0.3 mm within 100 s. This showed that the fabricated cutting tool is suitable to be applied at 200 m/min and not capable to be applied beyond 300 m/min.

Fig. 13 shows of the wear profiles for each cutting speed recorded at 90 s machining period. All cutting tools exhibited uniform flank wear, where abrasion marks were clearly visible with evidence of minor chipping and flaking observed at the cutting edges. This shows that the cutting tools developed possessed strong structural integrity to retain a solid edge during machining, even at the high cutting speeds. There are evidence of slight molten metal attachment at the side of the cutting edge in Fig. 13(b), (c) and (d).These reflect the heat generation developed at the specific area of cutting tools, suspected from the higher cutting speed. Such molten metal reflected the adhesive wear started to develop at the specific area which promote severe material lost due to adhesive seizure as the machining prolonged. In the previous study, the wear development of Al_2O_3 based cutting tool demonstrated severe breakage within short machining period [26]. On the other hand, the wear development of Al_2O_3-ZrO_2 based cut-

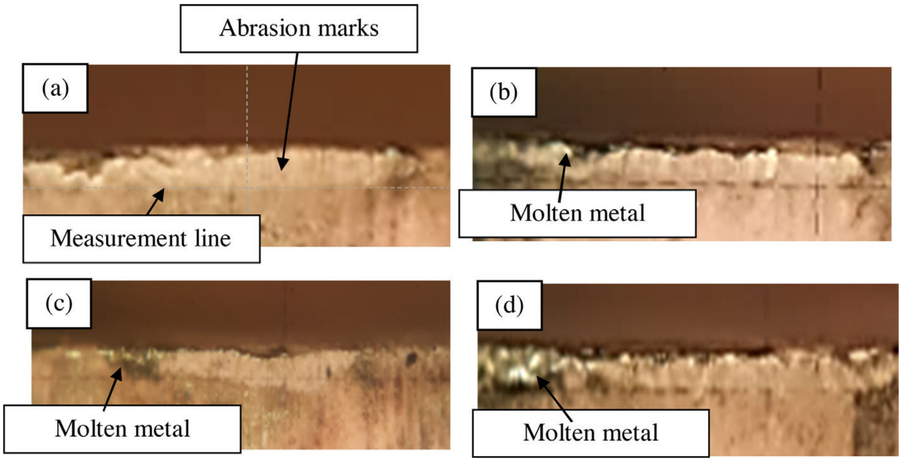

Fig. 13 – Shape of flank wear taken at 90 s average time at cutting speed of (a) 200 m/min, (b) 250 m/min, (c) 300 m/min and (d) 350 m/min.

ting tool demonstrated severe notches at the early stage of machining [16]. In the present study, the wear mechanism of developed Al_2O_3-ZrO_2-Cr_2O_3 presented uniform flank wear, which proves that the addition of just 0.6 wt% Cr_2O_3 contributed significantly to the structural integrity of cutting edge.

As suggested by Riu et al. [23], partial of Cr ion was diffused into the surface of Al_2O_3 in a form of shell layer during sintering. This shell layer, which is interpreted as a coating layer by Norfauzi et al. [16], grew the grains rapidly to become platelike shape and altered the grain size distribution into bimodal structure. Grain distribution with bimodal structure provided improvement in terms of slip resistance at the grain boundary due to anisotropy grains orientation. During machining, such improved microstructure facilitated stronger cutting edge to shear the material effectively and therefore lower the friction, reduce cutting heat and extend tool life.

The ZTA mixed with Cr_2O_3 composition is the material that can enhance the tool life of the ceramic cutting tools; the addition of Cr_2O_3 helped to coat the surface layers of the Al_2O_3 and ZrO_2 cutting tools, which were wear resistant and heat resistant during the machining processes. The use of Cr_2O_3 in the ceramic mixing material increased the levels of wear resistance and thermal resistance, which in turn facilitated in smoothening the process of machining. This notion is also stated by Azhar et al. [13] in their study, in which the addition of Cr_2O_3 to the ceramic mixtures provided resilience, wear resistance, increased hardness, and corrosion resistance. This Cr_2O_3-enhanced cutting tool provided a longer tool life and better performance in the machining processes.

4. Conclusion

Development of ceramic cutting tools consisting of Al_2O_3-ZrO_2 mixed with Cr_2O_3 with the selection of effective PEG binder and CIP pressure has been carried out. The cutting tools developed were evaluated by machining with AISI 1045 to assess the suitable cutting parameter and wear mechanisms. Some concluding analyses from the investigation are given below:

- Addition of PEG binder at 0.6 wt% was capable to produce compacted Al_2O_3-ZrO_2 ceramic body at 92.6% relative density with 62.5 HRc hardness.
- A CIP pressure of 300 MPa and dwell time of the 60 s were capable to produce the highest density and hardness of Al_2O_3-ZrO_2 at 95.8% relative density and 64 HRc.
- The addition of 0.6 wt% Cr_2O_3 on the 80 wt% Al_2O_3-20 wt% ZrO_2 was capable to increase up to 97% relative density, 71.03 HRc hardness, and 856.02 MPa bending strength.
- Machining of 80-20-0.6 wt% Al_2O_3- ZrO_2-Cr_2O_3 cutting tool on AISI 1045 with the cutting speed of 200 m/min obtained the highest tool life of 360 s. The cutting tool fabricated was not capable to machine beyond the cutting speed of 300 m/min.
- The addition of Cr_2O_3 provided friction reduction to the cutting edge, which facilitated less temperature generation during contact with the chip and comparison to the ZTA without Cr_2O_3 indicated that the cutting tool experienced deterioration at the cutting point, resulting in chipping and flaking.
- Wear mechanisms of the fabricated cutting tools were dominated by abrasive wear and flank.

Conflicts of interest

The authors declare no conflicts of interest.

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