INVESTIGATION OF PROPERTIES OF ALUMINA BASED CUTTING TOOL UNDER DIFFERENT SINTERING TEMPERATURE AND SOAKING TIME

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ABSTRACT: This study focused on the development of ceramic cutting tool based on the alumina powder that processed by powder metallurgy. The prosess started with preparation of powders of spray dried alumina that poured in a mould. Hydraulic hand press was utilised to press the sample in the form of round and trapezium inserts before compressed inside Cold Isostatic Press to produce the green body. The ceramic compacts were sintered at varied temperature from 1200°C to 1400°C with soaking time varied form 5 to 9 hours. The mechanical properties of alumina based cutting tools such as shrinkage size,hardness, density and microstructure were analysed. The results show that the density and hardness generally increased as the sintering temperature and soaking time increased. Maximum sintering temperature of 1400°C and 9 hours soaking time demonstrated capability to be applied as a domain sintering parameter for high performance cutting tool. In terms of microstructure, sintering temperature below 1300°C and 6 hours soaking time demonstrated insignificant characteristic to present particles packing. Thus, resulting lower density and hardness. Outcome from this study will be used to propose some improve or refinement for the cutting tool development in the future.

KEYWORDS: *Ceramic cutting tool, alumina, sintering, microstructure*

1.0 INTRODUCTION

Cutting tool is the one of the major factor that significantly influence the performances of machining process. There are several type of cutting tool material such as carbon tool steel, high speed steel (HSS), cemented carbide, ceramic, cubic boron nitride (CBN) and diamond [1-2]. These cutting tools can be categorised based on two conditions, which is single point tool that used only one cutting edge such as turning. The other one is multipoint tools that used in milling and drilling processes. The usage of cutting tool for a particular application depended on the type of machining, material to be machined, quality and quantity of production [3-4]. Usually, cutting tool materials must be harder than the material to be cut which enable them to shear effectively and withstand the heat generated in the cutting process.

Among many cutting tools that available in industry, ceramic cutting tools being one of the most dominant especially when dry machining applied [5-6]. Ceramic cutting tool normally manufactured by the combinations of ceramic powder that are pressed into insert under high pressure and sintered at high temperature. Ceramic based material generally possessing low thermal conductivity, inertand abrasive. Because of these reasons, ceramic materials have been widely used due to its admirable

properties especially in high temperature and high speed machining [7-8].

One of the major ceramic materials that been applied as cutting tool is alumina. Alumina, which known as aluminum oxide, is the most popular material to select as fabricate cutting insert because of its excellent hardness, electrical and thermal insulator behavior against the environment and the work piece [9-10]. Therefore, alumina based materials not only being nused as cutting tool but also other applications such as are in refractory (furnace wall), water filter, mixer (ball mill jar), polishing (grinder wheel) and various abrasive and refractory components [11-12].

To produce alumina that capable to be applied as cutting tools, raw powders of alumina should be carefully processed. The additional of binder could strengthen between reinforcement aprticles and matrix [13]. Several steps such mixing with binders, ball mill, insert to mold, pressing and sintering should be controlled in order to produce high density ceramic body with fine and uniform microstructure [13-14]. Among several processing stages, controlling pressing and sintering parameters are vital to produce perfect cutting tools. During pressing stage, combination of hand press together with cold isostatic pressure important for shaping the alumina compact. As the alumina powder pressed perfectly, the shrinkage, microstructure and hardness could be increased by controlling the sintering temperature and soaking time.

In this study, the effect of sintering temperature and soaking time on properties of alumina based cutting tool have been investigated. Intention of the study focused on the microstructure, density, hardness and dimension change as the sintering temprature and soaking time increased. The results obtained in this study will be used to design and produce the new ceramic cutting tool and determine the suitable die design for near net shape production of alumina-based ceramic cutting tool.

2.0 METHODOLOGY

Alumina powders that used in this study categorized as spray dry type. This powder considered treated for tiny granules which increase packing capavity when compacted together.. Figure 1 (a) shows the spray dry alumina powder used in this study. The powder was assigned to undergone ball milling for 12 hours to make sure that particles segregated with crushing action inside the ball mill jar as shown in Figure 1 (b). The ball milled powder the was weighted consistent at 2.5 g for each sample to provided consistent size of cutting tool as shown in Figure 1 (c). Next, the powder was inserted into the mould as hown in Figure 1(c). Inside the mould, powder was pressed by manual hydraulic press as shown in Figure 1 (d). The compacted powder has been ejected as a green body to obtain the required shape of the cutting tool. Further secondary compaction was implemented by Cold Isostatic Press (CIP) at the pressure of 350 MPa, for uniaxial compaction improvement as per Figure 1 (e). In the Figure 1 (f) the ceramic compact was sintered according to the sintering parameters as shown in Table 1.

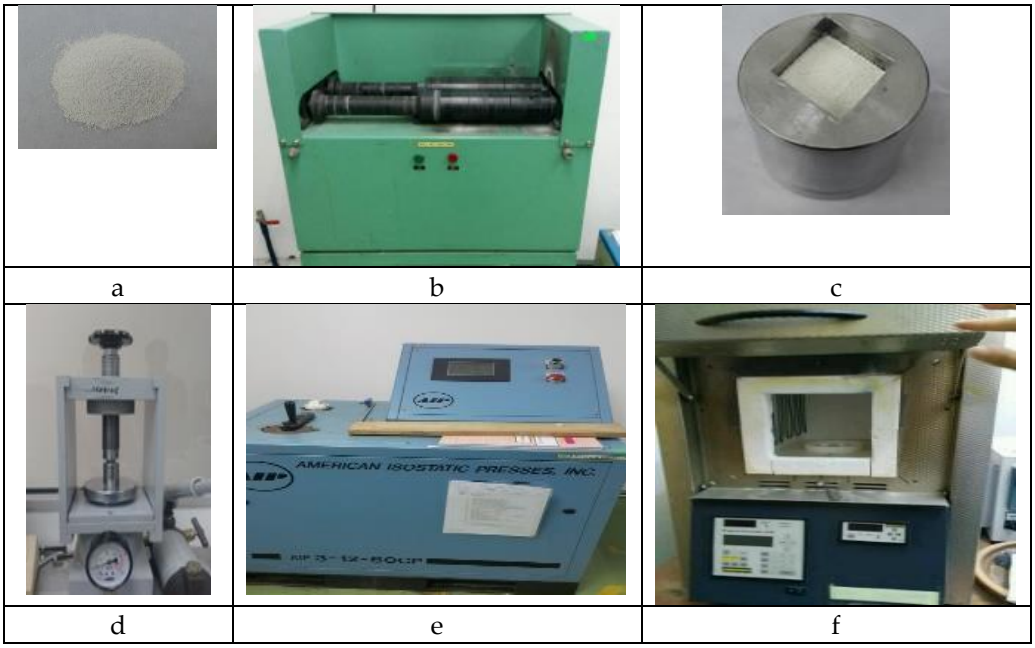


Figure 1. Spray dry processes

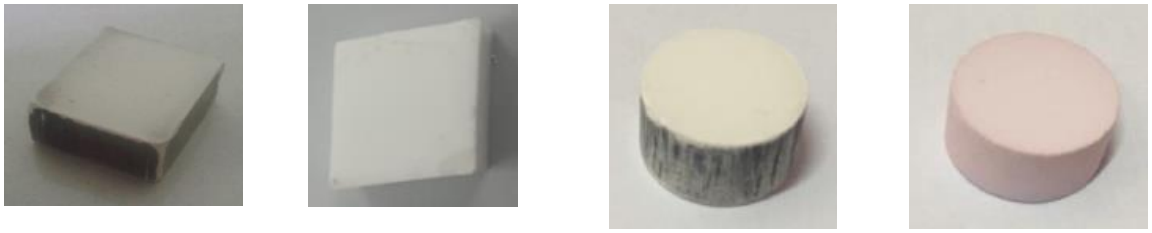
Table 1 Sintering parameter

SAMPLES	TEMPERATURE (°C)	SOAKING TIME
SAMPLE 1	1200	5
SAMPLE 2	1200	7
SAMPLE 3	1200	9
SAMPLE 4	1300	5
SAMPLE 5	1300	7
SAMPLE 6	1300	9
SAMPLE 7	1400	5
SAMPLE 8	1400	7
SAMPLE 9	1400	9

The sintered body of ceramic then were examined in terms of shrinkage by measuring the thicknes, width and length before and after sintering. Density and hardness were measured by Densitimeter and Vickers hardness tester respectively. Finally the microstructure of the sintered sample was analysed by Scanning Electron Microscopre (SEM). The samples were polished prior to microscopy observation.

3. RESULT AND DISCUSSION

Figure 2 shows the images of the compacted green body for both trapezium and round samples before and after sintering. These figure shows that the colour after sintered sample changed to clean white.



(a) (b) (c) (d)

Figure 2 Appearacne of comapcted green body befora and after sintering; (a) trapezium sample before sintering, (b) trapezium sample after sintering, (c) round sample before sintering and (d) round sample after sintering

Figure 3 and Figure 4 shows the effect of sintering temperature on the shrinkage for both size of trapezium and round cutting tools. The figures show that there are reductions in the size around 3% to 6% of the cutting tools before and after sintering for both shape. The analysis of shrinkage is important in order to prduce the mould for accurate cutting tool. This is also to make sure the cutting tool can be inserted into the tool holder.

During sintering, there were three stages occurred inside the particle packing. The first stage refer to the mobility of grain that started to concave necks between individual aprticles. As the sintering prolonged, which is at intermediate stage. The grain started to growth depending on the thermal expantion of alumina. The particles started to engaged each other as the grains expanded toward the boundary for each particles. As the sintering proceeded to the final stage, further expansion of alumina particle resulting diffusion at the grains boundary. On the same time, the porosity strated to diminish which increasing the density in the structure. Ultimatley, the structure of alumina provided better physical and mechanical properties and ready to be applied as cutting tool [13-15].

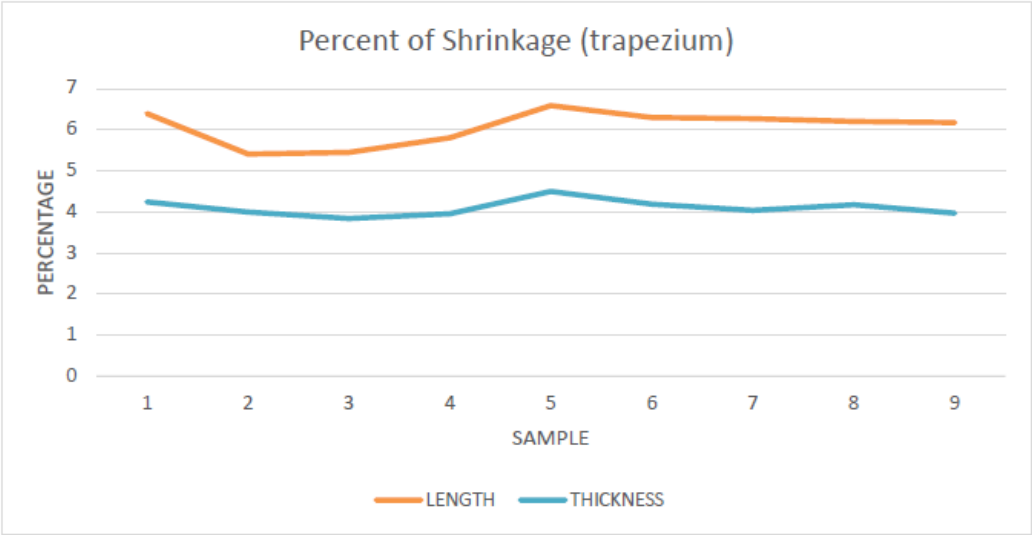


Figure 3 The shrinkage alumina compacts for trapeziumshape

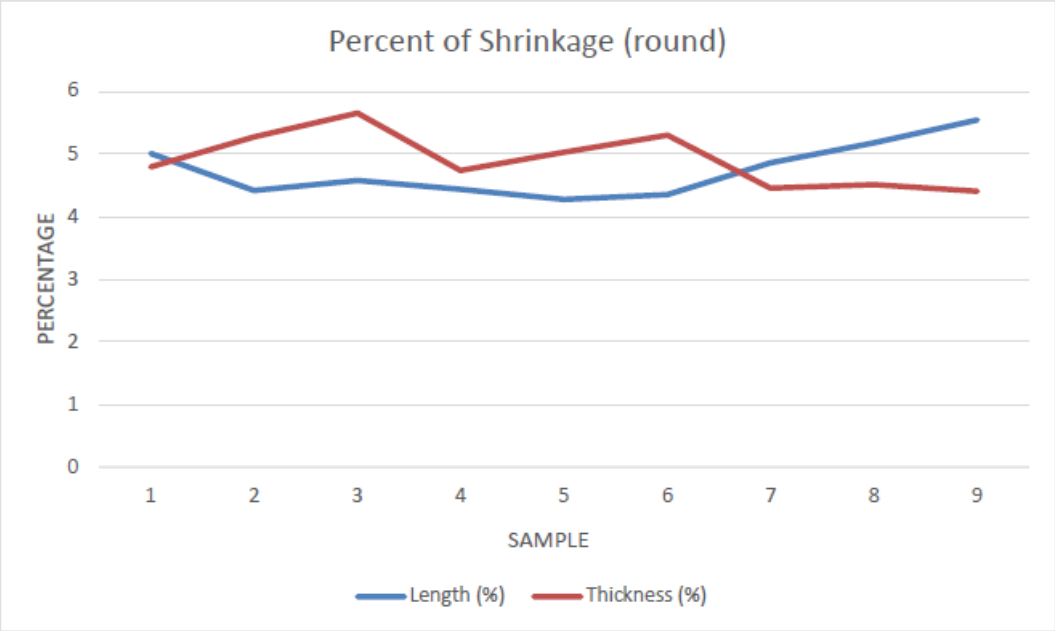


Figure 4. The shrinkage alumina compacts for round shape

Figure 5 show the effect of sintering temperature and soaking time on the relative densities of alumina-based ceramic cutting tool. The result shows that the samples that sintered from 1200°C to 1300°C demonstrated almost similar density, which is at the range of 75-76%. On the other hand, the sample that sintered with 1400°C achieved higher relative density as compared to the samples sintered at 1200°C and 1300°C. From the graph, it can be seen that the maximum relative density is 91.30% for trapezium sample that sintered 1400°C and 9 hours soaking time. Meanwhile for the round cutting insert sample the highest relatived density is 82.2% at 1400°C sintered pressure and 9 hours soaking time. This result reflected theorytical explanation that state higher sintering temperature and soaking time producing higher relative density of sample.

On the other hand, the percentage of porosity of the sintered bodies is inverse with the relative density. From the graph at Figure 6, it can be seen that the porosity of sample reduced as the higher sintering temperature and longer soaking applied. This phenomena is due to the particle expansion that lead to the close pores gap between the particles [16-17]. At the lower sintering temperature of 1200°C, significant amount if porosity reflected unability of lower sintering temperature of 1200°C to provide adequate particle expansion. After applied with 1400°C sintering temperature, the alumina particles were expanded and diffused at the grain boundary resulting interlocking grains that yield higher hardness. In additions, the contacted area within particles also will increases, resulting structural toughtening along partcles packing. Therefore, increasing relative density when the sintering temperature increased resulted from the formation of the string bond between particles.

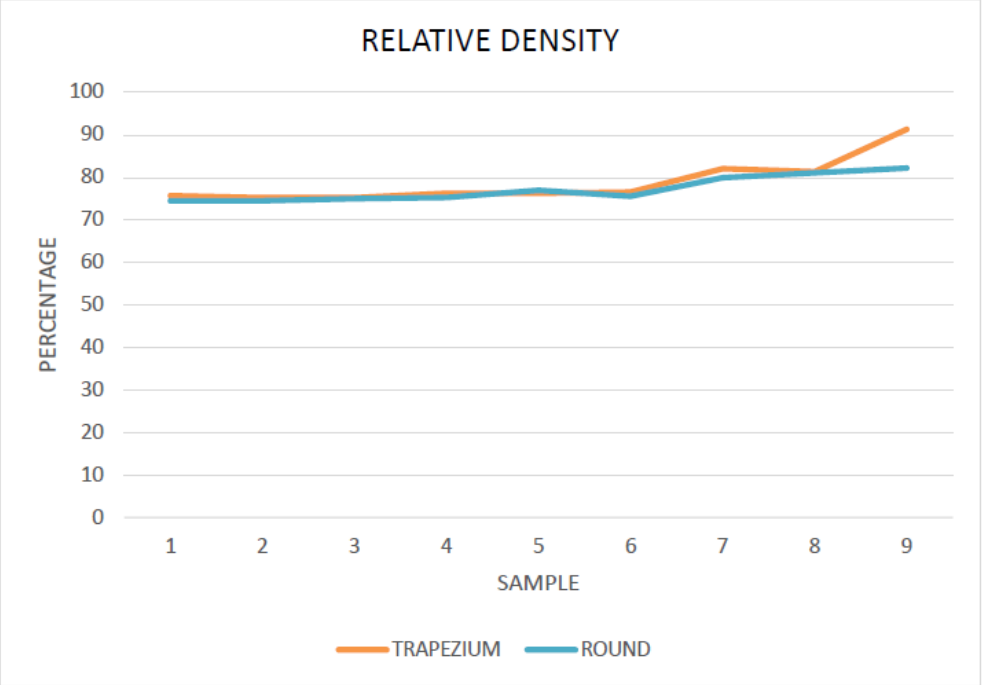


Figure 5. The relative density of alumina compact according to the sintered samples

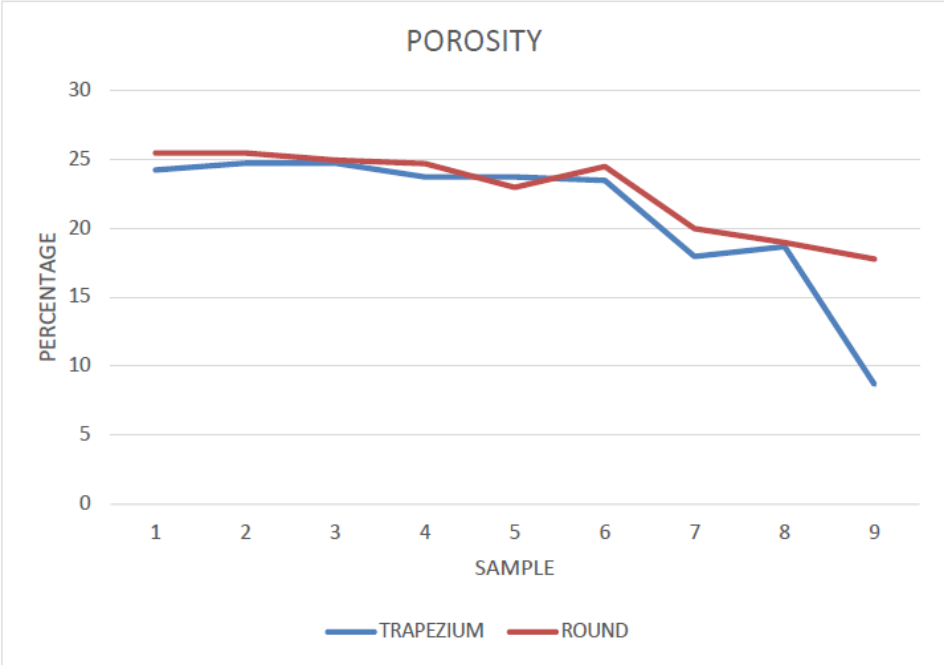


Figure 6. The porosity of alumina compact according to the sintered samples

Figure 7 shows the relationship between hardness and sintering temperature and soaking time for the round shape sample. It shows that the sample that sintered with 1400°C sintering temperature exhibited highest values of hardness as compared to the 1200°C and 1300°C.

Based on the graph hardness, at the sintering temperature of 1400°C, the hardness increased from 721.61 HRA to 803.34 HRA when soaking time increased from 7 to 9 hours. However, at the similar

soaking time, the hardness of samples for 1200°C and 1300°C sintering temperature resulted the hardness at 209.88 HRA to 485.67 HRA. Therefore, increasing sintering temperature form 1200 to 1400 resulting more than 50% increase in hardness. The relationship of between hardness and density is correlative each other. Hihg relative density resulting higher hardness and vice versa. At higher density of ceramic compact, it is expected tha the particles are packing close each other where less porosity appeared inside the structure. Less porosity reduce the chance of stress conceration and grain slipping when applied with load. Therefore, the resistance to deform will be higher, resulting higher harndess to the sample.

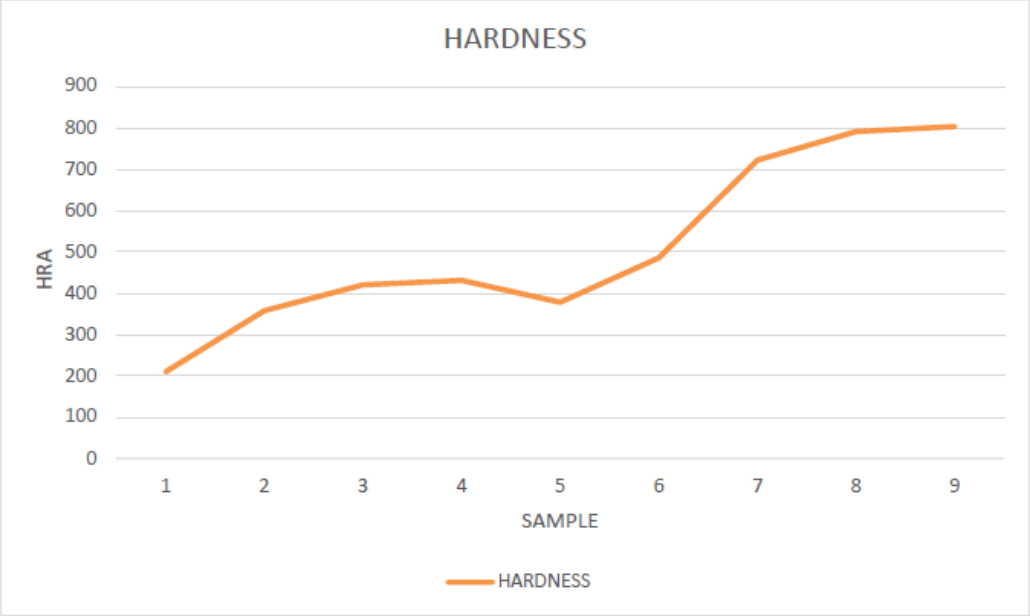


Figure 7. Harndess variation for sintered samples

Figure 8, Figure 9 and Figure 10 shows the microstructure observation of sintered samples at 1200°C, 1300°C, 1500°C and 5, 7, 9 hours soaking time respectively. For the samples that sintered at 1200°C, the microstructure demonstrated almost similar characteristics where most of the particles still not adequately expanded and inhibited bonding between particles. The microstructure appearance consistent for 5, 7 and 9 hours soaking time.This shows that sintering temperature at 1200°C with different soaking time not significantly contributed to the better particle compaction for dense ceramic body.

The sample that sintered with 1300°C from 5 to 9 hours soaking time exhibited different characteristics. Firstly, at the soaking rime of 5 hour presented similar characterisitcs as compared to 1200°C there are clear isolated particles that refrlected no thermal expansion for the particles invovled. As the soaking time increased to 7 and 9 hours, appearance of thermal expansion started to appear, reflected the heat form sintering process adequate to invoke energy for the particles to expand. Grain growth and some micro cracked in the middle of the green body were evidence presenting denser appearance of the particle packing [16-17].

Finally, samples that sintered at 1400°C demonstrated a better compaction appearance as compared to 1300°C. For both sintering temperature, the soaking hours of 9 hours exhibited better compaction that 7 and 5 hours. The sintered body also presented grain growth which represent the expansion of particles.

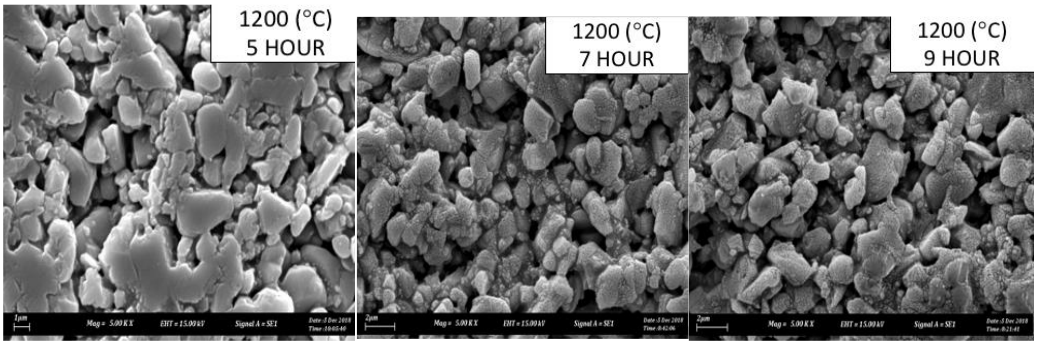


Figure 8. Microstructure characteristics for the sintered samples at 1200°C

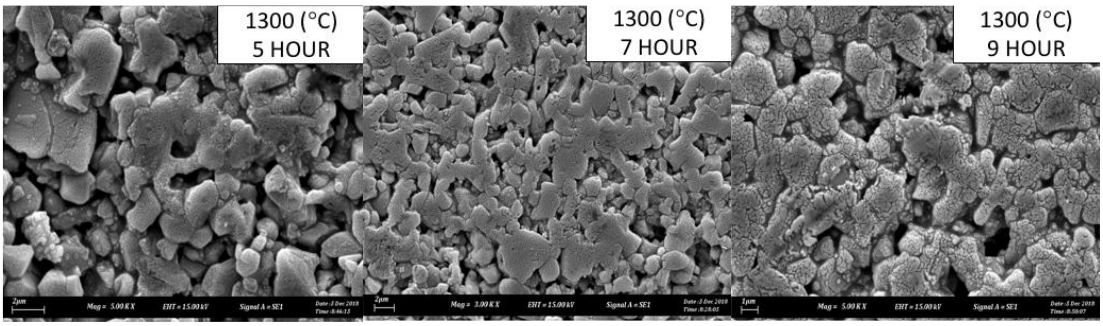


Figure 9. Microstructure characteristics for the sintered samples at 1300°C

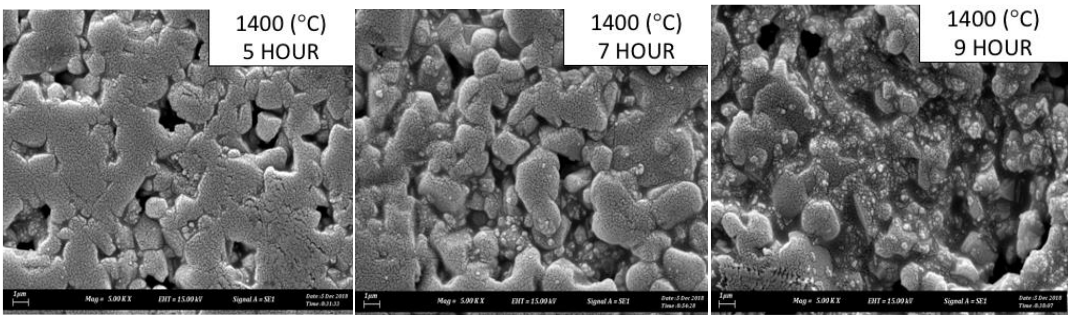


Figure 10. Microstructure characteristics for the sintered samples at 1400°C

4. CONCLUSION

This paper presents the fabrication of the alumina based ceramic cutting tool that sintereded with different temperature and soaking time from 1200°C to 1400°C for 5 to 9 hours respectively. Based on the experimental finding the following conclusions can be drawn:-

1. The density and hardness value of the cutting tool increase as the sintering temperature is increase. Cutting tool sintered at 1400°C at 9 hours soaking time resulting highest density and hardness of 2.77 g/cm^3 and 86.1 HRA respectively.

2. Temperature and soaking time of 1400 °C for 3 and 6 hours and 1300°C for 9 hours demonstrated characteristics of particels expansion that reflected the adequate aramter for sintering process.

3. Microstuture of the cutting tool sintered under 1300°C and 6 hours soaking time domenstrated isolated grain with limited sign of particles expansion. This resulting high porosity, which promoting lower density as well as hardness.

5. ACKNOWLEDGEMENT

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