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# The Effect of Sintering Temperature and Material Composition on The Mechanical Properties of Powder Metallurgy Products

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***Abstract:****Waste is a problem that is still hotly discussed today. One of the wastes that we often encounter is aluminum waste. Aluminum waste can indeed be re-smelted, but the results of the smelting produce even more dangerous waste, namely B3 ( Hazardous Toxic) waste. In addition to aluminum waste, there is also a lot of waste that we encounter in our daily life, namely glass waste. This study aims to maximize the potential of aluminum waste and glass waste by examining the effect of variations in sintering temperature and material composition on the hardness and compressive strength of the composite. This research was started by crushing the solid material into the mesh of 100, the next stage was mixing the powder and then printing it with 7 tons pressure load. The last step is sintering the specimens at temperatures of 390 o C, 490 o C, and 590 o C with 60 minutes holding time. The results show that the highest hardness value is 60 HRF and the highest compressive strength value is 235.59 MPa. Variation of sintering temperature has a directly proportional effect on the hardness and compressive strength values. Variation in the composition of material gives an inversely proportional effect on the two tests of mechanical properties when viewed from the percent addition of glass powder.*

***Keywords:****Sinter temperature, Powder metallurgy, Mechanical properties.*

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## I. INTRODUCTION

One of the wastes that is often found is aluminum waste which is usually produced from canned beverage bottles and leftover cutting of display cases. Aluminum waste can indeed be remelted, but the results of the melting will produce even more dangerous waste, namely Hazardous and Toxic Materials (B3) waste. According to Saraswati and Razif (2020), the aluminum smelting industry produces waste in the form of aluminum slag ash which is dumped around residential areas. Slag itself is a secondary ash resulting from the melting of aluminum solids that do not reach the boiling point of aluminum and are then reprocessed in a furnace. This aluminum slag waste is classified as B3 waste in PP 101 of 2014, has a code B313-2 from aluminum smelting industry activities with hazard category 2. Seeing the dangers caused by aluminum slag, it is necessary to process aluminum waste in a more appropriate way so as not to produce waste again. In additiontoaluminumwaste, thereisalsoglasswastefromusedbeveragebottles, leftoverglassfromfurniture making, brokenkitchenequipment, andleftoverbuildingglass. Glass wastetakes a very long timetodecompose, ittakesupto 1 millionyearstocompletelydecompose (Sylvia & Mahmudah, 2018). Ofcourse, ifthewasteis not recycledorreused, itwillcauseenvironmentalpollution. Althoughthere are factoriesthatrecycleandMSMEsthatmakecreationsfromglasswaste, in realityglasswasteisstillscatteredeverywhereand not allofitcanbeprocessedat once.

Aluminum and glass waste can be processed into composite products using the powdermetallurgymethod. The advantageofthepowdermetallurgytechniqueisthatitisableto mix differentmaterialssuch as metalsand non-metalstobecome a new material called a composite.Aluminum has greatpotentialtobeprocessedintocomposites. In additiontohavingseveraladvantagessuch as mechanicalpropertiesandcorrosionresistance as well as goodelectricalconductivity, aluminumcanalsobeused in variousareasoflifesuch as householdappliances, aircraft material needs, shipping, automotiveandothers (Tawan etal., 2019). In additiontoaluminum, glassisalso a goodreinforcing material becauseitsconstituentmaterials are dominatedbysilica ($SiO_2$) andhave a highmeltingpointandverystrongmechanicalproperties (Anggria etal., 2016).

Researchontheeffectofmixingtimeonhardnessandwearwasconductedby Nawangsari and Anuar (2016) usingsodalimeglasspowderandused piston powder as alternativematerialstoreplace non-asbestos brakepads. The study foundthatthemost optimal mixingtimewas 30 minuteswithhardnessandwearvaluesclosetocommercialbrakepadproducts, namely 41.296 HVN and 8.279 x 10 -

[12] m [3] / m. Another study wasconductedby Triadi etal. (2019) whostudiedtheeffectofsinteringtemperatureonthehardnessandcompressivestrengthof Al-Cu-SiCcompositesthrough a powdermetallurgyprocess. Heating was carried out at temperatures of 320 $^{o}$C, 420 $^{o}$C, and 520 $^{o}$C for 40 minutes. The results showed that the specimen had a high level of hardness and compressive strength at a temperature of 320-420 $^{o}$C. Further research is needed at higher temperatures above 520 $^{o}$C with a longer sintering duration to determine whether the mechanical properties can be further improved.

Anugraha and Widyastuti (2014) conducted a study on the effect of Sn composition and compaction variations on Cu-Sn composites on their hardness and density. The study used a powder metallurgy method for *frangible bullet projectile applications* . The results showed that the highest density value was produced at the Cu-5 wt% Sn composition with a compaction pressure of 500 Mpa of 7.446 g/cm3 . The increasing Sn composition and compaction given, the mechanical properties of the composite also increased. Seeingtheproblemsthatoccur in aluminumandglasswasteandthegreatpotential in theworldofpowdermetallurgyandcomposites, theauthorsprovide a breakthroughtofurtherresearchthepotentialofaluminumandglasswastetobeused as composites

## II. RESEARCH METHODS

This research wasconducted in theProductionLaboratory, andthe Materials Laboratoryofthe Department ofMechanical Engineering andtheStructureand Materials Laboratoryofthe Department ofCivil Engineering, Universityof Mataram . In this study, materialsused were aluminumwasteandglasswastetakenfromoneofthehouseholdfurniturecraftsmenanddisplaycases in the Mataram area. The equipmentused in this study includes a set ofequipmentforcrushingmaterialsintopowder, a set ofequipmentfor making specimens, andspecimen testing equipment. The specimen testing equipmentincludes a hardness tester in theformof*a universal hardness tester* with a testloadof 3-187.5 kgf, a compressivestrength tester withanaccuracyof 1 kN. This study usedvariations in sinteringtemperaturesof390 $^{o}$C, 490 $^{o}$C, and 590 $^{o}$C andvariations in thecompositionofaluminumandglass, namely 70:30, 80:20, and 90:10 percentbyweight. Severalcontrolledvariables are thesizeofthe 100 meshpowder, a mixingdurationof 15 minutes, a compactionloadof 7 tons, and a sinteringdurationof 60 minutes.

### 2.1. Hardness testing

Hardness testing in this study usedthe Rockwell method. A minor loadof 10 kg and a majorloadof 60 kg were used. The hardnessscaleusedwasthe*Rockwell* F hardnessscalewith a red dial. The testresultscanbereaddirectlyonthe dial indicatorafterindentation. The observationpositionmustbeparalleltothe dial indicatorsothatthereadingresults are moreaccurate. The testwasrepeated 3 timesforeachspecimen.

### 2.2. Compressivestrength testing

The compressivestrengthtest in this study wascarriedoutbyplacingthespecimenonthetesttool, whichwillthenbepressed until itbreaksandthepressureresultswillappearonthe analog panel in theformof kilo Newton (kN). To obtainthecompressivestrengthvalue (P), itisnecessarytocalculateusingthe formula below.

$$P = \frac{F}{A} \quad (1)$$

Information:
P= Compressivestrength (Pa)
F= Compressionload (N)
A= Surface area (m $^{2}$)

Meanwhile, tofindthesurface area of a cylindricalspecimen, the formula forthe area of a circleisused, namely:

$$A = \frac{1}{4}\pi d^2 \quad (2)$$

Information:
A= Area ofcircle (m $^{2}$)
d= Diameter ofcircle (m)

The testwasrepeated 3 timesforeachspecimen.

## III. RESULTS AND DISCUSSIONS

After conductingthetest, theresultsofthehardnessandcompressivestrengthvaluesofthespecimens were obtained, which were previouslyrepeated 3 timesoneachspecimen.

**Table 1. Testresult data**

| Temperature | Composition (Aluminum : Glass) (%) | Violence ( *Hardness* ) (HRF) | Compressive Strength ( *Compressive Strength* ) (MPa) |
|---|---|---|---|
| 390 °C | 90 : 10 | 37.33 | 150.38 |
| | 80 : 20 | 34.33 | 97.74 |
| | 70 : 30 | 31.5 | 45.11 |
| 490 °C | 90 : 10 | 42.33 | 192.98 |
| | 80 : 20 | 36.33 | 130.33 |
| | 70 : 30 | 33.67 | 57.64 |
| 590 °C | 90 : 10 | 60 | 235.59 |
| | 80 : 20 | 55.67 | 177.94 |
| | 70 : 30 | 41.67 | 70.18 |

**3.1. Hardnessvalue**

The resultsofthehardnesstestshowedthatthehighesthardnessvaluewasobtained in thespecimenwith a compositionof 90: 10 and a sinteringtemperatureof 590 °C, namely 60 HRF, followedbytemperaturesof 490 °C and 390 ° C. The samethingappliestoother material compositions, namelythehighesthardnessvalueisatthehighestsinteringtemperature. The smallesthardnessvalueofallspecimensis in thespecimenwith a compositionof 70: 30 and a sinteringtemperatureof 390 °C, namely 31.5 HRF. More detailsregardingtherelationshipbetweensinteringtemperatureand material compositionwithhardnessvaluecanbeseen in Figure 1 .

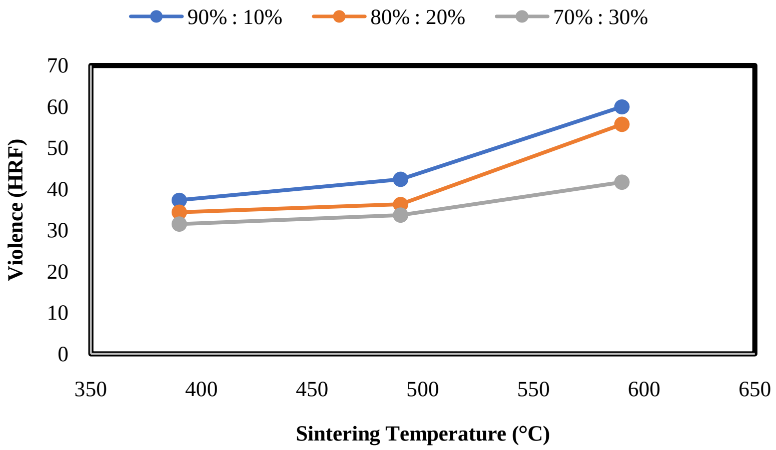


**Figure1. Graphoftherelationshipbetweensinteringtemperatureand material compositionwithhardnessvalue.**

Based on Figure 1, it can be seen that the sintering temperature is directly proportional to the hardness value of the specimen. Higher sintering temperatures provide higher hardness values for the test specimens. These results are in accordance with the research of Tawan et al. (2019) which found that the hardness value increased with increasing sintering temperature in aluminum composites. This event occurs because increasing the sintering temperature will make the powder grains soften and bond with other powders with a larger surface area. The increase in sintering temperature simultaneously increases the density of the specimen and decreases its porosity so that the specimen becomes harder. According to Dahliana et al. (2013), an increase in sintering temperature is related to an increase in density and a decrease in the percentage of porosity due to the increasing density of the particles in the sample so that there is a strong bond between one grain and another.

The composition of the material has an inverse effect when viewed from the percentage of glass powder addition. The lower the percentage of glass used, the greater the hardness value of the composite. The results of this study are similar to the study conducted by Anderson et al. (2018) which found a decrease in hardness value along with the addition of Cu elements to the Al-Si alloy. Anderson said that the material is characterized by reducing the toughness of the aluminum alloy. However, this study used a large range of glass powder additions, namely 10%, 20%, and 30% so that there is still an opportunity for further research on percentages below and above this range.

**Compressivestrengthvalue**

After conducting the test, it was found that the specimen with the highest compressive strength value was found at a sintering temperature of 590 $^{o}$ C and a composition of 90: 10, which was 235.59 MPa. While the lowest strength value was 45.11 MPa at a sintering temperature of 390 $^{o}$ C and a composition of 70: 30. Further information on the relationship between sintering temperature and material composition can be seen in Figure 2.

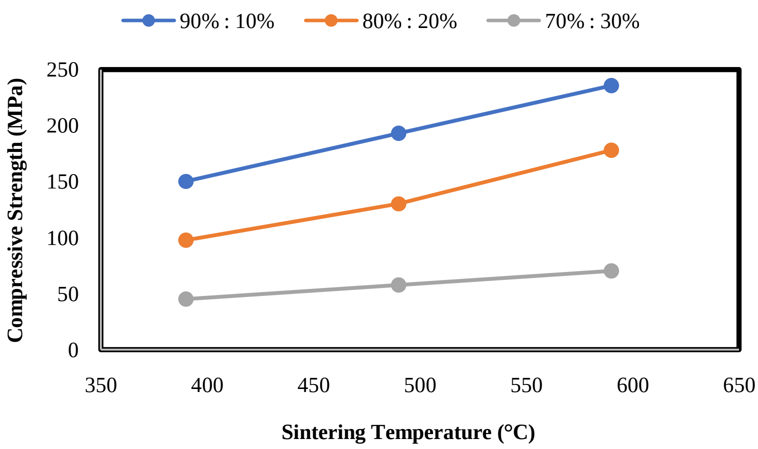


**Figure2. Graphoftherelationshipbetweensinteringtemperatureand material compositiononcompressivestrengthvalue.**

In Figure 2, it can be seen that the sintering temperature has a directlyproportionaleffectonthecompressivestrengthvalueofthespecimen. The higherthetemperature, thehigherthehardnessvalue. Thisresultis in accordancewiththeresearchof Yafie and Widyastuti (2014) whofoundanincrease in thecompressivestrengthvalueofthecompositesinteredfor 1 hour. The greatercompressivestrengthvalueoccursbecausethehighertemperatureaffectstheparticlemergingprocesstobecomedenserbecausetheparticleorgrainstructureissoftening. Accordingto Subiyanto and Subowo (2003), thehigherthesinteringtemperature, thelessporosityandthegreaterthebond area betweenparticles.

In theinfluenceofthecompositionofthe material, itcanbeseenthatthecompositionofthe material has aninverseeffectwhenviewedfromtheadditionoftheamountofglasspowder. Similarthings were alsoobtainedby Hermana and Widyastuti (2014) whoobtained a compressivestrengthvaluethatwasinverselyproportionaltotheadditionof Cu elements. Thisincidentmostlikelyoccurredbecauseofthebrittlenatureofglasswhichifaddedtoomuchtoaluminumwillreduceitsductilityandcausethecompressivestrengthofthecompositetodecrease.

## IV. CONCLUSION

Variations in sinteringtemperaturehave a directlyproportionalandsignificanteffectonthehardnessandcompressivestrengthvaluesofthecomposite. Variations in material compositionhaveaninverselyproportionaleffectonthehardnessandcompressivestrengthvaluesofthecompositewhen viewedfromthepercentageofglasspowderaddition, in addition, thesevariationsalsohave a significanteffectonthehardnessandcompressivestrengthvaluesofthecomposite.

**Conflict of interest**

There is no conflict to disclose.

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