Experimental Study of Single Action System Compacting Tool in Sealface Formation with Undercut

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Keywords: Compacting Tool, Powder Metallurgy, Sealface, Single-Action Tooling System.

Abstract: The sealface is one of the important components in the mechanical seal which functions to prevent leakage by utilizing two flat surfaces that rub against each other. In general, sealfaces are made through a machining process (material removal). However, one of the studies conducted a study on the formation of face seals with powder metallurgy technology seeking to maximize the use of raw materials. This research uses a press machine and a tool that works with a single action system compacting tool mechanism and produces powder metallurgical products with a simple sealface ring seal faced is classified into metallurgical products class 1 and 2. Seeing this, the authors try to use existing machines and tools to carry out an experimental study of single action system compacting tools in the manufacture of powder metallurgical products with class 3 and 4 classifications. This research produces sealface with undercuts (finished product) that have surface hardness and density values of 541.8 HV and 2.7 gr/mm3, as well as tool design recommendations that can correct the deficiencies that occur in this research.

1 INTRODUCTION

A mechanical seal is a mechanical device whose function is to prevent fluid from leaking from a space/container with a rotating shaft (Kurniawan, Yudianto, 2014). Mechanical seals have a low leakage rate when compared to other types of sealing devices, and have a longer duration of use (Syafi'i, Priangkoso, 2018). The working principle of the mechanical seal is to use the sealing surface as the main point to prevent leakage (primary seal) (Wijaya, 2018). The location of the sealing surface on the mechanical seal is shown in Figure 1.

Seal faces are generally made through a machining (material removal) process. However, in one of the studies at Polman Bandung, a study was conducted on seal face formation with powder metallurgy technology (Fachrul Rozy, Kurniawan). The purpose of this study is to strive for the use of raw materials to be maximized because, with this technology, raw material savings can be made up to 97% (Groover, 2010). In addition, sealface for seal face withh this method is also a component substitution step which was originallymade with the usual material removal manufacturing process to become an additive manufacturing. Figure 2. Is a sealface ring formed by powder metallurgy technology.

In the research process, powder metallurgy products classified into classes 1 and 2 were made with a simple sealface ring shape. The manufacture of sealfaces utilizes a press machine and compacting tools that are already available with a single action tooling system mechanism (one-way compaction).

Seeing this, the author tries to conduct an experimental study and utilize the available facilities to make powder metallurgical products with a higher classification class (class 3 or class 4). This is intended to see whether existing machines and tools can be utilized to produce more varied products. The form that the author takes is a seal face with a simple undercut.

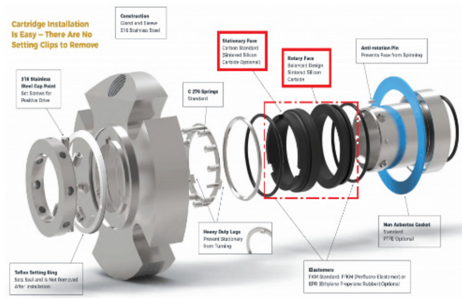

Figure 1: Seal face components on mechanical seal. Source: PT Aldea Citta Sejahtera.

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Figure 2: Finished product sealface ring formed by powder metallurgy technology *(Fachrul Rozy, Kurniawan)*.

2 LITERATURE REVIEW

2.1 Mechanical Seal

A mechanical seal is a mechanical device that prevents fluid leakage from a space/container with a rotating shaft. Mechanical seals prevent leakage by utilizing the contact of two flat surfaces (sealing faces), namely the stationary unit and the rotary unit. The two surfaces are in a sealing contact condition, due to the influence of the spring and the pressure from the system. Some of the advantages obtained by using a mechanical seal as a sealing device are that it can handle all types of fluids, can work even if misalignment occurs, can work both dynamically and statically with shaft rotation, and has a long lifetime.

In the mechanical seal there are 3 leakage containment points, namely:

a. Primary seal, the point of containment of leakage occurs in the sealing faces, namely the primary ring and the mating ring
b. Secondary seal, leakage containment point on the inner diameter of the primary ring
c. Tertiary Seal, leakage containment point on the outer diameter of the mating ring

The working principle of a mechanical seal in general is to utilize two very flat and smooth surfaces (sealface) of two componentseal facey the primary ring and the mating ring which are in a sealing contact condition. This condition is achieved so that there is a minimum but thick enough fluid film between the two surfaces (Flitney, 2007). Fluid film that acts as a cushion, serves to lubricate and cool the contact area

2.2 Powder Metallurgy

Powder metallurgy technology is a way of processing metal where the product is made of metal powder material. The product is pressed to the desired shape and then heated to bind the powder particles into a solid and strong mass (Groover, 2010). There basic stages in the conventional metallurgical process are the mixing/blending stage, the compacting/ compacting stage, and the sintering stage Figure 3.

Powder metallurgy technology is a way of processing metal where the product is made of metal powder material. The product is pressed to the desired shape and then heated to bind the powder particles into a solid and strong mass (Groover, 2010). There are three basic stages in the con Three basic stages in the conventional metallurgical process are the ending stage, the compacting/compacting stage, and the sintering stage. Figure 3.

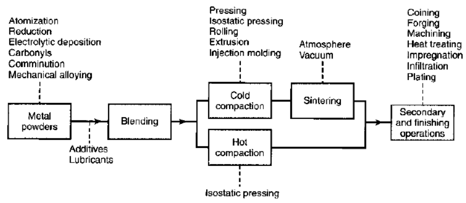


Figure 3: Powder metallurgical processes in general (Kalpakjian, Schmid, 2009).

a. The mixing process is a process of homogenizing metal powder materials to become metal alloys that can be used as basic materials in the solidification stage. At this stage, the metal powder is mixed with a binder (binder) and a lubricant (lubricant) based on both metal and non-metal.
b. The compaction process is the process of compressing metal alloys into a formation.
c. The sintering process is a process of heating the solidification (green compact) in a controlled furnace with a temperature below the melting point, in order to form a bond (fusion) of the particles. The goal is to increase the strength and hardness of the product.

In powder metallurgy technology, the formed products are classified according to the complexity of the compaction process (Groover, 2010). The following are the four classes that have been defined, which can be seen in Figure 4.

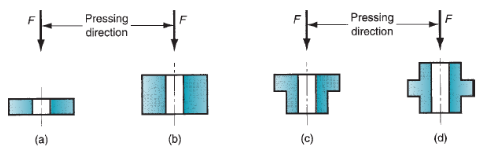


Figure 4: Powder metallurgical technology product classification (Groover, 2010).

- Class I, products with a simple shape and a fairly thin thickness. The compaction process for this product can be carried out from one side.

- Class II, products with simple shapes but thick enough. So the compaction process must be done from two sides.
- Class III, products that have two thickness levels and the compaction process needs to be carried out from two sides.
- Class IV, products that have several thickness levels and the compaction process is carried out from two sides using separate control settings so that each density of each level can be achieved properly.

2.3 Tooling System

In the powder compaction process, there are four tool systems that can be used (ASM Handbook Committee, 2015) namely: single-action tooling system, double-action tooling system, withdrawal tooling system, and die floating tooling system.

2.4 Specimen Testing

2.4.1 Hardness Test

Vickers hardness (HV) is a quotient obtained by dividing the applied load F (kgf) by the expanse area on the indentation surface (mm^2) of the workpiece taking into account the pyramidal shape with a square base and diagonal d and having the same peak angle as indenter of gem (ASM Handbook Committee, 2015). For the Vickers test, the surface of the test specimen should be flat and smooth in order to obtain accurate test results. The test specimen used in the Vickers hardness test shall not be less than 5 times the size of the indenter. Vickers hardness number can be obtained using the following equation:

$$HV = 1.854\ P/d^2 \quad (1)$$

P: given load (N)
d: the average diagonal length of the results

2.4.2 Density Test

Density is a measurement of the mass per unit volume of an object. The higher the density (density) of an object, the greater the mass of each volume. In this test, the Archimedes principle is applied to determine the density of the sample by weighing the sample in air and then in a floating liquid (usually distilled water). Then this density is compared with the theoretical density (Torosyan, Pak, 2019).

Actual Density

$$\rho m = \frac{ms}{(ms - mg)}\ x\ \rho H20 \quad (2)$$

ρm : actual density (gram/cm^3)
ms : dry sample mass (gram)
mg : mass of sample suspended in water (gram)
$\rho H20$: density of water (1 gram/cm^3)

Theoritical Density

$$\rho th = \rho SiC\ .VSiC \quad (3)$$

ρth: theoretical density
ρSiC: SiC density
VSiC: SiC mass fraction

3 EXPERIMENTAL METHOD

This research is divided into two stages, namely the tool modification stage and the experimental stage which can be seen in flowchart below.

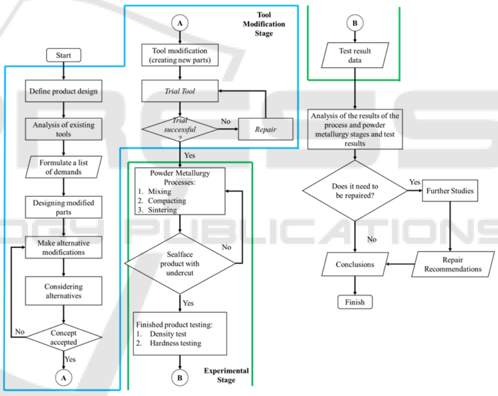


Figure 5: Flowchart of this research.

Tool modification is intended to adjust existing tools in order to form the desired product. The modification process is carried out to a minimum and as efficiently as possible. The goal is that there are not a lot of processing processes and new parts are made, so that it can save time and work costs. At the experimental stage, there are two processes that need to be carried out, namely the implementation of sealface formation with undercuts using powder metallurgy technology and testing of the results of making sealfaces.

3.1 Modification Step

3.1.1 Product Design

The shape of the sealface to be made is a sealface with an undercut. This shape takes reference from the ISO 3601 O-Ring sizing standard and uses some of the built-in dimensions of the tool. Working drawings can be seen in Figure 6.

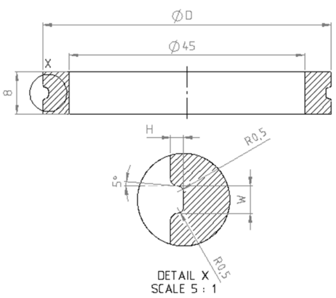


Figure 6: Product design for sealface with undercut. Where, D: 56 mm, W: 4mm, H: 1.5mm.

3.1.2 Tool Existing Analysis

After determining the shape of the product, a tool analysis is carried out to find out the specifications of the tools and parts that play a direct role in the formation of the product. The following is a description of the existing tool specifications which can be seen in Table 1.

Table 1: Existing Tool Specifications.

No.	Specification	Information
1.	Name	Compacting Tool
2.	Material	St.37 and HMD 5 HMD 5: Product-forming active parts St.37: Other parts that are not in contact with the product
3.	Dimension	208 X 239 X 248 mm
4.	Weight	± 18 Kg
5.	Type	Single-action tooling system The compaction carried out during the compaction process is only carried out from one direction, namely from the top.

In Figure 7 it can be seen that the construction of the active part forming the product on the existing compacting tool.

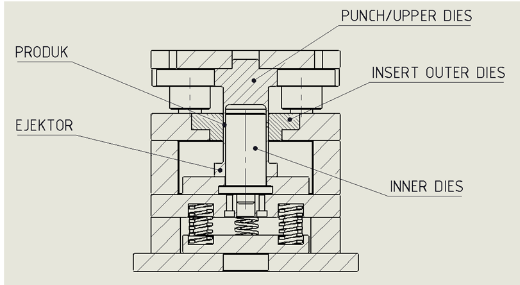


Figure 7: Active part layout.

Table 2 describes the function of each active part.

Table 2: Product-forming active parts.

No.	Component Name	Function	Other Information
1.	Punch	Plays a role during the compaction process, pressing metal powder from the top.	Dimension: 70 X 70 X 70 Material: HMD 5 Further process: Hardening (50-55 HRC)
2.	Insert Outer Dies	Product mold, forming the outer diameter of the product	Dimesion: Ø120 X 30 Material: HMD 5 Further process: Hardening (50-55 HRC)
3.	Inner Dies	Product mold, forming the inner diameter of the product	Dimesion: Ø60 X 100 Material: HMD 5 Further process: Hardening (50-55 HRC)
4.	Ejector	Parts for product ejection from molds Base of powder metallurgical products	Dimension: 15 X 70 X 70 Material: HMD 5 Further process: Hardening (50-55 HRC)

3.1.3 Demand List

After looking at the shape of the product and analyzing existing tools, a list of demands for the modification process can be issued which can be seen in Table 3.

Table 3: Demand list.

No.	Demand Variable	Demand
1.	Product geometry	Sealface with undercut Dimension : Ø56 X 8
2.	Product category	Class 3-4 powder metallurgical products.
4.	*Modification parts*	Modifications made to a minimum are only carried out on the active part forming the product. Additional parts are made in order to produce a product with the expected height, namely the ring setting. Product geometry.

3.1.4 Modification Alternative

There are two alternative modifications that the author made, namely: the alternative with direct ejection and indirect ejection. After considering in terms of manufacture and the working mechanism of the tool, an indirect ejection alternative was chosen whose layout can be seen in Figure 8.

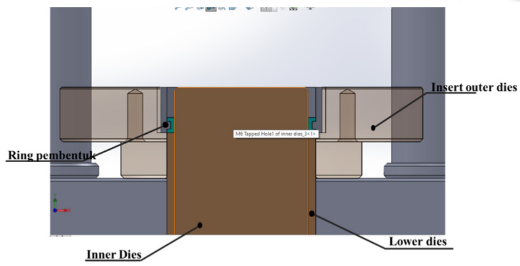


Figure 8: Selected alternative layout.

Concept of this alternative:

- The mold is divided into two parts, the left and the right.
- Green compact (compacting result) is ejected together with the forming block/mold. Then the green compact is removed / released from the mold manually.

3.2 Experimental Stage

There are several machines and tools used in the process of making sealfaces with powder metallurgy, including:

1. The mixing process uses a powder mixer machine.
2. The compaction process uses a hydraulic press machine.
3. The sintering process uses an annealing furnace.
4. For molds using compacting the results of the modifications that have been carried out with

4 ANALYSIS OF EXPERIMENTAL RESULTS

4.1 Forming Process with Powder Metallurgy Technology

4.1.1 Mixing

The ingredients that have been provided are then arranged in composition to get the right mixture. The following is the percentage of each constituent material to make a mixture of metal powders which can be seen in Table 4.

Table 4: Material composition for mixing.

Information	Material
Main Material	*Green Silicone carbide Powder (SiC)*
Binder (10% of the total weight of the main material)	*Hydrogenated casteroil Oleic Acid Liquid paraffin Vasseline petroleum*
Lubricant (0.1% of the total weight of the main material)	*Zinc Stearate*
Binder Composisiton	**Percentage**
Hydrogenated casteroil	8%
Oleic Acid	1%
Liquid paraffin	10%
Vasseline petroleum	81%

The author uses a binder composition with a percentage of 10%, this refers to the literature study (Torosyan, Pak, 2019) carried out as well as considerations when conducting trial and error in the experimental process.

Before the actual experiment process, the author conducted a preliminary study. The aim is to know the characteristics of the alloy with each composition. In the preliminary study, three types of alloys were made with a composition of 10% binder, 20% binder and 30% binder.

4.1.2 Compacting

During the compaction process, there are two process parameters that need to be considered, namely compaction pressure and holding time. For the compaction pressure, the authors set it at 30 tons while the holding time is 2 minutes. The amount of tonnage is determined from the results of the calculation of the cross-sectional area and compaction pressure which takes references from the literature (Upadhyaya, 2002).

4.1.3 Sintering

The sintering process is carried out in stages starting from a room temperature of 25°C to an optimum temperature of 1050°C. The purpose of the gradual process is to increase the temperature slowly with a stable holding time for each increase in temperature. This sintering method was chosen based on the results of the previous preliminary study. Figure 9 is a graph of the method of increasing temperature in the sintering process used.

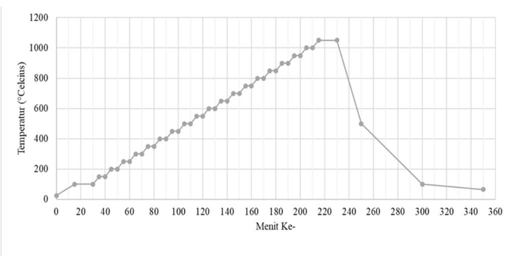


Figure 9: Graph of temperature rise in the sintering process.

4.2 Analysis of Formation Results

4.2.1 Mixing

The author uses a blend with 10% binder.

4.2.2 Compacting

The compaction process is carried out and the results are compared with previous studies that have been carried out in Polman, with the comparison results which can be seen in Figure 10.

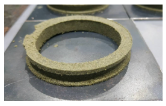
On Going Research	Previous research
	
The compaction process produces a green compact with less green strength compared to previous studies. When trying to lift the green compact, it crumbles. In plain view, the green compact looks more fragile, and not dense.	The compaction process produces a green compact with good green strength. When tried to lift the green compact does not crumble. In plain view, the green compact looks sturdy and solid.

Figure 10: Comparison of green compacts.

The difference that occurs is caused by the compaction carried out. In previous studies, compaction was carried out in stages with the aim that the print cavity could be completely filled. In the current study, the same method cannot be used, due to different geometric shapes. So that to optimize the formation of a green compact, compaction is only done once, although with this method there are still shortcomings that affect the results which can be seen in the discussion of density testing.

4.2.3 Sintering

After the compaction process is carried out, although the green compact obtained has poor quality, a sintering process is carried out in order to see the characteristics and properties of the finished product.

On Going Research	Previous research
	
The finished product looks fragile.	The finished product looks sturdy and solid.
The surface of the resulting product is rough.	The resulting surface is smoother than the current research

Figure 11: Comparison of finished products.

4.3 Testing Process

After carrying out all stages of the process of forming powder metallurgy technology, then testing is carried out. There are two mechanical properties that will be seen, namely hardness and density. Both of these properties are quite crucial mechanical properties of a sealface, both in terms of function and in terms of manufacturing methods. In terms of function, the sealface is an important component that has an important role in sealing leaks with a friction mechanism so that the wear level needs to be considered. However, due to the availability of facilities and cost, the authors take one other mechanical property that has a relationship with wear and tear, namely hardness (Mokhtar, 1982). Meanwhile, in terms of manufacturing methods, the process of making sealface products is a powder compaction method. So it is necessary to see the results of product density. These limits are taken for the standard sealface used for centrifugal pumps, with water type fluid (Tolbert et al., 1992).

4.3.1 Density Test

The hardness test standard used refers to ASTM B311. This method applies the Archimedes principle to determine the density of a sample by weighing the test specimen in air (dry measurement) and then in a floating liquid (usually distilled water) (wet measurement). Then this density is compared with the theoretical density (Taylor, McClain, Berrty, 1999). The test specimen used is a finished product sealface with an undercut.

4.3.2 Hardness Test

The author chose to use the Vickers hardness test, in which the testing standard used refers to ASTM E384. The author decided to use this type of test because the indentation area of the test specimen is quite narrow, so a small indenter is required. Similar to density testing, the test specimens used are finished products that have been polished to obtain a flat and glossy surface.

4.4 Analysis of Test Results

4.4.1 Density Test

In Figure 12, it can be seen that the density value obtained after carrying out density testing on the test specimen.

Test Specimen	Experiment Order	1	2	3
Test Specimen1	Dry measurement(gr)	9,8	9,7	9,9
	Wet measurement(gr)	6,4	6,3	6,3
	Actual Density (gr/mm^3)	2,9	2,9	2,8
Test Specimen2	Dry measurement(gr)	3,7	3,5	3,6
	Wet measurement(gr)	1,8	1,8	1,8
	Actual Density (gr/mm^3)	1,9	2,1	2,0
Test Specimen3	Dry measurement(gr)	4,1	3,9	4,0
	Wet measurement(gr)	3,0	2,8	2,6
	Actual Density (gr/mm^3)	3,7	3,5	2,9

	Actual Density (gr/mm^3)			
Replication	R1	R2	R3	$\bar{X}$
Test Specimen1	2,9	2,9	2,8	2,4
Test Specimen2	1,9	2,1	2,0	2,5
Test Specimen3	3,7	3,5	2,9	2,7

Figure 12: Density test data.

Based on the data that has been taken, it is known that this value is far from the nominal limit used as a reference. This could be because the formation method used is not the same, from the existing references it is not explained about the method used.

Therefore, this study compared with research related to the formation of sealface rings with powder metallurgy technology (Fachrul Rozy, Kurniawan), where the results showed that the highest density obtained was 3.00 gr/mm^3. This value has a difference of 0.3 gr/mm^3 from the highest density value (2.7 gr/mm^3) in this study. The difference in the results is not that far, it proves that the process stages and the same process parameters that have been adjusted can produce characteristics that are not much different. Indeed, the resulting density value has a less value, this can be caused by differences that occur in the compaction process.

Differences in density can occur due to the lack of metal powder present in the mold cavity, as well as the unevenness of the compaction force applied. There are variations in thickness (on the undercut) on the product and the use of ring settings that are the cause.

The pressure applied to the powder product is aimed at reducing the porosity by increasing the contact points between the powder particles. However, because during compaction a ring setting is used and there is an undercut shape, the compaction load does not directly affect the mixture and the compaction is restrained and only compacts the top part of the green compact. So if you look at the results, the green compact is a little dense at the top of the green product.

4.4.2 Hardness Test

In Figure 13, it can be seen that the hardness value obtained after carrying out the hardness test on the test specimen.

Point	Hardness Data (HV)	Vickers (HV)	Rockwell 45N
1.	533,8	530	56,2
2.	478,1	470	51,3
3.	541,8	540	57
4.	523	520	55
5.	488	480	52,2

Figure 13: Hardness test data.

The maximum hardness is 57 Rockwell-45. If the maximum value is compared with the table for the material properties of the sealface, it is known that the hardness obtained has not reached the standard nominal value (86-88 Rockwell-45). The hardness results obtained can be increased again, by increasing the sintering temperature. When the results of this study are compared with previous studies, the results are not so far off. In this study, the sintering process was carried out at a temperature of 1050°C and the maximum hardness was obtained, namely 514.17 HV 510 HV 54.7 Rockwell-45 N.

4.5 Further Studies

Based on the discussion of the results of the formation and test data, it ca be said that the sealface product with undercut in this study was not good and was classified into a reject product. This is based on the following results:

- Judging from the final result of the powder metallurgy process. The finished product has the characteristics of being brittle and having a rough surface. A rough surface indicates imperfect compaction, so that the SiC grains are still in their original shape and are not deformed. Meanwhile, brittle characteristics can occur because the product has poor interparticle bonds due to incomplete compaction.
- Judging from the results of the stages of the compaction process. At the stage of the compaction process, a green compact was obtained with brittle characteristics and poor green strength. This can be seen from the green compact's ability to maintain its shape. When subjected to slight shocks (held manually by hand) the green compact tends to crumble.

From these results, the authors decided that further studies were needed. Further studies are aimed at providing recommendations for improvements that need to be made based on the author's observations during the process of forming sealface products with undercuts. The recommendations for improvement that the authors propose are expected to improve existing deficiencies.

The following are failure points that are the focus of improvements that need to be made, the results of the author's observations:

- The resulting green compact has poor green strength, so it is easy to crush. This can be caused by the compacting process that does not reach the proper density.
- The molding mechanism that causes cracks in the green compact.
- The process of releasing the mold that still uses conventional methods

5 CONCLUSION

Based on the results of research on an experimental study of single-action system compacting tools in sealface formation with undercuts, the following conclusions can be drawn:

Machines and tools with single-action system compacting tools are not suitable for use in making class 3 and class 4 powder metallurgy products.

The assessment of the feasibility of this single-action compacting tool machine is based on the following results: Observation of phenomena that occur in each powder metallurgical process, which discusses the compaction process a lot both in terms of compaction work, compaction results, and the effect of compaction results on the finished product in terms of quality and characteristics. the final product The compaction process is the main focus in this discussion because the machine used plays an important role in the stages of the compaction process.

REFERENCES

Kurniawan, O., & Yudianto. (2014). “Kajian Kegagalan Kinerja Sil Mekanik Produksi Dalam Negeri,”. *Seminar Nasional - XIII-Rekayasa Dan Aplikasi Teknik Mesin*. No., Hal.

Syafi'i, M., & Priangkoso, T. (2018). "Penggantian Gland Packing Ke Mechanical Seal Pada Pompa Oli TCU Di PT. Polidayaguna Perkasa Ungaran,". Semarang.

Wijaya, R. (2018). "Landasan Teori - Mechanical Seal,". Jakarta.

Fachrul Rozy, O, P., & Kurniawan, "Analisis Pembentukan Sealface Dengan Teknologi Metalurgi Serbuk Menggunakan Metode Taguchi Dan Teknik Grey Relational Analysis," *J. Teknol. Dan Rekayasa Manufaktur (JTRM) POLMAN BANDUNG*.

Groover, M, P. (2010). "Powder Metallurgy," in *Fundamental of Manufacturing Materials, Processes, Andsystem*, 4th Ed., Danvers: John Wiley & Sons, Inc,.

Flitney, R. (2007). *Seals and Sealing Handbook*, 5th Ed. Oxford.

Kalpakjian, S., & Schmid, S, R. (2009). "Powder Metallurgy Processing and Equipment," in *Manufacturing Engineering and Technology*, 6th ed., New York: Pearson.

Samal, P., & Newkirk, J. (2015). Materials Standards and Test Method Standards for Powder Metallurgy. *ASM Handb*, *7*, 45-51.

Torosyan, K. S., & Pak, V. G. (2019, June). Influence of the binder composition on the properties of the silicon carbide green compacts and sintered parts prepared from the powders produced by SHS. In *IOP Conference Series: Materials Science and Engineering* (Vol. 558, No. 1, p. 012052). IOP Publishing.

Upadhyaya, G. S. (1997). *Powder metallurgy technology*. Cambridge Int Science Publishing.

Mokhtar, M. O. A. (1982). The effect of hardness on the frictional behaviour of metals. *Wear*, *78*(3), 297-304.

Tolbert, L. M., Nesselroth, S. M., Netzel, T. L., Raya, N., & Stapleton, M. (1992). Substituent effects on carbanion photophysics: 9-arylfluorenyl anions. *The Journal of Physical Chemistry*, *96*(11), 4492-4496.

Lobanoff Val, S., & Ross, R. (1992). Centrifugal pumps: Design and Application.

Kafkas, F., Karataş, Ç., Sozen, A., Arcaklioğlu, E., & Saritaş, S. (2007). Determination of residual stresses based on heat treatment conditions and densities on a hybrid (FLN2-4405) powder metallurgy steel using artificial neural network. *Materials & design*, *28*(9), 2431-2442.

R., P., Taylor, S., T., McClain, J., T., Berrty. (1999). "Uncertainty Analysis of Metal-Casting Porosity Measurements Using Archimedes's Principle," *Int. J. Cast Met. Res.* Vol., 11. No., 4. Hal., 247–257.

Hardness, A. B. (1999). Standard Test Method for Microindentation Hardness of Materials. *ASTM Committee: West Conshohocken, PA, USA*, *384*, 399.