ISSN 3031-7320

The Effect of Weight Fraction Goat Bone Charcoal and Rice Husk Charcoal on the Mechanical Properties Low Carbon Steel Carburizing

Rusnoto[1],. Doni Adi S[2],. Renggani Wilis, Galuh, [3]. Santosa, Irfan[4]
[1,2,3,4] Department of mechanical engineering, Universitas Pancasakti Tegal
Jalan Halmahera KM.1, Tegal, Jawa Tengah, Indonesia

Correspondence email :
rusnoto74@gmail.com

Abstract. Pack carburizing is a process of heat treatment and cooling of solid metal to change the physical and mechanical properties of the metal. The carburizing process adds carbon elements to the surface of low-carbon steel by heating at temperatures of 900°C - 950°C. Carbon elements can be obtained from goat bone waste and rice husks. Both carbon content is high enough to be used as raw materials for making activated charcoal. This study aims to determine the mechanical properties (hardness, tensile strength, and wear value) of the low-carbon steel pack carburizing process. The experimental research method combined goat bone charcoal and rice husk charcoal at 50%:50%, 40%:60%, and 25%:75% at 900˚C and quenched with mineral water. The maximal hardness test results were 756 VHN on a mixture of goat bone charcoal and rice husk charcoal at a composition of 25%:75%. The maximal tensile strength test results were 1338 MPa in a mixture of goat bone charcoal and rice husk charcoal with a composition of 40% and 60%. The maximal wear test results were 0.00035 mm^3/kg mixed variations of goat bone charcoal and rice husk charcoal with a composition of 25% and 75%.

Keywords: Low carbon steel, pack carburizing, hardness number, tensile test, wear test.

Introduction

Steel is one of the metals used in machine construction such as gears, shafts, and sprockets [1]. Steel generally has various kinds of alloying elements such as Sulfur (S), Carbon (C), Silicon (Si), Phosphorus (P), Manganese (Mn), and others. The carbon element has the most dominant influence on the mechanical properties of steel, but other elements cannot be ignored [2]. The carbon content in steel can affect the mechanical properties of the steel, for example, the properties of hardness, ductility, formability, and other mechanical properties. The addition of carbon content to steel can increase its hardness and tensile strength, but on the other hand, it makes it brittle and reduces its ductility [3].

The surface hardening process is the final stage of work to improve product quality. The surface hardening process aims to obtain a material that is hard on the surface and still maintains the ductility of the steel core. Low-carbon steel has the advantage of being easier to machine but cannot be hardened directly because the carbon content is less than 0.3%. The hardening process of low-carbon steel must be through the addition of carbon [4]. Izhyanti [5] stated that the process of increasing hardness but still maintaining ductility is the carburizing method. Carburizing is the process of adding carbon to the steel surface so that the surface becomes hard but the core remains ductile. The carburizing process is carried out by heating the workpiece in an environment that contains a lot of active carbon so that the carbon diffuses to the surface of the steel [6]. One of the elements to harden metal surfaces is activated charcoal, which is a porous solid containing 85-95% carbon, produced from carbon-containing materials by heating at high temperatures [7]. Activated charcoal is widely used as an adsorbent in gas purification, pulp refining, oil clarification, catalysts, and also for the purification of food products, including cleaning solutions of cane sugar, beet sugar, corn sugar, removing the taste and odor of drinking water, refining vegetable oil, and beverages. alcohol [8].
Several studies on the theme of pack carburizing have been carried out, Afriany [9] investigated the variations of $BACO_3$, $NACO_3$, and $CACO_3$ in the carburizing process of low carbon steel with coconut shell charcoal as media. The results of his research stated that the use of the $BACO_3$ catalyst caused an increase in the hardness test results. Hidayat, [10] investigated the process of carburizing low-carbon steel using coconut shell charcoal as media and then cooling it with water and oil, the results show that the oil cooler is able to increase the hardness value. The potential of goat bone was investigated by [11] to be used as activated carbon which was activated using sulfuric acid with a carbonization process to produce goat bone charcoal according to the Indonesian National Standard (SNI). Research on the pack carburizing process using mahogany sawdust with $BACO_3$ as an activator, heated at temperatures of 850^0C and 900^0C resulted in an increase in the hardness value of SS400 steel [12].
From some of the literature above, the use of charcoal / activated carbon materials has been carried out by many other researchers, however, no one has studied the combined method of goat bone charcoal and rice husk charcoal. This study aims to determine the mechanical properties (hardness, tensile strength, and wear value) of the low-carbon steel pack carburizing process. The experimental research method combined goat bone charcoal and rice husk charcoal at 50%:50%, 40%:60%, and 25%:75% at 900˚C and quenched with mineral water

Method

Experimental research on the mixed weight of goat bone charcoal and rice husk charcoal to find out the most optimal mixture variations in the carburizing process of low-carbon steel was carried out. The materials used for this research were low-carbon steel, goat bone charcoal, and rice husk charcoal. Variations in the weight of each material are seen in Table 1, as follows:

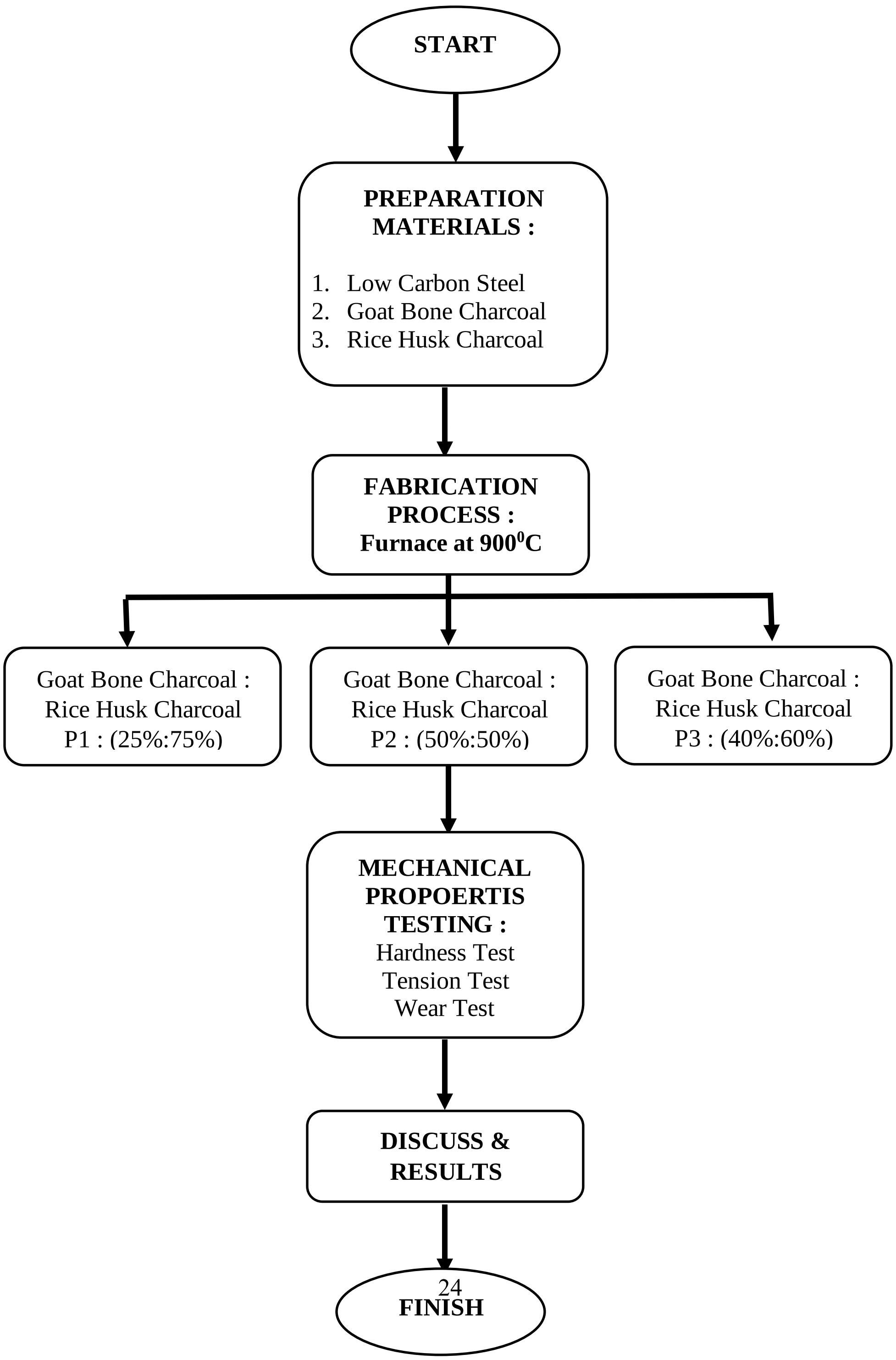
Table 1. Comparison of material composition.

Materials	**Composition**		
	P1	**P2**	**P3**
Goat bone charcoal	25%	50%	40%

ISSN 3031-7320

Rice husk charcoal	75%	50%	60%

The fabrication process is by cleaning the surface of the low carbon steel from corrosion and oil using sandpaper, then preparing 20 mesh size of goat bone charcoal powder and rice husk charcoal, respectively. Then put the bone charcoal powder, rice husk charcoal powder according to the composition, and low-carbon steel into the container and put it in the furnace until the temperature reaches 900^{0}C with a holding time of 1 hour. The next step is to remove the specimen from the container and quench using mineral water. For each hardness test using the Vickers method, tensile testing using the Universal testing machine, and wear testing using the Ogoshi method. The following Figure 1 explains the research flowchart.



 ISSN 3031-7320

Figure 1. Research Flowchart

Results and Discussion

The research results on mechanical properties including hardness, tensile strength, and wear resistance tests on charcoal mixtures will be described.

Table 2. Hardness test results

No.	**Sample**	**Value**		**Average value (HRV)**
		Test area	**Hardness Value (HRV)**	
1	**P**: Raw Material (Low Carbon Steel)	Point 1	128	130
		Point 2	129	
		Point 3	135	
2	**P1**: Goat bone charcoal-Rice husk charcoal (25%-75%)	Point 1	797.21	756
		Point 2	747.39	
		Point 3	724.22	
3	**P2**: Goat bone charcoal-Rice husk charcoal (50%-50%)	Point 1	383.06	392
		Point 2	391.91	
		Point 3	401.08	
4	**P3**: Goat bone charcoal-Rice husk charcoal (40%-60%)	Point 1	420.41	438
		Point 2	441.17	
		Point 3	452.13	

ISSN 3031-7320

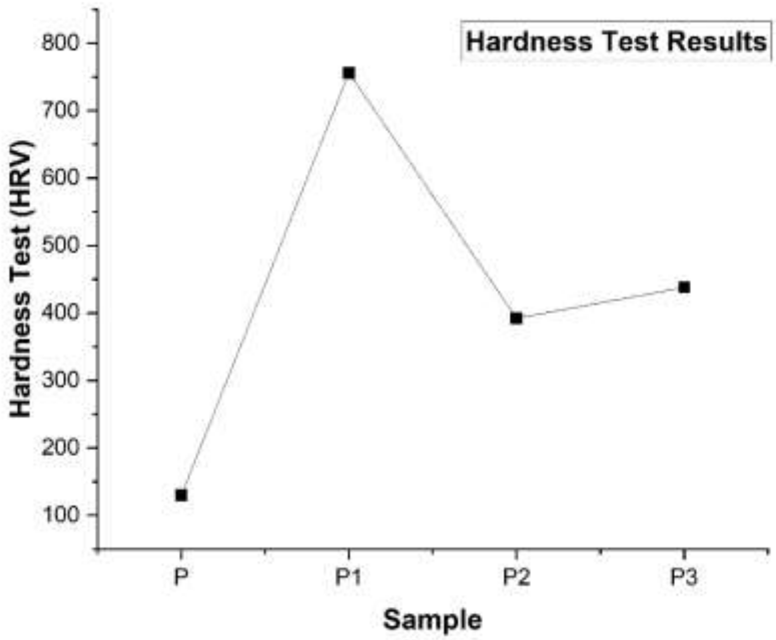


Figure 2. Hardness Testing Chart

Table 3. Tensile strength test results

No.	Sample	Test area	Cross-sectional area (mm²)	P Max (KN)	P Max (N)	Tensile strength (MPa)	Average value (MPa)
1	**P**: Raw Material (Low Carbon Steel)	Point 1	93.87	44.93	44930	478.71	481.45
		Point 2	98.10	43.81	43810	491.72	
		Point 3	96.27	45.62	45620	473.92	
2	**P1**: Goat bone charcoal- Rice husk charcoal (25%-75%)	Point 1	65.29	88.88	88.880	1361.27	1311
		Point 2	65.43	86.54	86.540	1322.53	
		Point 3	64.86	80.99	80.990	1248.63	
2	**P2** : Goat bone charcoal- Rice husk charcoal (50%-50%)	Point 1	65.72	80.960	80.96	1231.85	1205
		Point 2	60.65	61.230	61.23	1009.52	
		Point 3	64.29	88.300	88.30	1373.39	
3	**P3**: Goat bone charcoal- Rice husk charcoal (40%-60%)	Point 1	64.57	81.48	81.480	1261.73	1338
		Point 2	63.02	89.43	89.430	1419.05	
		Point 3	63.44	84.56	84.560	1332.83	

ISSN 3031-7320

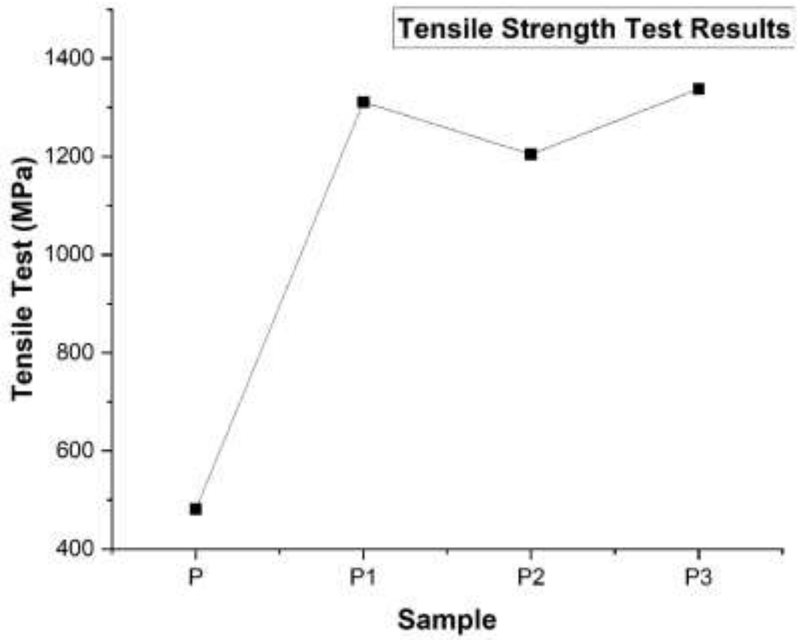
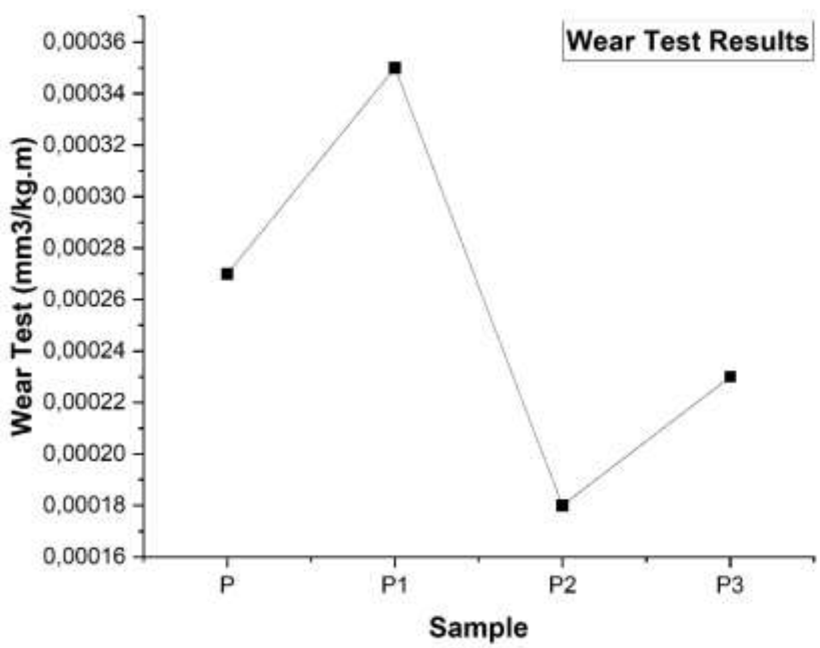


Figure 3. Tensile Testing Chart

Table 4. Wear test results

Code	Sample	Test area	Wear and Tear (mm^3/kg.m)	Average Wear (mm^3/kg.m)
P	Raw Material (Low Carbon Steel)	Point 1	0.00033	0.00027
		Point 2	0.00024	
		Point 3	0.00014	
	Raw Material (Low Carbon Steel)	Point 1	0.00017	
		Point 2	0.00024	
		Point 3	0.00017	
	Raw Material (Low Carbon Steel)	Point 1	0.00038	
		Point 2	0.00044	
		Point 3	0.00028	
P1	Goat bone charcoal- Rice husk charcoal (25%-75%)	Point 1	0.01690	0.00035
		Point 2	0.02790	
		Point 3	0.01848	
	Goat bone charcoal- Rice husk charcoal (25%-75%)	Point 1	0.01848	
		Point 2	0.01401	
		Point 3	0.02382	

	Goat bone charcoal- Rice husk charcoal (25%-75%)	Point 1	0.02790	
		Point 2	0.03484	
		Point 3	0.01541	
P2	Goat bone charcoal- Rice husk charcoal (50%-50%)	Point 1	0.00015	0.00018
		Point 2	0.00027	
		Point 3	0.00032	
	Goat bone charcoal- Rice husk charcoal (50%-50%)	Point 1	0.00020	
		Point 2	0.00029	
		Point 3	0.00020	
	Goat bone charcoal- Rice husk charcoal (50%-50%)	Point 1	0.00006	
		Point 2	0.00012	
		Point 3	0.00007	
P3	Goat bone charcoal- Rice husk charcoal (40%-60%)	Point 1	0.00024	0.00023
		Point 2	0.00047	
		Point 3	0.00032	
	Goat bone charcoal- Rice husk charcoal (40%-60%)	Point 1	0.00027	
		Point 2	0.00032	
		Point 3	0.00020	
	Goat bone charcoal- Rice husk charcoal (40%-60%)	Point 1	0.00009	
		Point 2	0.00006	
		Point 3	0.00012	



 ISSN 3031-7320

Figure 4. Wear Resistance Testing Chart

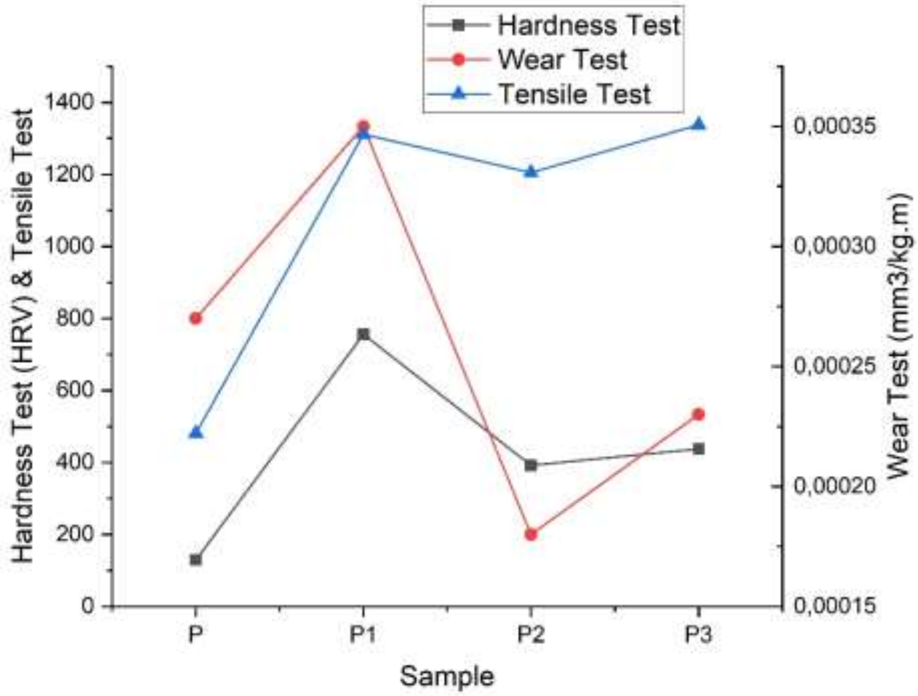


Figure 5. Characteristics Test P1, P2 and P3

The results of the hardness test using the Vickers method showed a significant value with the addition of a mixture of Goat bone charcoal - Rice husk charcoal compared to the raw material. The hardness test results for compositions P1, P2, and P3 showed 756, 392, and 438 HRV, respectively. The P1 Goat bone charcoal- Rice husk charcoal (25%-75%) composition shows a higher value than the other compositions shown in Table 2 and Fig 4.

Likewise, the results of the tensile test using the Universal Testing Machine (UTM) showed a significant increase in value with the addition of a mixture of Goat bone charcoal-Rice husk charcoal compared to the raw material. The results of the tensile test on the compositions P1, P2, and P3 showed 1311, 1205, and 1338 Mpa, respectively. The P3 Goat bone charcoal- Rice husk charcoal (40%-60%) composition shows a higher value than the other compositions shown in Table 3 and Fig. 3.

The results of the wear test using the Ogoshi method showed an increase in the wear value with the addition of a mixture of Goat bone charcoal-Rice husk charcoal compared to the raw material. The wear test results on compositions P1, P2, and P3 showed 35x10^{-}5, $18x10^{-5}$, and $23x10^{-5}$ mm^3/kg m, respectively. The P1 Goat bone charcoal- Rice husk charcoal (25%-75%) composition shows a higher wear value than the other compositions shown in Table 4 and Fig 4.

Based on the test results above, shows in Fig 5 that composition P1 is an effective composition because it experiences an increase in hardness test values and wear test results. The higher the hardness value compared to the raw material, and the less wear test compared to the composition of P2 and P3.

Conclusion

The conclusions of this study include:

1. The composition P1 of Goat bone charcoal - Rice husk charcoal, 25%-75% has hardness test results, tensile test results, and wear tests are 756 HRV, 1311 MPa, and 35x10^{-5} mm^3/kg m.
2. The composition P2 of Goat bone charcoal - Rice husk charcoal, 50%-50% has hardness test results, tensile test results, and wear tests are 392 HRV, 1205 MPa, and 18x10^{-5} mm^3/kg m.
3. The composition P3 of Goat bone charcoal - Rice husk charcoal, 40%-60% has hardness test results, tensile test results, and wear tests are 438 HRV, 1338 MPa, and 23x10^{-5} mm^3/kg m.
4. Raw material with sample code P or Low carbon steel, has hardness test results, tensile test results, and wear tests are 130 HRV, 481.5 MPa, and 27x10^{-5} mm^3/kg m.

References

1. Jo, B., Sharifimehr, S, Shim, Y., et al. (2017), “Cyclic deformation and fatigue behavior of carburized automotive gear steel and predictions including multiaxial stress states”, Int J Fatigue, Vol. 100, pp. 454– 465.
2. Chen, Z, Zhai, W and Wang, K. (2017), “Dynamic investigation of a locomotive with effect of gear transmissions under tractive conditions”, J Sound Vib, Vol.408, pp. 220–233.
3. Saedatul Fatimah, Ariswan. (2018),”Pengaruh Variasi Kandungan Unsur Logam Karakterisasi Menggunakan XRF dan OES Sebagai Penentu Tingkat Kekerasan Baja’, Journal Ilmu Fisika dan Terapannya, Volume 7 No. 3,pp.213-224.
4. Negara, D. N. K. P., & Muku, I. D. M. K. (2015). Pack Carburizing Baja Karbon Rendah. Jurnal Energi dan Manufaktur. 8(2).
5. Izhyanti, R.D., Putri, N.P. And Rohmawati, L., (2013). Analisa Struktur Mikro Baja Karbon Jis Scm 415 Pada Proses Pack Carburizing Menggunakan Media Arang Aktif Tempurung Kelapa”. Inovasi Fisika Indonesia. 2(01).
6. Suherman, W. (1987). Pengetahuan Bahan. Institut Teknologi Sepuluh November Surabaya. Surabaya.
7. Chand, Bansal, Roop, Meenakshi Goyal. (2005). Activated Carbon Adsorpsion. United States of America (USA): Lewis Publisher.
8. Wijayanti R. (2009). Arang Aktif Dari Ampas Tebu Sebagai Adsorben Pada Pemurnian Minyak Goreng Bekas. Tesis Program Pasca Sarjana, Bidang Ilmu Kimia, Institut Pertanian Bogor.
9. Afriany, R., Asmadi, A., & Nuryanti, S. Z. (2017). Analisa Pengaruh Variasi Katalis BaCO3, NaCO3 dan CaCO3 Pada Proses Karburasi Baja Karbon Sedang Dengan Pendinginan Tunggal. Palembang: Universitas IBA.
10. Hidayat, M.T. (2021). Pengaruh Variasi Media Pendinginan Pada Proses Carburizing Berupa Air, Oli SAE 10-40 W Terhadap Kekerasan Struktur Mikro dan Uji Tarik Pada Material Baja Karbon Rendah(ST-41). Skripsi. Teknik Mesin Universitas Muhammadiyah Surakarta. Surakarta.

11. Sari Wardani,. Elvrida Rosa. (2018). Potensi Tulang Kambing Sebagai Arang Aktif Yang Teraktivasi Asam Sulfat. Serambi Engineering Volume III No 2 ISSN: 2528-3561, pp.308-315.
12. Hidayatulloh et all. (2022). Material Characterization of SS400 After Pack Carburizing Treatment. Material Research Communication Volume 3 No 1 pp.13-21.