ANALYSIS OF MECHANICAL CHARACTERISTICS OF TOOTH BUCKET EXCAVATOR BASED ON DIFFERENT GRADE LEVELS

Akhmad Nurdin[1]*, Iqbal Zulfikar Alief Utama[1], Bagus Angger Prasetiyo[2]
Rosyidi Hidayat[3], Fajar Paundra[4], Fajri Kurniawan[4], Dzikrina Salsabila Yasmin[4], Abdul Muhyi[4]

[1]Department of Manufacturing Design Engineering Technology, Universitas Tidar
[2]Departemet of Mechanical Engineering, Universitas Tidar
[3]PT Aqpa Indonesia, Bekasi, West Java
[4]Departemet of Mechanical Engineering, Faculty of Industrial Technology, Institut Teknologi Sumatera
Email: akhmadnurdin@untidar.ac.id

Abstract

The purpose of this study is to comprehend the microstructure and hardness value of three distinct tooth bucket manufacturers. Three manufacturers' excavator tooth buckets—Canada Grade, China Grade A, and China Grade C—are compared for their mechanical characteristics. Among the tests are the Vickers method for measuring hardness, optical microscopy for examining microstructure, and chemical composition analysis. According to the results, the primary elements in all three specimens—carbon, silicon, manganese, and chromium—meet the DIN Grade 25CrMo4 standard. The martensite phase, which gives the Canada product its hardness and resistance to deformation, dominates its microstructure. The China Grade C product, on the other hand, has a more prominent ferrite phase, which raises ductility while decreasing hardness. Canada (570.24 HVN) had the highest hardness test value, followed by China Grade A (517.67 HVN) and China Grade C (468.09 HVN). This demonstrates that while Canada excels at withstanding heavy loads without damage, China Grade C is better suited for applications needing high wear resistance. Users of heavy machinery can use this study as a scientific guide when choosing bucket nails based on operational requirements, including material toughness and wear.

Keyword : tooth bucket, vickers hardness, microstructure, martensite phase, ferrite phase.

INTRODUCTION

The chemical composition of steel metal is directly impacted by the addition of alloy elements, as demonstrated by a number of related tests (Khasanah et al., 2024). The hardness value of the alloy metal can be determined by analyzing the composition observations of specific elements. For example, adding carbon elements (Malim et al., 2025), nickel elements (Sudarmanto, 2016), and chromium elements (Doloksaribu and Afrilinda, 2017) will raise the hardness value. Through microobservations, the addition of alloying elements to steel will alter the grain size and phase type, thereby influencing its mechanical properties (Septiawan, 2016).

Brinell testing can be used to review the properties of materials based on their hardness. The hardness test measures the hardness of a material by examining the pressure with an indenter (Nurdin et al., 2024). The hardness of the material is always positively related to its wear resistance value; the higher the hardness value, the greater the wear resistance value (Septiyanto, 2022), however overly hardness materials will often be brittle, which will reduce their resistance to shock or impact loads (Aprizal and Rizal, 2019)

A tooth bucket is a durable piece of machinery employed for crushing rocks, consequently enduring extreme pressure and friction during operation (Pratama, 2017). The tooth bucket in excavator heavy equipment is a consumable component that wears easily due to frictional interactions with materials containing various soils and rocks with varying degrees of variation and roughness. Environmental conditions, type of operation, rock type, and operator skill all have an influence on the wear level of this component (Haryatmoko and Hidayah, 2019). Furthermore, from a metallurgical perspective, the properties of the material employed also affect tooth bucket wear rate (Septiawan, 2016). In order to predict or assess the tooth bucket's toughness and durability (Burhannudin and Anshori, 2022), its hardness value can be reviewed in order to study its characteristics based on resistance to wear or friction. If data from laboratory tests is acquired, prediction and evaluation can be reviewed (Ismail et al., 2020).

Industrial product tooth buckets can be graded based on their service life and durability 500 up to 5000 operating hours (Ismail et al., 2020), to obtain a comparison of calculations when the unit is downtime (Burhannudin and Anshori, 2022). Based on this, a comparative study of the mechanical properties of materials from various industrial manufacturers is required to assess the quality differences provided by each manufacturer.

The purpose of this study is to examine the mechanics of machining and the structure of micromaterial teeth buckets from three different manufacturers. The benefit of this research is that it provides detailed information about the characteristics of each product, making it useful for the manufacturing industry when purchasing tooth buckets.

METHODS

This study included three tooth buckets from various manufacturers: Canadian Grade, China Grade A, and China Grade C. To determine the material's chemical composition, tests were performed. The three excavator tooth bucket products' chemical compositions were tested at Ceper Manufacturing Polytechnic, and the results are displayed in Table 1. The alloy content in the three products reaches 4.281% for Canada Grade, 4.644% for China Grade A, and 4.88% for China Grade C, indicating that the tooth bucket content of the three products is near the DIN Grade 25CrMo4 standard in the medium alloy steel category, according to the results of the chemical composition test. The material may adhere to a different standard because the Mn content is higher than the DIN Grade 25CrMo4 standard, while the Si and Mo contents are marginally lower than the standard. The DIN Grade 25CrMo4 standard is typically utilized in the production of vehicle axles, pressure tanks, aircraft structural components, and other items. It is consistent with AISI Grade SAE4130 and JIS G 4051 Grade SCM420.

The stages of this study (as illustrated in Figure 1) began with cutting to create smaller parts for specimens. After cutting the specimen, the next step in observing the microstructure and hardness was preparation, which included mounting, sanding, and polishing. Following the completion of the preparation process, the specimen's microstructure is examined and its hardness is tested. During microstructure observations, test specimens were etched, was carried out using 5% HNO_3 and 95% alcohol at a 70% concentration for 5 seconds, the standard used was ASTM E407. Microstructure is observed using a standard Carl Zeiss optical microscope with ASTM E3-01. To identify the specimen's phase, samples are taken from the right, left, and middle of the specimen to determine the observation points. In the meantime, the Vickers method (HVN) was used to conduct the hardness test and ascertain the specimen's hardness value. The ZHU 25CL universal hardness tester is used by the hardness tester.

Table 1. Specimen of Chemical Composition

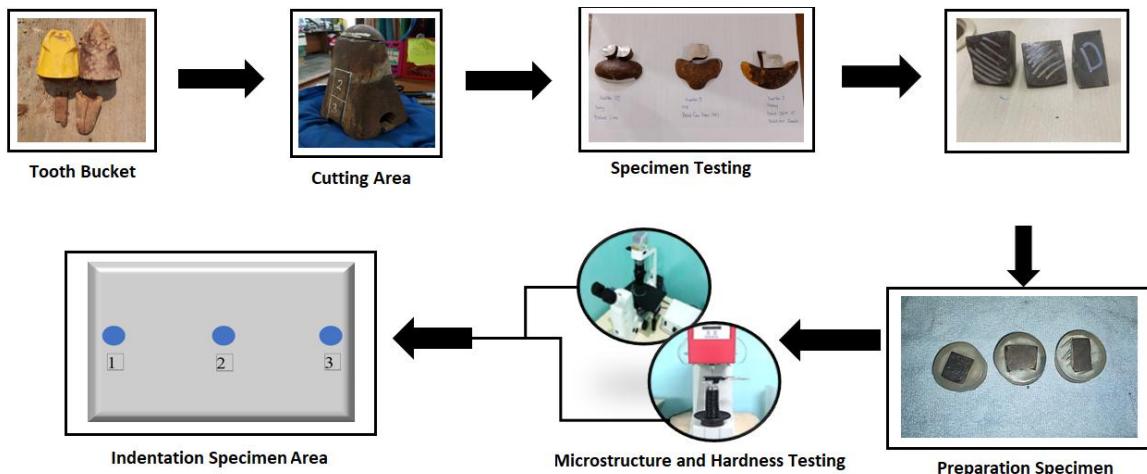| Komposisi (%)				
Unsur	Standar DIN GRADE 25CrMo4	Canada	China Grade A	China Grade C
C	0,22-0,29%	0,237%	0,285%	0,274%
Si	0,4%	1,238%	1,462%	1,535%
Mn	0,6-0,9%	0,973%	1,072%	1,274%
P	0,025%	0,024%	0,024%	0,024%
S	0,02-0,4%	0,022%	0,021%	0,021%
Cr	0,9-1,2%	1,797%	1,823%	1,861%
Mo	0,15-0,3%	0,273%	0,289%	0,210%
Ni	-	0,312%	0,234%	0,026%
Fe	-	95,03%	94,68%	94,67%

Figure 1. scheme for the research method

RESULTS AND DISCUSSION
Microstructure

The purpose of the microstructure test is to identify the phase or composition that forms in steel. Because each phase has a unique hardness, ductility, and other mechanical properties, the phases that result from the microstructure test are closely linked to the material's mechanical properties. To improve optical visibility and make it simpler to identify phases and determine grain boundaries, the specimen's surface must be etched. 5% HNO_3 and 95% alcohol at a 70% concentration were used for the etching process, which lasted five seconds. An optical microscope was used to test the microstructure.

Figure 2 presents the findings of microstructural observations of three excavator tooth bucket products. It demonstrates that all three products have a martensite phase that is the result of transformation without diffusion, trapping the carbon atoms as a whole (Prabowo et al., 2024). Regarding its properties, martensite will give the material hard qualities, but brittle qualities will likely become more prevalent. The hardness value will be positively impacted by high hardness, meaning that the material will typically be hard, wear-resistant, and deformation-resistant (Septiawan, 2016) (Septiyanto, 2022).
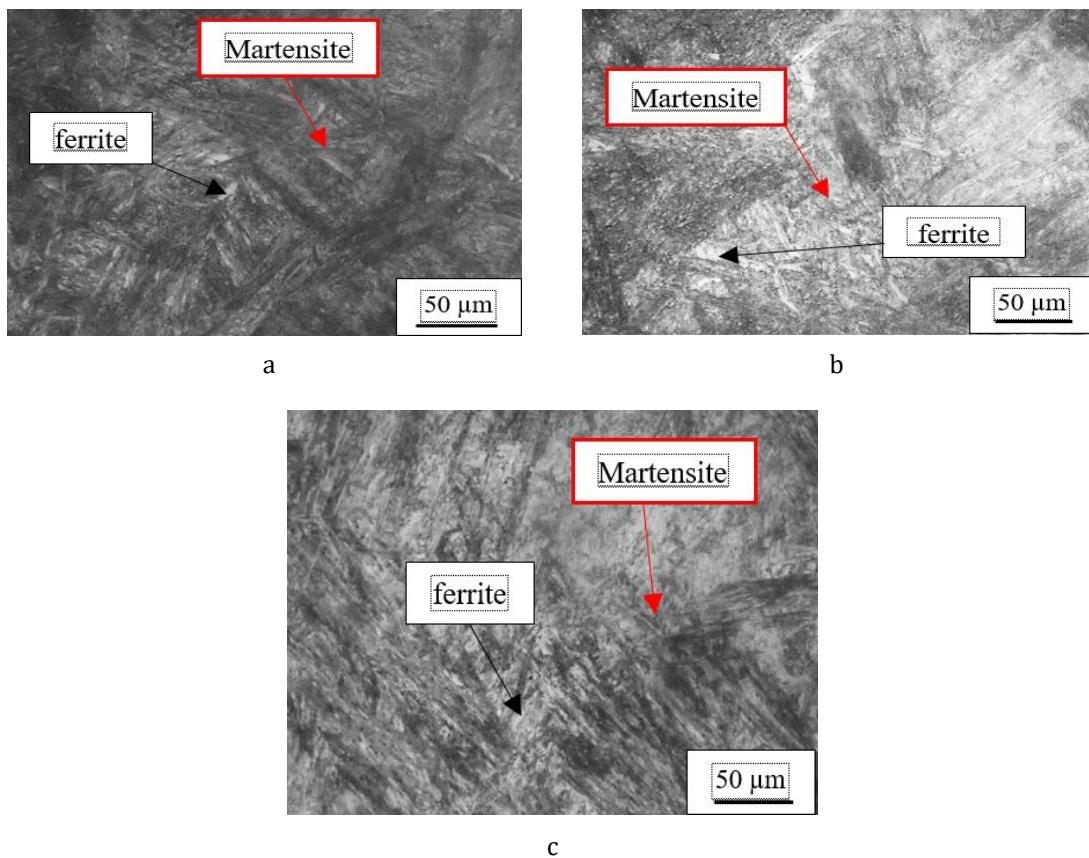

a

b

c

Figure 2. Microstructure results : (a) canada grade (b) china grade A (C) china grade C

The Image J application, which is based on the light color gradation representing the ferrite phase and the dark color indicating the martensite phase, can be used to examine the percentage comparison between phases in specimen observations. Figure 3 shows the results of the color gradation transformation using Image J referring to Figure 2, Based on the color presentation scan, the martensite phase is more dominant than the ferrite phase with the Canada grade product with a percentage of 36.86% ferrite phase and 63.14% martensite phase (Figure 3a), China grade A ferrite phase 36.86% and 60.9% martensite phase (Figure 3b), China Grade C ferrite phase 41.4% and 58.6% martensite phase (Figure 3c). The material's properties, particularly its hardness, are influenced by the phase form determined by microstructure studies (Nurdin et al., 2024)(Khasanah et al., 2024). The hardness value is directly impacted by the proportion of the martensite and ferrite phases (Aprizal and Rizal, 2019).
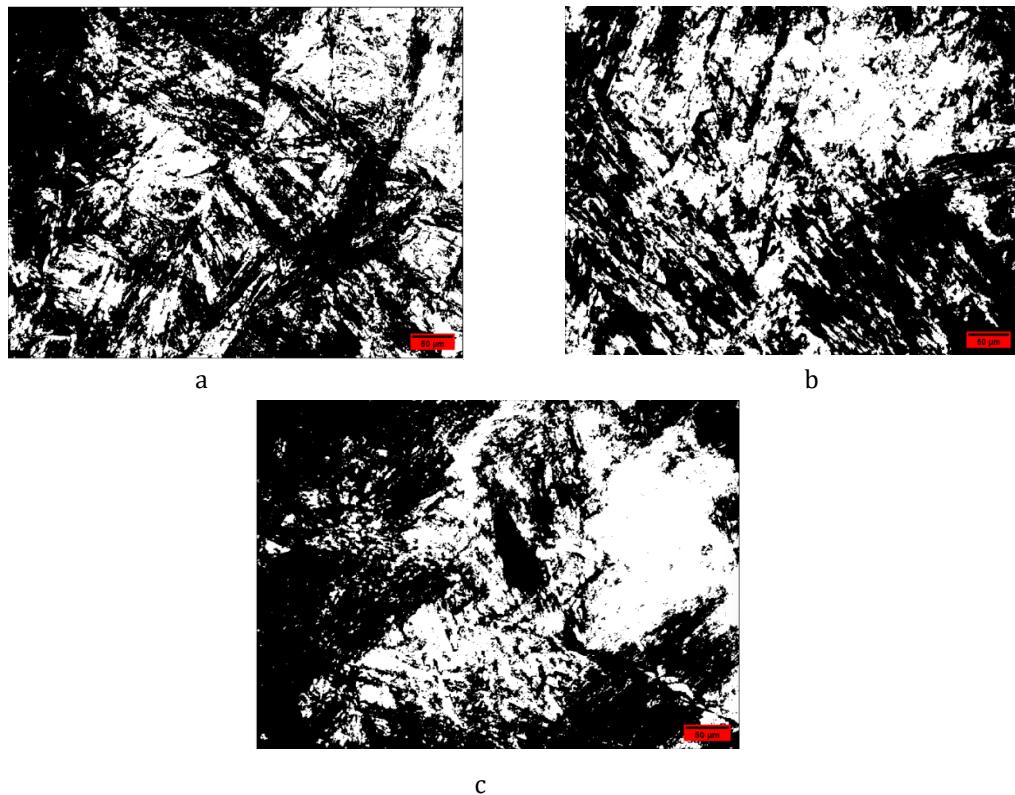
a

b

c

Figure 3. Results of the phase gradation of ferrite (light) and martensite (dark) using imagej:
(a) canada grade (b) china grade A (C) china grade C

Hardness

The purpose of hardness testing is to determine how well a material can tolerate surface shape changes brought on by loading (Rajagukguk et al., 2024). Three excavator tooth bucket specimens from various manufacturers were tested to ascertain their hardness levels. The hardness test results for three different manufacturers' excavator teeth buckets are present in Figure 4.

Figure 4 shows that the Canadian grade tooth bucket has the highest hardness with a value of 570.24 HVN, followed by China Grade A 517.67 HVN, and China Grade C 472.41 HVN. The difference in hardness results of these three products is determined by their composition as shown in Table 1, with a comparison of the amount of ferrite and martensite phases as shown in Figure 3. The wider and greater the percentage of the martensite phase as shown in Figure 3, the higher the hardness value will be, as shown in Figure 4. The high hardness values of these three grades of tooth bucket are influenced by the composition of the elements Manganese (Mn), Nickel (Ni), and Chrome (Cr) (Doloksaribu and Afrilinda, 2016)(Sudarmanto, 2016) as shown in Table 1.
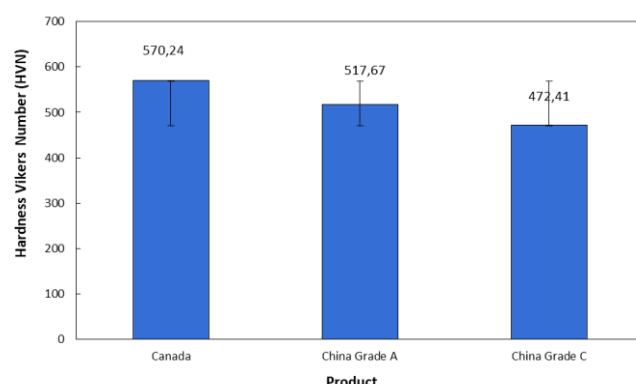

Figure 4. Hardness Vikers Diagram

Conclusion

Based on the research results, the three products analyzed through microstructural observations have martensite phases and ferrite phases with different percentages of each product. Each product has a higher percentage of martesite phase than ferrite phase, with Canadian products having a higher percentage of martensite phase up to 63.14% compared to China Grade A products with a percentage of 60.9% and China Grade C products 58.6%. The percentage value of the martensite phase increases, and has a proportional impact on the hardness value, based on the hardness value, Canadian products have the highest hardness up to 570.74 HVN, then China Grade A products 517.67 HVN, and China Grade C products 472.41 HVN.

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