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Effect of Austempering Go-Kart Rear Axle on Toughness Properties and Microstructure Morphology

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Abstract:- A Go-Kart is a four-wheeled vehicle that exhibits characteristics similar to a motorcycle. Additionally, since Go-Kartslack shock absorbers, it is crucial to use an engine that minimizes vibrations. The shaft, a typically circular rotating part, is oftenattached to elements like gears and endures continuous loads, which can lead to breakage. Shaft failures are common and often result from incidents caused by the need to use lightweight materials for faster performance. This study aims to examine the strength characteristics of the Go-Kart rear wheel shaft made from ASTM A414 Grade A steel after undergoing bending tests, impact tests, and microstructure analysis. Specifically, it investigates the effects of temperature on the toughness and curvature of the Go-Kart rear wheel shaft post-normalizing and tempering processes. Methods employed include heat treatment, three-point bending tests, Charpy impact tests, and ASTM E3-11 microstructure analysis. The highest impact value, 0.644joules/mm², was observed in specimen B, which underwent a normalizing process at 850°C and tempering at 300°C. The lowest impact value, 0.190 joules/mm², was found in specimen A, which underwent a normalizing process at 800°C and tempering at 250°C. The highest three-point bending strength, 2520.1 N/mm², was also recorded in specimen B, while the lowest, 2255.4 N/mm², was in specimen C, which underwent normalizing at 900°C and tempering at 350°C. Microstructure analysis revealed that higher temperatures during the normalizing and tempering processes result in the formation of more pearlite crystals and a denser microstructure.

***Keywords:-** ASTM A414 Grade A, Go-Kart Shaft, Impact Strength, Three-Point Bending Strength, Microstructure Morpholgy.*

I. INTRODUCTION

A go-kart is a type of transport vehicle that operates using a motor vehicle engine as its main source of power. The Go-Kart was first designed in California in 1956, by Art Ingels, and a race car designer at the Kraft kurtis company. The components of the Go-Kart include the frame, rear wheel axle, steering system, and other components. Among them all, the wheel shaft has the most important role in a vehicle including Go-Kart. However, of course there are adjustments in position and size so that it can be fully functional. [1]

However, shaft failures still occur frequently due to incidents. This incident occurs because Go-Kart shaft components must use lightweight materials to make the shaft work faster. However, the use of these lightweight materials can also damage Go-Kart shaft components at high speeds. Such incidents can cause economic losses. Therefore, incidents can be prevented by improving manufacturing procedures as well as normalizing and tempering processes..[2]

In addition, heat treatment is also needed to change the mechanical properties of low carbon steel. The working mechanism of heat treatment is a combination of heating and cooling with a certain time.

Therefore, research was conducted with ASTM A414 Grade A steel material analysis to determine and improve stable performance and identify potential problems. This research can involve track testing or an environment that matches racing conditions. Therefore, the research title is "Effect of Austempering on Microstructure". This research is expected to be used by racing industry players, especially the Mechanical Engineering Racing Team (MERT) Organization of Tarumanagara University.

II. MATERIAL AND METHODS

Amidst rapid technological advancements, numerous innovations have been made to enhance time efficiency, reduce costs, and improve product quality. In this chapter, we will explore the methods and materials used to create the Go-Kart wheel axle.

The shaft prioritized in this trial is the axle shaft. Typically mounted on the wheels of freight trains, this shaft does not endure a torsional load and sometimes remains stationary[3]. The materials and methods used are as follows. Material:

A. *Carbon Steel Material*

Axle shafts are typically constructed from carbon steel, specifically ASTM A414 Grade A. This particular steel is classified as low carbon steel, containing less than 0.3% carbon.

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Table 1: Composition of ASTM A414 Grade a Steel

Unsur kimia	Satuan	wt %
Besi	Fe	99.12
Carbon	C	0.156
Mangan	Mn	0.0023
Fosfor	P	<0.001 0
Sulfur	S	<0.005 0
Silikon	Si	0.028

Table 2: ASTM A414 Grade a Steel Material

Properties	Unit	Value
Tensile Strength	Mpa	310
Yeild Strength	Mpa	170
Elongation at break	%	26%
Hardness	HB	110
Elastic Modulus	GPa	190
Bulk Modulus	GPa	140
Shear Modulus	GPa	73
Physical Properties ASTM A414 GRADE A		
Density	X1000 Kg/m3	7.85
Melting Point	°C	1432

➢ *Charpy Impact Test Equipment*

This tool is employed to determine the strength of materials and gauge the toughness of metals when subjected toshock loading under controlled conditions.

➢ *Bending Test Equipment*

This device is utilized to assess the strength and mechanical properties of a material or structure. It works by exerting a load on the sample material and monitoring its reaction to the applied force.

➢ *Maple Furnance*

This tool is used to heat the specimen.

➢ *Calipers Measuring Instruments*

This tool is used to determine the length, outerdiameter and inner diameter of a shape.

➢ *Microstructure Microscope*

Used as a tool for microstructure testing.

- *Methods:*

In this method, researchers use a variety of methods to produce the best value and results from research. The existence of this process is. The existence of that process is:

➢ *Normalizing*

Normalizing is a heat treatment process where steel is heated to the austenite phase. The austenite microstructure formed then allowed to cool in open air to room temperature. This process alters the structure and properties of the material, enhancing its ductility and hardness.[9]

In this process, the steel is heated to a critical temperature ranging from 800°C to 900°C and maintained at that temperature (holding). Subsequently, the steel is cooled toroom temperature. The rate at which the steel is cooled greatly affects its mechanical properties: rapid cooling increases strength and hardness, while slower cooling results in reduced strength and hardness.

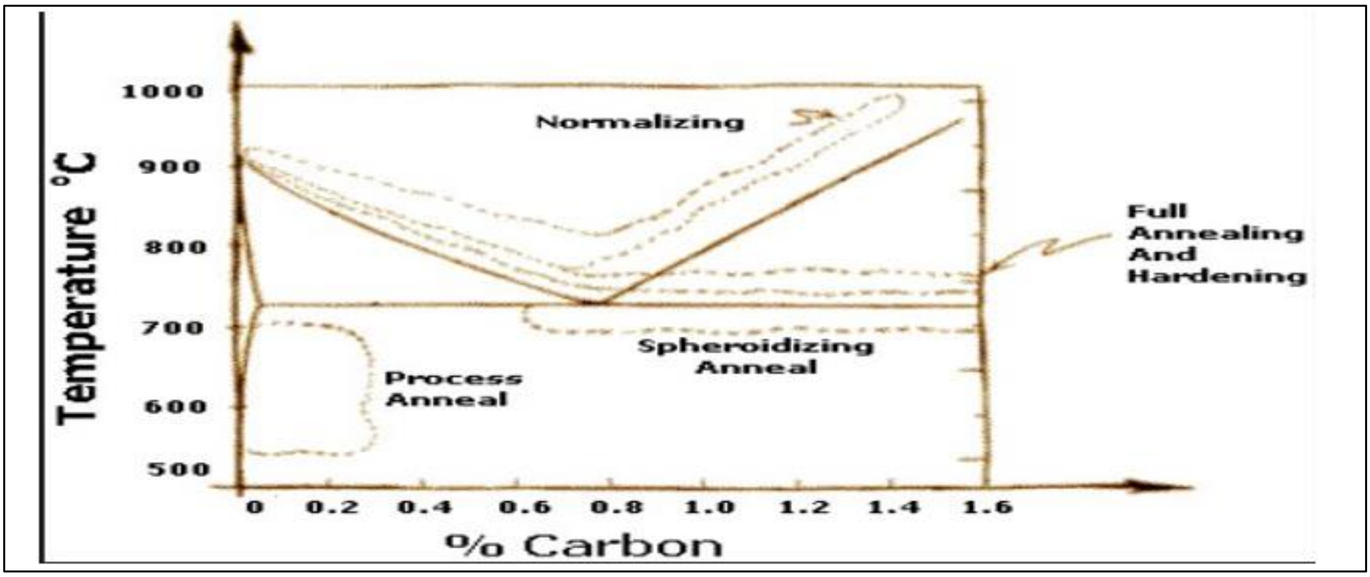

Fig 1: Normalizing Process

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➢ *Tempering*

This process entails reheating a metal previously hardened by normalizing to a temperature below its critical point for a specific duration, followed by a gradual cooling. Itspurpose is to alleviate residual stresses, lower hardness, and improve the metal's ductility and toughness, aiming for an ideal combination of these properties.[11]

➢ *Fe3C Phase Diagram*

This diagram serves to depict the correlation between temperature and phase changes during cooling, specifically in relation to varying carbon content (%C).

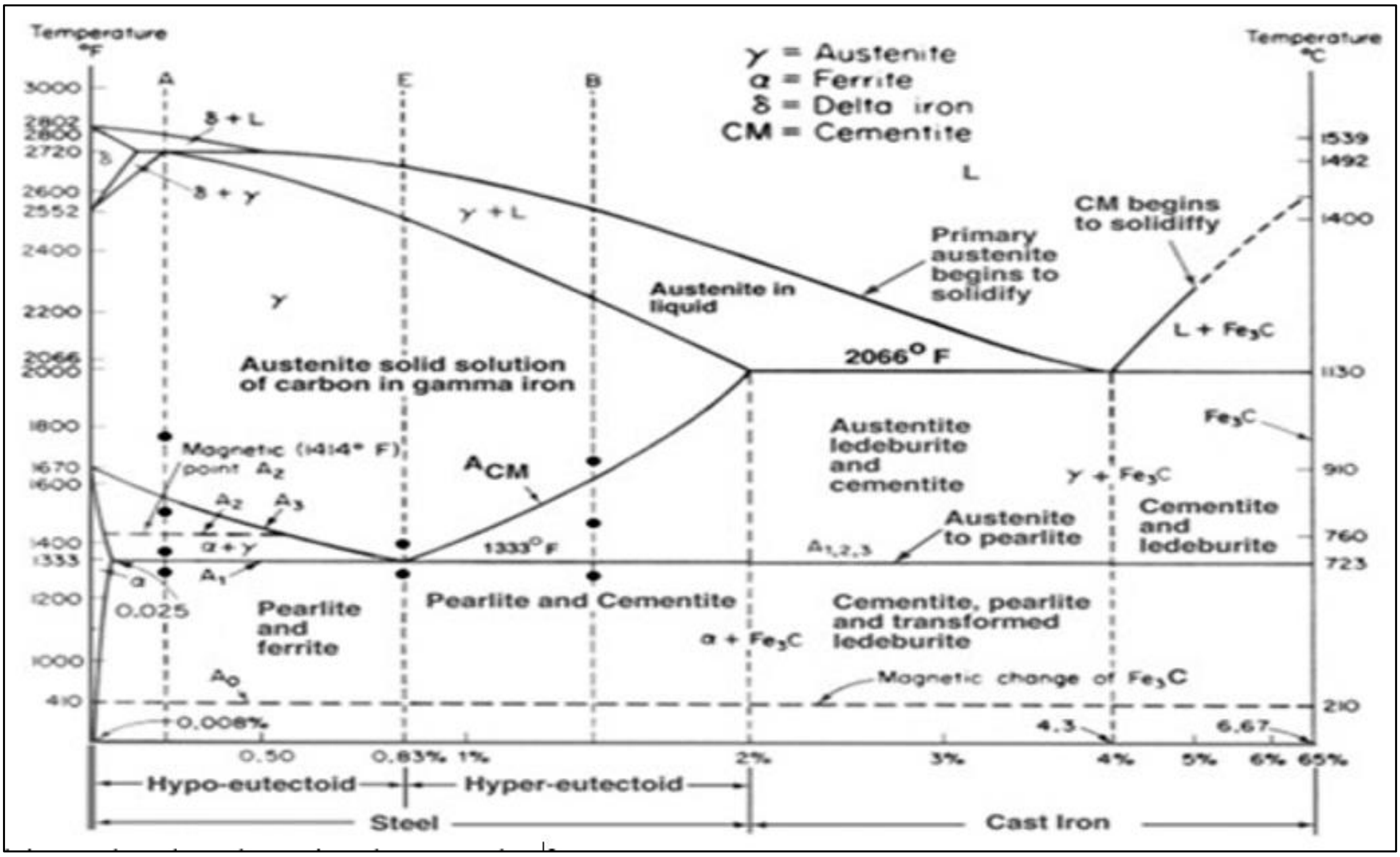

Fig 2: Fe3C Phase Diagram

➢ *Three-Point Bending Test*

3-point bending testing is a method where a specimenis placed on two pedestals with a single pressing point. The load is applied at the midpoint of the rod (0.5 L). This positioning ensures that the moment generated is maximal, as it is precisely at the center point (0.5 L) of the specimen.[5]

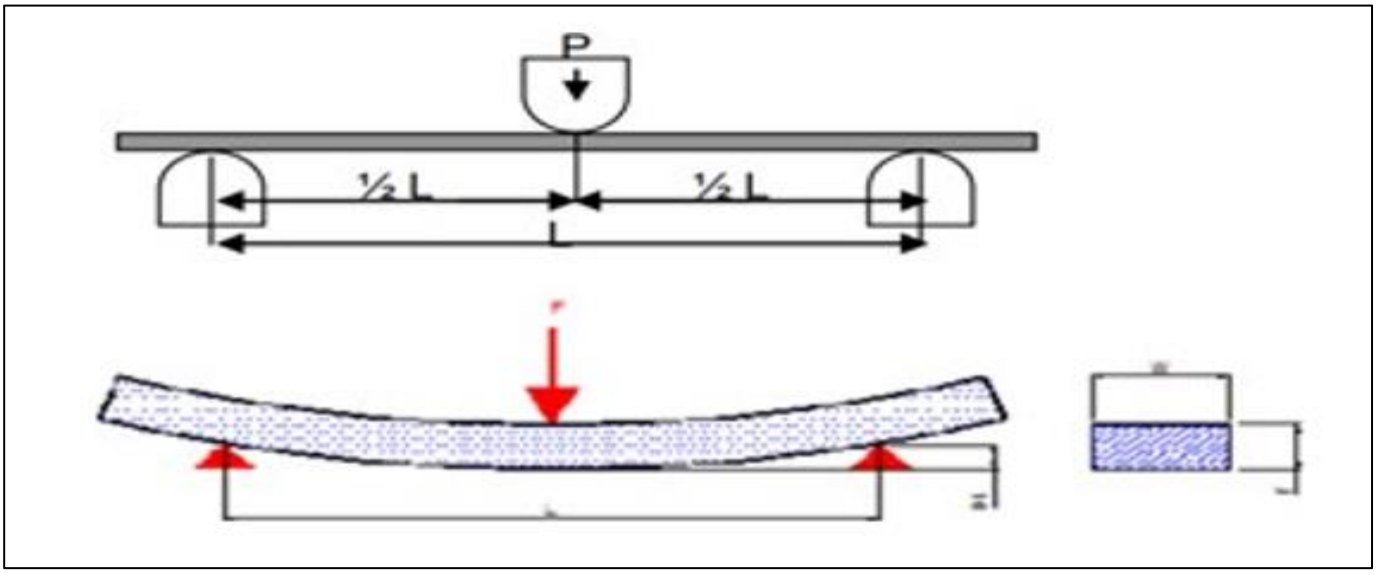

Fig 3: Schematic of Three-Point Bending Test

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With the equation used:

$$\sigma = \frac{3\ x\ P\ x\ L}{2\ x\ W\ x\ T^2}$$

Where:

σ = Bending Strength (N/mm2)
P = Press Load or Force (N)
L = Distance of two fulcrums (mm)
W = Specimen width (mm)
T = Thickness of specimen (mm)

➢ *Charpy Method Impact Test*

The Charpy V-notch test, also known as the Charpy impact test, is a standard method for evaluating the toughness of materials, especially at high strain rates. It measures the amount of energy absorbed by a material when fractured undera controlled impact. This absorbed energy is indicative of the material's ability to withstand sudden loading and is influenced by factors such as the ductile-brittle transition temperature. The Charpy V-notch test is widely used to assess the impact strength and resilience of materials.[7]

Impact test formula:

$$HI= \frac{GxD(cos\beta - cos\alpha).L}{A}\ \frac{GxD(cos\beta - cos\alpha).L}{A}\ \ (joule/mm^2)$$

Where:
D = 0.6345 m
G = 26.12 kg
L = 0.75m
cos λ = initial position angle of the pendulum

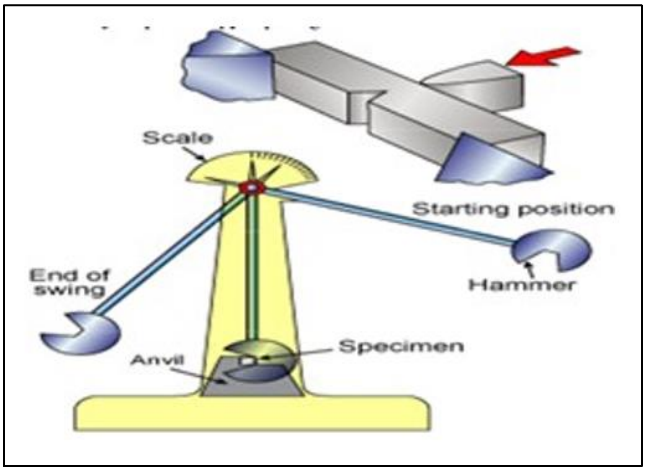

Fig 4: Schematic Illustration of Impact Testing

III. RESULTS AND DISCUSSION

A. *Metallography Testing*

This observation is based on the difference in the reflected rays of the metal surface that enter the microscope sothat different images occur. Then the metal surface that has been smoothed (polish) is dipped in a chemical medium (etching), then the metal surface will be seen more clearly.

➢ *Impact Testing Results*

The results obtained from the Impact testing method are as follows :

The formula used:

$$HI = \frac{G\ x\ D\ (coscos\ \beta - coscos\ \alpha)\ x\ L}{A}$$

$$\frac{G\ x\ D\ (coscos\ \beta - coscos\ \alpha)\ x\ L}{A} = (Joule/mm^2)$$

Where :
G = 26.12 kg
D = 0.6345
mL = 0.75 m

Table 3: Then the Results of Impact Testing with a Normalizing Process of 800°C and a Tempering Process of 250°C are

Sample	**A1**	**A2**	**A3**
Lengthy (mm)	55	55	55
Range (mm)	10	10	10
Dense (mm)	2	2	2
Cross section	20	20	20
Edge α (°)	144	144	144
Edge β (°)	83	107	106
Pendulum Axis Distanceto center of weight (m)	0.6345	0.6345	0.6345
Lever Arm(m)	0.75	0.75	0.75
Pendulum weight (kg)	26.12	26.12	26.12
Impact Energy (Joule/mm²)	0.386	0.069	0.115
Average (Joule/mm²)	0.190		

Table 4: Then the Results with Impact Testing with Normalizing Process 850°C and Tempering Process 300°C

Sample	B1	B2	B3
Lengthy (mm)	55	55	55
Range (mm)	10	10	10
Dense (mm)	2	2	2
Cross section	20	20	20
Edge α (°)	144	144	144
Edge β (°)	74	85	93
Pendulum Axis Distanceto center of weight (m)	0.6345	0.6345	0.6345
Lever Arm(m)	0.75	0.75	0.75
Pendulum weight (kg)	26.12	26.12	26.12
Impact Energy (Joule/mm²)	0.435	1.153	0.344
Average (Joule/mm²)	0.66		

Table 5: Then the Results with Impact Testing with 900°C Normalizing Process and 350°C Tempering Process

Sample	C1	C2	C3
Lengthy (mm)	55	55	55
Range (mm)	10	10	10
Dense (mm)	2	2	2
Cross section	20	20	20
Edge α (°)	144	144	144
Edge β (°)	81	87	83
Pendulum Axis Distanceto center of weight (m)	0.6345	0.6345	0.6345
Lever Arm(m)	0.75	0.75	0.75
Pendulum weight (kg)	26.12	26.12	26.12
Impact Energy (Joule/mm²)	0.059	0.187	0.386
Average (Joule/mm²)	0.211		

- *Then the Comparison Obtained from Each Test Result is:*

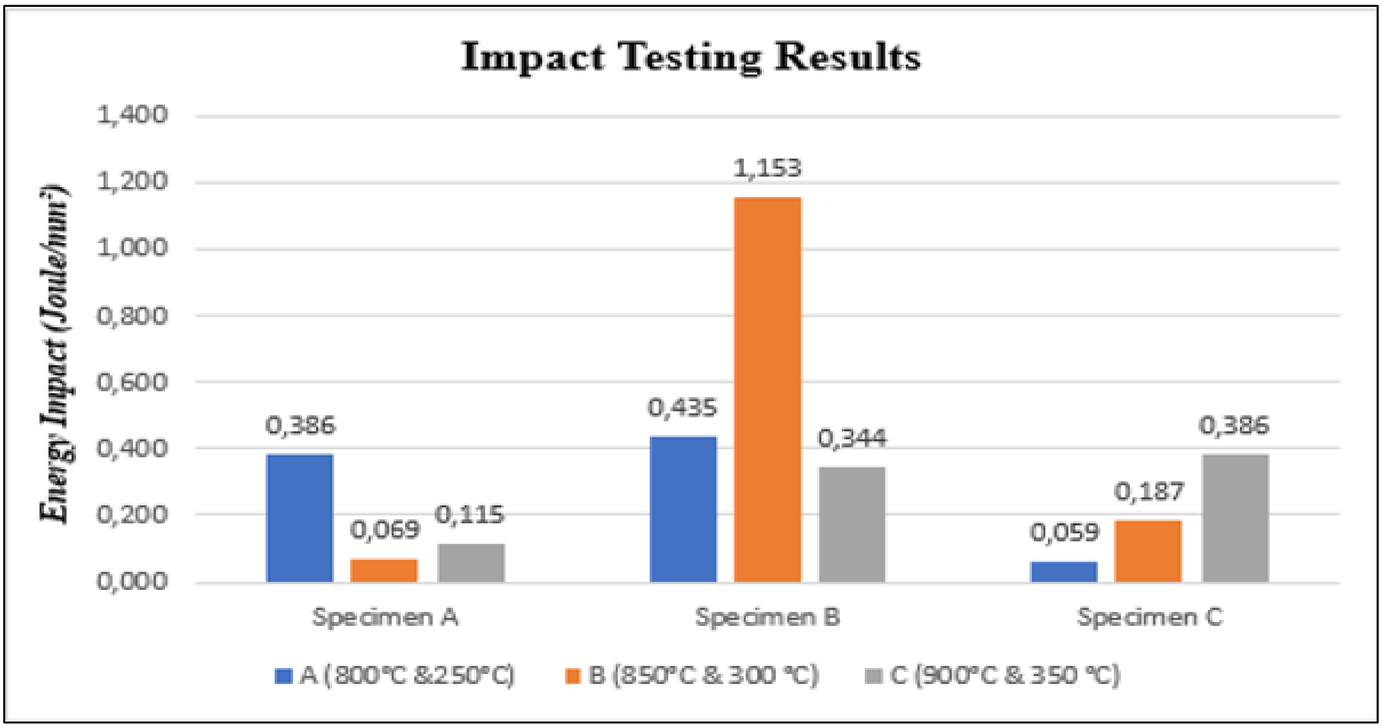

Fig 5: Comparison Results of Each Impact Test

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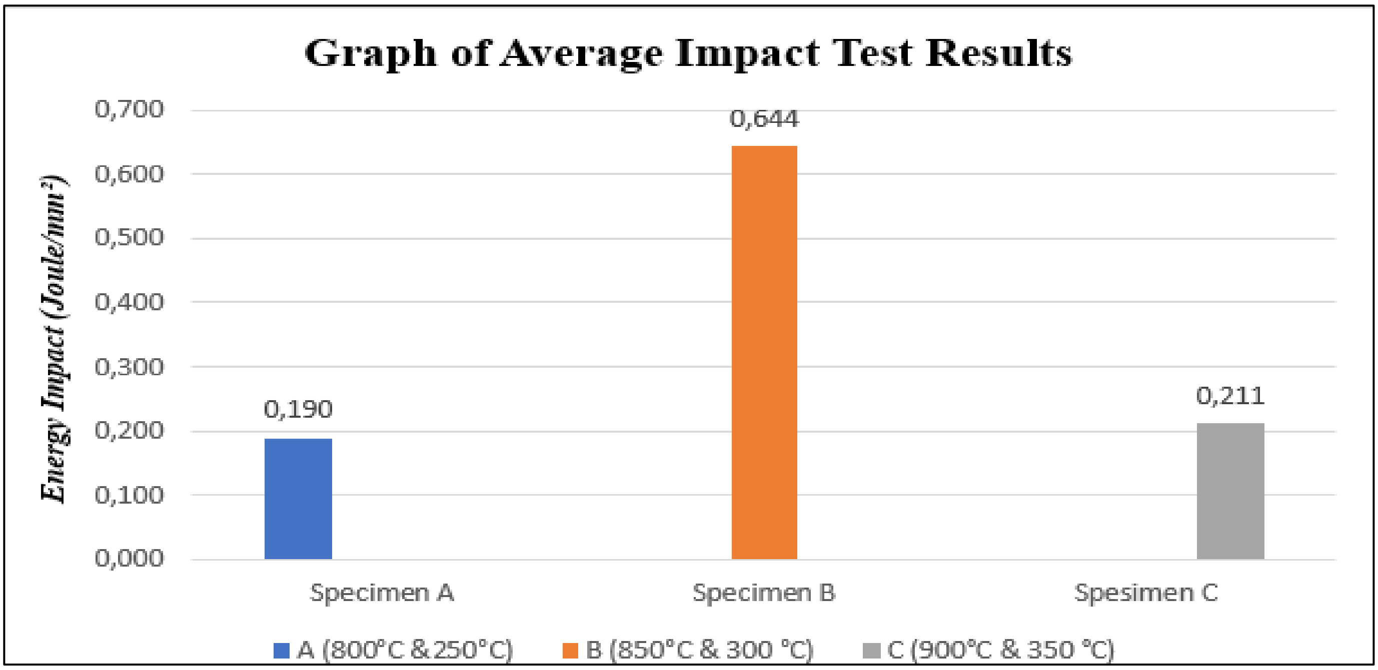

Fig 6: Graph of Average Impact Test Results

Based on the data presented in the graph, specimenB, which underwent the 850°C normalizing process and 300°C tempering process, achieved the highest impact energy value of 0.644 joules/mm². In contrast, specimen A, treated with the 800°C normalizing process and 250°C tempering process, recorded the lowest impact energy value of 0.190 joules/mm². This indicates that the material exhibits its maximum impact resistance under the conditions of the 850°Cnormalizing and 300°C tempering processes, specifically in specimen B.

B. *Bending Test Results*

The formula used is:

$$\sigma = \frac{3 \, x \, P \, x \, L}{2 \, x \, W \, x \, T^2}$$

Where

σ σ = Bending Strength (N/mm^2)
P = Press Load or Force (N)
L = Distance of two fulcrums (mm)
W W = Specimen width (mm)
T T = Thickness of specimen (mm)

Table 6: Then the Results of Bending Test testing with Normalizing Process 800°C and Tempering Process 250°C are

Sample	A1	A2	A3
Lengthy (mm)	250	250	250
Range (mm)	25	25	25
Dense (mm)	2	2	2
Force (kgf)	90	80	80
Force (N)	882.54	784.48	784.48
Interval Between two pivot point (mm)	200	200	200
Bending Strength (N/mm2)	2647.62	2353.44	2353.44
Median (Joule/mm²)	2451.5		

Table 7: Then the Results of Bending Test testing with 850°C Normalizing Process and 300°C Tempering Process are

Sample	B1	B2	B3
Lengthy(mm)	250	250	250
Range (mm)	25	25	25
Dense (mm)	2	2	2
Force (kgf)	90	85	82
Force (N)	882.54	833.51	804.092
Interval Between two pivot point (mm)	200	200	200
Bendingstrength (N/mm^2)	2647.62	2500.53	2412.276
Median (Joule/mm²)	2520.1		

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Table 8: Then the Results of Bending Test Testing with 900°C Normalizing Process and 350°C Tempering Process are

Sample	C1	C2	C3
Lengthy (mm)	250	250	250
Range (mm)	25	25	25
Dense (mm)	2	2	2
Force (kgf)	85	75	70
Force (N)	883.51	735.45	686.42
Interval Between two pivot point (mm)	200	200	200
Bending Strength (N/mm^2)	2500.53	2206.35	2059.26
Median (Joule/mm²)	2255.4		

➢ *Then the Comparison Obtained from Each Bending Test Test Result is:*

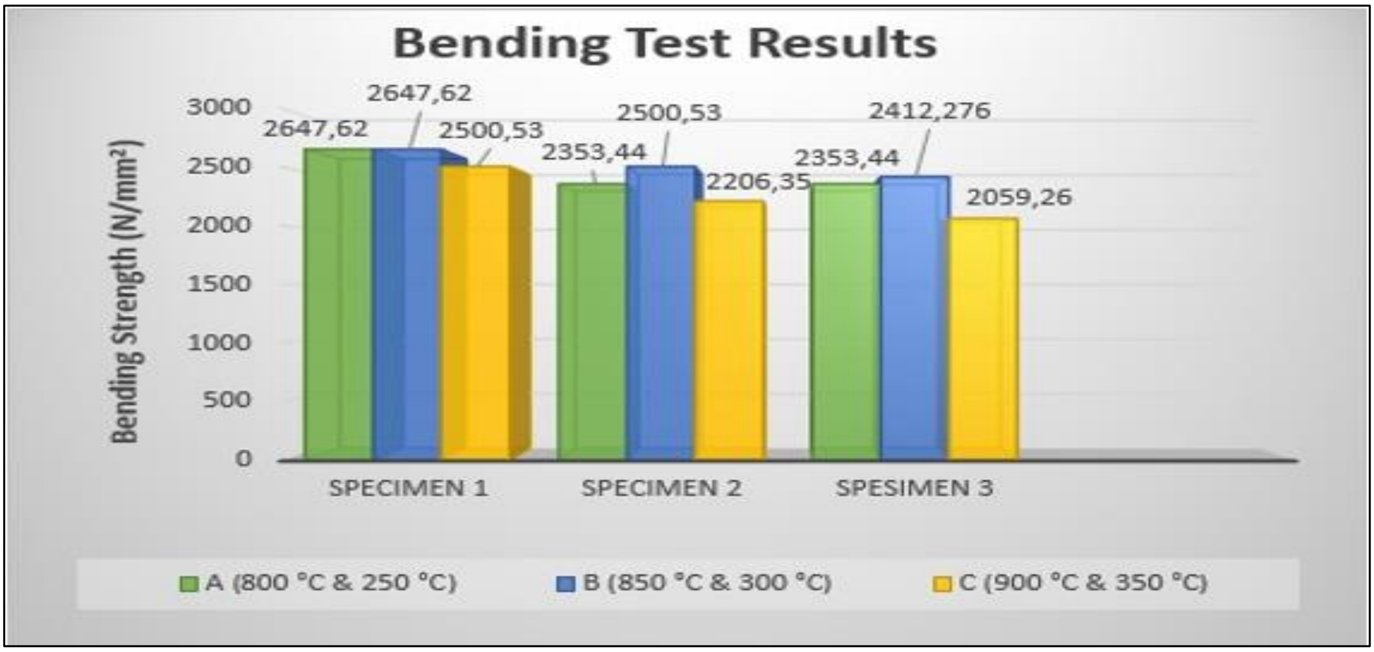

Fig 7: Results of Bending Test

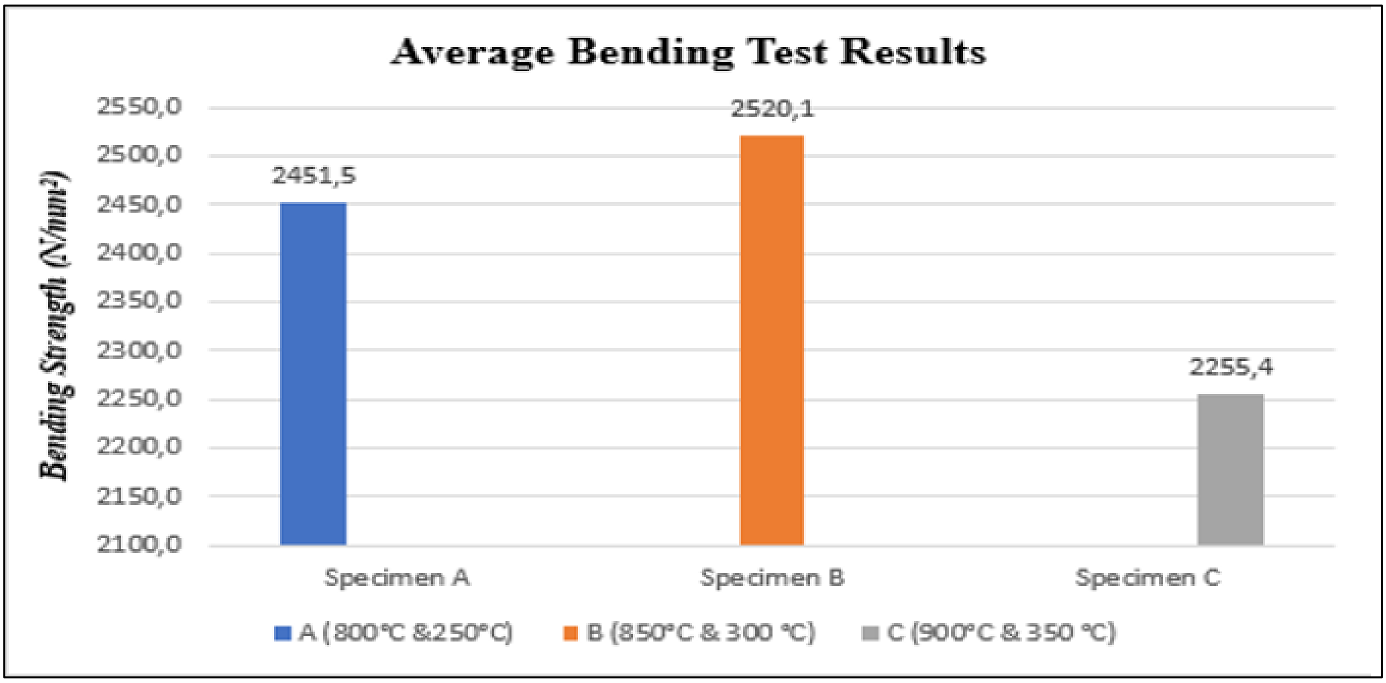

Fig 8: Graph of Average Bending Test results

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Based on the graph above, it is evident that specimen B, subjected to the normalizing process at 850°C and tempering at 300°C, exhibited the highest bending strength value of 2520.1 N/mm². In contrast, specimen C, treated with the normalizing process at 900°C and tempering at 350°C, showed the lowest bending strength value of 2255.4 N/mm².

➢ *Microstructure Observation Results*

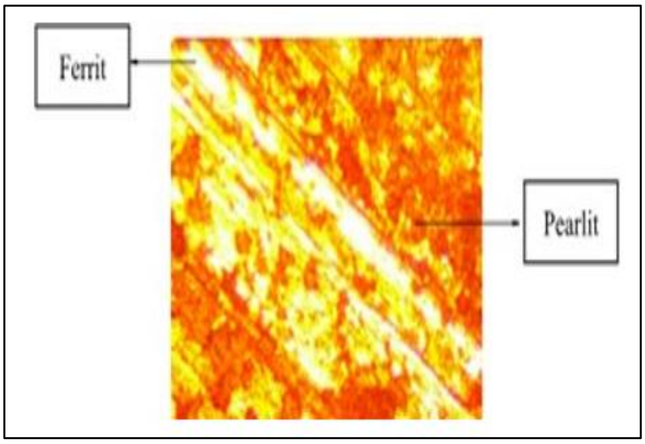

Fig 9: Microstructure without Normalizing and Tempering Process

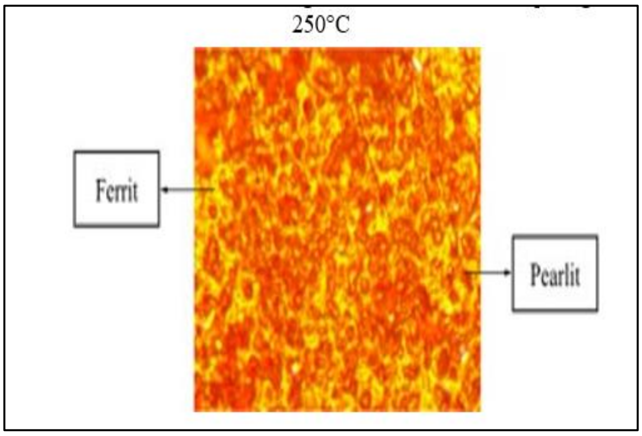

Fig 10: Microstructure of Normalizing Process 800°C and Tempering Process

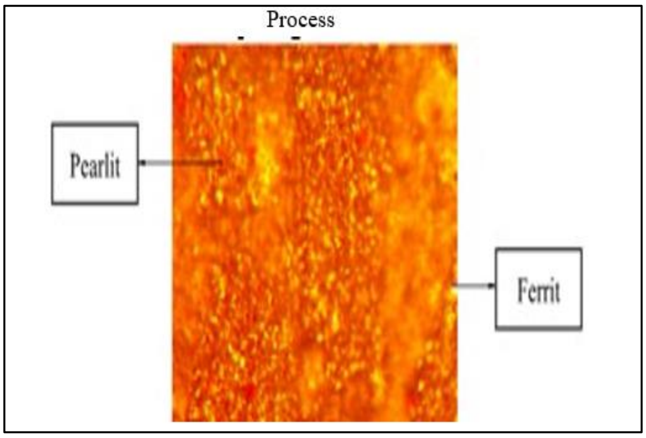

Fig 11: Microstructure of 850°C Normalizing Process and 300°C Tempering Process

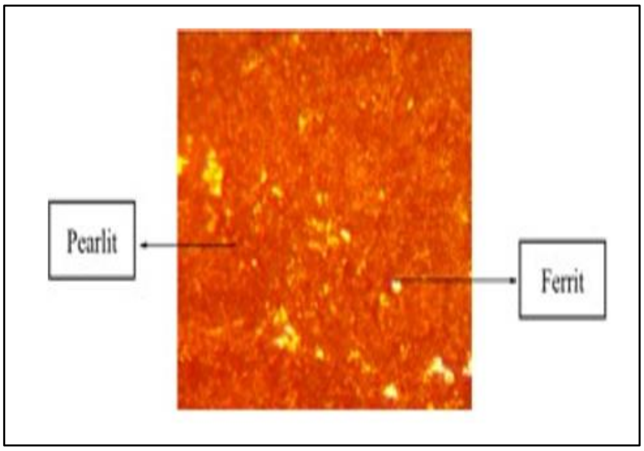

Fig 12: Microstructure of 900°C Normalizing Process and 350°C Tempering Process

In Figure 9 without Normalizing and Tempering Process, ferrite crystals are more dominant than pearlite crystals. Because pearlite is harder than ferrite, the surface of the specimen will have a low hardness as well. Figure 10, Figure 11, and Figure 12 show the structure of steel specimensafter heat treatment. The microstructure of ASTM A414 GradeA steel specimens after heat treatment with high temperature forms pearlite crystals into many and the microstructure becomes tighter.

IV. CONCLUSION

Based on the impact test results and averaging the data, it is evident that specimen B, subjected to the 850°C normalizing process and 300°C tempering process, experienced an increase in impact energy, yielding 0.644 joules/mm². In contrast, specimen A, treated with the 800°C normalizing process and 250°C tempering process, showed a decrease in impact energy, measuring 0.190 joules/mm².

Based on the bending test results and averaging the data, specimen B, treated with the 850°C normalizingprocess and 300°C tempering process, exhibited the highest bending strength at 2520.1 N/mm². In contrast, specimen C, treated with the 900°C normalizing process and 350°C tempering process, showed the lowest bending strength at 2255.4 N/mm².

Based on the analysis of microstructure testing, it canbe concluded that the higher the temperature used in the Normalizing and Tempering process, the more pearlite crystals form and the microstructure becomestighter.

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REFERENCES

[1]. R. K. R. B. M. H. S. M. R. N. Patil., "Static analysis of Go-Kart Chassis frame by Analytical and SolidWorks Simulation," *International Journal of Scientific Engineering and Technology*, vol. 3, pp. 661-663, 2014.

[2]. Siahaan, E., & Riza, A. (2020). Karakteristik Poros Roda Belakang Go-Kart melalui Proses Carburising padakondisi Variasi Temperatur Hardening terhadap Sifat Mekanis. *Karakteristik Poros Roda Belakang Go-Kart Melalui Proses Carburising Pada Kondisi Variasi Temperatur Hardening Terhadap Sifat Mekanis.*

[3]. Mananoma, F., Sutrisno, A., & Tangkuman, S. (2016). Perancangan Poros transmisi dengan daya 100 HP. *JURNAL POROS TEKNIK MESIN UNSRAT*, *6*.

[4]. Setiawan, A., & Agus Yulianto, S. T. (2014). *Pengaruh Prosentase Karbon Pada Baja Karbon Proses Electroplating Tembaga* (Doctoral dissertation, Universitas Muhammadiyah Surakarta).

[5]. BAHRI, D. S. PENGUJIAN BENDING 3 TITIK (GALDABINI).

[6]. Achmad, M. I. (2017). Perencanaan Poros Roda Belakang Pada Gokart. *RODA GIGI: Jurnal Teknik Mesin*, *1*.

[7]. Y. Handoyo., "Perancangan alat uji impak metode charpy kapasitas 100 joule," *Jurnal Ilmiah Teknik Mesin*, vol. 1, pp. 45-53, 2014.

[8]. N. K. Saini, R. Rana, M. N. Hassan and K. Goswami, “Design and Impact Analysis of Go-Kart Chassis,”*International journal of applied engineering research*, vol. 14, 2019.

[9]. Wurdhani, R., Budiarto, U., & Amiruddin, W. (2020). Pengaruh Perlakuan Panas (Heat Treatment) Normalizing Terhadap Kekuatan Impak Aluminium 6061 Pengelasan MIG dengan Variasi Posisi dan Bentuk Kampuh. *Jurnal Teknik Perkapalan*, *9*(1), 70-78.

[10]. Panuh, D., Yulianto, D., Rahman, H. A., & Baharuddin, N. A. (2019). Peningkatan Ketangguhan Impact Pisau Mesin Pemotong Rumput Dengan Cara Perlakuan Panas Menggunakan Media Pendingin Coolant Radiator Dan Udara. *Journal of Renewable Energy and Mechanics*, *2*(01).

[11]. Prayitno, D., & Roberto, I. (2021). PENGARUH TEMPERING TERHADAP LAJU KOROSI BAJA S45C. *METRIK SERIAL TEKNOLOGI DAN SAINS (E) ISSN: 2774-2989*, *2*(2), 59-64.