Static Analysis of Single Shaft Hub Wheel Cover to Determine The Strength Level of The Cover

Ishak Rizaldy Eka Kurnia*[1], Benazir Imam Arif Muttaqin[2], Huki Chandra[3]
[1,2,3]Department of Industrial Engineering , Telkom University, Surabaya, Indonesia
[1*]ishak.rizaldy.20@student.ie.ittelkom-sby.ac.id, [2]imambenazir@telkomuniversity.ac.id, [3]hukichandra@telkomuniversity.ac.id

ARTICLE INFO

Article history:
Received 22 March 2024
Revised 24 April 2024
Accepted 07 June 2024
Available online 14 June 2024

Keywords:
Cover
Simulation Static
Static Load
Wheel Hub

ABSTRACT

The cover on the wheel hub serves to protect the most important components and support the weight coming from the body, so it must be designed as well as possible to support the existing weight. The cover on the wheel hub also functions as a balance when driving so that the cover is made with strong material and is not easy to corrode because the part is often subjected to mechanical pressures. The problems that occur in the Nusantara Energy Manufacturing company (MEN) make researchers want to develop a cover design on a single shaft wheel hub to increase the strength of the cover in receiving pressure from vehicles, drivers, and passengers. In this research, a simulation study is carried out to design the cover and perform static simulations to determine the value of deformation and stress that occurs in the single shaft wheel hub cover. The material used in the cover design is Aluminum Alloy 6061 with a load value of 2177 N and 2912 N. The maximum deformation value on the MEN cover is 0.272 mm, a strain value of 0.007, and a stress value of 730.805 N/m2 with a load of 2177 N. At 2912 N loading, the maximum deformation value is 0.111 mm, a strain value of 0.003, and a stress of 307.538 N/m2. It can be concluded that the MEN cover has a higher static value than the YMMotorcover. There are several factors such as the thickness of the cover on the parts used as supportpoints.

1. Introduction

There are various types of electric vehicle transportation. One of them is a molis. Molis stands for electric motorcycle. Molis is in great demand from the wider community, especially for people who live in cities. Motors from electric vehicles are abbreviated as BLDC or Brushless DC. This motor has 2 types, namely Mid-Drive and Wheel Hub, where the Wheel Hub is located on the rear wheel and integrates with the wheel, while the Mid-Drive is in the middle of the frame and requires a transmission when moving the rear wheels. Mid-Drive has disadvantages including its high price, requires a transmission to drive the rear wheel and difficult disassembly if at any time there is damage to the motor [1].

Wheel Hub has several advantages including, a much cheaper price, and does not require a transmission when moving the motor. The wheel hub has a hollow shaft which functions as a support for the motor so that it can rotate smoothly [2]. This hollow shaft is locked on both swim arm arms. The hollow shaft on the wheel hub has two types, namely single shaft, and double-sided shaft. In addition to the number of shafts, the difference between the two-wheel hubs lies in the design of the wheel hub cover [1].

Many things must be considered when designing a single-shaft wheel hub, namely durability, safety, cost, and others [3]. Not only that, one of the most important components of the single-shaft wheel hub besides the shaft is the cover. Where this component functions as a protector as well as a weight support that comes from the motorcycle body and the weight of passengers [4]. So that these components must be designed as well as possible so that they can support the existing loads.

One of the workshops that serves electric vehicle conversions is CV Manufaktur Energi Nusantara. The company, located in Surabaya, is researching and developing an electric scooter, a type of vespa sprint 150 matic. The vespa sprint vehicle weighs 147 kg [5]. The vehicle requires a transmission to drive the rear wheel has a tire with a size 12 ring and is locked on the rear drum. The drum functions as a support for the weight of the vehicle and the weight of the passengers. A double shaft wheel hub can be installed on the Vespa Sprint. However, this requires redesigning the transmission of the vespa. The impact of redesigning the transmission is that it costs a lot of money.

The problems that occur in the company make researchers want to do the design of the single shaft wheel hub cover. This research aims to increase the strength of the cover in receiving pressure from vehicle loads, riders, and passengers [6]. So far, one of the efforts that can be made to increase the strength in accepting the compressive force of a product design is through static simulation. As carried out by Muhammad Fayrus in simulating a single sided hollow shaft for E-Scooter volta wheel hub products with type 302 [1]. Considering the importance of strength analysis on the wheel-hub cover to ensure the wheel-hub cover can withstand the load, it is necessary to carry out a static analysis test. In previous research, static analysis tests had never been carried out on a CV MEN, so to guarantee the strength of the material it is necessary to carry out a comparative test between YMMotor and CV MEN as a comparison of material strength values where YMMotor has already been involved in the electric scooter vehicle business. Based on these problems, this research aims to analyze the strength of CV MEN's cover wheel hub and compare it with YMMotor as a benchmark product that already exists.

1.1. Related Companies

This research was conducted at one of the electric vehicle conversion workshops in Surabaya, namely CV Manufaktur Energi Nusantara. The company was founded by Telkom University Surabaya lecturers and established in 2020. The MEN company helps the government to overcome the fossil energy crisis. One of the efforts is to provide electric vehicle parts with local dynamo (Electric Motor) products. Currently the company is conducting research on a single shaft wheel hub cover where the cover will be subjected to a static analysis process in this study.

1.2. Electric Vehicles

Electric vehicles are vehicles whose main power source is an electric motor, where the motor is given a voltage by the battery [6]. Electric vehicles have several important components, namely: 1) Battery, 2) Controller, 3) Motor, 4) Vespa Matic transmission, 5) Cover Wheel Hub.

1.3. Things to Consider when Designing the Cover

The position of the wheel hub cover is located below and is prone to friction and water exposure. In terms of material selection, several factors must be considered, for example, materials that are lightweight, strong, and have high corrosion resistance. In general, wheel hubs are made of aluminum 6061 alloy. Because the material is lightweight and resistant to corrosion [7] Al6061 material has AlO (OH) and Al (OH) 3 content and there are other elements such as calcium, potassium, magnesium, sodium, iron, and oxygen and the material includes light metals [8]. This research uses Aluminum Alloy 6061 materials because the material is commonly used in automotive or other construction equipment and the material has heat resistance properties, as well as good weldability [7].

1.4. Stress Concept and Strain

Stress is the ratio between the tensile force acting on the surface area of the object. Basically, the concept of stress can be defined as the amount of force acting on a unit area and is formulated as follows:
Stress formula:

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

where σ= stress (N/m^2); F= force (N) and A= surface area (m^2). The concept of stress and strain can be illustrated with 2 square beams, which can be seen as a beam loaded with a force (F) at the ends as shown in Figure 1.

DOI: https://doi.org/10.52435/jaiit.v6i1.537

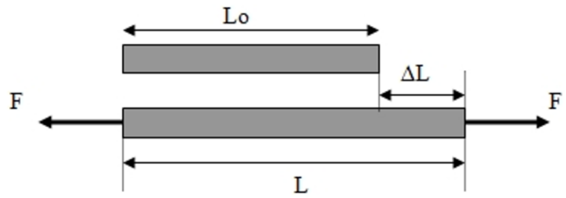

Figure 1. Beams Before and After Being Stretched

The beam is loaded with an axial force and experiences a change in length, this is called strain. Since stress acts in the direction perpendicular to the plane surface, it is called normal stress [9]. Strain is expressed as the increase in length per unit length of stress at a point calculated after the strain is measured. Systematically the strain can be formulated as follows:

Strain formula:

$$\varepsilon = \frac{\Delta L}{L} \quad (2)$$

where ε = Strain; ΔL = total length gain (mm) and L = starting length (mm). The relationship of stress and strain can be formulated as follows:

Elastic modulus formula:

$$E = \frac{\sigma}{\varepsilon} \quad (3)$$

where E = elastic modulus; σ = stress and ε = strain.

2. Methods

There are 2 proposed designs of the single shaft wheel hub cover concept. In this study the design to be compared is the cover design from YMMotor, because the YMMotor cover already has a finished product and is an example of a design in making the MEN cover design. The second cover uses the MEN company cover, because CV Manufaktur Energi Nusantara is researching and developing a single shaft wheel hub cover with a diameter reference equalized with the comparison cover, the method used during the design process of the cover is carried out by interview method when conducting research and design designer.

In general, the material used in making the cover is made of aluminum alloy 6061 because the material is lightweight and has high resistance to corrosion [8]. The datasheet of aluminum alloy 6061 can be seen in Table 1 below.

Table 1. Properties Aluminum Alloy 6061

Material	*Density*	*Yield Strength*	*Ultimate Tensile Strength*	*Elastic Modulus*	*Poisson's Ratio*
Aluminum *Alloy* 6061	2700	275 Mpa	124 Mpa	69.0 Gpa	0.33

The process of designing a 3D design, the software is used to design the proposed design and conduct static simulations carried out on the single shaft wheel hub cover [10]. In this study, a static loading test was carried out. Static loading is to test the cover design when given a static force continuously and does not involve dynamic loads because based on the formulation of the problem this research focuses on the results of the strength of the cover design when given a force and the type of force acting on the proposed cover there is only a static force because there is no distance between the force acting on the center point so that the moment value is zero [11]. At the stage of the simulation process, a FEM (Finite element method) or finite element method is analyzed, which is suitable for calculating forces in internal forces [12].

Finite Element Method is a numerical method used to obtain solutions to differential problems or integral equations [13]. Because these equations are often used as models in engineering problems. In engineering practice and academic research, the physical system observed is very complicated because it involves a continuum with geometry shapes, loading, and support conditions. Therefore, numerical solution methods are needed to obtain solutions to these problems [14].

The test was carried out twice with the first test weighing the driver and vehicle, the second test with the weight of the driver, passenger, and vehicle. The test used an MSI laptop with Intel Core i7 gen 10 specifications with a NVIDIA GeForce GTX 1660 Ti graphics card and 8 RAM.

After conducting static simulation testing, the next step is to collect simulation data. The data include deformation, strain, and stress [15]. After collecting the required data, at this stage an analysis will be carried out on the results of the cover design, the data collected will be analyzed to answer the objectives of the problem formulation above and conclusions will be drawn from the design results on both covers [16].

3. Results and Discussions

3.1. 3D Design Draft of YMMotor Cover

The results of 3D design on the YMMotor single shaft wheel hub cover model. In Figure 2 can be seen the results of 3D design YMMotor, where the cover has a diameter of 225 mm with a cover thickness of 31 mm. The YMMotor cover has 4 bolt holes with a diameter of 12 mm located in the middle of the cover, where the bolts function as a holder on the wheels that have 4 holes. In the center of the cover is a bearing with a diameter of 61.75 mm with a height of 15 mm up, the bearing is also found on the inside cover with a height of about 16.75. There is also at the end of the cover a bolt hole that serves to lock the cover on the rotor with a diameter of 4 mm. The back of the cover in place of the bolt is a little thick because the area functions as a bolt holder when mounted on alloy wheels, the thickness is around 10 mm. Next, the results of the YMM cover rendering will be shown in Figure 2.

3.2. 3D Design Draft of MEN Cover

The 3D design of the MEN cover can be seen in Figure 2. The cover has an outer diameter of 225 mm. The cover has 5 bolt holes in the middle of the cover with a diameter of 8 mm which serves as a holder on the wheels, in the center of the front cover there is a circle with an inner diameter of 38.5 mm with a depth of 9 mm to the end of the center of the cover it serves to place the shaft. At the end of the cover has 8 bolt holes with a diameter of 6.5 mm as a lock on the rotor. Towards the rear view of the cover there is a bearing holder with an outer diameter of 68 mm and an inner diameter of 52 mm where it has a height of 14 mm. The bearing holder functions as a bearing housing which will later become a shaft holder during assembly can be seen in Figure 3 rendering of the MEN cover.

Figure 2. YMMotor Front View Rendering

Figure 3. MEN Front View Rendering

 DOI: https://doi.org/10.52435/jaiit.v6i1.537

3.3. Determination of Loading Points on Single Shaft Cover

Determination of the loading point on each cover serves to select the part of the cover surface that is subject to load when the simulation will be carried out [17]. The loading point on the cover is selected at a place that is used as a holder when given a load. In the simulation test of the two covers, the selected loading is a torque/rotation load. Because the cover experiences rotation when mounted on the wheel hub.

3.4. Determination of Limiting Conditions on the Cover

The condition limitation points or fix support given to the MEN and YMMotor covers is located at the bolt holder and bearing holder located in the center of the cover, where the bolt becomes the loading point because the place becomes a support for the wheels while the bearing holder functions to support the entire wheel hub. Can be seen in Figure 4 and Figure 5 the loading point given to the cover.

Figure 4. Load on MEN Cover

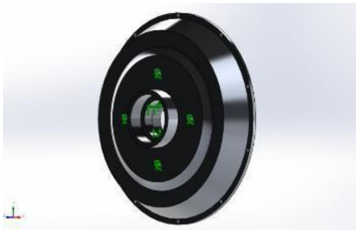

Figure 5. Load on YMMotor Cover

3.5. Static Simulation of Loading on Single Shaft Cover

After conducting static simulation tests on both covers, the next step is to select the results of deformation, stress, and strain. The selection of the deformation value is chosen with the smallest value because deformation has an impact on changing the shape of an object when given a force. The selection of strain is also selected with the smallest value because strain has an impact on the increase in length of an object when given a force. Yield strength on both covers has a value of 55,148, because both covers use 6061 aluminum alloy material. It was concluded that the YMM cover was chosen because it had the smallest value.

There are several factors that cause the YMMotor cover to have a thicker cover thickness than the MEN cover, as well as the bolt holder located in the middle of the YMMotor cover has a rather thick layer, this has an effect because the bolt holder point has a different cover thickness compared to the MEN cover, the thickness of the bearing holder which is thinner than the YMMotor cover is the cause of the MEN cover having a high static value. It can be seen the difference in the pictures below the YMMotor cover and the MEN cover in the deformation results with 2177 Newton loading. It can be seen the MEN cover in the left picture and the YMMotor cover in the right picture. In the front view, the surface of the MEN cover does not change significantly. However, the deformation results on the cover get a large value compared to the YMM cover. On the YMM cover there is a change in the circle line in the center. The YMM cover changes shape when given a force but has a small deformation value. It can also be seen from the side view deformation results, where both covers have changes in the cover surface area, both covers experience changes towards the bottom. This is because the anchoring point on the cover is selected at the bolt holder and bearing housing and is given a torque force.

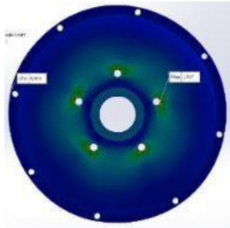

Figure 6. Strain Results Front View of MEN Cover

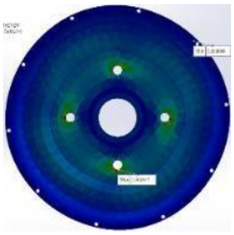

Figure 7. YMMotor Cover Deformation Result

Figure 6 and Figure 7 explain the comparison of strains that occur on both covers from the front view. In the figure, the YMM cover experienced changes in the cover surface area caused by the influence of strains that occurred in the bolt place. The front view of the MEN cover does not appear to have a significant change, but the cover also experiences strains in the same section as the YMM cover.

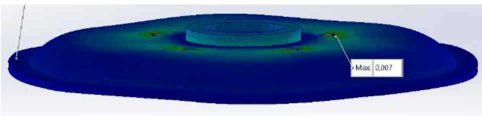

Figure 8. Strain Results Side View of MEN Cover

Figure 9. Strain Results Side View of YMMotor Cover

Figure 8 and Figure 9 show the results of strains that occur on both covers in the side view. The MEN cover shows that the surface of the cover affected by the strain has changed towards the bottom and the locking bolt has changed shape. On the YMM cover, changes occur in the locking part of the bolt, the cover does not experience changes in the upper area, because that part of the cover has a thickness contained in the bolt holder.

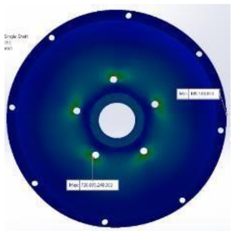

Figure 10. Front View Stress Result on MEN Cover

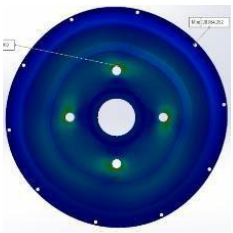

Figure 11. Front View Stress Result on YMMotor Cover

 DOI: https://doi.org/10.52435/jaiit.v6i1.537

Furthermore, Figure 10 and Figure 11 can be seen the results of stress in the front view. The MEN cover shape has stress in the place of the retaining bolts. However, the stress that occurs on the cover does not show changes in the cover surface area when viewed from the front view. In the right picture, the YMM cover experiences changes in surface conditions at certain angles. The surface of the cover transforms from a circle to a square.

Figure 12. Stress Results Side View of MEN Cover

Figure 13. Stress Result of YMMotor Cover Side View

Furthermore, in Figure 12 and figure 13 can be seen the side view of the MEN cover. The cover changes in the area around the bearing place. These changes are caused by the stress that occurs in the area. The YMM cover experienced significant changes at the bottom of the cover. Where at the bottom there is a change.

3.6. Stress and Strain on the Proposed Cover

At this stage, the stresses and strains that occur in the proposed cover will be explained. As explained above. The loading point given to the cover is located at the bolt place on the wheel holder and the bearing place in the center of the cover. This test uses torque with a clockwise rotation direction, and it can be seen in Figure 14.

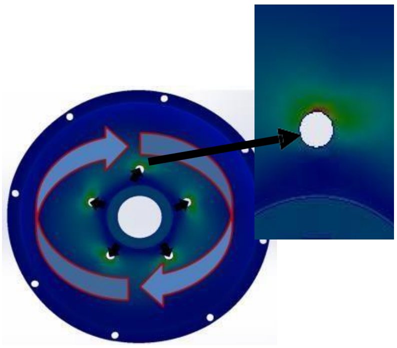

Figure 14. Stress Result on Proposed Cover

In Figure 14 the blue arrow indicates that the load is applied in a clockwise direction. The result of stress on the cover is shown in the black arrow. Where the stress moves from the place of the wheel holder bolt to the surface of the cover until it finally disappears. The strain results on the proposed cover can be seen in the figure below.

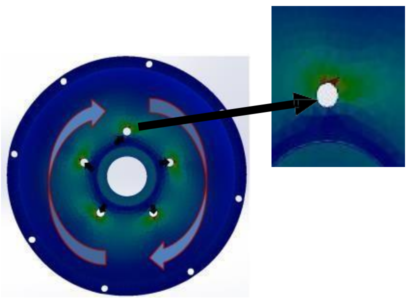

Figure 15. Strain Results on the Proposed Cover

In Figure 15 can be seen the test results of the strain. The loading and force applied to the cover are the same as the previous test. It can be seen the results of strains that occur on the proposed cover. At the place of the bolt for the alloy wheel there is a strain that occurs which is marked in green and there is a slight red color, which indicates that the maximum strain occurs in that area. Strain on the proposed cover moves in the area around the bolt place because the section was chosen to be the loading point during the simulation test. The strain value moves from where the bolt moves to the outside of the area on the surface of the outer cover and the green color transforms into blue. This indicates that in the blue area no strain occurs.

3.7. Result Implications

Based on the simulation results on the cover, related companies can use the YMMotor cover design as a reference for making the next cover. The thickness of the cover as well as the points prone to deformation, strain, and stress can be equalized with the comparison cover [18]. Related companies can make the design in the middle of the cover thicker because in that area there is a support point that functions to support the wheel hub, and the design of the bolt holes is designed with the same thickness as the YMMotor cover to reduce the occurrence of strains at that point.

The MEN cover in the long term is not recommended because, from the simulation test results, the deformation, strain, and stress values have a large value compared to the YMMotor cover. The thickness of the bolt holder and the thickness of the cover is one of the factors causing the simulation value to be high and it is also necessary to conduct experimental studies to validate the results of the simulation [19].

4. Conclusion

The conclusions obtained from the static analysis of the proposed design on the MEN cover are that the cover was carried out two tests with the first test of the weight of the driver and vehicle with a load value of 2177 N. The results obtained were the maximum deformation value of 0.272 mm, strain value of 0.007, stress value of 730.805 N/m². The second test with the weight of the rider, passenger, and vehicle with a load value of 2912 N. The maximum deformation value of 0.111 mm, strain value of 0.003, stress value of 307.538 N/m² was obtained. Comparisons made on the two covers can be concluded if the proposed design on the MEN cover has higher deformation, strain, and stress values than the YMMotor cover [20]. There are several factors for the occurrence of the simulation test value, namely thickness, cover radius, and bolt diameter on a cover that is less thick.

References

[1] M. Fayrus, "Desain dan Pemodelan Dinamis Single Sided Hollow Shaft in Wheel Hub BLDC Motor 2KW Melalui Pembebanan Statis dan Dinamis dengan Menggunakan Metode Elemen Hingga," Surabaya, 2021.

[2] R. D. Putranto, "Pengembangan Prototype in Wheel Brushless DC Motor 2kW sebagai Sistem Powertrain pada Skuter Elektrik," Surabaya, 2022.

[3] E. Supriyanto, "Manufaktur dalam dunia Teknik Industri," jurnal.unnur, 16 January 2020. [Online]. Available: https://jurnal.unnur.ac.id/index.php/indept/article/view/118. [Accessed 8 April 2023].

[4] M. S. D. Ellianto, "Rancangan Bangun dan Simulasi Pembebanan Statik pada Sasis Mobil Hemat Energi Kategori Prototype," *Jurnal Engine : Energi, Manufaktur, dan Material*, vol. 4, no. 2, pp. 53-58, 2020.

[5] C. Candra, "Sensasi Jelajah 2 Pulau Bersama Vespa Sprint 150 i-Get," Redaksi Otosia, Bali, 2018.

 DOI: https://doi.org/10.52435/jaiit.v6i1.537

[6] R. Addwiyansyah, "Desain dan Implementasi Sistem untuk Peningkatan InWheel Hub Motor dari 1kW ke 2kW sebagai Power Train E-Scooter," Surabaya, 2023.

[7] N. H. Sari, Material Teknik, Yogyakarta: CV Budi Utama, 2018.

[8] M. N. Wicaksono, "Analisa Variasi Holding Time pada Aluminum 6061 Terhadap Uji Impak, Struktur Mikro, dan Uji Kekerasan," Institut Teknologi Sepuluh Nopember, Surabaya, 2018.

[9] Wibawa, "Simulasi Umur Fatik Rangka Main Landing Gear menggunakan Metode Elemen Hingga," *Dinamika Teknik Mesin,* vol. 10, no. 2, pp. 120-126, 2020.

[10] Y. Adiyanda, "Pria Indonesia urutan ke-115 rata-rata Tinggi Badan Dunia, Belanda Paling Jangkung," Kabar Banten, 12 Agustus 2021. [Online]. [Accessed 21 Juni 2023].

[11] A. Felani, "Analisis Statis Kontruksi dan Lance Tube Sootblower Tipe Motorised Rotary Menggunakan Software Solidwork 2016," *Rekayasa Mesin,* vol. 12, no. 2, pp. 243-250, 2021.

[12] W. F. Tjong, Pengantar Metode Elemen Hingga Untuk Analisis Struktur, Depok: PT RajaGrafindo Persada, 2021.

[13] P. R. A. Hajar Isworo, Metode Elemen Hingga, Banjarmasin: Universitas Lambung Mangkurat, 2018.

[14] A. Kurnia, "Efek Rumah Kaca oleh Kendaraan Bermotor," *Jurnal Pendidikan Fisika dan Sains,* vol. 4, no. 2, pp. 1-9, 2021.

[15] A. D. Mustaqiem, "Analisis Perbandingan Faktor Keamanan Rangka Scooter Menggunakan Perangkat Lunak Solidwork 2015," *Jurnal Teknik Mesin,* vol. 9, no. 3, pp. 164-172, 2020.

[16] T. Shantika, "Simulasi Tegangan pada Chasis Kendaraan Listrik Crossover," *Jurnal Kajian Teknik Mesin,* vol. 5, no. 1, pp. 15-21, 2020.

[17] E. Prasetyo, "Analisis Kekuatan Rangka pada Mesin Transverse Ducting Flange (TDF)," *Rekayasa Journal of Science and Technology,* vol. 13, no. 3, pp. 299-206, 2020.

[18] M. I. Iski, "Analisis Tegangan pada Poros Engkol Sepeda Motor Honda GL Pro Neotech Menggunakan Solidworks 2021," *VOMEK,* vol. 4, no. 3, pp. 43-48, 2022.

[19] S. B. Kokate, "Material Optimization of Wheel Hub using Finite Element Analysis," *International Research Journal of Engineering and Technology ,* p. 7253, 2019.

[20] E. W. Abryandoko, "Menggambar Teknik," repository, 23 Desember 2020. [Online]. Available: https://repository.penerbitwidina.com/id/publications/332318/menggambar-teknik. [Accessed 22 Maret 2023].

This page intentionally left blank

DOI: https://doi.org/10.52435/jaiit.v6i1.537