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FEASIBILITY OF CIRCULAR BLADE FOR CUTTING OIL PALM FRONDS

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ABSTRACT

This study examined the feasibility of using a circular cutter blade for oil-palm frond cutting to address limitations of current harvesting tools, such as high energy consumption, poor cut quality, and high cutting resistance. The circular blade manufactured from XW41 material was developed through design modelling and validation using SolidWorks software, followed by the fabrication of sample. The results showed that the circular blade achieved an effective cutting force of approximately 530 N at 9,000 rpm, producing clean and consistent cuts with minimal deformation (≤ 0.06 mm) under applied load. The stress was evenly distributed across the blade surface, confirming its mechanical stability during operation. Field observations further revealed that the circular blade could efficiently sever fronds with reduced vibration and cutting resistance, although minor inconsistencies in surface smoothness indicated areas for improvement. Overall, the findings demonstrate the technical viability of a circular cutter blade for oil-palm harvesting, suggesting potential for enhanced cutting efficiency and reduced operator fatigue.

Keywords: circular cutter, cutting force, fresh fruit bunch, harvesting tools, oil palm fronds.

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INTRODUCTION

Harvesting of oil palm fresh fruit bunch (FFB) is a critical task in oil palm plantations. Traditionally, this process was performed manually using tools such as sickles and chisels with oscillating cutting mechanism being one of the primary methods. This concept has been improved with the development of various cutting instrument utilised in the harvesting of oil palm trees at specific heights (Azaman et al., 2022). However, these cutting tools frequently experienced high levels of vibration due to accelerating and decelerating motion of the cutting blade. CANTAZ has been reported to generate significant hand-arm vibration (Jelani et al., 2019), causing physical strain and vibration-related health issues among harvesters (Noraiman et al., 2019). Furthermore, comparisons between engine- and battery-powered cutters revealed that conventional systems still demand relatively high energy input (Ahmad et al., 2023; Suthakar et al., 2024).

A promising alternative is the use of a circular cutting blade, which has been widely adopted in the processing of lumber and bamboo (Ding et al., 2023; Krilek et al., 2023), plant stem trimming (Zhang et al., 2019) and rice harvesting (Dixit et al., 2022). However, it is not commonly used in oil palm harvesting. The circular cutting motion is hypothesised to be able to reduce power consumption and improve efficiency by providing a continuous cutting action (Yusuff et al., 2024). It allows for efficient pruning, making the process quicker compared to manual methods. Furthermore, the precision of the circular blade minimises damage to the tree and surrounding

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fronds, ensuring that the tree remains healthy and productive (Kang et al., 2023). Despite its potential, there is a lack of comprehensive study on the mechanics and feasibility of using circular saws for cutting oil palm fronds.

A study by Oyedeji et al. (2022) evaluated the use of circular cutter in their tree climber-mounted pruning system and found it to have improved efficiency and safety compared to manual harvesting methods. This study suggested that circular blades can improve the speed and precision of frond harvesting, while also potentially reduce physical strain on workers. Another study indicated that the circular cutting blade's torque, power, and energy consumption increased steadily with crop's maturity during harvesting. That model was found to be accurate in predicting parameters for improved tractor-mounted harvester (Ayorinde & Owolarafe, 2024). However, more comprehensive evaluation was still needed to fully understand the efficiency, cut quality, and impact on frond condition when using circular cutter blades for oil palm harvesting.

The objective of this study was to explore the practicality and benefits of implementing circular cutting blade in harvesting oil palm fronds by analysing key factors such as cutting force and the influence of operational parameters (feed rate, rotation speed, frond width). Notably, this work represents the first reported experimental study of XW41-based circular blades for oil palm frond harvesting, supported by finite element analysis (FEA), fabrication, and field trial. The findings provide valuable insights into the technical and economic viability of adopting circular cutting blade, paving the way for more efficient and sustainable agricultural practices.

MATERIALS AND METHODS

Material Characteristics

The material used in this study was the American Iron and Steel Institute (AISI) XW41 which the most suitable choice for circular cutter blade due to its compatibility with the hardening process involved in fabrication as well as its versatility in shearing and fine cutting applications. The XW41 material is an alloy tool steel with exceptional hardness and outstanding wear resistance, making it ideal as cutting blade that requires both a long-lasting sharp edge and ability to tolerate abrasive forces. In addition, XW41 has excellent dimensional stability, even after the hardening process, hence reducing the probability of distortion or warping during manufacturing and usage. The mechanical properties of XW41, along with its chemical composition are shown in *Table 1* and *2* respectively.

TABLE 1. MECHANICAL PROPERTIES OF WX41

Item	Mechanical properties
Ultimate tensile strength (MPa)	2,181
Strain (%)	1.62
Compression strength (MPa)	3,472
Strain under compression (%)	8.5
Bending strength (MPa)	2,951
Achievable hardness (HRC)	60-62
Charpy resilience (J)	25

TABLE 2. CHEMICAL COMPOSITION OF XW41

Chemical composition (wt%)								
C	Si	V	Cr	Mn	Mo	P	S	Fe
1.51	0.23	0.36	11.92	0.35	0.87	0.02	0.004	84.7

Circular Blade Design Model

SolidWork software was used to design a 3D model of circular cutter shape and geometry with respective blade (*Figure 1*) with dimensions as listed in *Table 3*. The circular cutting model was specifically designed with four blades to ensure smooth cutting process without any clogging when cutting fibrous fronds (Wang et al., 2023). The numerical simulation of cutting blade performance was carried out by using finite element analysis (FEA), where the cutting force applied to the area of the blades were in contact with the object being cut. In this case, the cutting force required to cut oil palm fronds was up to 524 N, depending on the height of the palm, as well as thickness and maturity of the frond (Ishak, 2021). The circular blade was subjected to centrifugal force at the same time due to rotational speed (9,000 rpm) produced by the brush cutter that was being used. The blade thickness of this model was 3.5 mm. The total distribution of the von Mises' stress, which is equivalent to tensile stress in the model was evaluated together with the displacement.

Fabrication Process

Electrical discharges were utilised within the wired electrical discharge machining (EDM) process to achieve precise cutting of the XW41 plates. Through controlled movement of an electrically charged wire across the materials workpiece, controlled sparking eroded the material workpiece to the desired shape. Wire EDM was employed for precise profiling, cutting, or fabrication of complex geometries like circular blades. This technique enabled the production of intricate or customised blade designs with exceptional precision and accuracy (Priyadarshini et al., 2019).

Turning was conducted by a local manufacturer utilising lathe machine. The XW41 material workpiece, with initial 7 mm thickness, underwent

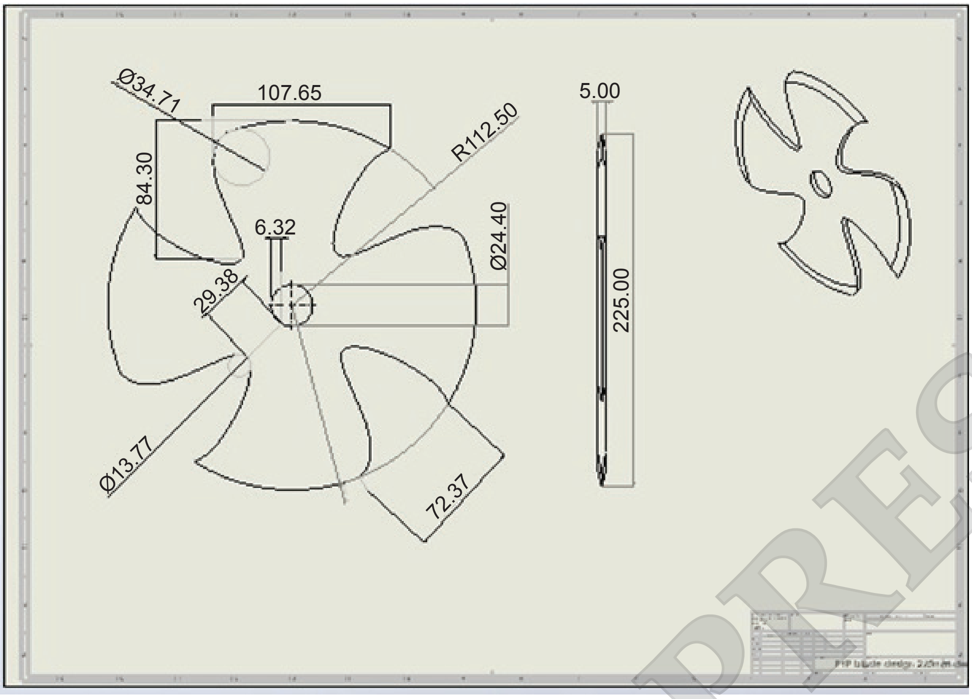

Figure 1. Schematic drawing of cutting blade model.

TABLE 3. DIMENSION OF CUTTING BLADE

Profile	Specification
Total diameter of circular shape (mm)	225
Blade thickness (mm)	3.5
Diameter of each blade (mm)	107.65
Diameter of central hole (mm)	25.40
Curvature diameter of the blade (mm)	34.7
Radius of cut profile Curvature (mm)	112.5
Gullet spacing – minimum (mm)	13.77
Gullet spacing – maximum (mm)	72.37
Blade width (at the widest point)	29.38

machining to achieve reduced thickness of 3.5 mm in accordance with the desired design and specifications (*Figure 2*). The machining procedure necessitated utilisation of a specialised triangular nose medium ground (TNMG) carbide lathe cutting tool, due to the high hardness of the material's work shape. The sample's workpiece was then cut into desired circular cutting blade using wire EDM process before the heat treatment process.

Heat Treatment and Finishing Process

The circular blade sample was heat-treated to 840°C at 12°C/min over 60 min. This initial heating stage was to bring the material to a suitable homogenised phase. The temperature was then increased rapidly to 1,060°C at 4°C/min for 30 min for austenitisation. The blade sample was then quenched in oil bath for martensitic phase before undergoing tempering at 200°C at 10°C/min for 210 min. This sudden cooling prevented the transformation of softer phases and promoted it into harder microstructure. Tempering stage was performed to relieve internal stress and improve the toughness and ductility of the material while maintaining its strength. Finally, the circular blade sample was allowed to reach room temperature by air cooling over a duration of 210 min. The specific temperature, heating or cooling rates, and holding times in each stage are shown in *Figure 3*. Once tempering process was completed, the circular blade sample was ground and polished to achieve the desired final dimensions and surface finish.

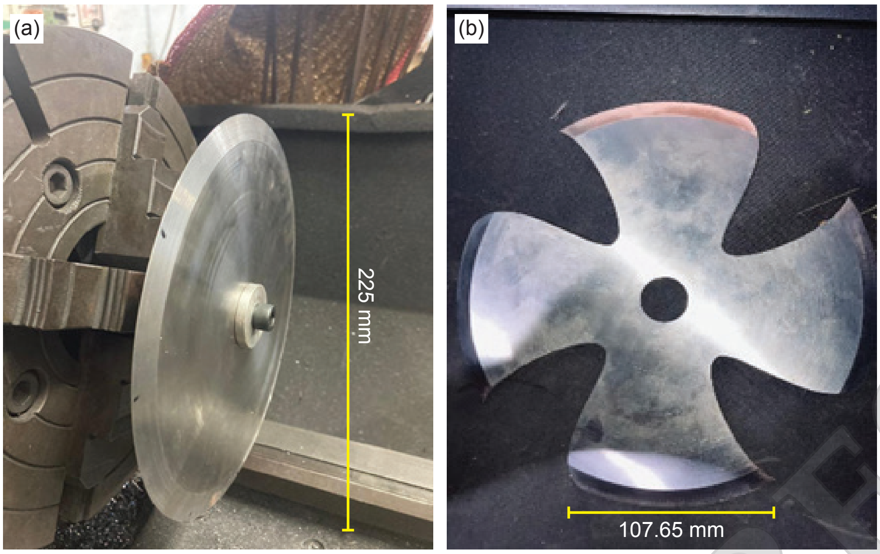

Figure 2. Turning process of (a) thickness reduction of sample and (b) final shape of circular cutting blade.

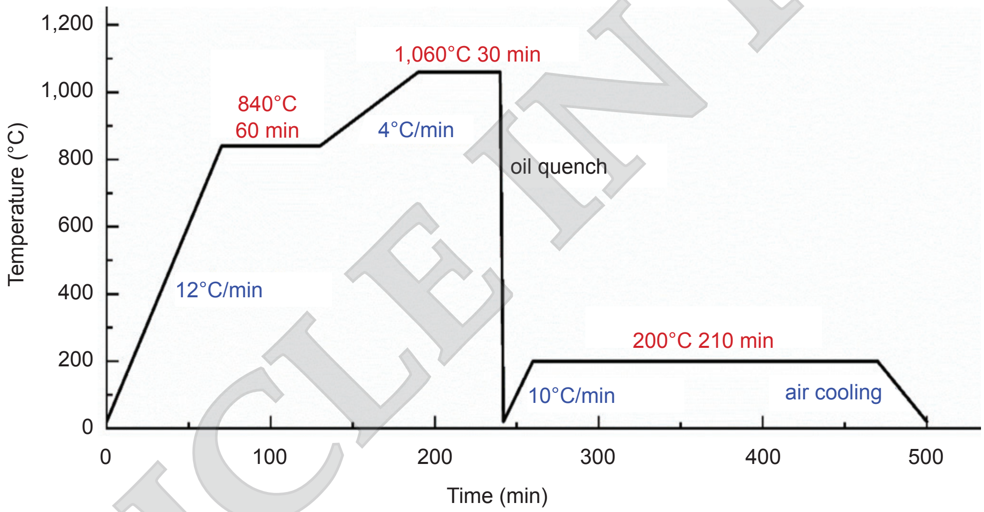

Figure 3. Heat treatment process for cutter blade.

RESULTS AND DISCUSSION

Deformation Response and Stress Distribution Analysis

The performance of circular cutter blade on cutting force application was assessed using a static structural test. Stress and displacement were accurately captured by simulation when force of 530 N were applied. The area of force application was shown by arrows (*Figure 4*), and a centrifugal force of 9,000 rpm was applied where the blade joined the rotor. Fixed geometries were set at fitting areas with material attributes taken into consideration. Area of the force applied showed maximum deformation of 0.06 mm in size (*Figure 4a*). This smaller deformation response indicated effective force absorption by the blade. This was aligned with findings by Bílek et al. (2018) where it was reported that slightly thicker circular blade could increase stiffness strength of the blade itself. With continued use, the localised deformation confined to the tip could result in sharpening, providing users with noticeable benefit. As indicated by the colour scale in *Figure 4b*, the blade appeared blue, showing a low level of stress on its surface, which explained why deformation was limited to 1 mm. This showed that stress was evenly distributed on the circular cutter blade due to its width.

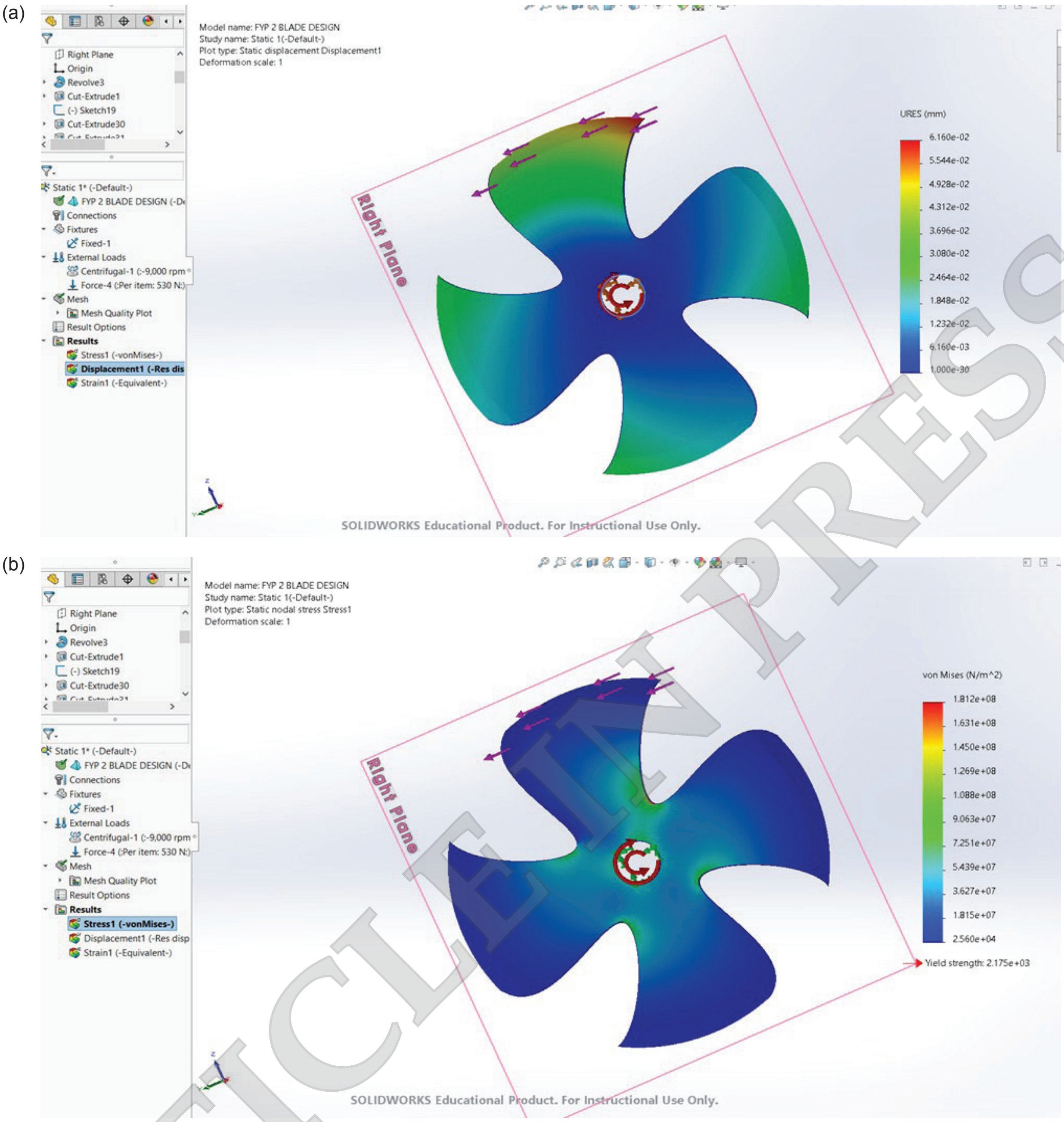

Figure 4. Finite element analysis (FEA) of (a) deformation response, and (b) von Mises stress distribution for circular blade design model.

These findings are consistent when benchmarked with recent models and studies. Qun & Mohd Ripin (2023) reported through their cutting force model (1,000 to 2,500 rpm) that force decreases with increasing speed. The results value of 530 N at 9,000 rpm follows this trend, although that the speed reflects the circular cutter's operating condition, giving a feasible cutting force comparable to reported ranges. Similarly, Suthakar et al. (2024) showed that knife curvature and material strongly affect cutting force and energy. These comparisons suggest that the circular blade achieves cutting forces within practical ranges, while further validation at lower rpm and feed conditions is recommended.

Field Trial Performance

Figure 5 shows the cutting profile of oil palm fronds using the circular cutting blade. The fronds were found to be effectively cut although there were inconsistencies in the surface quality of the cuts. In this context, it is important to note that the quality of the cut surface plays a crucial role in harvesting performance. A uniform cut surface is important because smoother cuts minimise tissue damage at the frond base, thereby reducing the risk of pest or pathogen entry, and also indicate greater cutting efficiency, lower friction, and reduced energy losses. This was also reported by Svoreň et al. (2022) where it was claimed that surface waviness of the cut by circular saw was affected by cutting parameters such as cutting height and feed speed. This could be influenced by various elements, including the dynamic behaviour, oscillation, and deflection of the saw blade away from the cutting plane (Kopecký & Rousek, 2012). In addition, dynamic stability of the circular saw blade had significant impact on the surface quality of the product, as well as the longevity of the machinery and equipment used in processing. Ding et al. (2023) reported that heat and vibration produced during sawing can have considerable impact on the dynamic stability of circular saw blades. Qun & Mohd Ripin (2023) discovered that reducing cutting friction resulted in a more uniform cutting surface. This led to reduction in friction between the blade and oil palm fronds, resulted in lower energy consumption and increased efficiency.

Challenges and Future Work

The circular cutter blade developed in this study focused primarily on cutting capability with work emphasised on profile design and analysis as suggested by Qun & Mohd Ripin (2023). Geometry of blade teeth played a crucial role in cutting performance. Investigating the influence of tooth shape and arrangement on cutting forces can lead to more efficient designs. Studies have shown that varying the number of teeth affects both noise level and wear of the blade edges, which can be critical in optimising performance for specific harvesting conditions (Kvietková et al., 2015). Future work will expand on this preliminary study by using computational modelling to explore a wider range of blade geometries and how they influence cutting efficiency. In addition to the modelling work, upcoming studies will also include more detailed experimental measurements such as cutting force time data, frond dimensions and conditions, feed rate, as well as power or energy requirements during cutting. These measurements will provide a clearer picture of the actual cutting behaviour from the moment the blade contacts the frond until it completes the cut, allowing for more accurate determination of the maximum cutting force, cutting energy and other performance parameters that were beyond the scope of this initial feasibility assessment.

Other important consideration was the surface treatment of blade, such as application coatings. Coating technology might provide impact solution on cutting performance by improving of wear resistance and reducing friction. Myna et al. (2021) claimed that specific coatings on circular blades can minimise dust formation and clogging during cutting, which not only enhanced occupational safety but also affected the energy consumption of the cutting process.

CONCLUSION

Harvesting FFB is an important operation that has significant effect on oil palm is productivity as conventional methods are being challenged by

Figure 5. The cutting profile of oil palm fronds using circular blade cutter.

the demand for increased efficiency and reduced worker risk. This study explored the potential of circular cutter blade as an innovative alternative to conventional harvesting tools, particularly in harvesting activities. Results from the study showed that cutting of fronds using circular blade was effective with cutting force of up to 530 N with 9,000 rpm rotation speed. However, the inconsistency in quality of the cutting surface indicated the need for continual study and development in this area. The cutting feasibility of circular blade can revolutionise oil palm harvesting practices, leading to increased productivity and sustainability in the plantation sector. Therefore, further innovation is important to validate these findings and to explore its adaptability. The findings from this study can be the basis for future innovations in harvesting techniques, promoting more efficient and sustainable agricultural practices in the oil palm industry.

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REFERENCES

Ahmad, M. R., Md Radzi, M. K. F., Ramli, A. S., Mohd Khalid, M. A., Azaman, M. I. H., Ibrahim, A., Mohd Faudzi, A. A., Muhamed, A. A., & Zakariah, H. (2023). Evaluation and comparison of the ergonomics, performance and economics of battery-powered and engine-powered palm oil harvesting tools: Cantas Elektro. *Jurnal Kejuruteraan*, *35*(4), 811–821. https://doi.org/10.17576/jkukm-2023-35(4)-03

Ayorinde, T. A., & Owolarafe, O. K. (2024). View of mathematical modelling of a kenaf harvester. *Agricultural Engineering International: CIGR Journal*, *26*(2), 113–124. https://cigrjournal.org/index.php/Ejounral/article/view/9127/4229

Azaman, M. I. H., Ramli, A. S., Mdradzi, M. K. F., Ahmad, M. R., Khalid, M. R. M., Bakri, M. A. M., Kamil, Y. M., & Mahdi, M. A. (2022). Feasibility study of oil palm harvesting using pulse fibre laser system with different lenses. *Journal of Oil Palm Research*, *34*(3), 488–496. https://doi.org/10.21894/JOPR.2022.0005

Bílek, O., Šuba, O., & Baďurová, J. (2018). A numerical simulation of static stiffness and strength of circular saw blade. *MATEC Web of Conferences*, *210*, 04031. https://doi.org/10.1051/matecconf/201821004031

Ding, Y., Ma, Y., Liu, T., Zhang, J., & Yang, C. (2023). Experimental study on the dynamic stability of circular saw blades during the processing of bamboo-based fiber composite panels. *Forests*, *14*(9), 1855. https://doi.org/10.3390/F14091855

Dixit, J., Saxena, A., & Hakak, F. A. (2022). Adaption of modified brush cutter for rice harvesting. *CIGR Journal*, *24*(1), 90–101. http://www.cigrjournal.org

Ishak, K. A. (2021). *Assessment of force required during cutting oil palm fronds* [Master thesis]. Universiti Sains Malaysia.

Jelani, A. R., Mohd; Hafizi Azaman, I., & Ahmad, R. (2019). The effect of vibration isolator on the magnitude of hand-arm vibration (HAV) of the oil palm motorised cutter (CANTAS). *Journal of Oil Palm Research*, *31*(1), 86–94. https://doi.org/10.21894/jopr.2018.0062

Kang, J., Zhang, J., Sun, D., & Song, W. (2023). Experimental investigation of cutting performance for circular saw blade body modification by resin layers toward green manufacturing. *International Journal of Advanced Manufacturing Technology*, *128*(7–8), 3105–3121. https://doi.org/10.1007/S00170-023-11979-W/METRICS

Kopecký, Z., & Rousek, M. (2012). Impact of dominant vibrations on noise level of dimension circular sawblades. *Wood Research*, *57*(1), 151–160.

Krilek, J., Melicherčík, J., Kuvik, T., Kováč, J., Gendek, A., Aniszewska, M., & Mareček, J. (2023). Analysis of cutting forces in cross-sawing of wood: A study of sintered carbide and high-speed steel blades. *Forests*, *14*(7), 1395. https://doi.org/10.3390/F14071395

Kvietková, M., Gaff, M., Gašparík, M., Kaplan, L., & Barcík, Š. (2015). Surface quality of milled birch wood after thermal treatment at various temperatures. *BioResources*, *10*(4), 6512–6521.

Myna, R., Hellmayr, R., Georgiades, M., Leiter, L. M., Frömel-Frybort, S., Wimmer, R., & Liebner, F. (2021). Can surface coating of circular saw blades potentially reduce dust formation? *Materials*, *14*(18), 5123. https://doi.org/10.3390/MA14185123

Noraiman, M., Fadzil, M., Bahri, S., & Tamrin, M. D. (2019). The effect of hand arm vibration symptoms among palm oil harvester with the usage of CANTAS machine in Selangor. *Human Factors and Ergonomics Journal*, *4*(1), 13–24.

Oyedeji, A. N., Umar, U. A., Kuburi, L. S., Edet, A. A., & Mukhtar, Y. (2022). Development and performance evaluation of an oil palm harvesting robot for the elimination of ergonomic risks associated with oil palm harvesting. *Journal of Agricultural Engineering*, *53*(3). https://doi.org/10.4081/JAE.2022.1388

Priyadarshini, M., Biswas, C. K., & Behera, A. (2019). Machining of sub-cooled low carbon tool steel by wire-EDM. *Materials and Manufacturing Processes*, *34*(12), 1316–1325. https://doi.org/10.1080/10426914.2019.1662035

Qun, S., & Mohd Ripin, Z. (2023). Analysis of the energy consumption of motorised circular saw when cutting oil palm frond. *Journal of Oil Palm Research*, *37*(1), 110–121 https://doi.org/10.21894/jopr.2023.0063

Suthakar, B., Jany Giles, A., & Donesh Pandi, M. (2024). Material and curvature of the oil palm harvesting knife and their effects on force and energy requirements. *Journal of Oil Palm Research*. https://doi.org/10.21894/jopr.2024.0059

Svoreň, J., Naščák, L., Barcík, Š., Koleda, P., & Stehlík, Š. (2022). Influence of circular saw blade design on reducing energy consumption of a circular saw in the cutting process. *Applied Sciences*, *12*(3), 1276. https://doi.org/10.3390/APP12031276

Wang, G., Zhang, W., Diao, X., Ji, M., Fei, B., & Miao, H. (2023). Analysis of harvesting methods of moso bamboo. *Buildings 2023*, *13*(2), 365. https://doi.org/10.3390/buildings13020365

Yusuff, M. A., Wong, K. S. M., Zakaria, K. A., Sudin, M. N., & Daud, N. M. (2024). Structural design and mechanism analysis of palm oil harvester. *Jurnal Kejuruteraan*, *36*(1), 357–363. https://doi.org/10.17576/jkukm-2024-36(1)-33

Zhang, C., Chen, L., Xia, J., & Zhang, J. (2019). Effects of blade sliding cutting angle and stem level on cutting energy of rice stems. *International Journal of Agricultural and Biological Engineering*, *12*(6), 75–81. https://doi.org/10.25165/IJABE.V12I6.4604