DESIGN AND DEVELOPMENT OF OMNIDIRECTIONAL INDUSTRIAL CONVEYOR SYSTEM

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

By

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRACT

The design and development of an omnidirectional industrial conveyor system represent a significant advancement in the fields of material handling and manufacturing automation, requiring careful consideration of factors such as material weight, width, and motor speed for optimal installation and maintenance. These conveyors, engineered for multidirectional movement, present unique challenges, including complex requirements and heightened maintenance costs, necessitating regular upkeep to prevent performance issues. In contrast to conventional conveyors, the omnidirectional system facilitates seamless movement, thereby optimizing space utilization and enhancing agility in manufacturing processes. This project adopts a comprehensive approach, encompassing initial design requirements through to actual development and functionality evaluation, utilizing 3D modeling software such as Catia V5 and integrating additive manufacturing techniques, including 3D printing for components like the Omni Wheel. Stress analysis conducted using ANSYS revealed maximum load capacities of 200N for a roller and 100N for an omni wheel. Testing involved evaluating load, speed, current, and energy consumption, demonstrating that the DC roller motor could not transport a 10kg load at low speed but could do so at high speed, while the DC omni wheel similarly failed to move a 10kg load at low speed and a 14kg load at high speed, highlighting the motors' dependence on elevated speeds for effective load mobility. Current draw increased with load, stabilizing at low speeds for loads that the motors could not move, with temperature assessments indicating that the DC omni wheel motor reached 44.5°C and the roller motor 41.1°C after 45 minutes, suggesting thermal stress and the need for cooling solutions. Load tests revealed significant performance variations, with the gap roller RPM decreasing from 256 to 205 (a 19.92% reduction) and current increasing from 0.92A to 2.65A (a 188.04% increase), while the omni wheel's RPM dropped from 661 to 0 (a 100% decrease) and current rose from 4.33A to 12.53A (a 189.38%

increase). The prototype effectively moved a 14kg item, demonstrating satisfactory performance, thus confirming that omnidirectional delivery prototypes are effective and suitable for transporting items in all directions.

ABSTRAK

Reka bentuk dan pembangunan sistem penghantar industri omnidirectional mewakili kemajuan yang ketara dalam bidang pengendalian bahan dan automasi pembuatan, memerlukan pertimbangan teliti faktor seperti berat bahan, lebar dan kelajuan motor untuk pemasangan dan penyelenggaraan yang optimum. Pengangkut ini, direka bentuk untuk pergerakan pelbagai arah, memberikan cabaran unik, termasuk keperluan yang kompleks dan kos penyelenggaraan yang meningkat, yang memerlukan penyelenggaraan yang kerap untuk mengelakkan isu prestasi. Berbeza dengan penghantar konvensional, sistem omnidirectional memudahkan pergerakan lancar, dengan itu mengoptimumkan penggunaan ruang dan meningkatkan ketangkasan dalam proses pembuatan. Projek ini mengguna pakai pendekatan komprehensif, merangkumi keperluan reka bentuk awal hingga kepada pembangunan sebenar dan penilaian kefungsian, menggunakan perisian pemodelan 3D seperti Catia V5 dan menyepadukan teknik pembuatan aditif, termasuk pencetakan 3D untuk komponen seperti Roda Omni. Analisis tekanan yang dijalankan menggunakan ANSYS mendedahkan kapasiti beban maksimum 200N untuk penggelek dan 100N untuk roda omni. Ujian melibatkan penilaian beban, kelajuan, arus dan penggunaan tenaga, menunjukkan bahawa motor penggelek DC tidak boleh mengangkut beban 10kg pada kelajuan rendah tetapi boleh melakukannya pada kelajuan tinggi, manakala roda omni DC juga gagal untuk menggerakkan beban 10kg pada kelajuan rendah kelajuan dan beban 14kg pada kelajuan tinggi, menyerlahkan pergantungan motor pada kelajuan tinggi untuk mobiliti beban yang berkesan. Cabutan semasa meningkat dengan beban, menstabilkan pada kelajuan rendah untuk beban yang tidak dapat digerakkan oleh motor, dengan penilaian suhu menunjukkan bahawa motor roda omni DC mencapai 44.5°C dan motor penggelek 41.1°C selepas 45 minit, mencadangkan tekanan terma dan keperluan. untuk penyelesaian penyejukan. Ujian beban mendedahkan variasi prestasi yang ketara, dengan RPM penggelek jurang berkurangan daripada 256 kepada 205 (pengurangan 19.92%) dan arus meningkat daripada 0.92A kepada 2.65A (peningkatan 188.04%), manakala RPM roda omni turun daripada 661 kepada 0 (penurunan 100%) dan arus meningkat daripada 4.33A kepada 12.53A (peningkatan 189.38%). Prototaip berkesan mengalihkan item 14kg, menunjukkan prestasi yang memuaskan, sekali gus mengesahkan bahawa prototaip penghantaran omnidirectional adalah berkesan dan sesuai untuk mengangkut item ke semua arah.

DEDICATION

The sake of Allah, my Creator and my Master,

My great teacher and messenger, Muhammad (May Allah bless and grant him), who taught us the purpose of life,

My great parents, who never stop giving of themselves in countless ways, who leads me through the valley of darkness with light of hope and support,

My beloved brother and sister,

To all my family, the symbol of love and giving,

My friends who encourage and support me,

All the people in my life who touch my heart, I dedicate this research.

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I am indebted to my parents for their love, prayers, concern, and sacrifices in raising me and preparing me for the future. I would like to thank my sisters for their continued prayers and support.

Finally, I would like to thank my I want to thank you for trusting me. I want to thank me for doing all the hard work. I want to thank you for not having a day off. I want to thank you for never giving up. I want to thank me for always being a giver and trying to give more than I receive. I want to thank mine for trying to do more right than wrong. I want to thank me for just being me all the time.

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LIST OF ABBREVIATIONS

3D	-	Three-dimensional
EOCC	-	E-Pattern Omniwheel Cellular Conveyor
Lbs	-	Pound
2D	-	Two-dimensional
DOF	-	Degrees of Freedom
CAD	-	Computer-Aided Design
BOM	-	Bill of Material
MIG	-	Metal Inert Gas
Kg	-	Kilograms
°C	-	Celsius
ROI	-	Return of investment
HOQ	-	House of Quality
GI	-	Galvanized Iron
CNC	-	Computer numerical control
Pa	-	Pascal
N	-	Newton
e	-	micron
PLA	-	Polylactic acid
m	-	Meter
mm	-	millimeter

D	-	Diameter
L	-	Length
V	-	Voltage
AC	-	Alternating Current
DC	-	Direct Currant
W	-	Power
A	-	Ampere
Hz	-	Frequency
Rpm	-	Revolution per minute
η	-	Efficiency of the motor
P	-	Power in watts (W)
V	-	Voltage in volts (V)
I	-	Current in amperes (A)
kWh	-	Kilo watt hour

CHAPTER 1

INTRODUCTION

This chapter outlines and describes the project's background, problem statement, objective, and scope.

1.1 Project Background

An omnidirectional conveyor is a specialized type of material handling system designed to move items in any direction, including forward, backward, left, right, and diagonally, providing a high degree of flexibility in industrial applications. The utilization of customized wheels or rollers that permit multidirectional movement allows for the achievement of this exceptional capability. The earliest versions of omnidirectional transportation used ball casters or spherical wheels, and the idea dates back to the early 20th century. But it wasn't until the middle to end of the 20th century that substantial developments in material science and engineering made it possible to create omnidirectional conveyor systems that are more reliable and effective. The Figure 1.1 shows the omnidirectional conveyor in industry.

Figure 1.1: The omnidirectional conveyor in industry (Versatile conveying system, 2018)

Conveyor systems that may travel in any direction, including diagonal ones, are known as omnidirectional conveyor systems. It is frequently used for the movement of materials and goods in the manufacturing and logistics sectors. Numerous benefits come with using omnidirectional conveyor systems, such as improved material handling process efficiency, flexible route reconfiguration, and package classification and sorting (M. Q. Zaman, H.-M. Wu, 2023). Bengt Ilon created the Mecanum wheel in 1973, which was one of the first inventions in this industry. The Mecanum wheel can travel in any direction when driven and regulated appropriately because it uses a set of rubberized rollers angled relative to its axis. An important turning point in the advancement of omnidirectional conveyance was reached with this invention. The Figure 1.2 shows the omnidirectional conveyor.

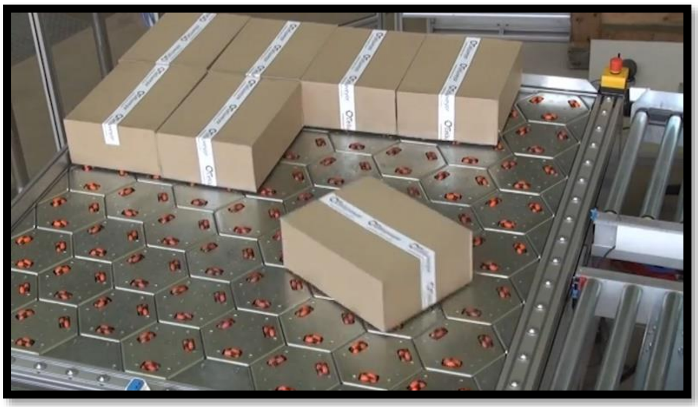


Figure 1.2: The omnidirectional conveyor. (Alexandra Appolonia and Exa Zim, 2018).

Research into manufacturing processes and innovation in new products are essential to the growth of manufacturing industries. The raw material becomes the product during processing. Sorting is crucial in this situation because manufacturing businesses typically produce the same models with minimal variations in height, color, weight, or shape. When sorting comparable objects, human labor was an option in the past. But these days, industries can't afford human error while sorting these products because of rising output and the need to minimize labor costs for such an unskilled operation. Due to this, business was compelled to atomize the sorting procedures.

Creating automated systems with little maintenance, extended durability, and user-friendliness is the primary goal of industrial automation. This project's primary goal is to create a system that will allow targeted objects to be transported independently in each direction. Additionally, things must be moved while rotating or their direction must be modified while traveling. Since then, numerous new conveyor systems and omnidirectional wheel designs have appeared, each with special qualities and uses. These days, omnidirectional conveyors are employed in a variety of sectors, such as manufacturing, distribution, warehousing, and logistics, where the capacity to precisely and efficiently transport goods in numerous directions is essential for operational optimization.

The industry will undoubtedly benefit from the study's findings when it comes to using the omnidirectional conveyors deal with the individual wheels or rollers' alignment and synchronization, especially with respect to the axis orientation. Misalignment may result from improperly calibrated components or from aging-related wear and tear. This mismatch may cause the conveyor system to jam or stop altogether, as well as unevenly distribute loads and diminish efficiency. To guarantee proper performance and avoid such problems, these components need to be regularly maintained and monitored. Next, the omnidirectional conveyors with characteristics that can prevent congestion and ensure an even fit. Additionally, the omnidirectional conveyor's design forgoes the collection of waste or foreign items on it. Lastly, assess the omnidirectional conveyance system's usefulness and functionality by minimizing system damage.

1.2 Problem Statement

Optimal installation and maintenance of conveyor systems require meticulous consideration of factors such as material weight, width, and motor speed. Appropriately selecting these specifications is essential for enhancing the system's overall performance, reducing operational costs, and ensuring long-term reliability. By precisely aligning these specifications with the intended application, one can achieve a more efficient and effective material handling process.

Omnidirectional conveyors, designed for multidirectional movement of packages, present distinct challenges compared to traditional linear and fixed conveyors. Their installation and maintenance are particularly demanding due to their complex design requirements. These systems generally require extensive space to accommodate their multidirectional capabilities. Additionally, they necessitate significant wiring and a variety of mechanical components to function effectively. This complexity not only increases the initial setup time and costs but also leads to higher maintenance expenses over the conveyor's lifecycle.

The intricate nature of omnidirectional conveyors implies that any malfunction or wear in a single component can impact the entire system, necessitating regular and comprehensive maintenance checks. Ensuring all mechanical parts are in optimal condition is crucial to prevent downtime and costly repairs. Furthermore, the need for specialized knowledge and tools to maintain and repair these systems further contributes to the overall maintenance burden.

Therefore, while omnidirectional conveyors offer enhanced flexibility and efficiency in material handling, their implementation demands a strategic approach to installation and maintenance. This approach is necessary to manage the associated costs and ensure consistent and reliable performance.

1.3 Objectives

The objectives of the project consist of:

i. To determine design requirement of omnidirectional industrial conveyor system.

ii. To design and develop of omnidirectional industrial conveyor system.
iii. To evaluate functionality and usability the omnidirectional industrial conveyor system.

1.4 Scope of the Project

In further detail, the project involves meticulously designing the layout of the omnidirectional conveyor to maximize efficiency in material handling workflows. This includes strategically placing the conveyor's omnidirectional wheels, chosen for their ability to move in any direction with minimal resistance, thereby optimizing maneuverability and throughput.

The integration phase focuses on seamlessly incorporating these wheels into a cohesive system that can handle varying loads and navigate complex environments effectively. Performance optimization efforts are geared towards enhancing speed, accuracy, and reliability, ensuring the conveyor meets stringent industrial standards.

Testing protocols are crucial throughout the development process to validate design choices and performance expectations. This iterative approach allows for adjustments and refinements to be made, ultimately leading to a robust conveyor system that can be scaled for broader industry applications.

Additive manufacturing plays a pivotal role in producing the conveyor wheels, offering advantages such as design flexibility, rapid prototyping, and the ability to create complex geometries that traditional manufacturing methods may struggle with. Meanwhile, the cutting process utilized for the frame structure emphasizes precision and durability, ensuring the conveyor can withstand rigorous operational demands over its lifecycle.

By focusing solely on the construction aspects of the conveyor, the project ensures a thorough exploration of design and manufacturing considerations, laying a solid foundation for future integration with control systems and other operational components in industrial settings.

CHAPTER 2

LITERATURE REVIEW

This chapter offers an in-depth review of the topic that will be covered in this study. The selected topics evidence is associated with a review supported by an interpretation from the article, journal, book, and other numerous sources. This information will aid in the creation of a detailed outline of the selected topic that must be emphasized throughout the stages of the study.

2.1 State of the art of omnidirectional conveyor

An omnidirectional conveyor represents a conveyance system capable of autonomous movement in any direction along diverse trajectories. Its design caters to intricate material flow requirements, finding application across industries to facilitate seamless operations in assembly lines and goods transfer(Zhou et al., 2023). Distinguished by its adaptable orientation to meet specific producer specifications, the omnidirectional conveyor is anticipated to experience heightened demand amidst evolving production paradigms and escalating automation needs. Typically comprising compact hexagonal modules propelled by electronic motors, this system enables the concurrent and autonomous movement of multiple objects. Pioneering developments in omnidirectional modular conveyors, exemplified by the E-Pattern Omniwheeled Cellular Conveyor, are a subject of scholarly investigation, promising enhanced flexibility and efficacy in material handling. Positioned as an innovative solution for package transportation, this technology aspires to deliver trajectory adaptability coupled with elevated energy efficiency (Zaher et al., 2022).

Moreover, the E-Pattern Omniwheeled Cellular Conveyor (EOCC) represents a novel category of conveyor system that amalgamates the advantages inherent in both omnidirectional conveyors and cellular conveyors. Figure 2.1: A top view screenshot of the proposed E-pattern omniwheeled cellular conveyor (EOCC). The EOCC employs sophisticated camera and image processing methodologies to realize a centralized system, exhibiting superior robustness in comparison to conventional decentralized systems (Keek et al., 2021). Figure 2.2 show the mechanism model of omnidirectional conveyor systems.

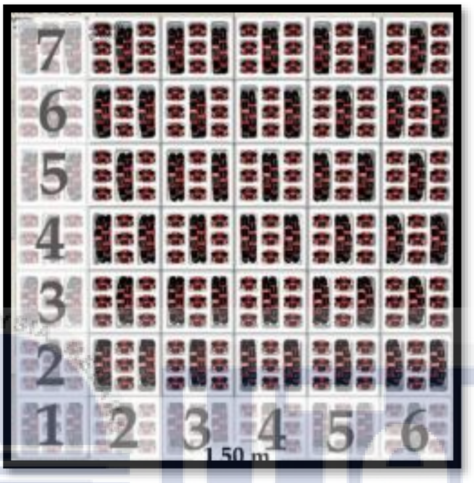


Figure 2.1: A top view screenshot of the proposed E-pattern omniwheeled cellular conveyor (EOCC) (Keek et al., 2021).

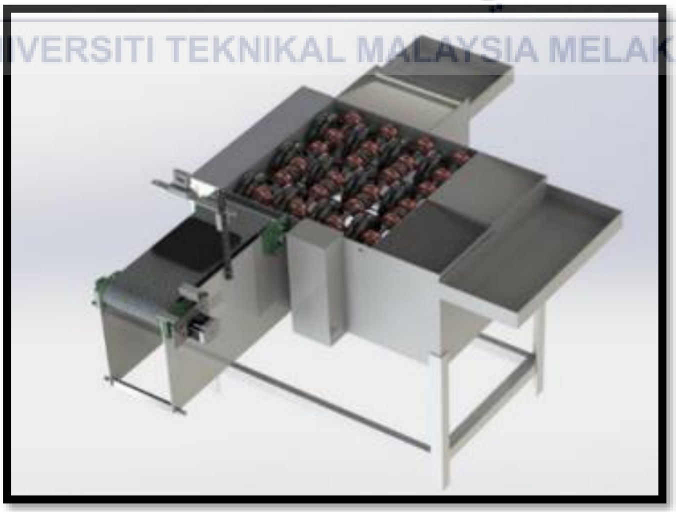


Figure 2.2: Mechanism model (Salazar et al., 2019).

2.1.1 The mechanics of an Omnidirectional Conveyor

The E-Pattern Omniwheeled Cellular Conveyor (EOCC) is designed with omnidirectional proficiency, facilitating multidirectional movement to augment the overall adaptability and efficiency of the conveyor system. Capitalizing on cellular conveyor technology, EOCC integrates multiple conveyor cells capable of autonomous object movement. The system incorporates cameras and advanced image processing methodologies to establish a centralized configuration, providing enhanced control and precision in contrast to decentralized systems. Remarkably, EOCC introduces a unique actuator activation method, enabling regulated movement of cartons along the conveyor. This holistic design underscores the amalgamation of omnidirectional attributes, cellular conveyor technology, sophisticated imaging, and specialized actuation mechanisms within the EOCC system, thereby enhancing its advanced functionality in material handling applications (Keek et al., 2021). Figure 2.3 show the examples of force to each application can be realized at omnidirectional conveyor systems.

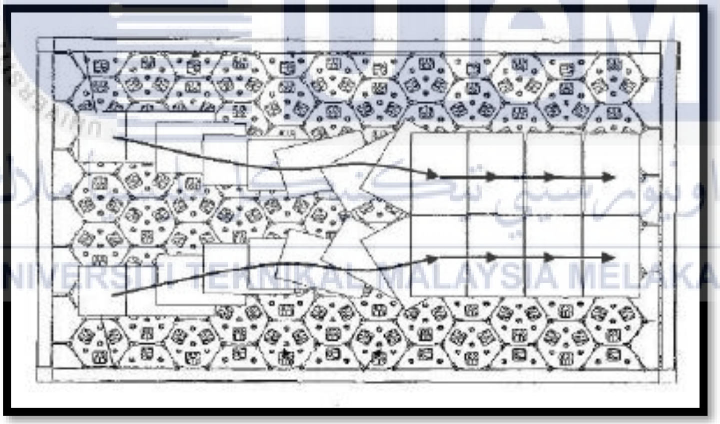


Figure 2.3: Examples of force to each application can be realized by omnidirectional conveyor (Keek et., 2021).

Omnidirectional conveyors epitomize sophisticated systems meticulously engineered to facilitate the transit of objects in multiple directions, thereby presenting an elevated level of adaptability and operational efficiency across a diverse spectrum of applications. An omnidirectional conveyor system represents a category of conveyance mechanism capable of traversing in unrestricted directions, encompassing diagonal movements. Widely employed within the manufacturing and logistics sectors, this system serves the purpose of transporting various goods and materials. The utilization of omnidirectional conveyor systems affords numerous benefits, including the classification and sorting of packages, adaptable route reconfiguration, and heightened efficiency in the processes related to material handling (Zaman & Wu, 2023). Among the noteworthy extant omnidirectional conveyor systems and associated technologies is Omnia's Transpose Conveyor Transfer Tables, acknowledged for their simplicity, scalability, and applicability to diverse conveyor functions, offering efficacious solutions for the streamlined handling of materials.

An exemplary innovation in the realm of omnidirectional conveyor technology is the E-Pattern Omniwheeled Cellular Conveyor. Crafted to cater to the demands of highly flexible material flow, this system incorporates omnidirectional driving gears, augmenting its adaptability in diverse operational scenarios (Keek et al., 2021). Furthermore, the Omnidirectional Conveyor System Module, comprising a minimum of two conveyor units arranged adjacently, introduces a distinctive configuration where the effective orientations of the conveyor wheels are positioned at an angle unequal to 180 degrees. These pioneering advancements collectively contribute to the progression of conveyor systems, fostering efficiency in material handling processes.

Expanding the breadth of omnidirectional technologies are the Ergotronix Ergo Roll Multi-Directional Conveyor Rollers. Recognized for their versatility in comparison to conventional ball transfer rollers or skate wheels, these rollers facilitate smooth and secure material transfer and directional changes. Compatible with both gravity-driven and motorized conveyor configurations, these rollers exhibit varying load capacities per unit, spanning from 12.5 lbs to 90 lbs. These advancements are poised to enhance operational efficiency, minimize downtime, and seamlessly integrate into existing conveyor systems spanning industries such as manufacturing, logistics, and material handling (Zaman & Wu, 2023).

2.2 State of the art on method in developing omnidirectional conveyor

Omnidirectional conveyors represent a class of conveyor systems capable of moving objects in any direction. The integration of omnidirectional modular conveyors is anticipated to be imperative in the trajectory of conveyor technologies, owing to their inherent flexibility and efficiency. Various types of conveying systems are presently available, each employed based on the diverse requirements of industries. The incorporation of omnidirectional capability and modularization into conveyor systems constitutes a noteworthy and promising advancement. The distinctive wheel configuration and specially devised algorithm facilitate the independent transfer, orientation, and positioning of diverse objects. Omnia, as a provider, offers omniwheel conveyor systems characterized by high durability, reduced manual maintenance requirements, and scalability concerning load capacity, size, and weight.

This study concentrates on the design and establishment of a control system for an E-Pattern Omniwheeled Cellular Conveyor. The research specifically addresses the evolution of modular omnidirectional conveyors, envisaged as indispensable in the forthcoming landscape of conveyor technologies, owing to their intrinsic flexibility and efficiency. The investigation emphasizes the creation of transporting tables with omnidirectional capabilities, grounded in the utilization of omnidirectional driving gear (Keek et al., 2021). This research centers on control strategies designed for compact conveyor modules facilitating omnidirectional transportation. The study underscores the application of omnidirectional conveyors to enhance the efficiency and adaptability of material handling systems. The primary focus of the investigation lies in the advancement of small-scale conveyor systems characterized by identical and intelligent modules, equipped to address diverse challenges encountered in transportation and sorting tasks (Uriarte et al., 2019).

2.2.1 Design Requirements omnidirectional conveyor

In the realm of mechanical design, the envisaged system is meticulously engineered to exhibit omnidirectional movement capabilities, thereby conferring upon it the inherent flexibility to traverse effortlessly in all spatial directions and rotate as necessitated. The design paradigm embraces modularity, employing diminutive hexagonal modules to augment both flexibility and operational efficiency (Ajarekar et al., 2021). This modular configuration not only facilitates facile assembly, disassembly, and reconfiguration but also fosters scalability and adaptability to diverse layouts. Additionally, the integration of omnidirectional conveyor units, each furnished with multiple omnidirectional conveyor wheels, substantiates the system's proficiency in achieving seamless motion within both two-dimensional and three-dimensional spatial domains. This all-encompassing design strategy endeavors to optimize material handling processes by furnishing a conveyor system characterized by versatility and adaptability.

This method facilitates the cohesive functioning of the system as a unified entity through the dynamic grouping of multiple modules into a virtual cluster, scalable to the necessary system size. The study is dedicated to investigating the path planning and sorting aspects pertinent to omnidirectional-wheel conveyors (Zaher et al., 2022). This paper centers on the design and creation of an omni-directional mobile robot equipped with four Mecanum wheels, approached systematically. The comprehensive integration of this entire system is achieved within the framework of an intelligent manufacturing system (Qian et al., 2017).

2.3 Effectiveness Assessment of the Omnidirectional Conveyor

The transmitter system module contains exactly two omnidirectional transmitter units arranged in tandem, providing the ability to aim transmissions in any direction independently along a two-dimensional (2D) axis. This configuration allows the simultaneous transfer of objects, similar to compartments, using individual lanes. Especially, when the direction of operation along both axes of the conveyor is aligned in parallel, limiting the movement to a single direction becomes obvious. Alternatively, using three omnidirectional transmitter units adjacent to each other allows action commands for the conveyor wheels across three different conveyor units. This arrangement reduces the effect of parallel directions, ensuring effective motion along different axes. Targeted transport of objects in every direction in 2D is possible independently of each other and additionally circular, however (Zaher et al., 2022), more than three, such as four or five omni directional conveyor units may be provided as shown in Figure 2.4.

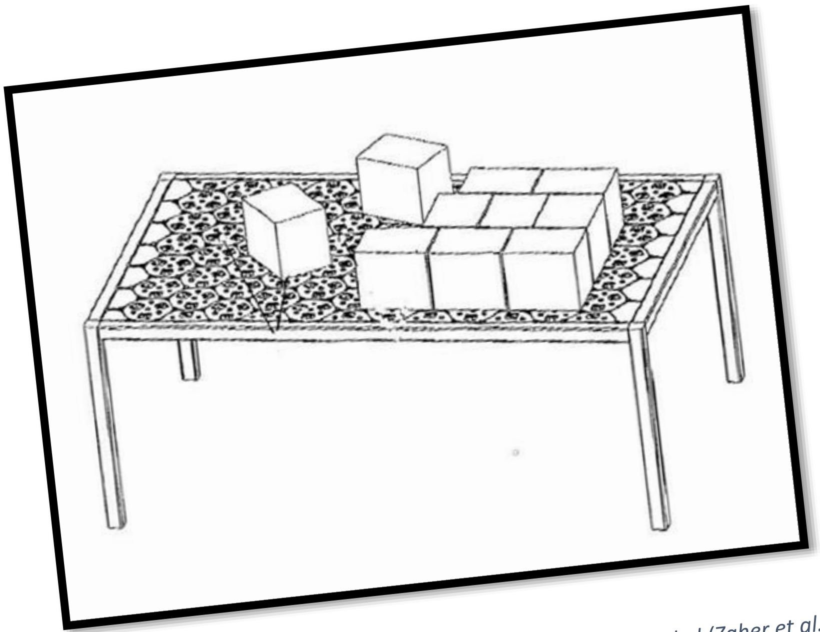


Figure 2.4: As shown four or five omnidirectional transmitter units can be provided (Zaher et al., 2022).

2.3.1 Hexagonal omnidirectional wheeled conveyor system.

The case study under consideration involves the utilization of a hexagonal omnidirectional wheeled conveyor. The control system designed for this prototype is reliant on a singular vision sensor for the purpose of tracking the trajectory of the conveyed package. A prototype of a hexagonal omnidirectional wheeled conveyor has been fabricated for the purpose of this research investigation. The prototype exhibits dimensions of 138.56 cm in length and 90 cm in width. The conveyor comprises hexagonal modules designed to facilitate the transportation of flat squared packages. Each hexagonal module is equipped with three omnidirectional wheels featuring a radius of 3.5 cm and orientation angles of 0°, 120°, and 240°. These wheels operate at a maximum speed of 127 rpm, resulting in a package velocity of 0.47 m/s in a singular direction along the conveyor (El-sayed et al., 2022). Figure 2.5 show hexagonal omnidirectional wheeled conveyor prototype.

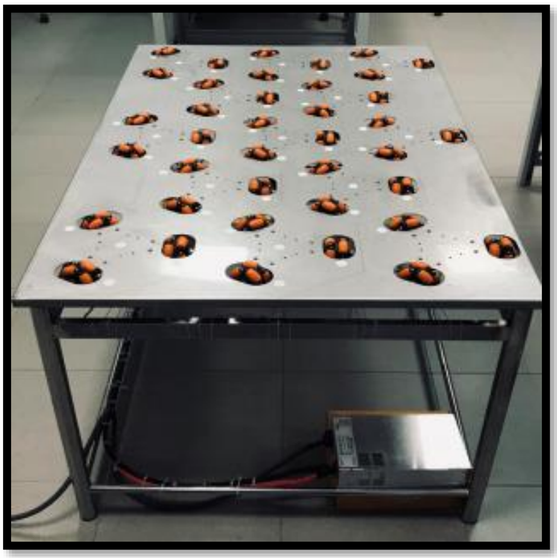


Figure 2.5: Show hexagonal omnidirectional wheeled conveyor prototype (El-sayed et al., 2022).

The omnidirectional wheeled conveyor is configured as an amalgamation of modules arranged in a hexagonal grid formation. The constructed prototype encompasses thirteen hexagonal cells, housing a total of thirty-nine wheels. The minimal area required for a package in transit on the conveyor corresponds to the area of one individual cell. Incoming packages from external conveyor belts are systematically sorted on the hexagonal conveyor by directing each package type to a designated destination. Figure 2.6: Robot hexagonal plate with cutouts for the wheels. The Figure 2.7 show the three unique regular tessellations at omnidirectional conveyor systems.

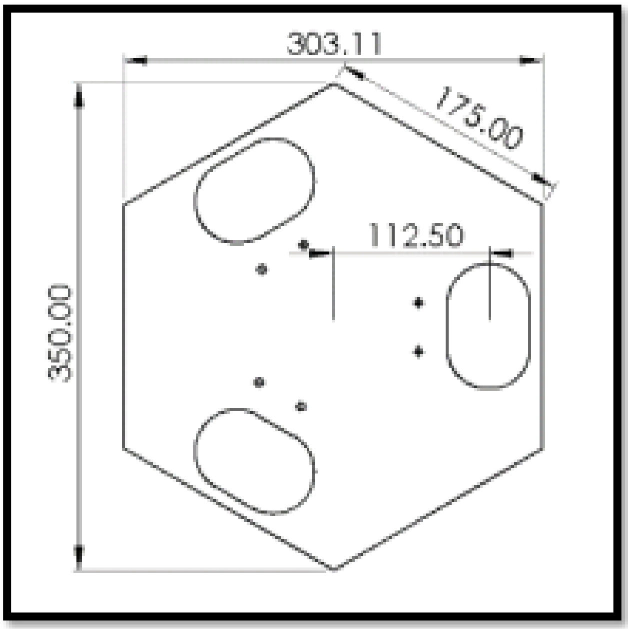


Figure 2.6: Robot hexagonal plate with cutouts for the wheels. (With Dimensions)

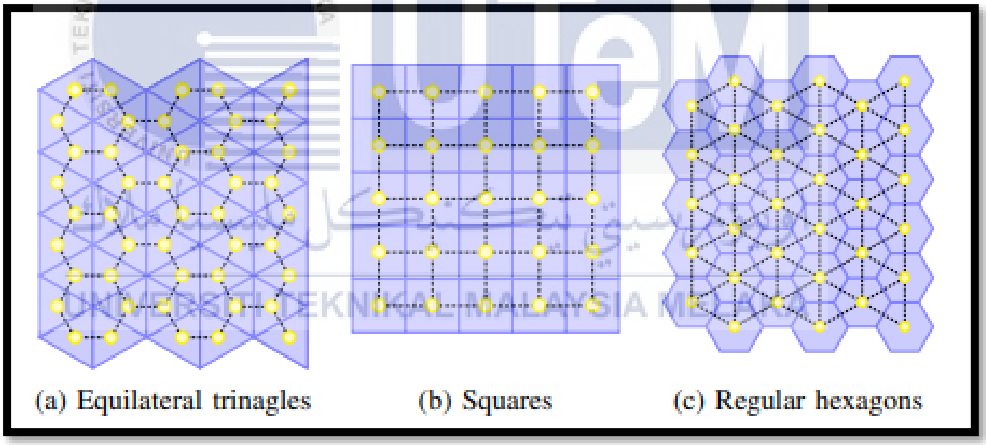


Figure 2.7: The three unique regular tessellations (El-sayed et al., 2022).

Additionally, an innovative cellular transmitter, referred to as a "luveyor cell," was introduced. The transmitter is constructed from a set of uniform hexagonal cells, and each cell is equipped with three independently driven omnidirectional wheels(Youssef et al., 2022), as illustrated in Figure 2.8. This system shows versatility in various Intralogistics applications, exhibiting the ability to efficiently sort and transfer multiple packages simultaneously. from diverse source points to different destination points with a significant degree of accuracy. In addition, it is adept at collaborating in palletizing operations by configuring precise and manageable shapes for each pallet level.

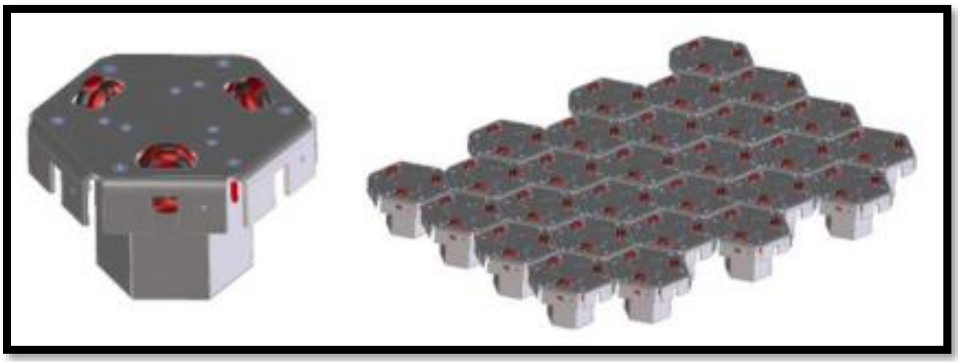


Figure 2.8: Cell module and a complete omnidirectional wheeled conveyor (Youssef et al., 2022).

2.4 Type of omnidirectional wheel.

Wheels constitute a fundamental element in omnidirectional mobile conveyors, facilitating the requisite locomotion for the movement of conveyors. Various wheel types are employed in robotics, encompassing standard wheels, orthogonal wheels, spherical wheels, Mecanum wheels, and universal wheels. Each category presents distinct merits and constraints, and the selection of wheels is contingent upon the precise application and stipulated criteria of the omnidirectional conveyor system (Almusawi & Akkad, 2023.).

Specialized wheels are crafted with an operative axis that imparts directed motion (either forward or backward) and an inert axis typically comprising revolving rollers arranged perpendicularly to the operative axis. This discourse delves into the existing commercially accessible variants of specialized wheels, notably Omni wheels and Mecanum wheels. (Almusawi & Akkad, 2023.)Additionally, an examination is conducted on non-commercial wheel types, such as Orthogonal wheels and Omni-ball wheels.

2.4.1 Universal/Omni-wheels

Omni-wheels represent a distinct wheel category facilitating optimal omnidirectional mobility for robots employing three or more wheels. This wheel design incorporates multiple passive rollers affixed to the outer periphery of the wheel, positioned at 90-degree intervals relative to the shaft. The axes of these rollers are orthogonal to the wheel shaft, contributing to the enhanced omnidirectional movement capabilities of the robot (Kanjanawanishkul, 2015). Figure 2.9. shows different Omni wheel design.

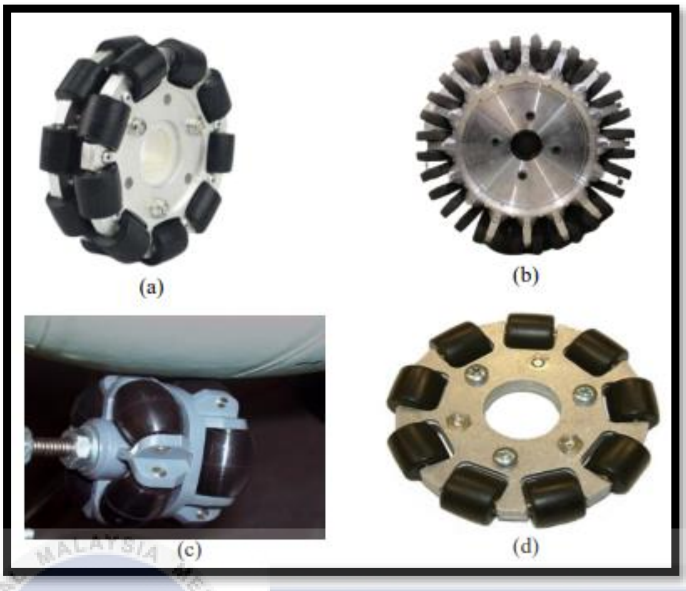


Figure 2.9: Shows (a) Omni wheel double, (b) Active omni wheel with internal rollers, (c) Omni-wheel, (d) Omni wheel singular (Almusawi & Akkad, 2023.)

2.4.2 Mecanum wheel.

The Mecanum wheel bears similarity to the Omni wheel; however, it diverges by incorporating rollers positioned along the outer circumference at a 45-degree angle to the active axis. This configuration facilitates movement in arbitrary directions. The Mecanum wheel exhibits three distinct rotations: roller rotation, wheel rotation, and slip rotation relative to the vertical axis(Song & Byun, 2004). The Mecanum wheel is invented in 1973 (Kanjanawanishkul, 2015), It finds application in contexts necessitating elevated stability, exemplified in instances such as the deployment of Mecanum wheels in wheelchairs and forklifts (Kim et al., 2012), as well as high maneuverability (Sun et al., 2021), Certain specialized wheel configurations may exhibit diminished load-bearing capacities, despite their advantages in high-load applications. A notable weakness inherent in Mecanum wheels pertains to the design of their mechanical structure, contributing to perceptible horizontal and vertical vibrations (Bae & Kang, 2016).

Additionally, there is a propensity for slip, resulting in odometry inaccuracies with Mecanum wheels. Negotiating uneven or sloping terrain poses challenges for Mecanum wheels as the wheel rim makes contact with the ground instead of the rollers. However, this issue can be addressed by subdividing the rollers into two or three centrally mounted slides as shown in Figure 2.10. The mecanum wheel also has a slower moves from the Omni wheel when the robot rotates (Kundu et al., 2016).

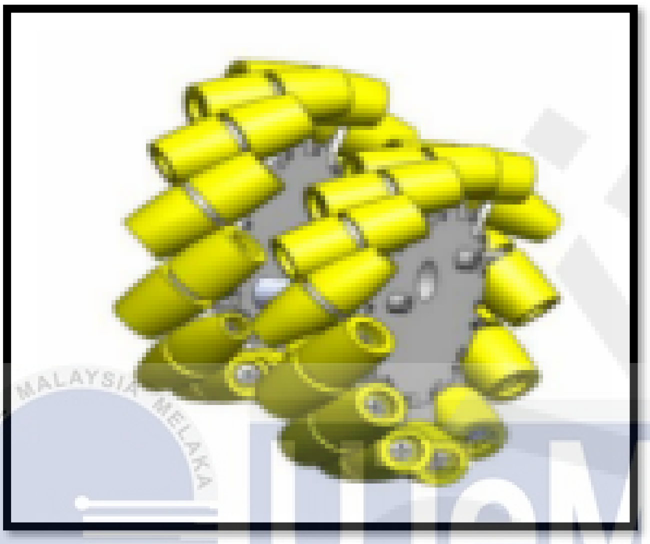


Figure 2.10: Assembled of elliptical Mecanum double wheel (Almusawi & Akkad, 2023)

2.4.3 Orthogonal wheel

Orthogonal wheels encompass a segmented ball structure featuring two pairs of balls positioned along the front axis, displaying diverse configurations as illustrated in Figure 2.11. Inspired by the Omniwheel model, each ball within the wheel possesses dual degrees of freedom, facilitating rotation along both axes—both wheel and frame axles. This deliberate design enables omnidirectional motion. Primarily devised for low-speed operations to mitigate vibrations, orthogonal wheels exhibit a straightforward structure. These attributes render them a favorable option across diverse applications, notably in the realms of mobile robotics and material handling systems (Pin & Killough, 1994).

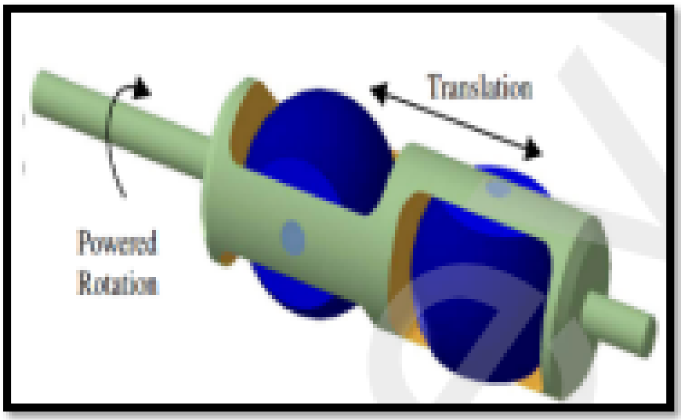


Figure 2.11: Leading axis inspired by the Omniwheel model (Mourioux et al., 2023.).

Nevertheless, it is imperative to underscore that realizing the complete efficacy of this wheel within a sophisticated system necessitates additional scrutiny. Subsequent research endeavors could delve into avenues for refining the wheel design to suit varied applications and assessing its performance in more demanding environments. The attainment of omnidirectional reach and holonomic capability in the omnidirectional conveyor is facilitated through the utilization of three principal axes, as depicted in Figure 2.12. The examination of control methodologies and dynamic models for this approach has already been explored in previous studies (Jain & Watanabe, 1998).

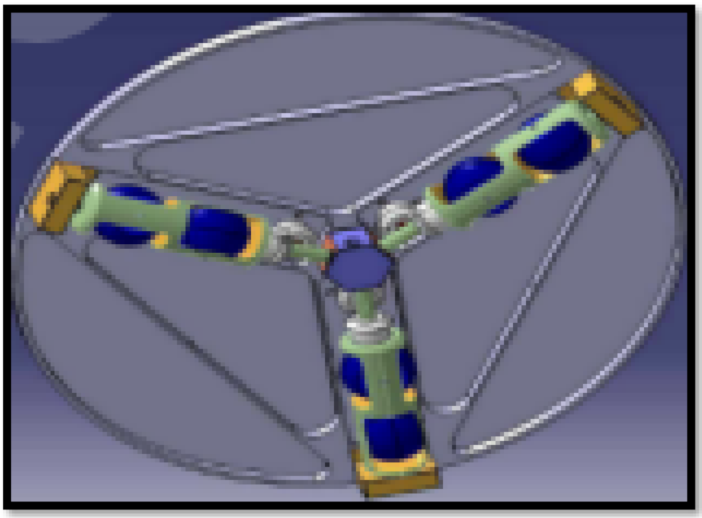


Figure 2.12: A platform consists of three axes of orthogonal Wheels (Mourioux et al., 2006).

Through the amalgamation of these configurations, omnidirectional conveyors exhibit the capacity to traverse in any direction without necessitating reorientation, rendering them well-suited for applications demanding heightened maneuverability. Various Orthogonal wheel types, including lateral assembly and longitudinal assembly, have undergone scrutiny concerning their kinematic models and fundamental concepts in relevant scholarly investigations (Mourioux et al., 2006.).

2.4.4 Ball/spherical wheel

Spherical or ball wheels are formulated to address contact-induced vibrations and ground irregularities, with the additional purpose of surmounting obstacles and augmenting load-bearing capacities. A spherical wheel comprises two hemispherical wheels that rotate passively, along with one active shaft capable of active rotation. The inherent simplicity in the design of this wheel, relative to other wheel types, enhances its reliability and facilitates straightforward maintenance procedures (Almusawi & Akkad, 2023.).

The design of the ball wheel adheres to the principle of a ball and socket connection, wherein the ball corresponds to the wheel, and the socket corresponds to the ground. This wheel configuration possesses the capability to maneuver in any direction, with the control system adept at modifying the wheel's orientation and speed to attain the desired movement. Extensive testing and validation of ball wheels across various applications have yielded promising outcomes, particularly in terms of stability, efficiency, and maneuverability (Runge et al., 2016).

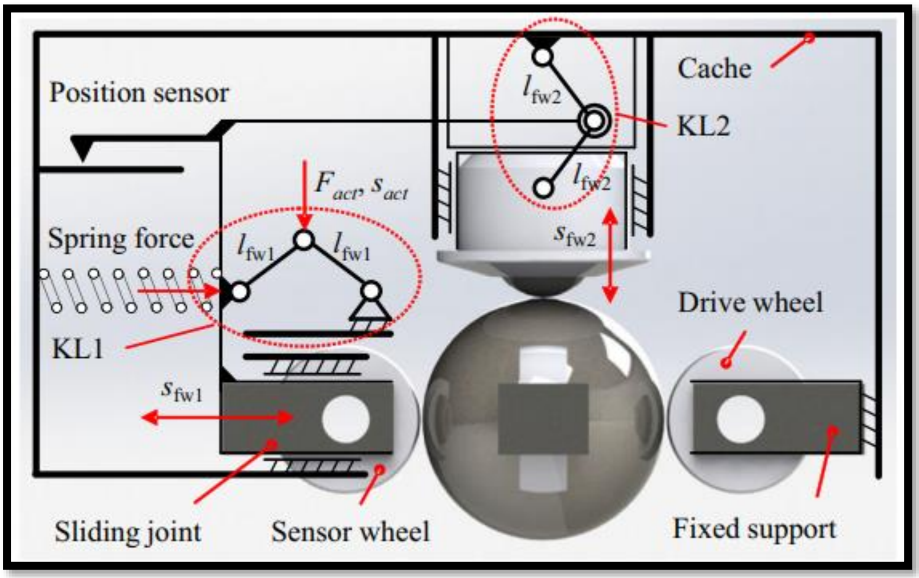


Figure 2.13: Free-wheel mechanism (Runge et al., 2016).

In a scholarly investigation conducted by Tadakuma et al. (Touching Point on Ground Outer Passive Wheel Inner Passive Wheel Axis of Rotation Fig. 3: The Problem of Omni Wheel in Odometry, 2015), the primary objective is to address the challenge of climbing capability through the development of a specialized spherical wheel known as the "Omni-Ball." The author employs a holonomic omnidirectional vehicle fitted with this wheel to empirically validate the findings, demonstrating the robot's capacity to ascend steps with a height of up to 23.5 mm. This study introduces a novel methodology to surmount established limitations in robotic performance and holonomic characteristics, substantiating the efficacy of the proposed solution through experimental validations. Figure 2.14. shows A 3D model of a hemispherical wheel.

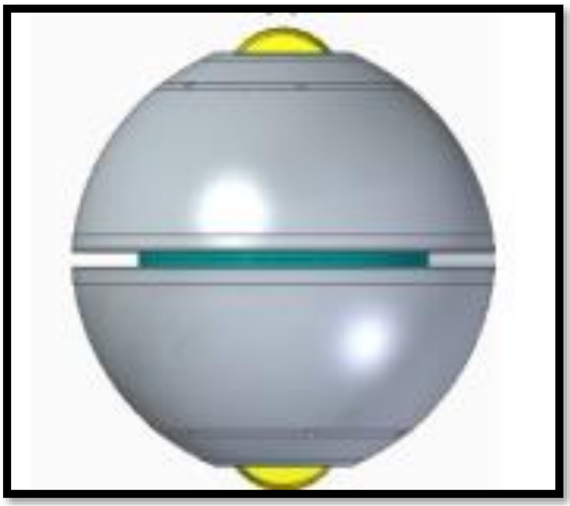


Figure 2.14: Shows A 3D model of a hemispherical wheel (Almusawi & Akkad, 2023.).

In a study conducted by researchers referenced as (Design and Control of Ball Wheel Omnidirectional Vehicles Mark West H a r u h i k o Asada, 2009), a prototype has been devised for a fully mobile omnidirectional vehicle employing specialized wheels. The primary objective of this study is to enhance the mobility and refine the dead reckoning execution, particularly in response to wheel slippage, thereby achieving system balance. Additionally, the researchers are engaged in the design and experimental evaluation of control systems tailored for the omnidirectional vehicle.

2.4.5 Standard wheels

Standard wheels, recognized as the predominant wheel type employed across a spectrum of vehicles and mobile robotic platforms, are alternatively referred to as round or cylindrical wheels. Typically composed of durable materials such as hard rubber or polyurethane, these wheels are affixed to the motor shaft or wheel axle. Notable for delivering elevated traction and stability on level and smooth surfaces, standard wheels, nevertheless, exhibit constraints in terms of maneuverability and omnidirectionality. They may encounter challenges such as getting lodged or slipping on rough or uneven terrain (Almusawi & Akkad, 2023.).

In order to surmount this limitation, a modified version of the wheel has been devised. However, adhering to conventional handling methods proves challenging as the wheel is incapable of executing omnidirectional motion owing to non-holonomic constraints. Alterations to the wheel mechanism are imperative for achieving omnidirectional capability, exemplified by the incorporation of active castor wheels, as depicted in Figure 2.15. The utilization of active castor wheels has been implemented to address issues related to slippage and to establish a redundant motion system for robotic applications.

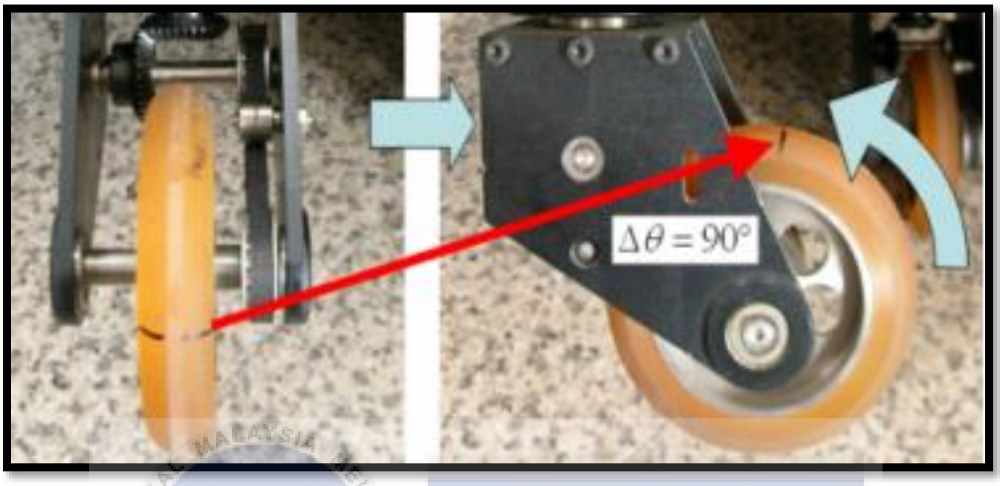


Figure 2.15: Active caster wheels (Almusawi & Akkad, 2023).

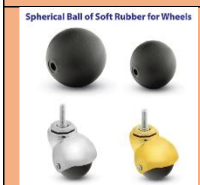
In a study conducted by researchers referenced as (Almusawi & Akkad, 2023), an integrated omni-directional mobile robot is implemented featuring active castor wheels. The robot is equipped with three motors for steering wheels and an additional three motors for propulsion. Numerous investigations have concentrated on enhancing the design, control algorithms, and materials for standard wheels to optimize their performance in mobile robotics. For instance, in a study by (Ping Li et al., 2005), a robot was designed with powered caster wheels capable of executing omnidirectional motion, as all degrees of freedom (DOF) could be controlled. The research objectives included minimizing slippage issues commonly associated with standard wheels. In a separate study (II. ASOC-DRIVEN OMNIDIRECTIONAL MOBILE ROBOT, 2011.), researchers devised a robot incorporating four offset active limbs with caster wheels enabling omnidirectional motion, even on uneven terrain. The study results indicate an odometry error of approximately 5-6%. Another study by (Jung et al., 2015) involved a kinematic and motion analysis, focusing on the design of a planar multiarticulated omnidirectional mobile robot equipped with three castor wheels. Figure 2.16. steering wheel.

Figure 2.16: Steering wheel (Almusawi & Akkad, 2023).

2.4.6 Summarizing advantages, disadvantages, and limitations of different types of wheels.

Table 2.1: Summarizing advantages, disadvantages, and limitations of different types of wheels

Type of wheel	Advantages	Disadvantages	Restrictions/limitations
 Omni-wheel	The system offers high maneuverability, a minimal turning radius, diagonal movement, and the ability to rotate in place, ensuring smooth and stable motion.	The wheel experiences discontinuity with the ground, high vibration, sensitivity to rough terrain, dust, and small obstacles, low traction, high power consumption, limited load capacity, and constraints on outdoor use, rendering it comparatively expensive to other wheel types.	The wheel exhibits challenges in mitigating vibration, has payload limitations, constrained speed and efficiency on uneven surfaces, difficulties in controlling lateral movement, heightened vulnerability to vibration and shock, and a limited range of available sizes and types.

 Mecanum wheel	The system demonstrates high responsiveness, simplicity in control, structural simplicity, omnidirectional movement capability, effective traction on flat surfaces, and the ability to move laterally and diagonally.	The system exhibits sensitivity to dust, high costs, susceptibility to small obstacles and slipping, low load capacity, sensitivity to rough terrain, discontinuity with the ground, high vibration, slower rotation compared to Omni wheels, elevated energy consumption due to friction, limited load capacity, diminished mobility on uneven surfaces, and reduced effectiveness at high speeds.	The system faces challenges in eliminating vibration, with payload limitations, restricted applicability in rough or uneven terrain, and limitations in high-speed applications, heavy load capacity, and precision or accuracy requirements.
 Conventional type of the Orthogonal wheel	The system exhibits low vibration, insensitivity to fragments and dirt, superior stability attributable to its orthogonal arrangement, and the capability to handle heavy loads without slippage.	The system features low load capacity, constrained maneuverability due to fixed wheel orientation, increased spatial requirements owing to the orthogonal arrangement, and sensitivity to terrain changes, potentially necessitating adjustments in wheel height and angle for optimal performance.	The system operates solely at low speeds, introduces uncertainty in movement due to roller gaps, exhibits restricted ability for omnidirectional motion, limited capability to turn in confined spaces, and may necessitate additional control mechanisms for enhanced maneuverability and precision.
 Ball/Spherical	The system enables omnidirectional movement, effortless motion in any direction, exhibits strong stability for heavy	The system is cost-prohibitive, has low load capacity, complex control requirements, intricate configuration,	The system's small surface area may lead to sinking or getting stuck in soft or uneven terrain, rendering it unsuitable for high-speed movement due to

wheel	loads, low rolling resistance for efficiency and energy conservation, and is easily maintainable and repairable, suitable for deployment on uneven or rough surfaces.	limited market availability, necessitates specialized mounting mechanisms, and exhibits constrained maneuverability on soft surfaces without an auxiliary material covering the wheel surface.	potential wheel bouncing. Additionally, it may produce operational noise, exhibit limited traction on slippery or wet surfaces, and require skillful operators for proper control.
 Standard wheel	The system is insensitive to road conditions, adept at overcoming small obstacles, characterized by a simple and reliable design, easy to manufacture and maintain, available in diverse sizes and materials, and well-suited for a broad spectrum of applications encompassing both indoor and outdoor usage.	The system lacks omnidirectional motion capabilities, exhibits constrained maneuverability relative to omnidirectional and Mecanum wheels, necessitates a minimum turning space, and encounters challenges in lateral or diagonal movement.	The system, without modifications to the wheel mechanism, lacks the ability for omnidirectional motion, thereby restricting its applicability. It may experience slippage on surfaces like wet or uneven terrain, leading to limited traction on slippery surfaces or inclines.

CHAPTER 3

METHODOLOGY

3.0 Project Flowchart

A flowchart forms a schematic illustration that depicts a dynamic procedure or workflow through a series of interconnected boxes, depicting a sequential progression of steps. It serves as a visual representation of an algorithm or procedural approach designed to accomplish a specific task. Flowcharts find widespread application in corporate settings for the purpose of researching, documenting, or administering a process or program. An ongoing project uses flowcharts as an instrumental way to visually describe the procedural complexity involved in designing and developing an omnidirectional industrial conveyor system.

This research focuses not only on designing and developing omnidirectional industrial conveyor systems but also on examining the selection of wheels and motors used. It is important, before starting work, to ensure the development parameters and methodology. Next, the suitability of the process for the fabrication of the omnidirectional transmitter is based on the manufacturing process according to the facilities available at the University.

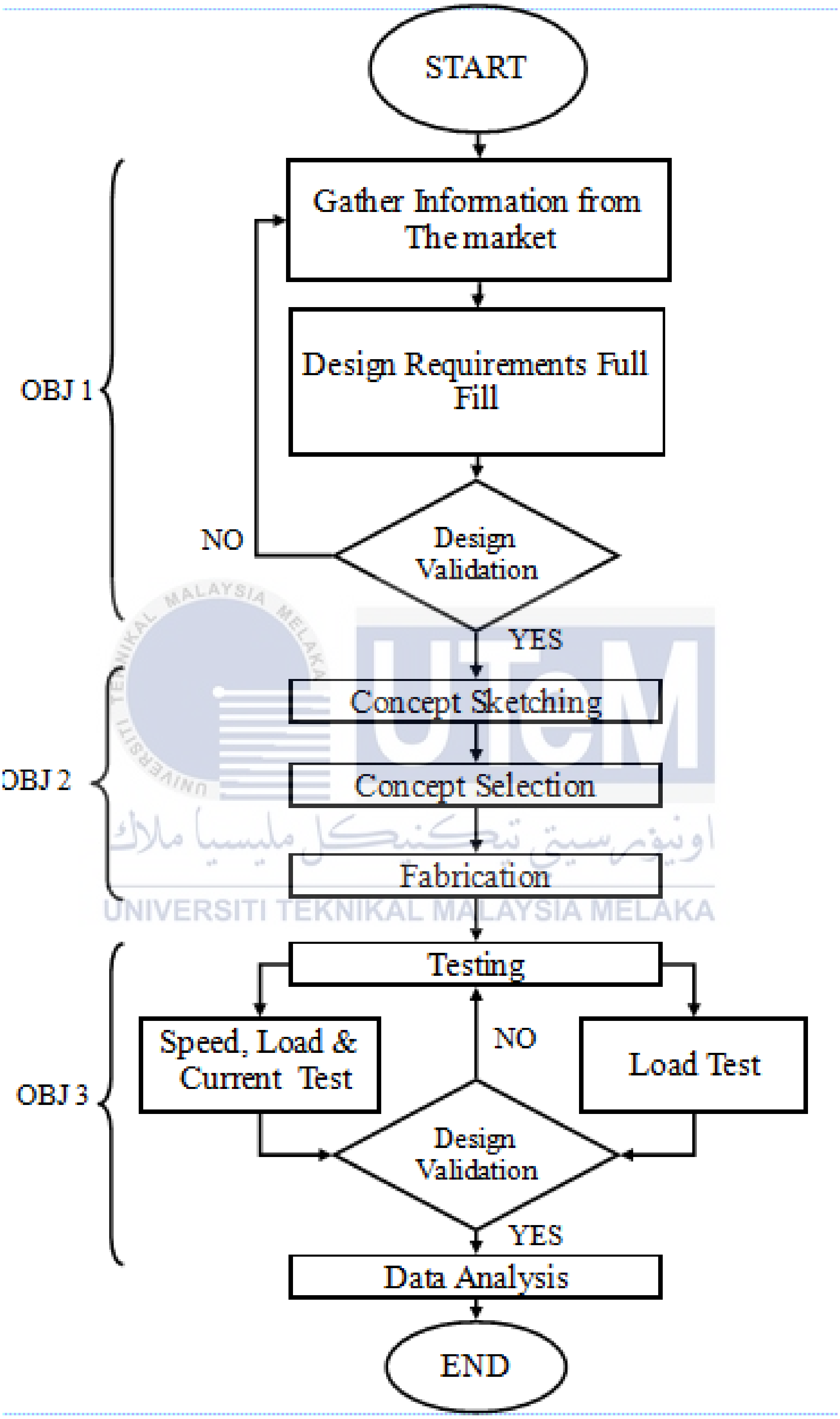


Figure 3.1: Flowchart of this project

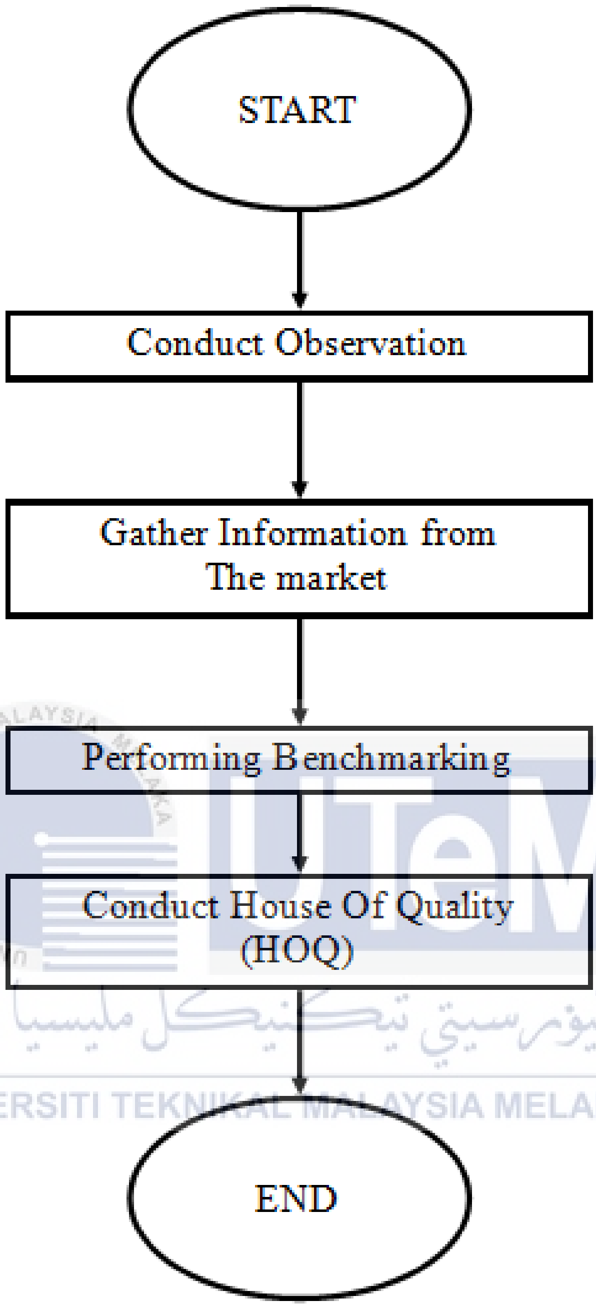


Figure 3.2: Flowchart of objective 1

3.1 Introduction

This section addresses the whole product design process, from start to finish. This part will also go through the research methods and techniques. In furthermore, the methods of data sampling are discussed in this chapter. There's also a breakdown of the idea selection technique, which will be utilised to choose the best overall design.

3.1.1 Design requirements of Omnidirectional Conveyor

To ensure omnidirectional conveyor functionality, safety and efficiency, several elements must be carefully considered during design. Omnidirectional conveyors are special because they can move in any direction, providing material handling flexibility. Therefore, designing an omnidirectional transmitter requires compliance with various important prerequisites to ensure its optimal functionality. Because of this, stability and balance are important to ensure that the transmitter remains stable during the transport of the load to avoid any possible overturning incident. Additionally, consideration of maximum load capacity is essential to reduce the possibility of damage, with the design carefully supporting the efficient movement of items. Accuracy and precision in movement form such an important aspect, demanding careful control and coordination throughout the design process.

As such, the need to facilitate ease of maintenance needs to be taken into account with the design providing uncomplicated access to components for necessary repairs or adjustments. Additionally, the integration of energy-efficient features assumes importance for cost-effectiveness and sustainable practices. To ensure material compatibility is paramount, transmitters can efficiently handle items of various sizes, shapes and weights. In addition, the implementation of safety measures, such as obstacle detection sensors and emergency stop systems should be placed on the omnidirectional conveyor as a critical requirement for accident prevention. In addition, designing an omnidirectional conveyer design is important for user safety. Finally, the design must strike a judicious balance between functionality and cost-effectiveness is fundamental in the creation of an efficient and economically viable omnidirectional conveying system.

3.1.2 Collect information from the market omnidirectional conveyor design

The scholarly journal extensively explores the mechanical design aspects inherent to omnidirectional conveyors, providing detailed insights into the deployment of specialized components, specifically omnidirectional conveyor units integrating multiple omnidirectional conveyor wheels. This deliberate design choice is of particular significance due to its capacity to facilitate continuous and fluid motion within both two-dimensional (2D) and three-dimensional (3D) spatial environments. The integration of multiple omnidirectional wheels within these conveyor units contributes substantively to heightened maneuverability and adaptability, thereby enabling the conveyor system to navigate seamlessly in all directions. This literature-derived revelation underscores the paramount importance of incorporating omnidirectional conveyor wheels and units as integral components in achieving optimal performance and versatility in material handling processes across a spectrum of spatial orientations.

Additionally, conducting comparative benchmarks against existing omnidirectional conveyor systems, with a particular focus on metrics including efficiency, modularity and control capability, constitutes a valuable methodology for establishing performance benchmarks and clarifying much-needed design requirements. Through a careful examination of the operational efficiency of existing systems, a critical evaluation of the modular aspects of their design, and a thorough evaluation of the effectiveness of the control mechanisms used, a nuanced and comprehensive understanding of industry standards and optimal practices is realized. This benchmarking protocol facilitates the determination of important performance indicators and design criteria, thereby guiding the formulation of innovative omnidirectional conveyor systems that are ready to not only meet but potentially exceed established benchmarks, particularly in terms of holistic efficiency, modular adaptability and accuracy in control functions.

3.1.2.1 Product specification.

This section will explain the product specification required in the omnidirectional conveyor product during the developing process by performing the user need translation, technical specification, similar product benchmark, and the house of quality analysis approaches.

3.1.2.1.1 Translation of each User Needs.

Here are the product specifications for omnidirectional conveyor products derived from survey analysis by translating user needs.

1) Performance and Efficiency
   i. **Speed and Durability:** The system should handle high volumes of material with efficient movement to maintain or increase production rates.

ii. **Payload Capacity:** The ability to transport various sizes and weights of loads without compromising performance.

2) Flexibility and Adaptability

i. **Multi-Directional Movement:** The ability to move in any direction (forward, backward, sideways and rotational) to navigate complex paths and tight spaces.

ii. **Scalability:** The ability to easily expand or reconfigure the system as production demands grow or change.

iii. **Versatile:** Suitable for a wide range of materials and packaging, from small parts to large pallets.

3) Safety and Ergonomics.

i. **Employee Safety:** Safety features to prevent accidents, such as emergency stops, safety guards, and collision avoidance systems.

ii. **Ergonomics:** Designs that minimize physical stress on workers, such as easy access for loading and unloading.

4) Reliability and Maintenance.

i. **Durability:** Robust construction to withstand harsh industrial environments, including exposure to dust, chemicals and extreme temperatures.

ii. **Low Maintenance:** Minimal maintenance requirements with easy access to components for repair and replacement.

5) Cost and ROI.

i. **Initial Investment:** Competitive pricing that fits operating budget constraints.

ii. **Operating Costs:** Energy efficient systems that minimize operating costs.

iii. **Return on Investment (ROI):** Clear benefits in terms of productivity, efficiency and cost savings over time.

6) Customization and Support.

i. **Customization Options:** The ability to customize the system to meet specific operational requirements, including size, speed, and load handling characteristics.

ii. **Technical Support:** Availability of robust customer support and training services for installation, operation and troubleshooting.

7) Environmental Considerations.

i. **Energy Efficiency:** Systems that use less power and contribute to lower overall energy consumption.

ii. **Sustainability:** The use of environmentally friendly materials and processes in the manufacture of the conveyor system.

3.1.2.1.2 Technical Specification.

The technical specifications for omnidirectional industrial conveyor systems are detailed criteria that ensure the system meets performance, safety, and operational standards. Below are the key technical specifications:

1) Mechanical specifications.

i. **Load Capacity:** Maximum load weight per unit area (eg, kg/m²).

ii. **Conveyor Speed:** Adjustable speed range (eg, 0.1 to 2 meters per second).

iii. **Dimensions:** Length, width and height of the conveyor unit, including the size of the modular parts.

iv. **Material Handling Capacity:** The type and size of material that can be handled (eg, pallet size, box dimensions).

v. **Drive System:** The type of drive mechanism used (eg, electric motor, servo motor).

2) Movement Ability.

i. **Degrees of Freedom:** Number of axes of movement (eg, forward/backward, lateral, rotational).

ii. **Movement Accuracy:** Position and movement accuracy (eg, ±1 mm).

3) Safety features.

i. **Emergency Stop:** Presence and type of emergency stop mechanism.

ii. **Collision Avoidance:** The type of collision avoidance system used.

4) Construction and Durability.

i. **Frame Material:** The type of material used for the conveyor frame (eg, stainless steel, aluminum).

ii. **Surface Material:** Type of conveyor surface (eg, rubber, PVC, metal roller).

iii. **Durability:** Specifications on operational life and maintenance intervals.

iv. **Environmental Resistance:** Resistance to environmental factors (eg, temperature range, humidity, chemical exposure).

5) Power and Energy Specifications.

i. **Power Supply:** Voltage and frequency requirements (eg, 220V, 50/60Hz).

ii. **Energy Consumption:** Average and peak power consumption (eg, kWh).

6) Environmental Specifications.

i. **Operating Temperature Range:** Minimum and maximum operating temperature.

ii. **Humidity Range:** Acceptable humidity level for operation.

iii. **Sound Level:** Maximum noise output (eg, dB level).

7) Maintenance and Serviceability.

i. **Maintenance Requirements:** Regular maintenance tasks and intervals.

ii. **Accessibility:** A design feature that allows easy access for maintenance and repair.

iii. **Spare Parts Availability:** Spare parts availability and specifications.

8) Customization Options.

i. **Modularity:** Ability to add or remove parts.

ii. **Configuration Options:** Different configurations for specific applications (eg, heavy duty, high speed).

iii. **Custom Features:** Availability of custom features to meet specific user needs.

3.1.3 Benchmarking on Existing/Similar Products.

3.1.3.1 Similar Product 1.

Product Name: Dynamic Conveyor ***(Dynamic Conveyor, 2024)***

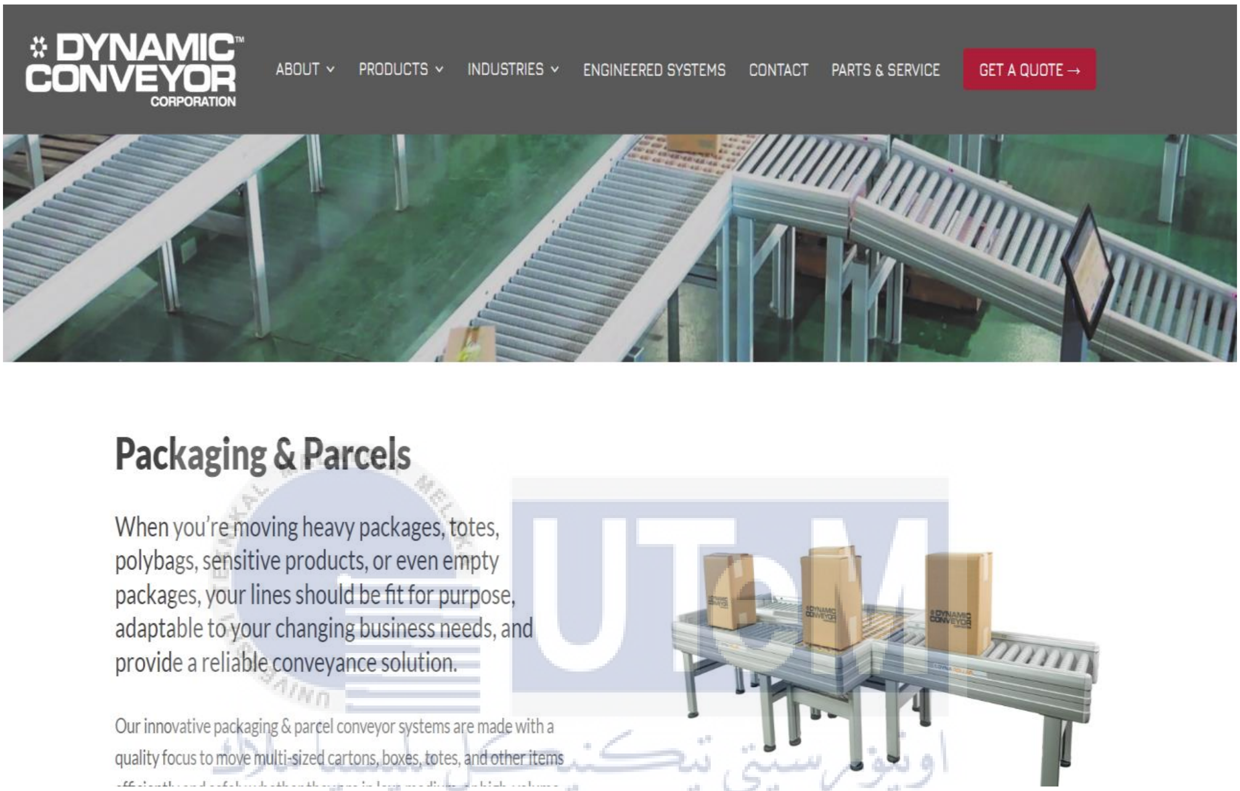


Figure 3.3: Dynamic Conveyor.

Product Description.

Dynamic Conveyor Corporation produces advanced conveyor systems that aim to increase efficiency and productivity in material handling processes. Our offerings include customizable modular conveyors, customizable DynaCon systems, hygienic DynaClean conveyors for food handling, and bespoke hybrid specialty conveyors. In addition, we provide a wide range of accessories and options, including conveyor belts, side guards, motor configurations and automation solutions. Choose Dynamic Conveyors to benefit from a flexible, robust and environmentally sustainable solution that improves operational performance.

The key features of the Dynamic conveyor include:

- Customizable Modular Conveyors: Easily adjustable and reconfigurable to meet changing needs.
- Versatile DynaCon Systems: Tailored designs for specific operational requirements with easy maintenance.
- Sanitary DynaClean Conveyors: Hygienic and easy to clean, ideal for food handling and compliant with safety standards.
- Hybrid Specialty Conveyors: Custom-engineered solutions for unique and challenging applications.
- Comprehensive Accessories and Options: A variety of conveyor belts, side guards, motor options, and automation systems to enhance functionality and efficiency.

Functionality.

Dynamic Conveyor systems are designed to efficiently transport materials within industrial settings. They offer:

- Customizability: Modular designs that can be easily adjusted and reconfigured to fit specific operational needs.
- Versatility: Suitable for a wide range of applications, from general material handling to specialized processes like food handling.
- Reliability: Robust construction using high-quality materials ensures durability and long-term performance.

Advantages.

- Flexibility: Modular components allow for easy adaptation to changing production requirements.
- Efficiency: Enhances workflow by streamlining material handling processes.
- Customization: Tailored solutions cater to unique operational challenges, improving overall efficiency and productivity.
- Hygiene: DynaClean conveyors meet food safety standards with easy-to-clean designs, reducing contamination risks.

Disadvantages.

- Cost: Initial investment and maintenance costs can be higher compared to standard conveyor systems.
- Complexity: Custom configurations may require specialized knowledge for installation and maintenance.
- Space Requirements: Depending on the configuration, modular systems may occupy more floor space than traditional conveyor setups.

3.1.3.2 Similar Product 1.

Product Name: Omnia *(Omnia Wheel, 2023)*

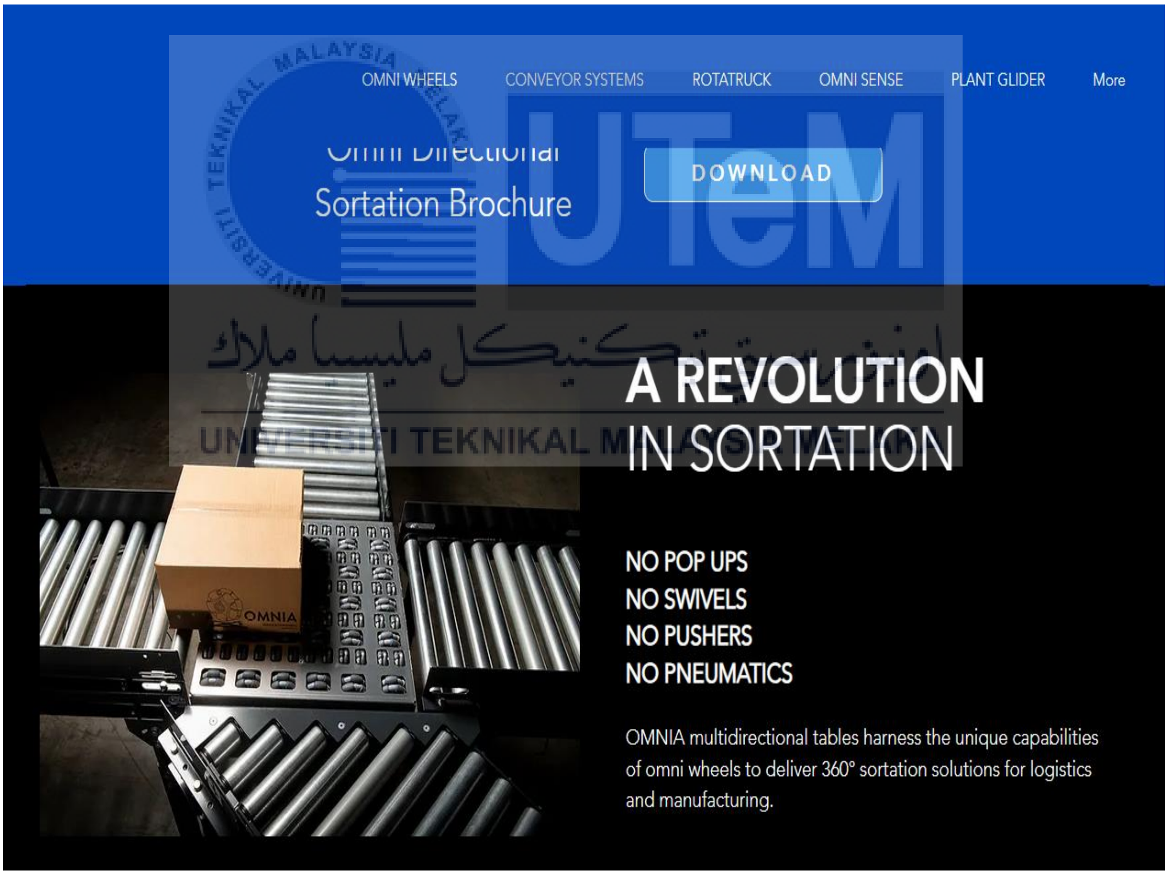


Figure 3.4: Omnia.

Product Description.

Omniawheel focuses on advanced wheel technologies that improve mobility and transportation solutions. Their offerings feature Omniawheel systems capable of moving in multiple directions, adaptable designs for various uses, and efficient solutions designed to optimize maneuverability and energy efficiency. By utilizing state-of-the-art materials and integrated technologies, Omniawheel ensures durable and dependable performance across different sectors, facilitating smooth operations and enhancing productivity.

The key features of the Omnia include:

- Multidirectional Capability: Omniawheel systems can move in multiple directions, enhancing maneuverability.
- Customizable Designs: Tailored solutions for diverse applications, allowing flexibility in deployment.
- High Efficiency: Optimized for energy consumption and maneuvering efficiency, contributing to improved operational performance.
- Advanced Materials: Utilization of cutting-edge materials for durability and reliability in various environmental conditions.
- Integrated Technologies: Compatibility with advanced control systems and automation, ensuring seamless operation and enhanced user experience.

Functionality.

Omnia is designed with advanced wheel technology that enables multi-directional movement, enabling smooth maneuverability in multiple directions. It is designed to enhance mobility and transportation solutions across different industries by providing versatile mobility capabilities.

Advantages.

- Multi-Directional Movement: Enables smooth and precise movement in all directions, increasing flexibility and efficiency in handling tasks.
- Adaptability: Offers a design that can be adapted to meet specific application requirements, adapting to a variety of operational requirements.
- Energy Efficiency: Optimized to reduce energy consumption during operation, contributing to cost savings and environmental sustainability.
- Durability: Using advanced materials that ensure longevity and reliability, suitable for demanding industrial environments.

- Enhanced Productivity: Facilitates enhanced productivity by streamlining movements and reducing handling time.

Disadvantages.

- Initial Cost: Higher initial investment compared to traditional wheel systems due to advanced technology and materials.
- Complexity: Requires specialized knowledge for installation, maintenance and integration with existing systems.
- Space Requirements: Depending on the configuration, the Omnia system may require more space than a conventional wheel setup.

3.1.4 House of Quality (HOQ).

The House of Quality (HOQ) methodology commences by discerning customer requisites and converting them into technical specifications. This is accomplished via a matrix that delineates the interrelationships between customer needs (WHATs) and technical requirements (HOWs), allocating significance and contentment evaluations to each intersection. This matrix facilitates prioritization of technical endeavors based on their impact on customer contentment, directing the design and advancement process towards achieving specific objectives and refining product excellence. It represents a structured approach ensuring continual alignment with evolving customer demands and preferences, thereby promoting ongoing enhancement and innovation in product development and quality assurance.

3.2 Design and development of Omnidirectional Conveyor.

The procedure of conceptualizing and fabricating an omnidirectional conveyor, undertaken to transform raw materials into a finished product based on the chosen design, is elucidated through a flow chart, as depicted in figure 3.2. This section will expound upon the intricacies of the production process integral to product development, along with an analysis of the efficacy exhibited by the resultant product.

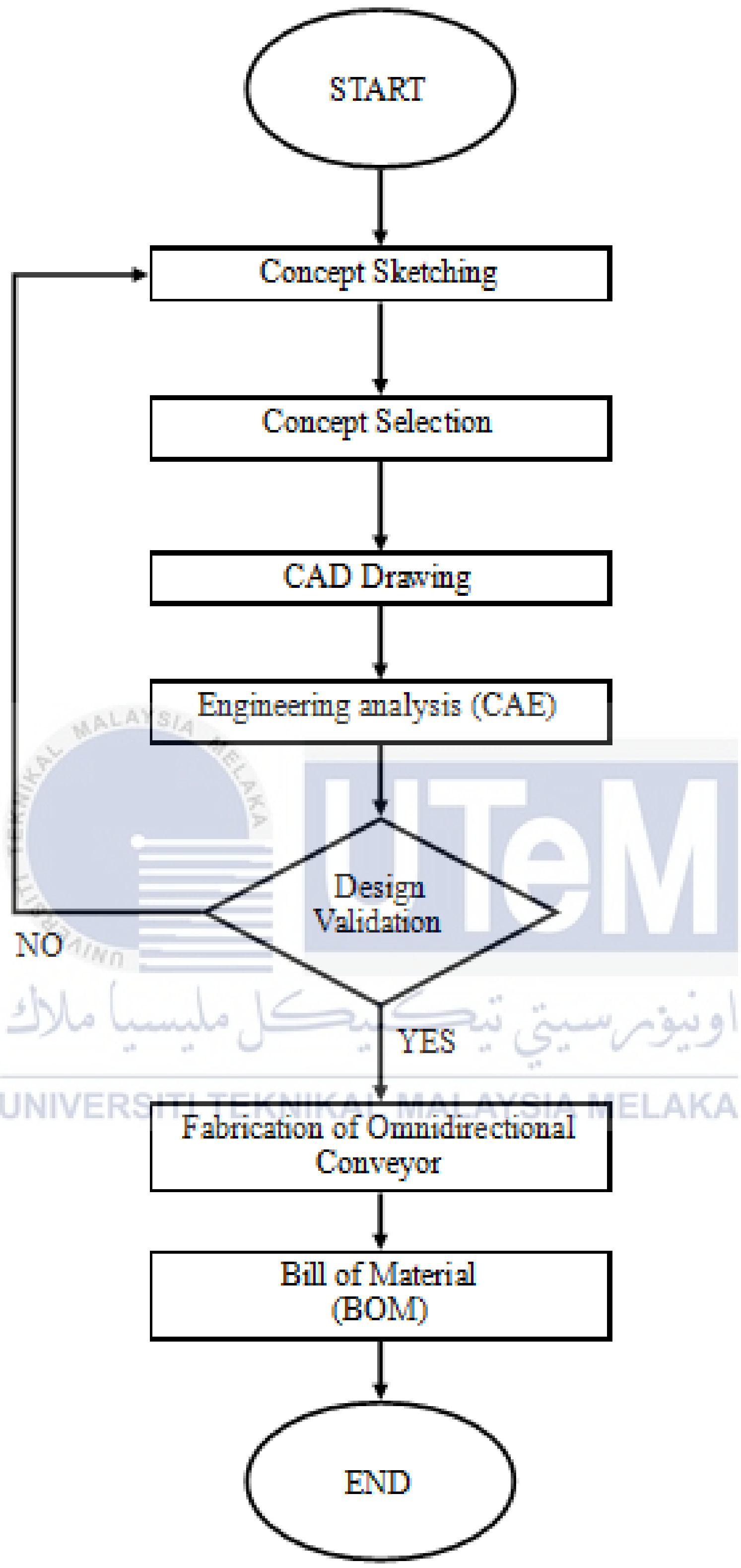
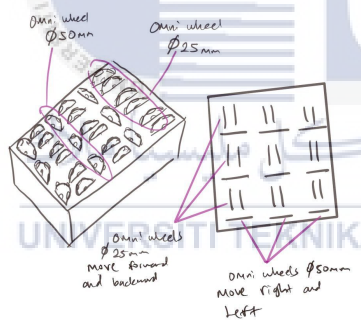
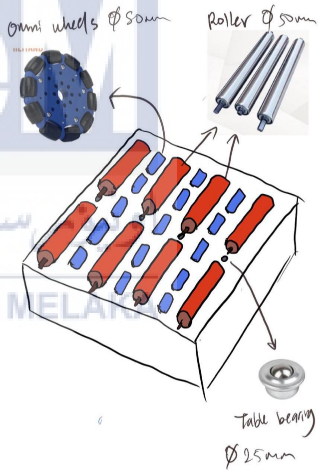
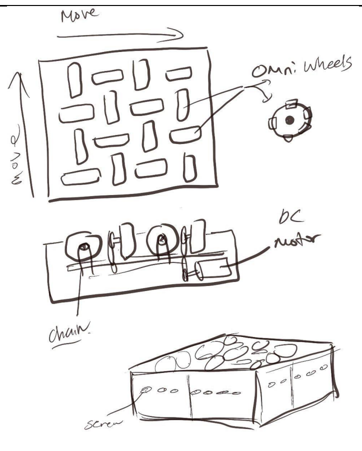
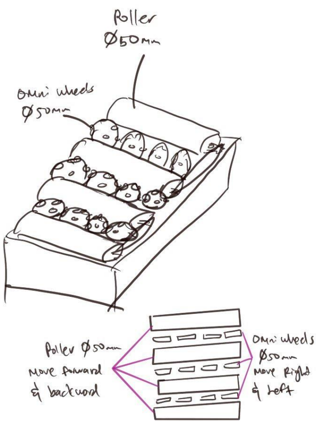


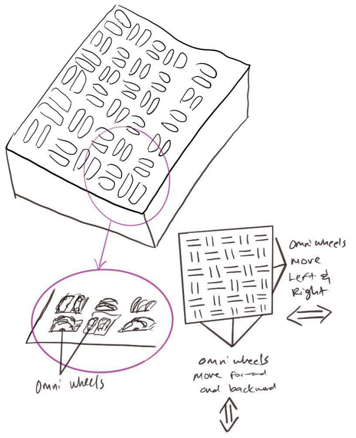
Figure 3.5: Flow chart of design and development of Omnidirectional Conveyor.

3.2.1 Concept sketching.

In the conceptual design phase of product development, a comprehensive depiction of the overarching concept of the product was formulated. Diverse models of the omnidirectional conveyor shelf were incorporated directly in response to the articulated requirements of ultimate consumers. Preliminary drawings played a pivotal role in scrutinizing the intricate technical dimensions of the design, affording early insights and potential resolutions to challenges, constraints, and opportunities, encompassing factors such as structure and construction techniques, in advance of the product's development for end-user application. The conceptual design details of the discussed product are presented in Table 3.1.

Table 3.1: Product conceptual design.

Concept	Design	Concept	Design
1		4	
2		5	

3	

3.2.2 Concept selection.

The process of concept selection served as a fundamental analytical instrument employed to refine a compilation of prospective product concepts to a singular, superior concept. This methodological approach aided in the identification of the most pragmatic and viable alternative among a spectrum of proposed conceptual sketches. Within this framework, two distinct procedural classifications were demarcated: concept screening and concept scoring.

3.2.3 Concept screening.

Concept screening denotes a method utilized to diminish the multitude of ideas typically generated for a novel product by refining the scope of the process. The ensuing steps outline the procedural sequence adhered to during the screening of the implementation concept.

The initial step involved in this methodology was the formulation of a comprehensive table delineating the criteria and ideas pertinent to the approach. The selection criteria necessitated a correlation with customer requirements, and the conceptual origins were to be traced back to ideas generated through the process of conceptual sketching. Subsequent to constructing the matrix, symbols denoted as (+, 0, and -) were assigned to evaluate each category against the reference concept. The symbol (+) indicated superiority, (0) denoted equivalence, and (-) signified inferiority in comparison to the concept reference. The cumulative frequency of rating scales for each concept was amalgamated, enabling the determination of the net score by subtracting the frequency of "-" from that of "+". The significance of each concept was established by its comparative performance against others. Decision-making processes involved considerations such as eliminating the concept with the lowest score or amalgamating two concepts, retaining only features marked with a "+". Upon the completion of the concept screening phase, the initial concepts were narrowed down to two or three, subsequently subjected to further refinement in subsequent investigations. The conceptual framework for the concept screening method is presented in Table 3.2.

Table 3.2: Framework of concept screening

Selection criteria	Concept 1	Concept 2	Concept 2	Concept 4	Concept 5
Performance and Efficiency.	+	-	-	+	+
Safety.	-	+	+	+	-
Reliability and Maintenance.	-	-	+	-	+
Customization and Support.	-	-	-	+	+
Flexibility and Adaptability.	+	+	-	-	+
Sum '+' s	2	2	2	3	4
Sum '0' s	3	3	3	2	1
Total	-1	-1	-1	1	3
Rank	5	5	5	2	1
Continue	NO	NO	NO	YES	YES

3.2.4 Concept scoring.

Concept scoring represented an enhanced and intricately detailed iteration of the concept screening process. A table akin to the one constructed for concept screening was devised, with the refinement of incorporating weights for each criterion. The determination of the weight assigned to each criterion was contingent upon the prioritized demands associated with these criteria. Utilizing a rating scale ranging from 1 to 5, each presented idea was systematically assessed in accordance with the parameters outlined in Table 3.3.

Table 3.3: Rate for concept scoring rating

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

To ascertain the comprehensive score, the summation of the assigned weight and rating for each selection criterion was computed and subsequently multiplied by the total count of criteria. When computing the aggregate scores for each concept, the cumulative weights for all ideas were totaled. Ultimately, the concepts were arranged in ascending order based on their overall scores, and the concept securing the highest score was chosen for further development into a finalized concept, delineated in Table 3.4.

Table 3.4: Concept scoring

Evaluation Criteria	Weight (%)	Concept 4		Concept 5	
		Ranking (1-5)	Weight score	Ranking (1-5)	Weight score
Performance and Efficiency.	30	4	1.2	5	1.5
Safety.	10	5	0.5	2	0.2
Reliability and Maintenance.	15	5	0.75	4	0.45
Customization and Support.	30	2	0.6	5	1.5
Flexibility and Adaptability.	15	2	0.3	5	0.3
Total Score		3.35		3.95	
Rank		2		1	
Continue		NO		YES	

3.2.5 CAD drawing.

An identified front-end tool for omnidirectional conveyor design and development featured CAD Software. In particular, Computer Aided Design (CAD) software, exemplified by applications such as CATIA, has emerged as an important resource for them and refining the mechanical constituents important to conveyor systems. This state-of-the-art software facilitates a comprehensive and precision-driven approach to iteratively conceptualize, model and improve mechanical elements, emphasizing its importance in the advanced process of omnidirectional conveyor design and development.

Computer-Aided Design (CAD) is a method employing computer software for the generation of three-dimensional (3D) models, enabling the visualization of product structures. In this study, CAD drawings were generated using Catia V5. An illustration of a 3D model crafted with Catia V5.

3.2.6 Engineering analysis (CAE).

A thermal structural analysis report performed using ANSYS software is presented in this paper. The aim of this analysis is to measure the strength performance of omni wheels and rollers to find heat flow, heat flux, total deformation, equivalent stress and safety factor. The investigation considers diverse operating conditions and offers insight into static structural tactics to improve design.

3.2.7 Fabrication of Omnidirectional Conveyor.

Fabrication is the procedural transformation of raw or semi-finished materials into final goods. This undertaking can be initiated through the utilization of either raw materials or semi-finished materials. In this segment, each fabrication technique essential for the production of an omnidirectional conveyor is delineated through a flowchart, as presented in figure 3.6, and will be elaborated upon comprehensively within this section.

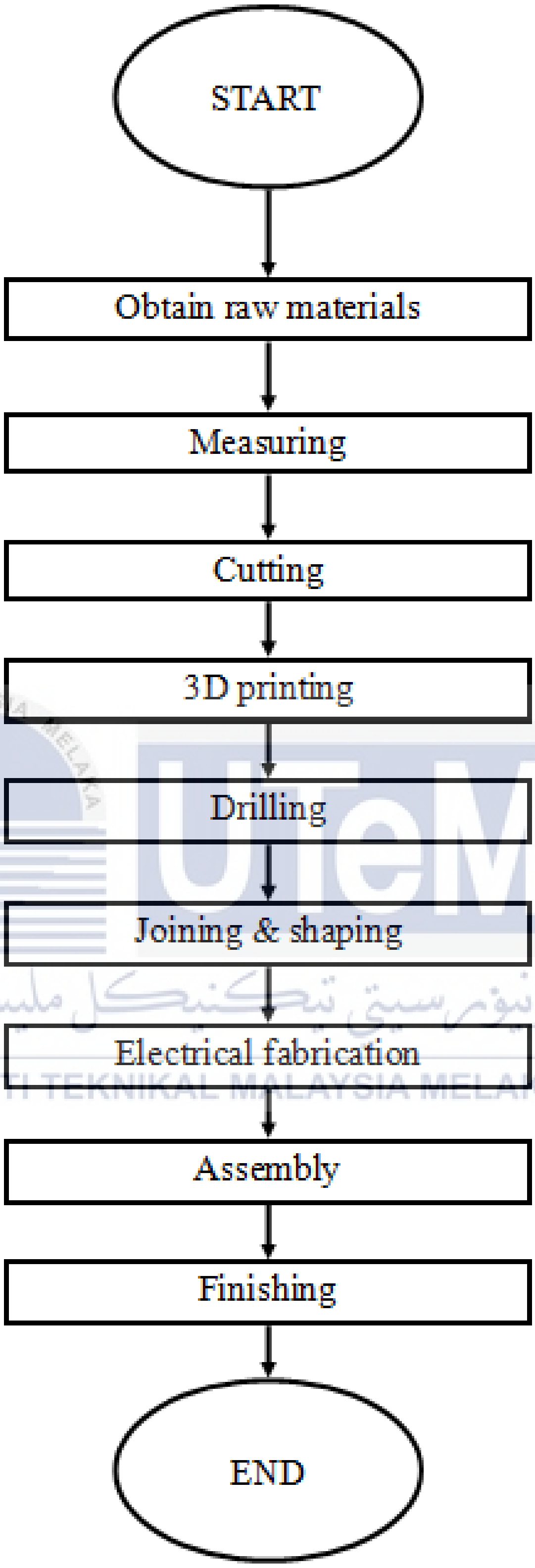


Figure 3.6: Flowchart of fabrication a omnidirectional conveyor.

3.2.7.1 Obtain raw materials.

3.2.7.2 Measuring & Marking.

The marking methodology serves as a means to transfer a design onto a workpiece. In the manufacturing of individual-piece articles, this procedure encompasses initial steps essential for subsequent operations, including cutting, forming, and joining. Precision in marking is crucial, necessitating careful adherence to the measurements outlined in the drawings to ensure the accuracy of the final product's dimensions.

3.2.7.3 Cutting.

The cutting operation involves the utilization of a cutting tool to sever material in accordance with predetermined measurements or marks on the work material.

3.2.7.4 3D printing

The 3D printing methodology involves several key steps to transform a digital design into a physical object using additive manufacturing technology. Initially, 3D models were created using Computer-Aided Design (CAD) software. This digital model is then sliced into thin horizontal layers by slicing software, which generates instructions (G code) for the 3D printer. The printer then deposits the material layer by layer, such as plastic. Post-processing steps may include removing the support structure, sanding or curing, depending on the material used. This process enables complex geometries, customization and rapid prototyping, revolutionizing manufacturing across multiple industries from aerospace to medical. D printing.

3.2.7.5 Drilling.

The drilling procedure is employed for the creation of a circular cross-sectional hole in solid materials. In this process, a hand drill, featuring drill bits that are threaded into it, is utilized. Notably, two distinct categories of drill bits are applied, denoted as "pilot drill bits" and "osteotomy widening drill bits.

Conventional procedure dictates the initiation of hole drilling with a smaller pilot drill, followed by transitioning to a larger drill to finalize the drilling process. Employing the appropriate pilot drill is imperative to prevent the larger drill from slipping on the material being drilled, thereby mitigating potential safety hazards and averting project failure.

3.2.7.6 Joining & shaping.

Welding is a manufacturing process used to join materials, usually metals or thermoplastics, by inducing their melting. This procedure involves the melting of the workpiece, and in certain cases, the introduction of a filler material, resulting in the formation of a molten pool that solidifies into a solid joint upon cooling. Widely used in various industries for construction and structural integration, the current project uses Metal Inert Gas (MIG) welding for the assembly of frame components and body plates. MIG welding uses a disposable wire electrode and a shielding gas to protect the weld pool from atmospheric contaminants, making it a widely adopted method known for its efficiency and adaptability. Furthermore, subsequent shaping such as banding is used to bend the omnidirectional body of the conveyor.

3.2.7.7 Electrical fabrication.

Electrical fabrication includes the systematic creation and integration of electrical systems or devices. It begins with the design phase using CAD software for schematic development and component selection. Following this, materials are acquired, and assembly involves complex tasks such as soldering, wiring, and integrating components into a cohesive unit. Comprehensive testing verifies functionality and compliance to standards, with strict quality control measures implemented. Process documentation and regulatory compliance are essential, culminating in careful packaging and shipping to ensure accuracy and compliance to the specifications required for a reliable electrical system.

3.2.7.8 Assembly.

The assembly procedure is a technique wherein components of a product are interconnected through either permanent or semi-permanent methods in a pre-established sequence until the finalization of the product. The integration of product segments is achieved through the application of a rivet, a bolt, and a nut, resulting in the formation of a cohesive structure.

3.2.7.9 Finishing.

The concluding phase in the fabrication process is the product finishing process. During this stage, alterations are made to the surfaces of the workpiece to eliminate machining marks, scaling, or pitting. The product finishing procedures can enhance both the appearance and performance of the product by eliminating burrs, commonly known as sharp edges. Following the finishing process, the material exhibits smooth edges.

3.2.8 Bill of Material (BOM).

A Bill of Materials (BOM), frequently referred to as such, serves as a centralized repository of information outlining all assemblies, sub-assemblies, parts, and raw materials essential for the production of a single unit of the ultimate product. The provided bill of materials furnishes comprehensive information including the quantity, value, and product description of each constituent component. The components comprising the omnidirectional conveyor are enumerated in Table 3.5, located subsequently.

Table 3.5: Bill of Materials (BOM).

Part No.	Part Name	Details	Material	Quantity	Cost per Unit (RM)	Cost (RM)
1	Side body	Thickness: 1.5mm Length: 983x295mm	GI Plate	1	RM 20.00	RM 20.00

2	Front body	Thickness: 1.5mm Length: 430x350mm	GI Plate	1	RM 12.00	RM 12.00
3	Backward body	Thickness: 1.5mm Length: 430x350mm	GI Plate	1	RM 13.00	RM 13.00
4	Acrylic side body	Thickness: 3mm Length: 230x180mm	Acrylic	2	RM 6.00	RM 12.00
5	Acrylic front body	Thickness: 3mm Length: 100x70mm	Acrylic	2	RM 3.00	RM 6.00
6	Acrylic backward body	Thickness: 3mm Length: 370x100mm	Acrylic	1	RM 5.00	RM 5.00
7	Mild steel hollow	Thickness: 1mm Length: 20x4000mm	Mild steel	1	RM 25.00	RM 25.00
8	Stainless steel roller	Thickness: 1mm Length: 250mm Diameter: 50mm	Stainless steel	4	RM 10.00	RM 40.00
9	Omni wheel	Thickness: 4.5mm Diameter: 50mm	Mild steel & PLA	12	RM 8.00	RM 96.00
10	Plate omni	Thickness: 3mm Length: 310x250mm	GI plate	1	RM 8.00	RM 8.00
11	Bearing roller	Thickness: 10mm Inner diameter: 15mm Out diameter: 25mm	Stainless steel	8	RM 6.00	RM 48.00
12	Bearing omni	Thickness: 10mm Inner diameter: 10mm Out diameter: 25mm	Stainless steel	12	RM 2.50	RM 30.00
13	Long gear	25H, 8teeh Length: 30mm	Mild steel	20	RM 9.00	RM 180.00
14	Short gear	25H, 8teeh Length: 20mm	Mild steel	21	RM 9.00	RM 189.00
15	Chain	25H	Steel	5	RM 14.00	RM 70.00

		Length: 500mm				
16	Rod stainless steel	Length: 250mm Diameter: 8mm	Stainless steel	4	RM 3.80	RM 11.20
17	Bearing rod stainless steel	Thickness: 30mm Inner diameter: 8mm Out diameter: 18mm	Stainless steel	4	RM 5.50	RM 22.00
18	Screw	M12	Mild steel	39	RM 0.50	RM 19.50
19	Bolt nut omni	M12	Mild steel	12	RM 0.30	RM 3.60
20	Control speed	12V DC motor speed controller reversible switch	Plastic	3	RM 24.00	RM 72.00
21	Converter AC to DC 10A	Power supply DC12V 10A transformer AC220V to DC12V converter	Aluminium Alloy	1	RM 37.00	RM 37.00
22	DC motor 248rpm	12VDC, torque 10kgf.cm, 5.5A, 41.3W Diameter: 8mm Length: 20mm	Aluminium Alloy	1	RM 265.00	RM 265.00
23	DC Motor 955rpm	12VDC, torque 10kgf.cm, 4.6A, 50.5W Diameter: 8mm Length: 20mm	Aluminium Alloy	1	RM 95.00	RM 95.00
23	12V Electric motor linear	DC gear push up down motion cylinder	Aluminium Alloy	1	RM 100.00	RM 100.00
24	Wire	2core, 15A Length: 1500mm Diameter: 1mm	Cooper	1	RM 10.00	RM 10.00
					TOTAL	RM 1388.30

3.3 Evaluation the functionality of Omnidirectional Conveyor

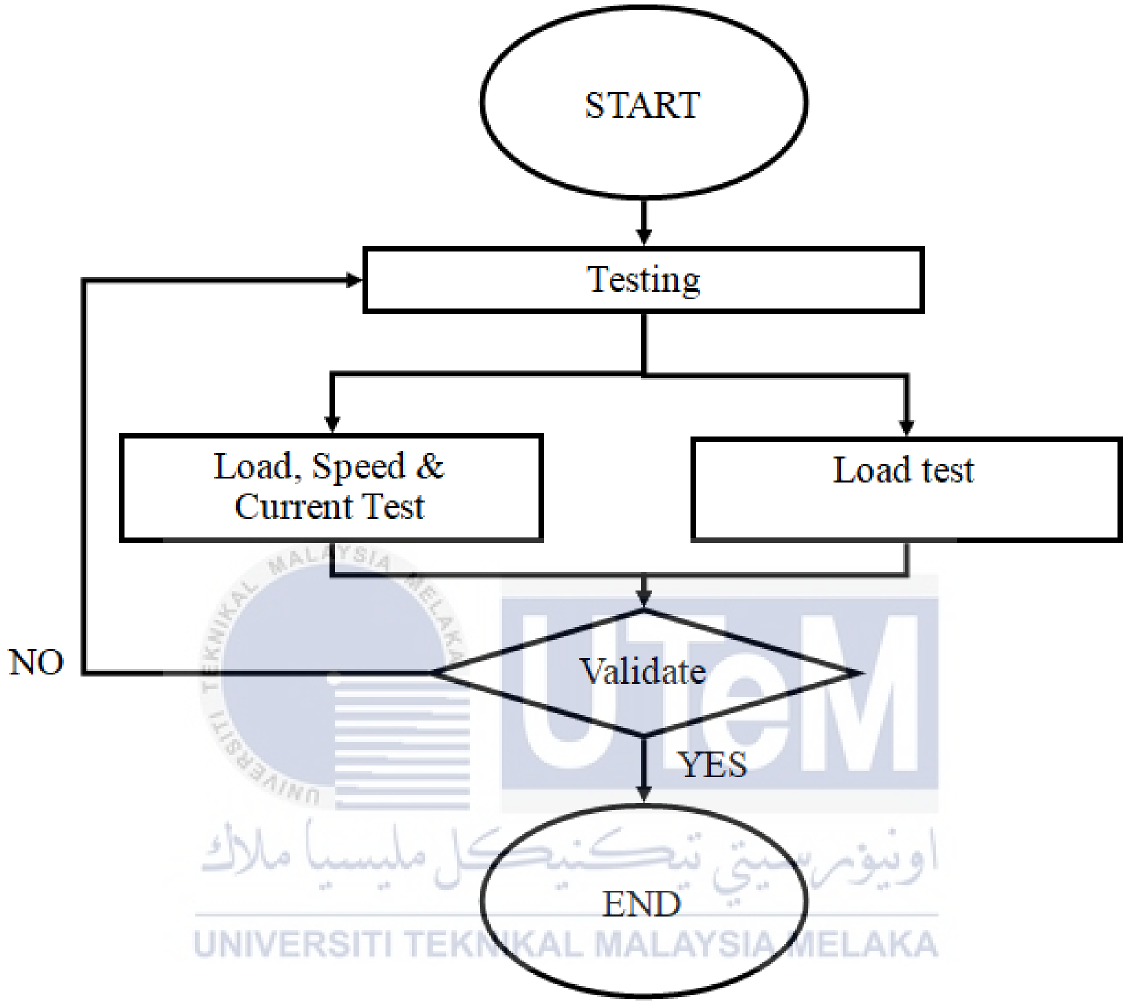


Figure 3.7: Flow chart the evaluation functionality of Omnidirectional Conveyor.

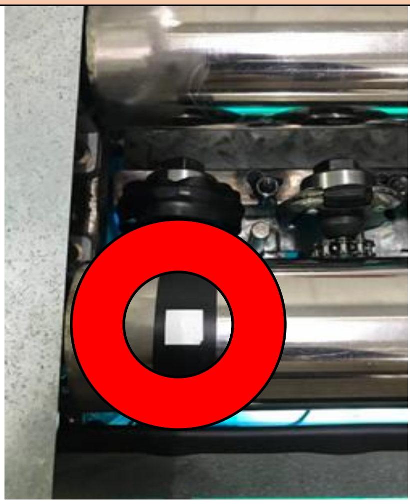
3.4 The procedure of load test.

This method use the equipment like Digital Revolution Per Minute (rpm) meter for speed test, Digital Multimeter for calculate the currant, and dumbbell for the load test at the Omnidirectional Conveyor product. Figure 3.6 show the digital rpm meter, digital multimeter, and dumbbell for the testing.

Figure 3.8: The digital rpm meter, digital multimeter, and dumbbell.

Table 3.6 show the method use for the speed test using the digital rpm meter at the Omnidirectional Conveyor product. Speed test at the roller and omni wheels conveyor.

Table 3.6: Step use digital rpm meter at the roller and omni wheels Conveyor.

Step	Picture	Description
Roller		
1.		Paste the reflective sticker on the roller for digital rpm meter use.
2.		Place a digital rpm meter on the roller to read the rpm speed.
3.		Put a load and a digital rpm meter on the roller to read the rpm speed.

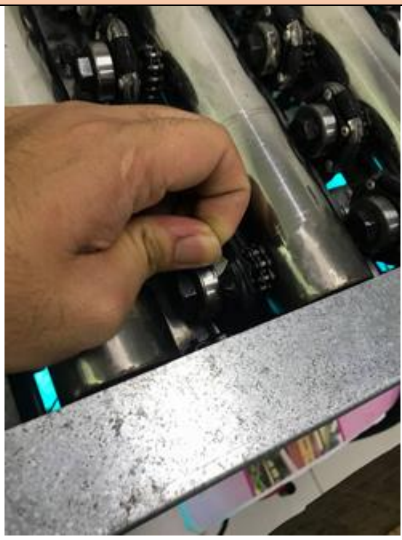
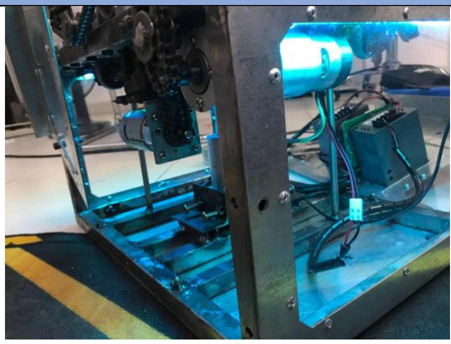
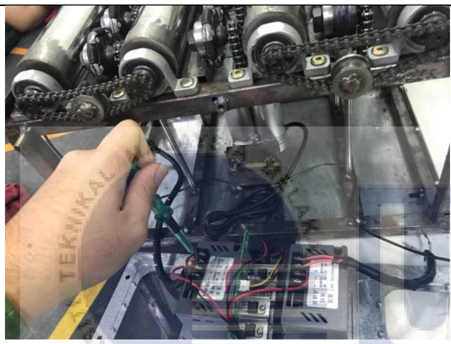
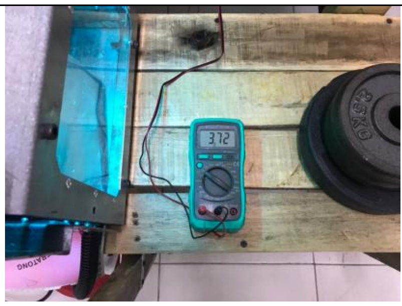
Omni Wheels		
1.		Paste the reflective sticker on the Omni wheel for digital rpm meter use.
2.		Place a digital rpm meter on the omni wheel to read the rpm speed.
3.		Put a load and a digital rpm meter on the omni wheel to read the rpm speed.

Table 3.7 show the method use for the current test using the digital multimeter at the DC motor roller and omni wheels at Omnidirectional Conveyor product.

Table 3.7: Step use the digital multimeter at the DC motor roller and omni wheels Conveyor.

Step	Picture	Description
1.		Open the omnidirectional conveyor body
2.		Disconnect the positive wire on the DC motor and connect it to the com wire on the digital multimeter and then the negative wire on the multimeter is connected to the positive slot on the DC motor.
3.		Test run DC motor after installing digital multimeter.
4.		Dapat bacaan currant pada digital multimeter

For the load test use the dumbbell which is diverse load and then put it in the box. Figure 3.9 show the sample the dumbbell put it in the box.

Figure 3.9: the sample dumbbell put it in the box for the load test at the Omnidirectional Conveyor product.

Figure 3.10 show the digital meter check temperature, this digital meter use for check the temperature at the DC motor roller and omni wheels after the all test.

Figure 3.10: the digital meter temperature and example for check temperature at DC motor.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Product and Technical Specification of Omnidirectional Conveyor.

These are product specifications and technical specifications derived from existing product benchmarks. table 4.1 below shows the product specifications and technical specifications before going through the house of quality (HOQ) process.

Table 4.1: Product and Technical Specification.

No.	**Product specification.**	Technical Specification.
1.	Performance and Efficiency	Mechanical specifications.
2.	Flexibility and Adaptability	Movement Ability.
3.	Safety and Ergonomics.	Safety features.
4.	Reliability and Maintenance.	Construction and Durability.
5.	Cost and return of investment (ROI).	Power and Energy Specifications.
6.	Customization and Support.	Maintenance and Serviceability.
7.	Environmental Considerations.	Environmental Specifications.

4.1.1 House of Quality (HOQ) of omnidirectional industrial conveyor.

The figure 4,1 below is a house of quality for the omnidirectional industrial conveyor product with their competitor.

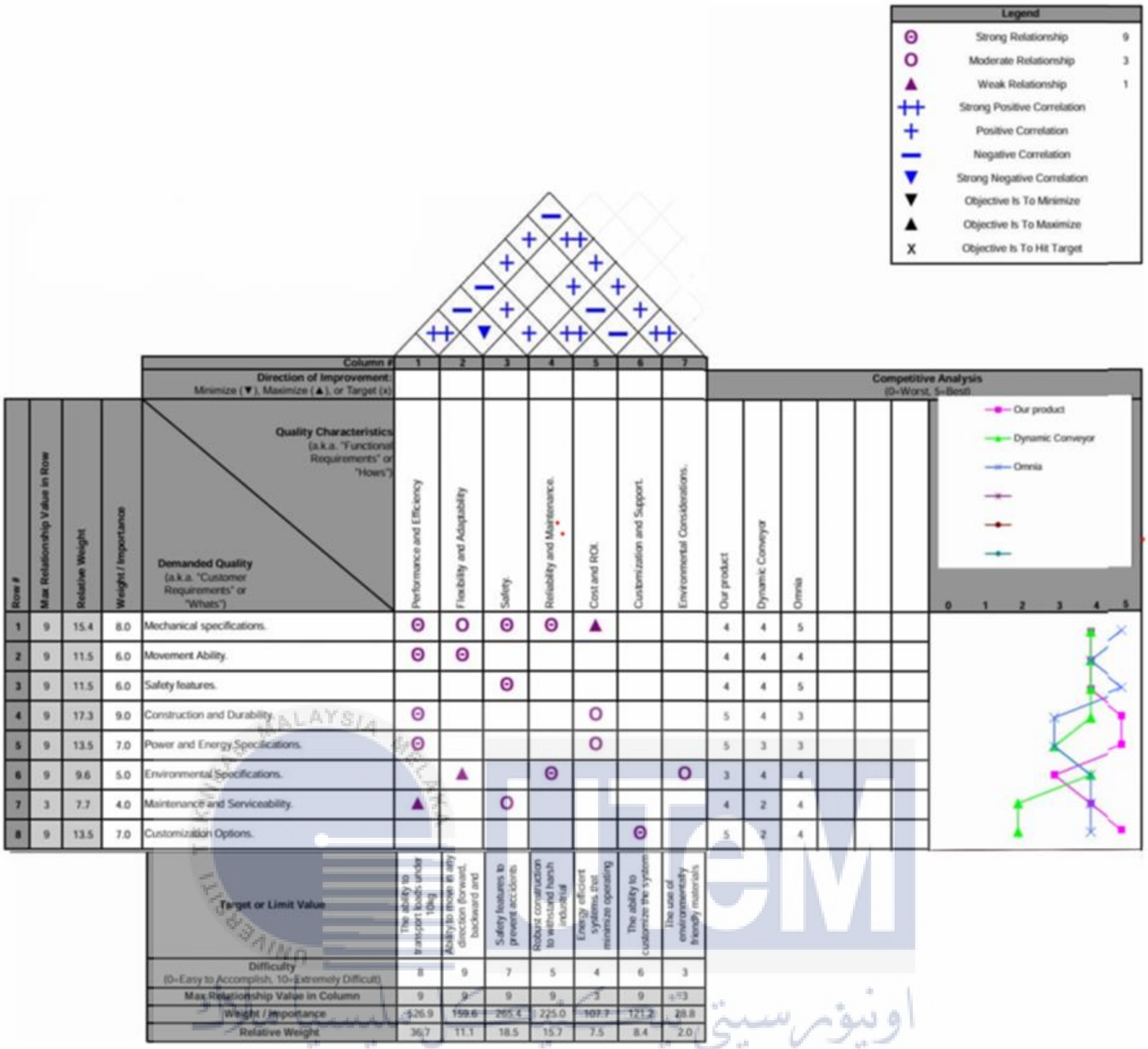


Figure 4.1: House of Quality (HOQ) of Omnidirectional Industrial Conveyor Product.

Based on the HOQ analysis above, the mechanical performance aspect is the highest demand by users requirements in technical specifications, which have a relative weight of 36.7, followed by safety features with 18.5, and reliability and durability with 15.7. Furthermore, a competitive analysis was performed to make comparisons and benchmarks from similar products on the market namely Dynamic Conveyor (Dynamic Conveyor, 2024) and Omnia (Omnia Wheel, 2023). Besides, Omnidirectional conveyor products can perform well in all aspects compared to similar products, except in a compact design because competing products are high cost and expensive to maintain.

4.1.2 List of the finalized Product Specification.

The table 4.2 below is the ranking of the technical specification of user needs according to the priority order.

Table 4.2: The ranking of priority technical specifications for the Omnidirectional Conveyor product.

Rank	Technical Specification	Description
1	Mechanical specifications.	Mechanical specifications outline the technical details and features of a mechanical system or component, including dimensions, materials, tolerances, and performance criteria.
2	Safety features.	Omnidirectional conveyors have safety sensors, protective guards and automatic shutdown to ensure safe operation and avoid accidents.
3	Construction and Durability.	The omnidirectional conveyor features robust construction and is designed for long-lasting durability.
4	Movement Ability.	The omnidirectional conveyor enables seamless movement in any direction, allowing for flexible and precise positioning.
5	Power and Energy Specifications.	Energy-efficient omnidirectional conveyors minimize operating costs.
6	Maintenance and Serviceability.	Omnidirectional conveyor are simplified through its modular design, easily accessible components, and integrated diagnostic systems.
7	Environmental Specifications.	Omnidirectional conveyors are designed to transport materials in any direction, using a system of multidirectional wheels or rollers for flexible and efficient movement.

Based on the table above, the most important aspect that consumers consider is the product mechanical performance aspects for packages. A strong product can be used by various package weights. Users can improve achievement performance in product markets and demand industries, especially new ones product platform. Next, the rating of safety features and aspects of reliability and durability are also necessary for product development to improve machine productivity and efficiency.

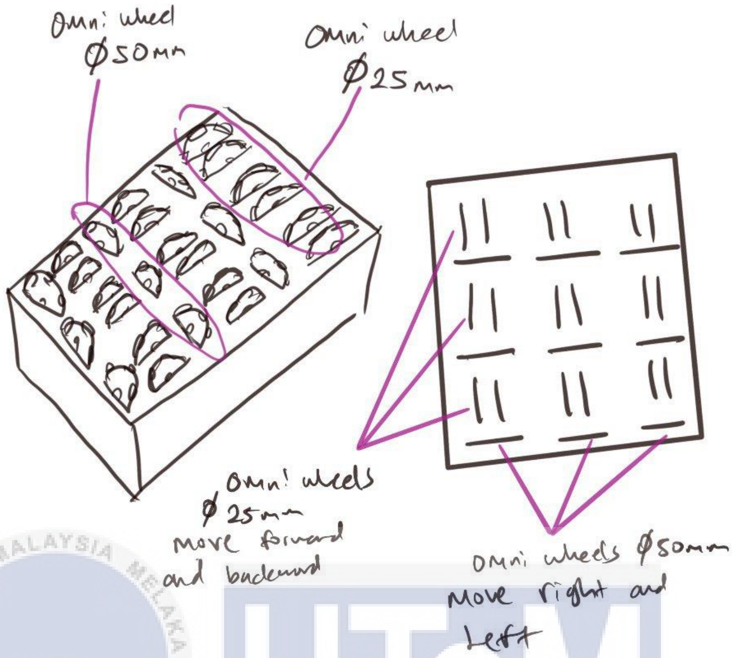
4.2 Design and Development of Omnidirectional Conveyor.

This section will discuss the design development process, which consists of initial conceptualization, concept screening, concept scoring, and detailed conceptualization phases.

4.2.1 Concept sketching.

The five best design concepts have been shortlisted to continue with the concept screening and scoring phase. Therefore, table 4.3 shows a sketch of five design conceptualization for the Omnidirectional Conveyor product.

Table 4.3: Product conceptual design.

<table>
<tr><th>No. of Concept</th><th>Sketching of Design Concept</th></tr>
<tr><td>1.</td><td>
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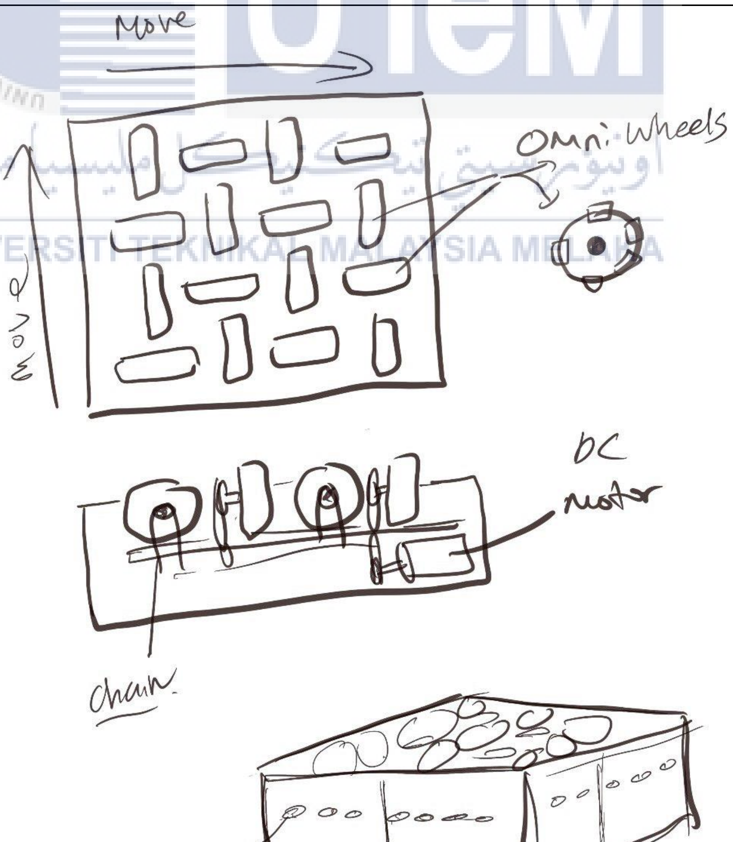
<tr><td>2.</td><td>
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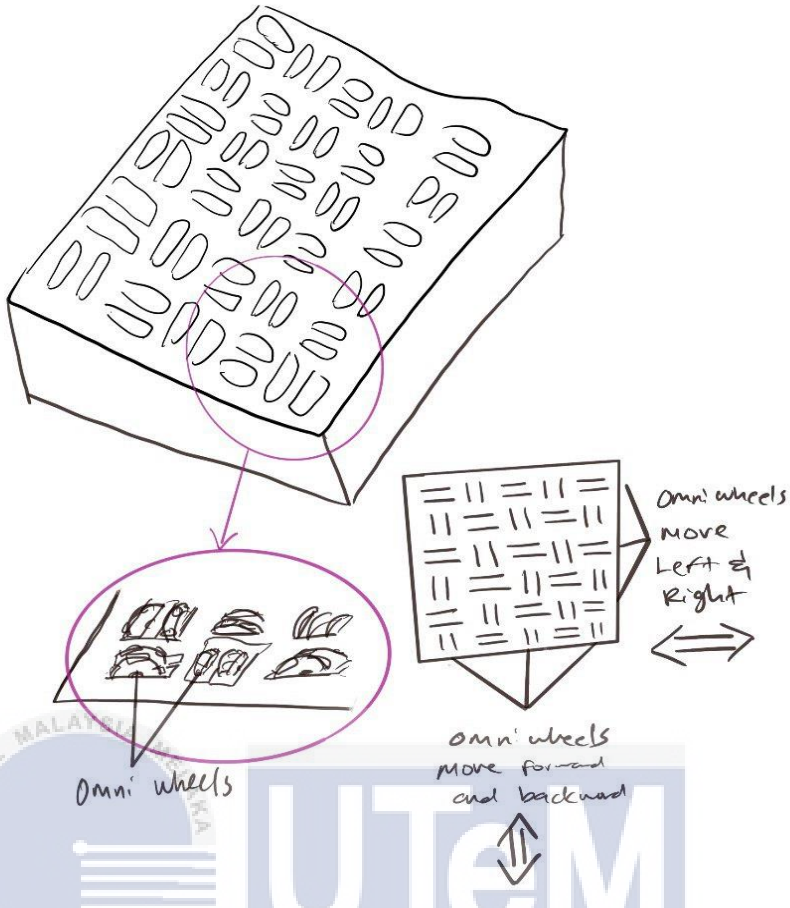
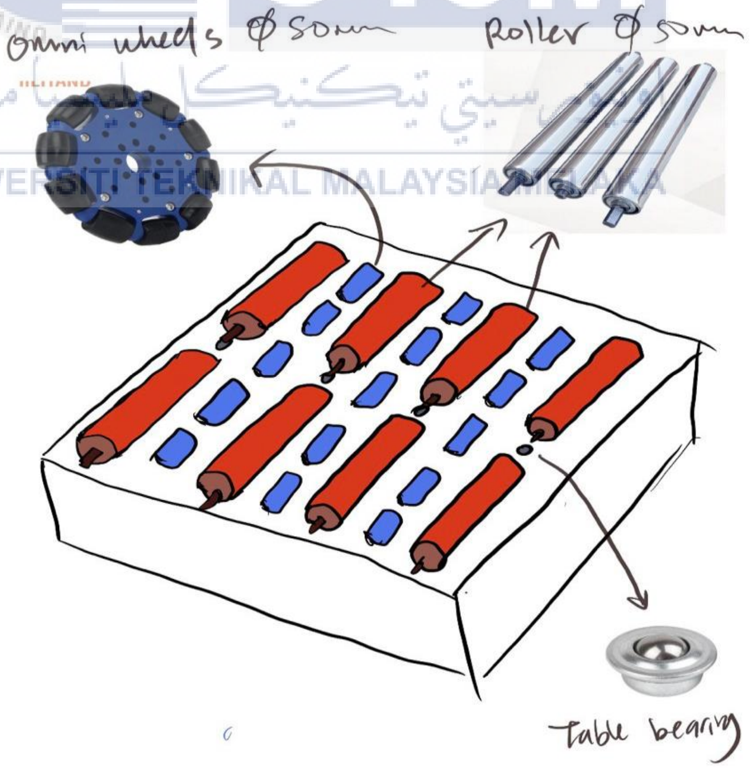
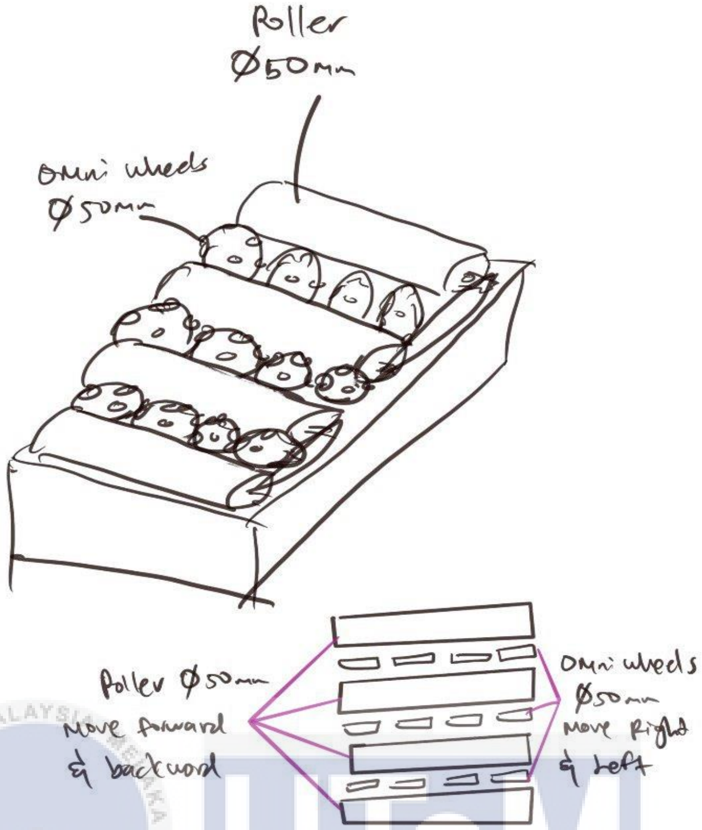
<tr><td>3.</td><td>
</td></tr>
<tr><td>4.</td><td>
</td></tr>
</table>

5.	

4.2.2 Concept Selection Process.

The discovery of the idea of the Omnidirectional transmitter concept is reviewed and discussed in this chapter. The best omnidirectional transmitter designs were selected using Concept Selection a process consisting of two stages: Concept Screening Matrix and Concept Scoring Matrix.

4.2.2.1 Concept screening.

Following the information from each previous design concept discussion, concept screening was done for the Smart Excursion Dryer product, as shown in Table 4.4. Based on the concept screening table below, according to the concept screening ranking as a result, concept 5 got the highest score, followed by concept 4. Therefore, the design concept 4 and 5 it was decided to proceed with the following procedure and conduct the concept scoring determine the best concept.

Table 4.4: Framework of concept screening

Selection criteria	Concept 1	Concept 2	Concept 2	Concept 4	Concept 5
Performance and Efficiency.	+	-	-	+	+
Safety.	-	+	+	+	-
Reliability and Maintenance.	-	-	+	-	+
Customization and Support.	-	-	-	+	+
Flexibility and Adaptability.	+	+	-	-	+
Sum '+' s	2	2	2	3	4
Sum '0' s	3	3	3	2	1
Total	-1	-1	-1	1	3
Rank	5	5	5	2	1
Continue	NO	NO	NO	YES	YES

4.2.2.2 Concept scoring.

According to Table 4.5, design concept 5 obtained the highest score position which is 3.95 compared to design concept 4, which only produced 3.35. Hence, the design concept 5 was chosen to produce the Omnidirectional Conveyor Product. Table 4.5 shows a concept scoring phase was conducted for the Omnidirectional Conveyor product.

Table 4.5: Concept scoring

Evaluation Criteria	Weight (%)	Concept 4		Concept 5	
		Ranking (1-5)	Weight score	Ranking (1-5)	Weight score
Performance and Efficiency.	30	4	1.2	5	1.5
Safety.	10	5	0.5	2	0.2
Reliability and Maintenance.	15	5	0.75	4	0.45
Customization and Support.	30	2	0.6	5	1.5
Flexibility and Adaptability.	15	2	0.3	5	0.3
Total Score		3.35		3.95	
Rank		2		1	
Continue		NO		YES	

4.2.3 Detail Conceptualization.

4.2.3.1 Sketching Conceptualization

Based on the concept scoring, concept 5 was chosen as the best design concept because it has the highest position in the design concept of examination and evaluation methods. Next, it is analyzed using the concept scoring evaluation method. Based on the results of the selection criteria, concept 5 is the best design concept that best matches the requirements. Figure 4.2 show the design concept that has been selected for the omnidirectional conveyor product.

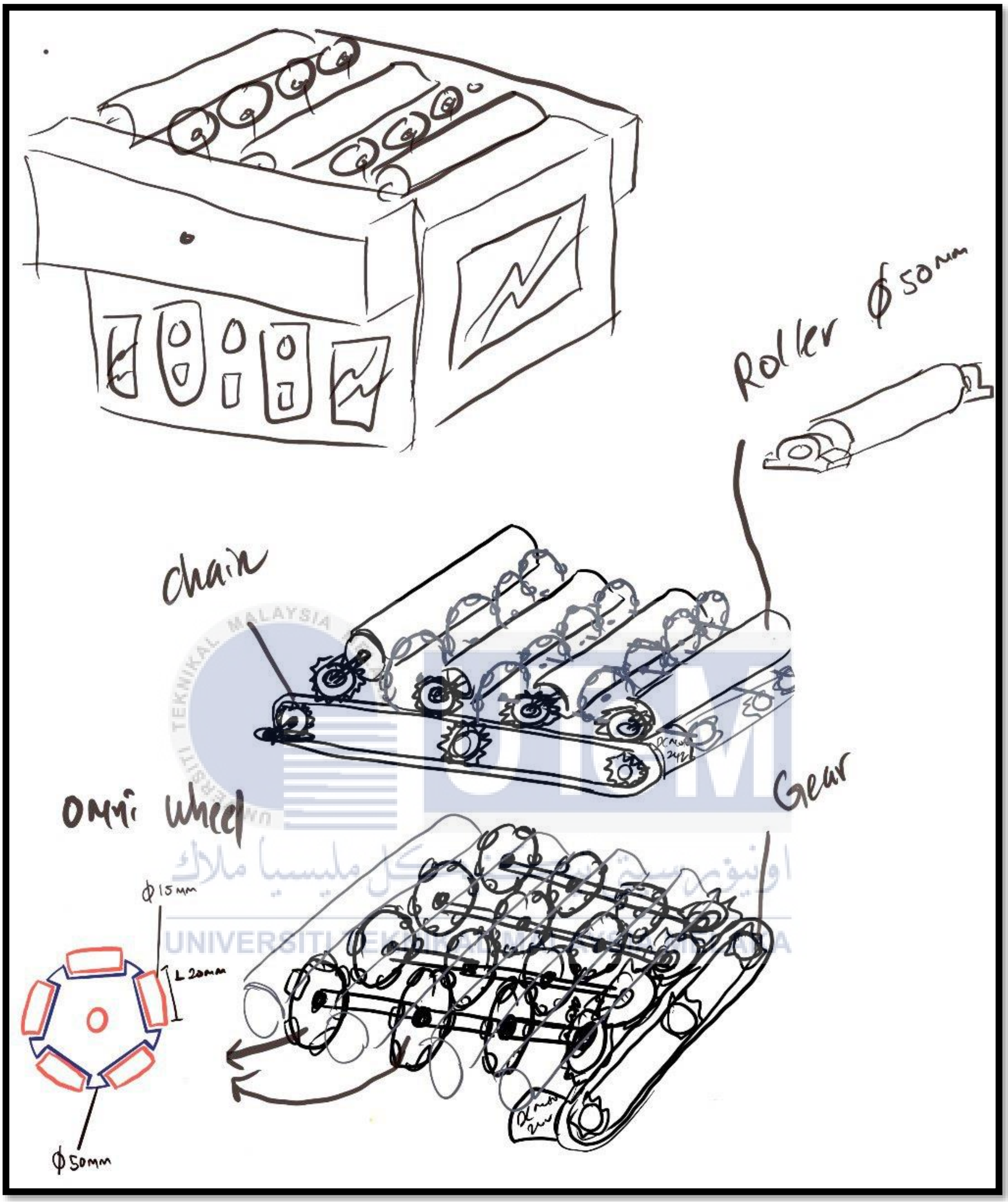
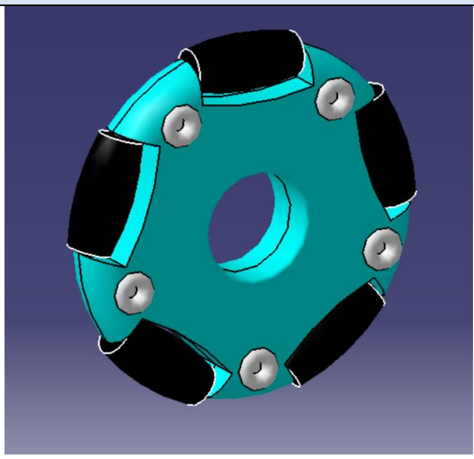
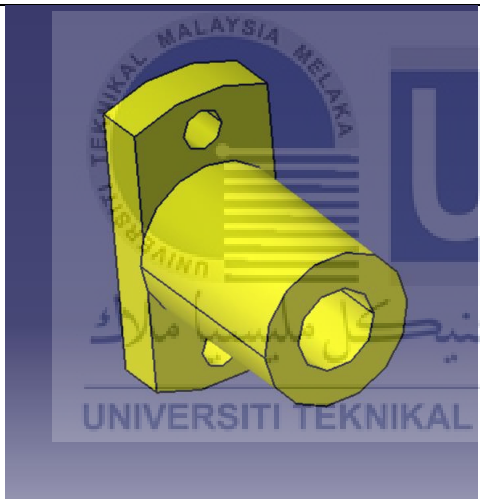
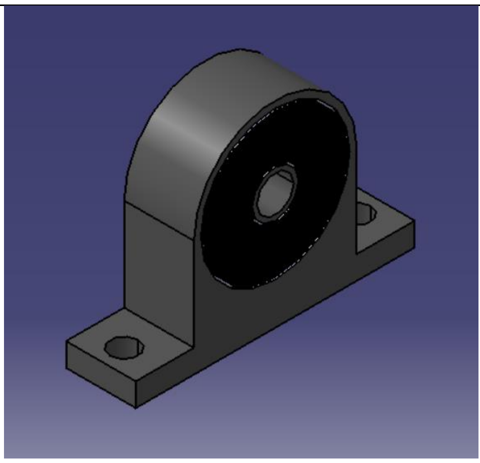


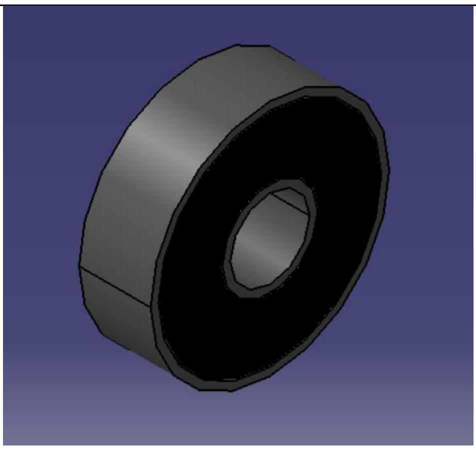
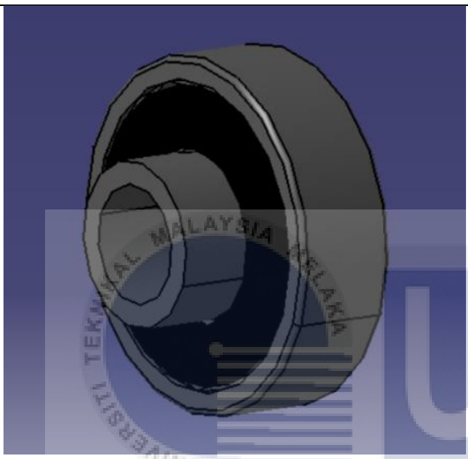
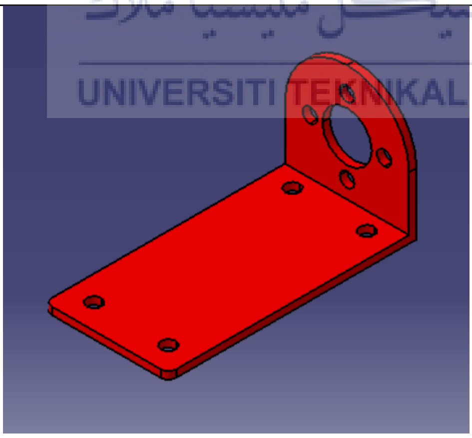
Figure 4.2: The design concept that has been selected for the omnidirectional conveyor product.

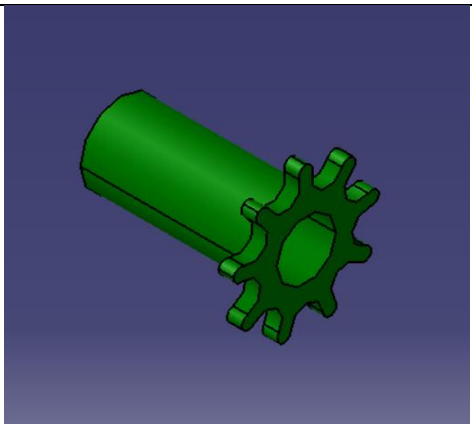
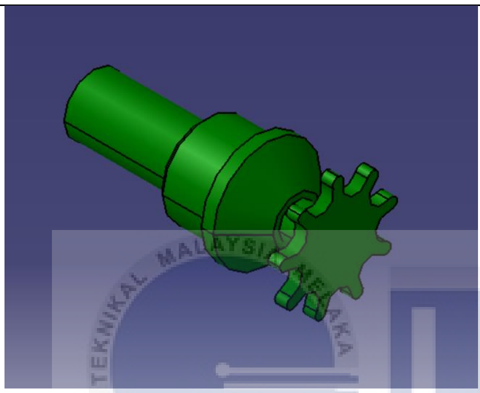
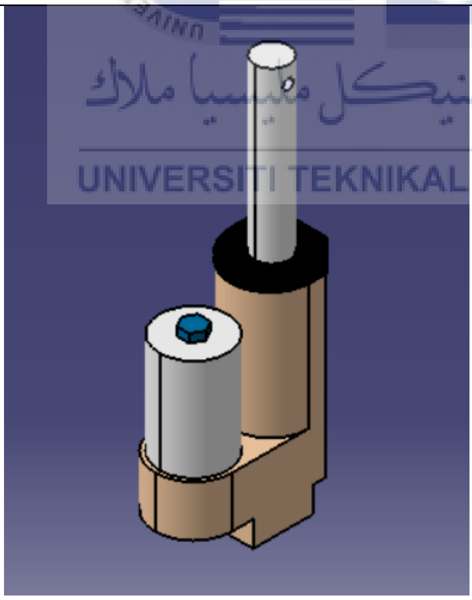
4.2.3.2 CAD drawing.

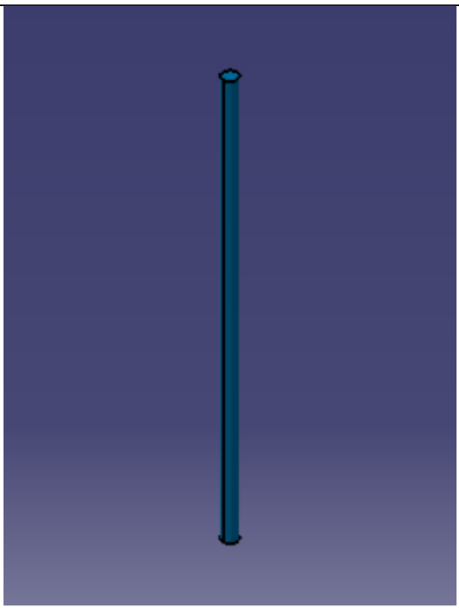
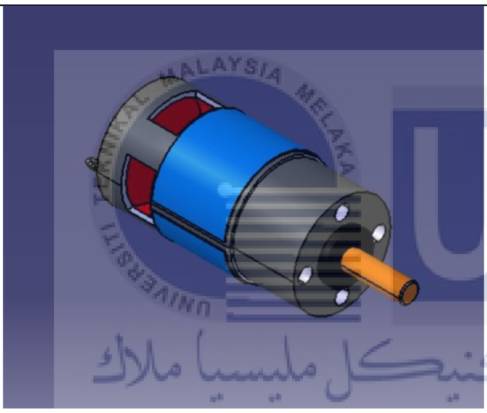
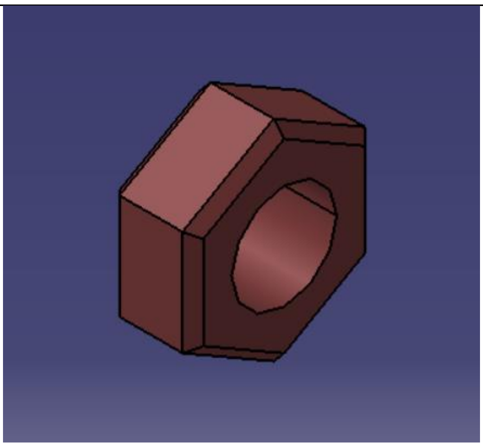
Table 4.6 shows the 3-dimensional model for each component for the Omnidirectional Conveyor product with their features and functions.

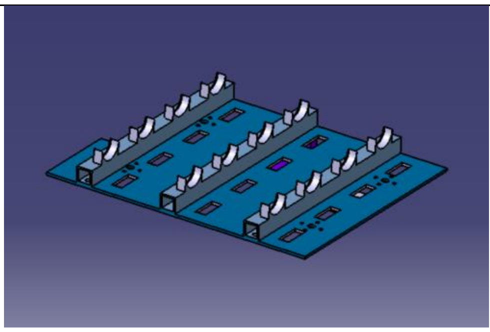
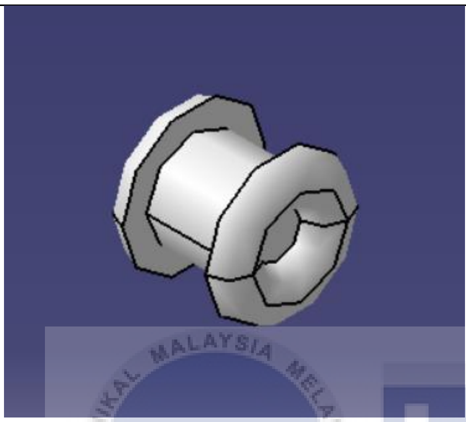
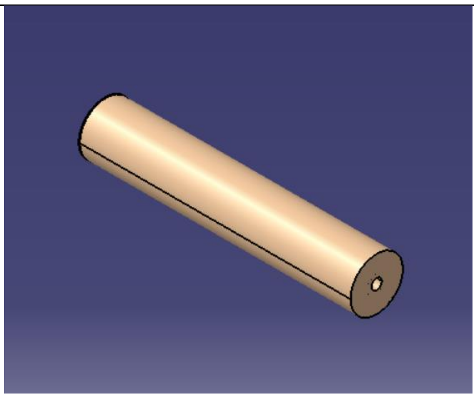
Table 4.6: Part CAD

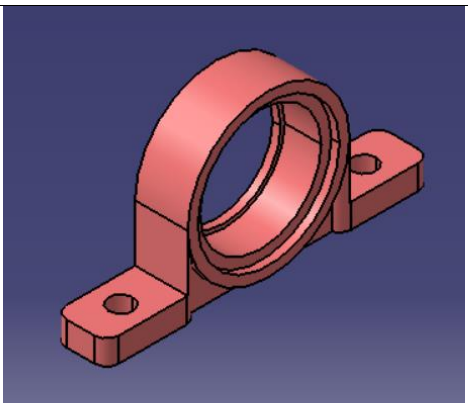
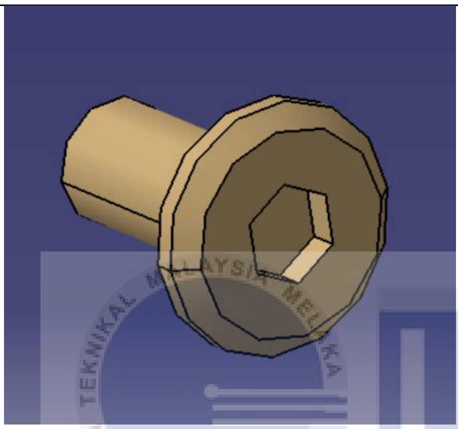
No.	Components	Function
1.	 Omni wheel	To shift the load to the right and to the left on the conveyor
2.	 Bearing lift	To move the omnidirectional plate up and down
3.	 Bearing omni plate	To move the rod omni wheels

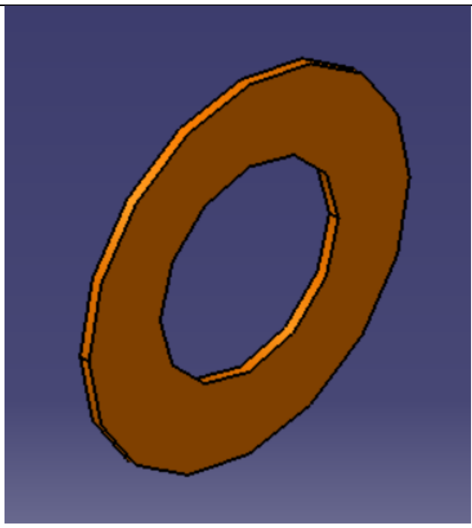
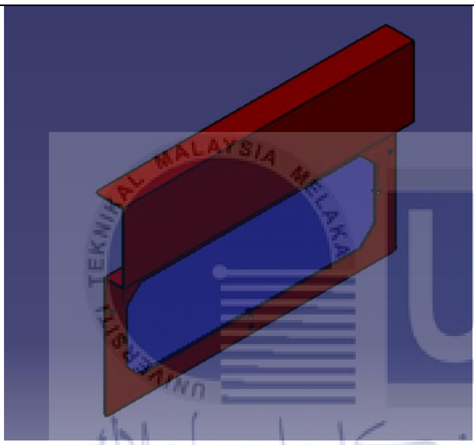
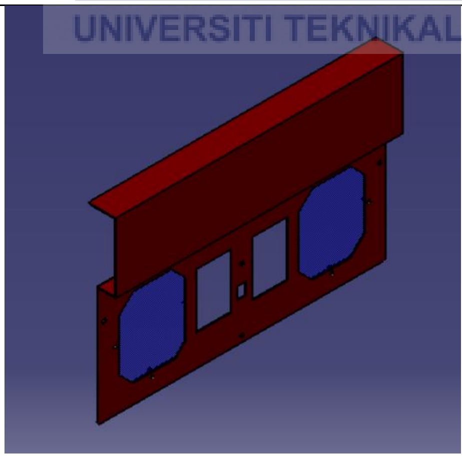
4.	 Bearing omni wheel	To move the omni wheels
5.	 Bearing roller	To move the roller
6.	 Bracket motor	To hold the DC motor on the conveyor

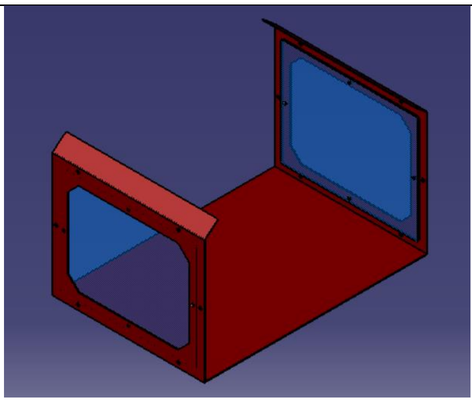
7.	 Long gear	Gear to move the omni wheel
8.	 Omni gear	Gear to move the omni wheel and roller
9.	 Linear electric DC motor	To move the omnidirectional plate up and down

10.	 Rod lift	To move the omnidirectional plate up and down
11.	 DC motor	To move the roller and omni wheel
12.	 Nut omni	To fasten the omni wheel to the omnidirectional plate

13.	 Omni plate	To be placed omni wheel
14.	 Rivet	To fasten the omni body and wheels
15.	 Rod omni	To put a long gear to drive the omni wheel
16.	 Roller	To move the load forward and backward on the conveyor

17.	 Housing bearing	To place roller bearings
18.	 Skrew	To bind various objects on the omnidirectional conveyor
19.	 Speed control	To control the speed of DC motor omni wheels and roller along with clockwise and counterclockwise movement

20.	 Omni washer	To give some clearance to the omni wheels and omni gears
21.	 Back body with acrylic	To prevent any foreign object from entering the body along with the safety of the user
22.	 Front body with acrylic	To prevent any foreign object from entering the body along with the safety of the user

23.	 Side body with acrylic	To prevent any foreign object from entering the body along with the safety of the user

4.2.3.3 Assembly Model

Figures 4.3, 4.4, 4.5, and 4.6 illustrate the assembly model for the omnidirectional conveyor product, including the 3D, top, bottom, right, left, front, back, and omnidirectional views.

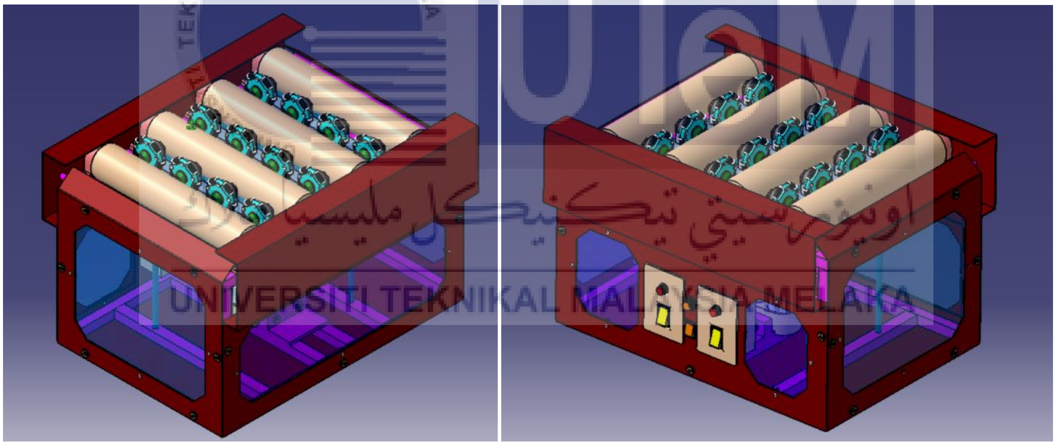


Figure 4.3: 3D view of assembly model.

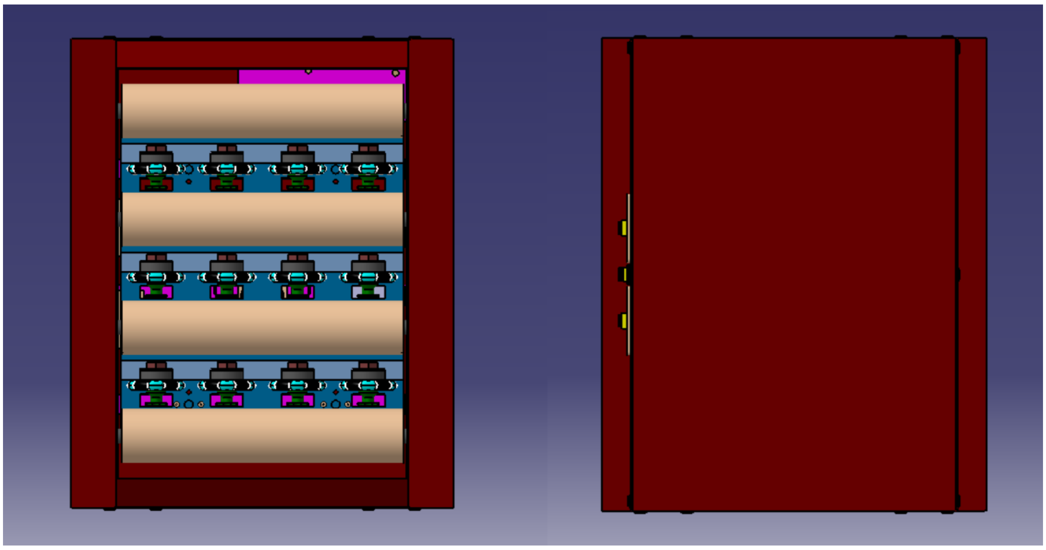


Figure 4.4: Top and bottom view of assembly model.

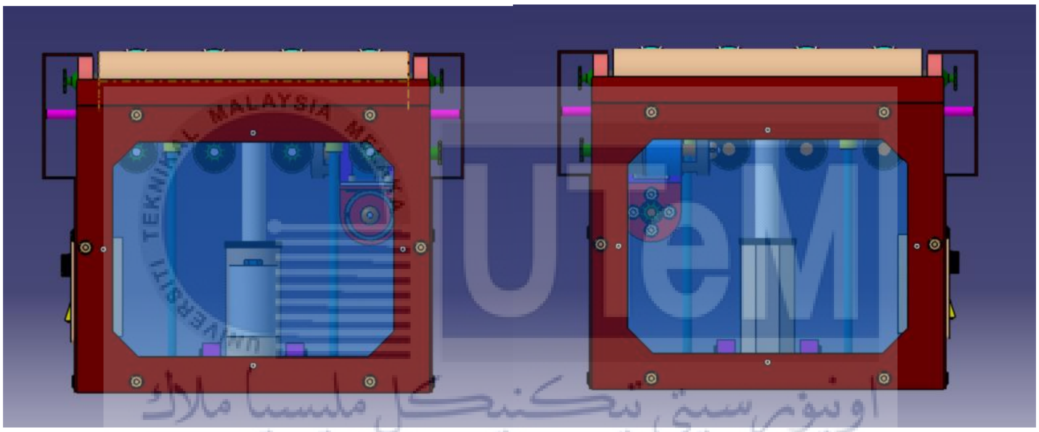


Figure 4.5: Right and left view of assembly model.

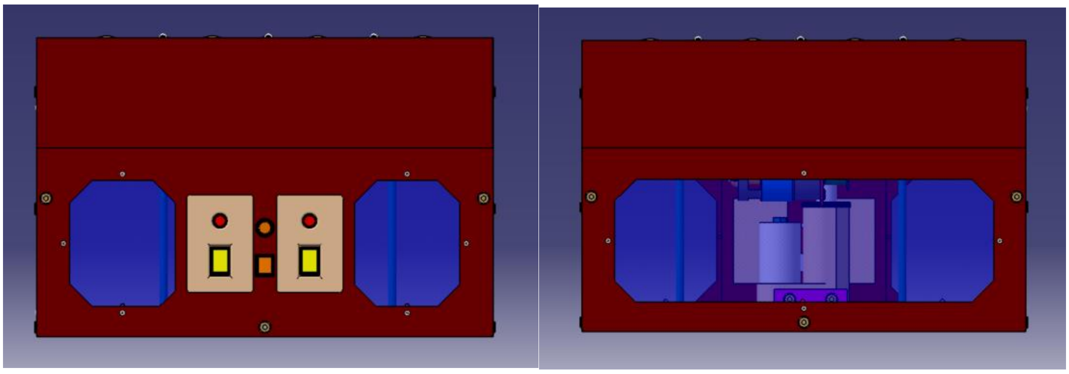


Figure 4.6: Front and back view of assembly model.

Figure 4.7 show the plate full assembly with omni wheel at the omnidirectional plate. This plate also can plug and play at roller conveyor.

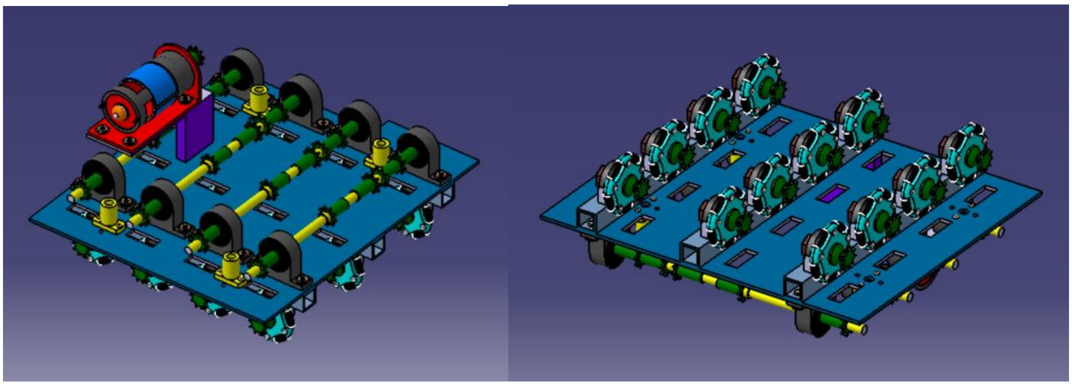


Figure 4.7: Assembly model of omnidirectional wheels.

4.2.3.4 Exploded View.

Figures 4.8, 4.9, and 4.10 show the top, front and back of exploded views for the Omnidirectional Conveyor product.

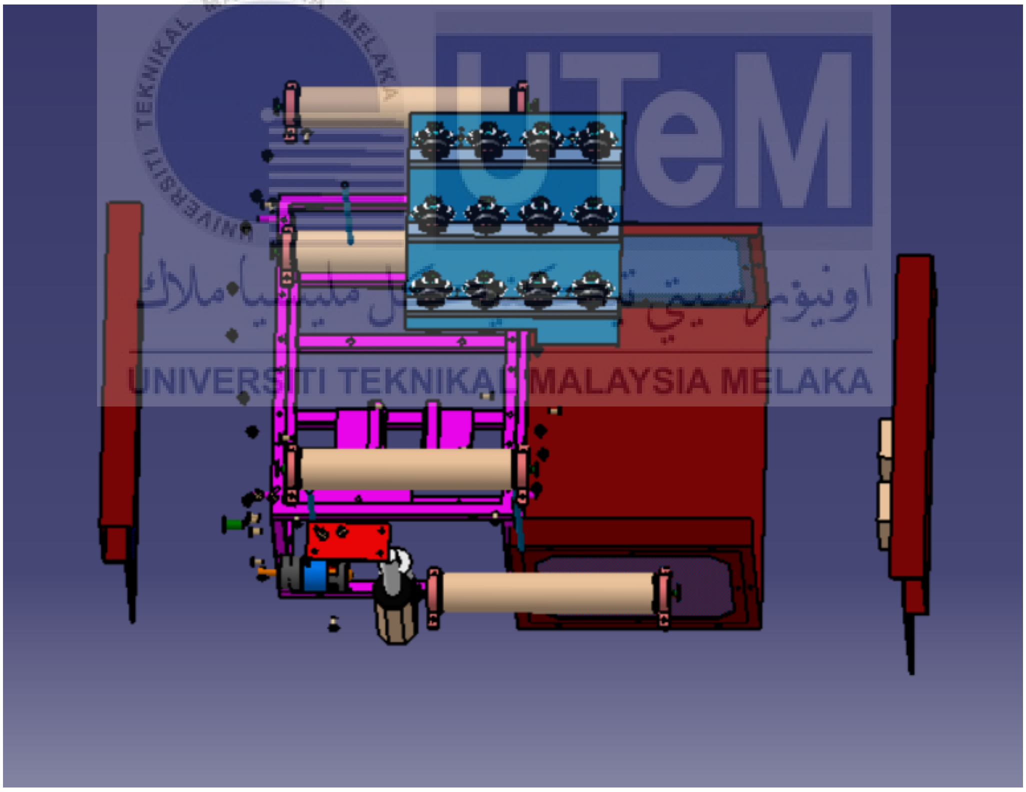


Figure 4.8: Top View of Exploded Model

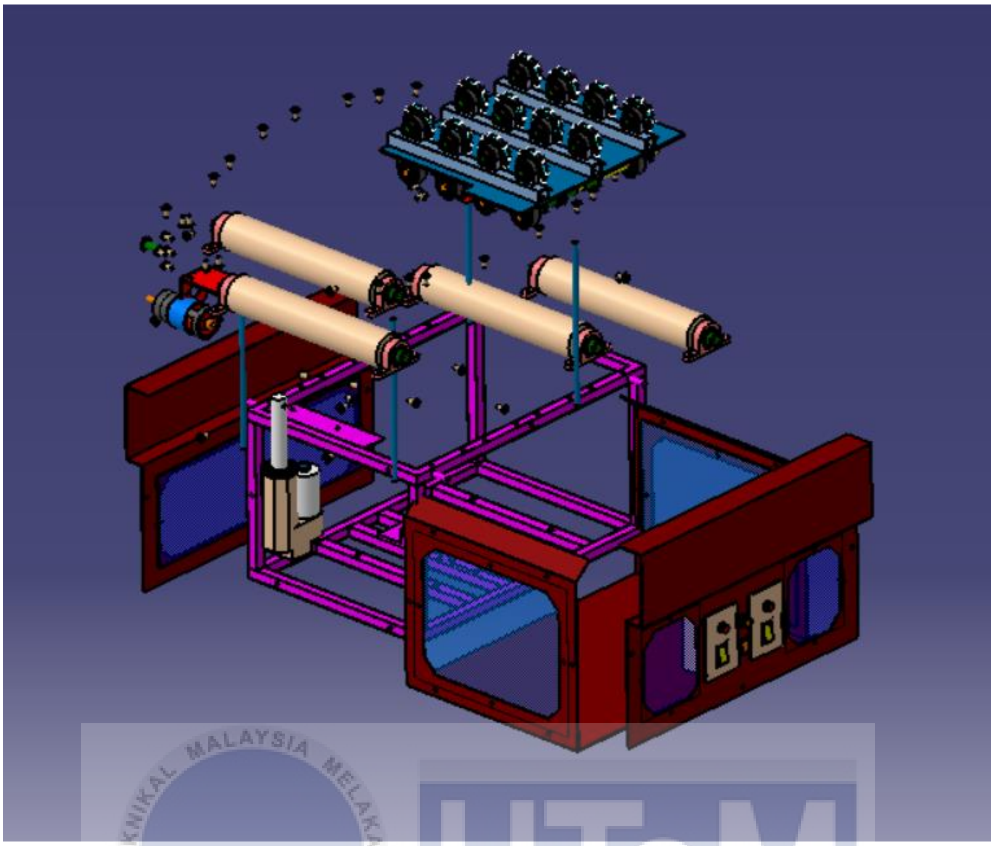


Figure 4.9: Front View of Exploded Model

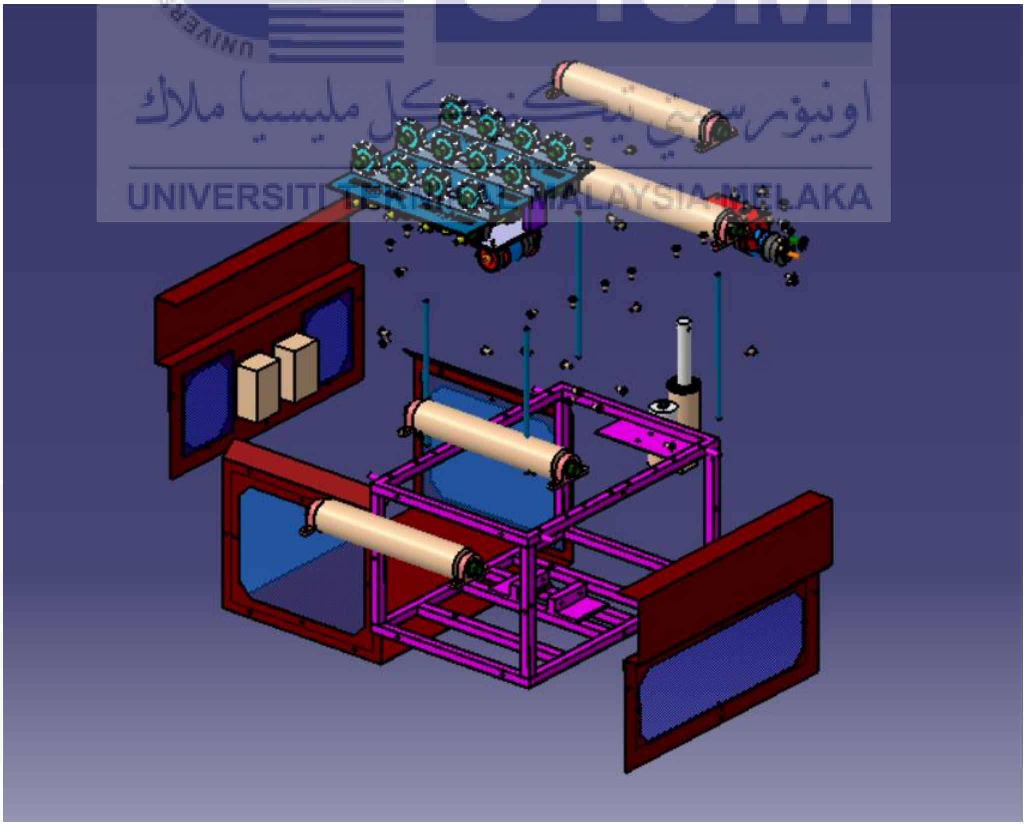


Figure 4.10: Back View of Exploded

Figures 4.11 show the exploded views for the Plate Omnidirectional Conveyor product.

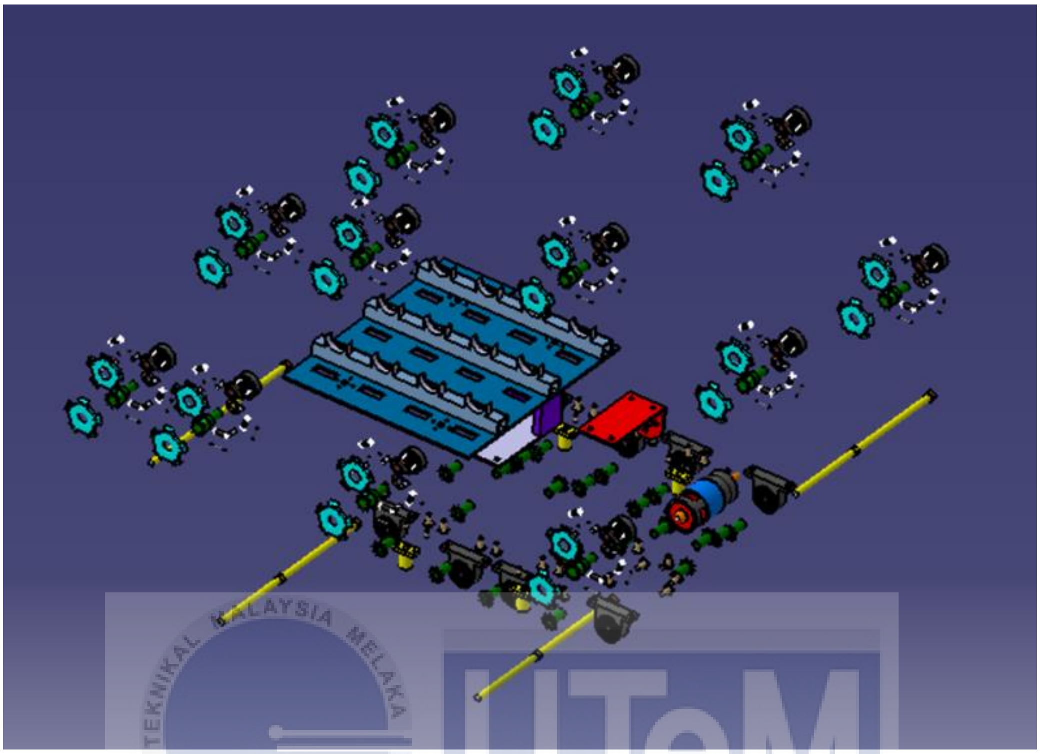


Figure 4.11: The Exploded views for the Plate Omnidirectional

Figures 4.12 and 4.13 show the exploded views for the Omni Wheel and Roller at the Omnidirectional Conveyor product.

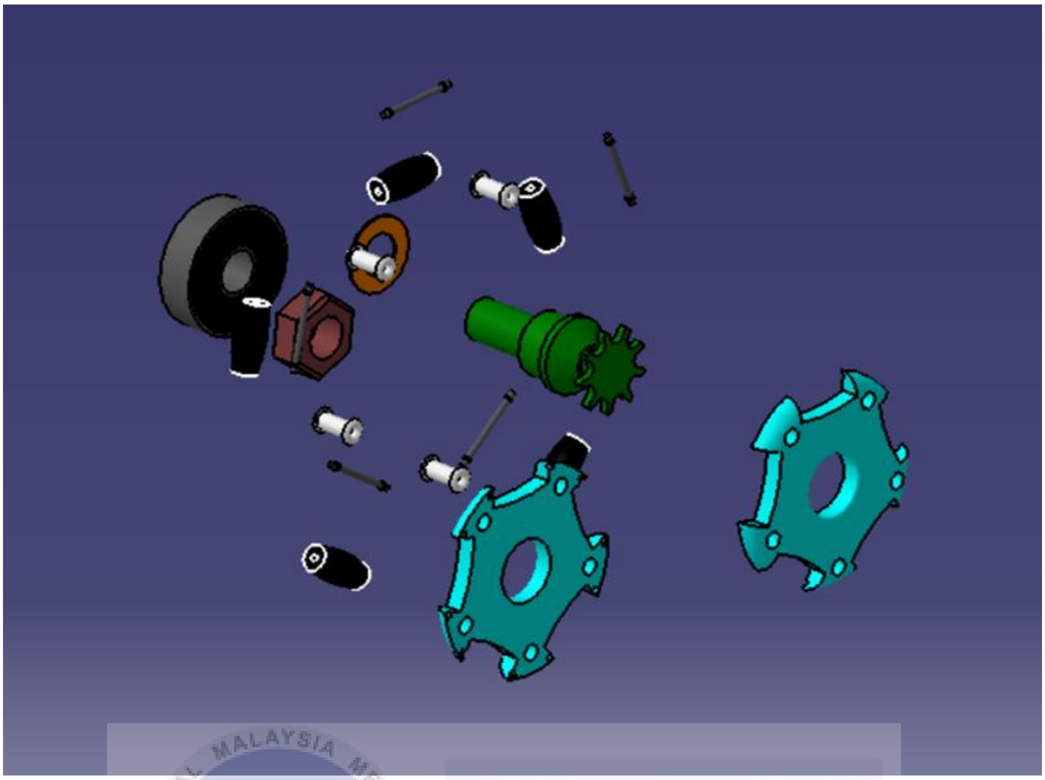


Figure 4.12: The Exploded view for Omni Wheel.

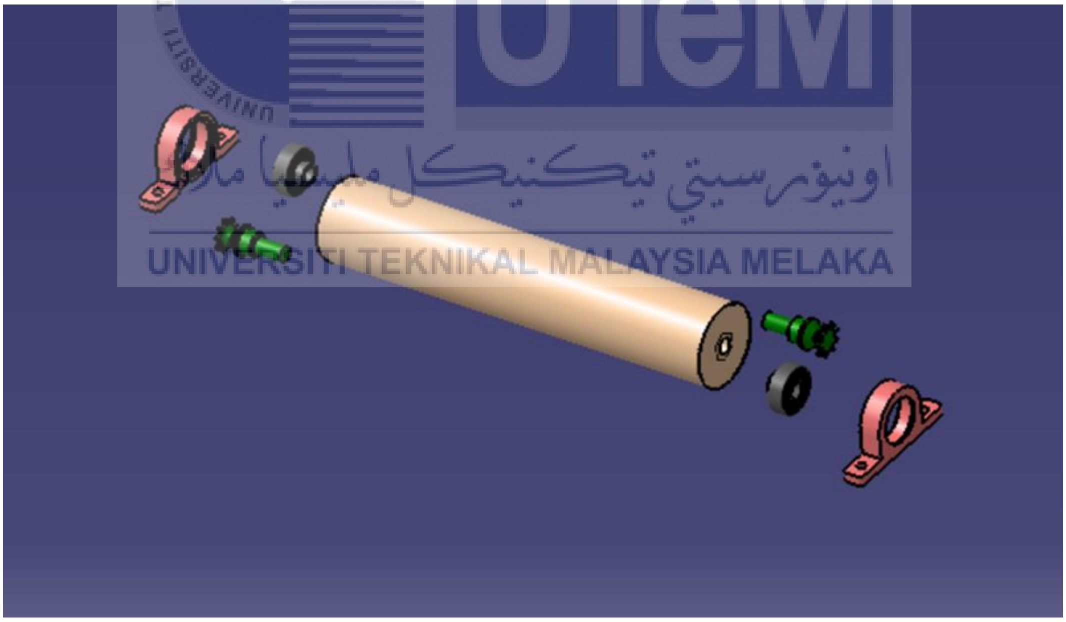


Figure 4.13: The Exploded view for Roller.

4.2.3.5 Circuit diagram.

The Omnidirectional Conveyor product is supplied through a single-phase power supply (240V 50Hz) and controlled with a 13A switch plug to turn it on. Next, AC power converted to DC power using an AC to DC converter (12V 10A / 60W), and the power is distributed equally through the terminal solid state supply to DC load components such as speed controller to control the DC motor. Figure 4.14 depicts a schematic circuit diagram consisting of electrical components used to fabricate the Omnidirectional Conveyor product with wire connection.

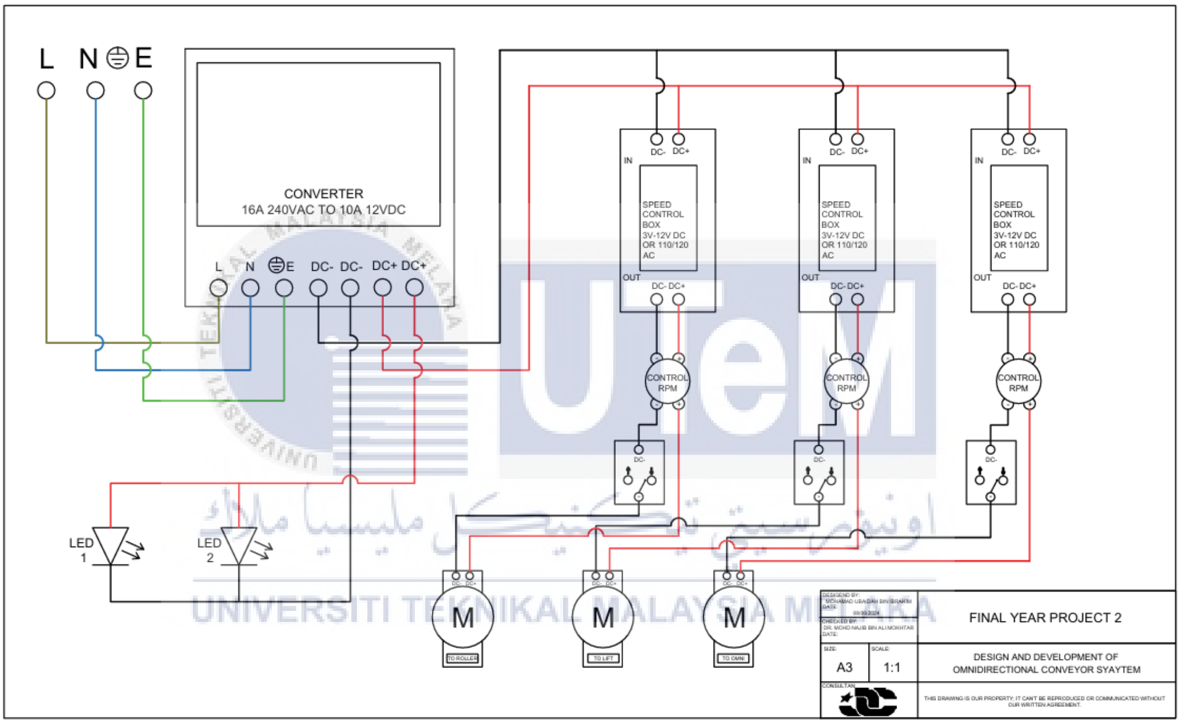
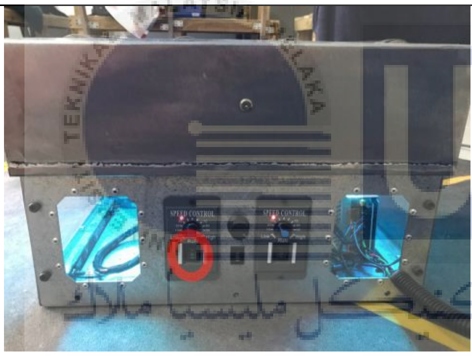


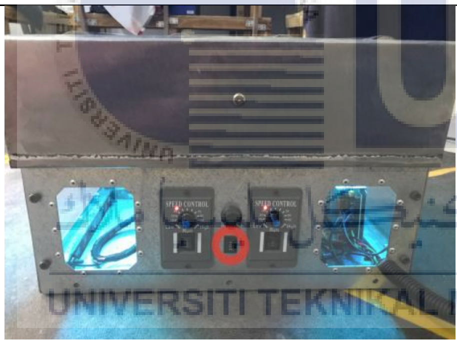
Figure 4.14: Schematic Circuit Diagram

4.2.3.6 User Interface and How to Use the Products.

Table 4.7 shows the details of the procedure about the user interface and how to use the products.

Table 4.7: User interface along with detailed procedure on how to use the products.

No.	Procedures	Descriptions
1.	 Put the load at omnidirectional conveyor	Place the load on an omnidirectional product conveyor to be delivered to a predetermined destination
2.	 Switch I and II for roller	Switch I and II to move the roller forward and backward
3.	 Motor speed for roller	The motor speed is matched with the desired roller rpm speed

4.	 Switch I and II for omni wheel	Switch I and II to move the omni wheel right and left
5.	 Motor speed for omni wheel	The motor speed is matched with the desired omni wheels rpm speed
6.	 Switch I and II for liner motor	Switch I and II to move the liner motor up and down
7.	 Motor speed for liner motor	The motor speed is matched with the desired liner motor rpm speed

4.2.4 Engineering analysis (CAE).

A thermal structural analysis report performed using ANSYS software is presented in this paper. The aim of this analysis is to measure the strength performance of omni wheels and rollers to find heat flow, heat flux, total deformation, equivalent stress and safety factor. The investigation considers diverse operating conditions and offers insight into static structural tactics to improve design.

Figure 4.15: Analysis of Omni wheel and roller using ANSYS software.

Figures 4.16 and 4.17 show the static structural part, we set the fixed support at the bearing and PLA wheel of the Omni Wheel For the force, we just set it at 100 N.

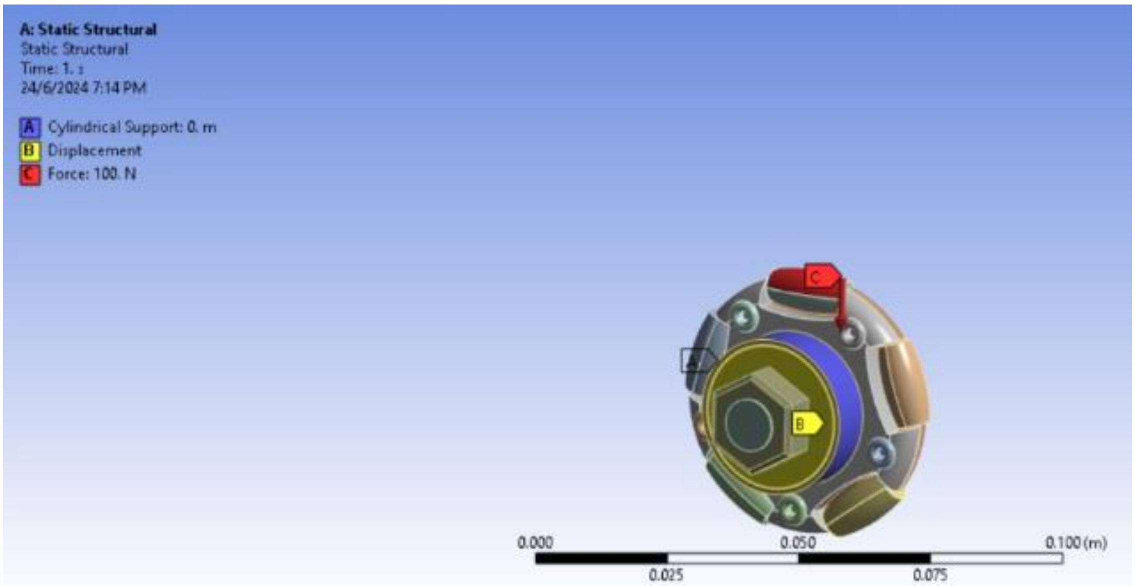


Figure 4.16: The fixed support at the bearing and PLA wheel of the Omni Wheel.

Table of Design Points

	A	B	C	D	E	F
1	Name	P1 - Force Z Component	P2 - Total Deformation Maximum	P3 - Safety Factor Minimum	Retain	Retained Data
2	Units	N	mm			
3	DP 0 (Current)	-100	0.01276	1.3532	☑	✓

Figure 4.17: The Force Parameters of Omni Wheel.

Figures 4.18 and 4.19 show the result of the static structural part that we applied to the Omni Wheel. For the static structural result, we observe the total deformation and equivalent stress. For the total deformation we get the maximum value is 1.276e-005 m and for equivalent stress we get the maximum value is 1.5297e+008 Pa.

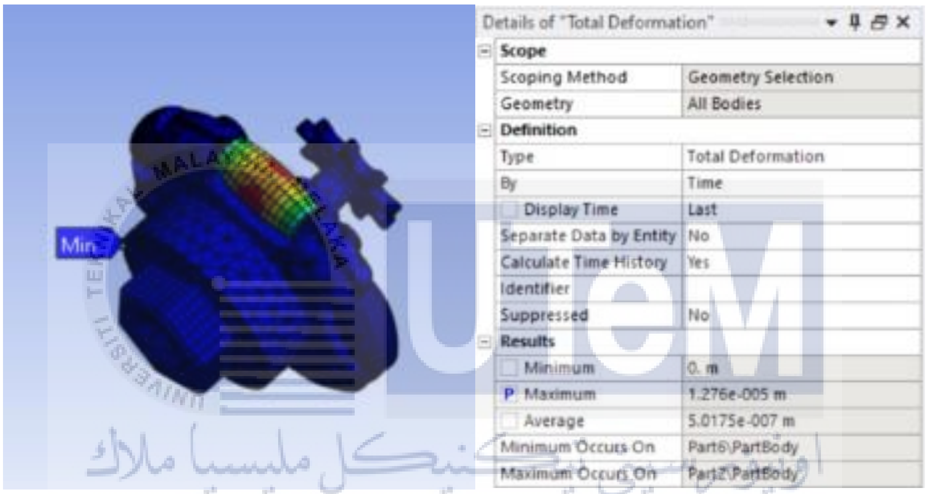


Figure 4.18: Total Deformation Result of Omni Wheel.

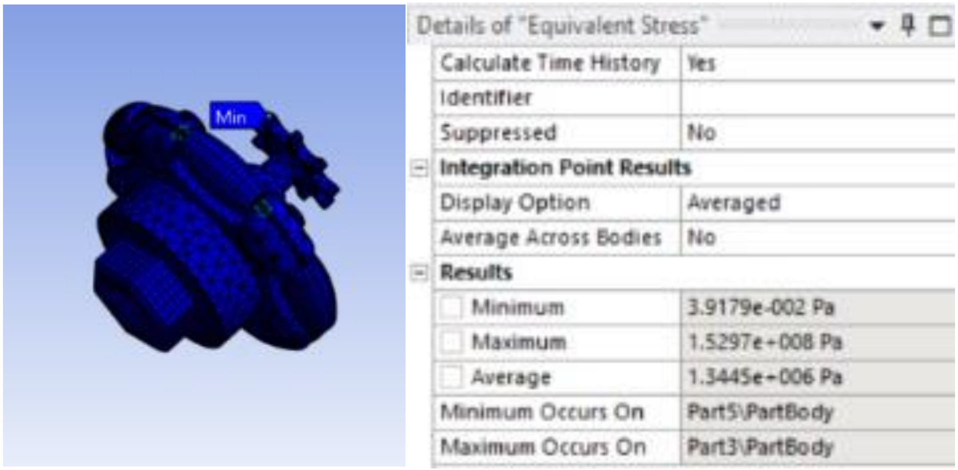


Figure 4.19: Equivalent Stress Result of Omni Wheel.

Figures 4.20 and 4.21 show the static structural part, we set the fixed support at the bearing and pipe stainless steel of the Roller For the force, we just set it at 200 N.

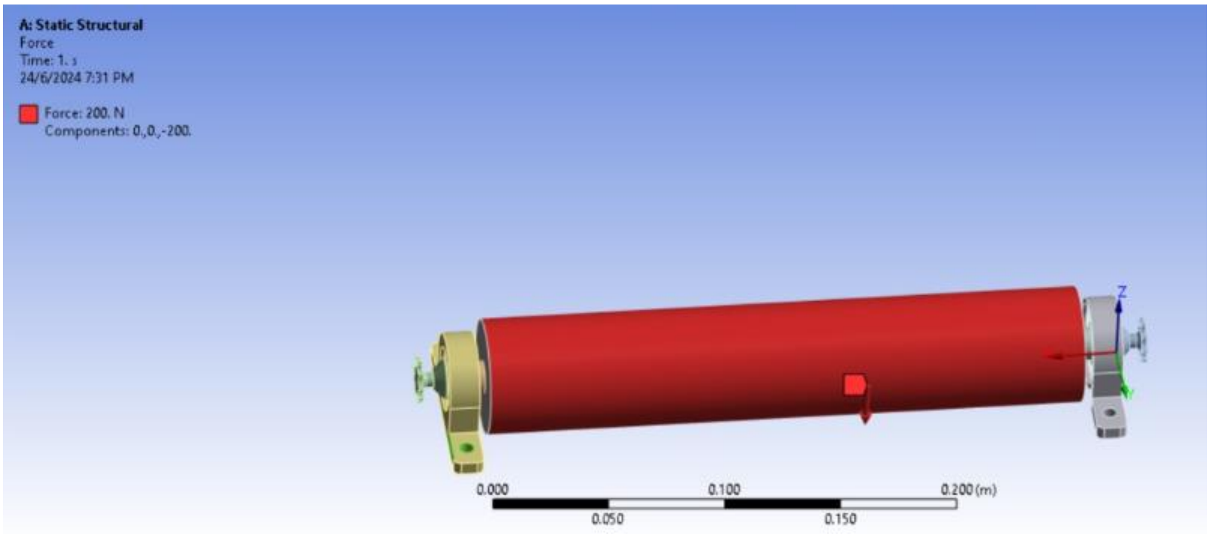
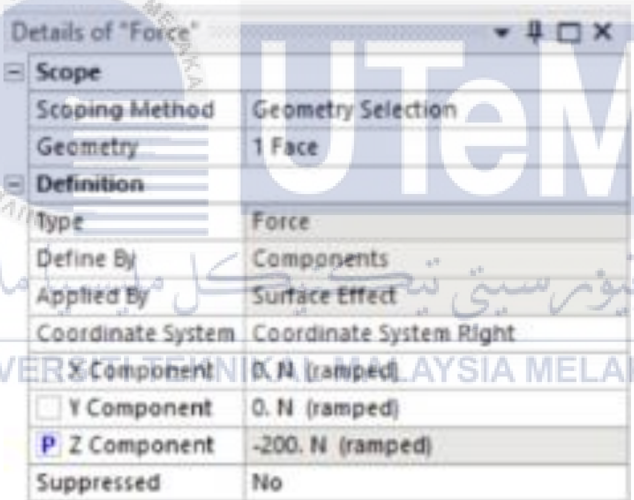


Figure 4.20: The fixed support at the bearing and pipe stainless steel of the Roller.



Details of "Force"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Force
Define By	Components
Applied By	Surface Effect
Coordinate System	Coordinate System Right
X Component	0. N (ramped)
Y Component	0. N (ramped)
Z Component	-200. N (ramped)
Suppressed	No

Figure 4.21: The Force Parameters of Roller.

Figures 4.22 and 4.23 show the result of the static structural part that we applied to the Roller. For the static structural result, we observe the total deformation and equivalent stress. For the total deformation we get the maximum value is 7.3074e-006 m and for equivalent stress we get the maximum value is 1.687e+007 Pa.

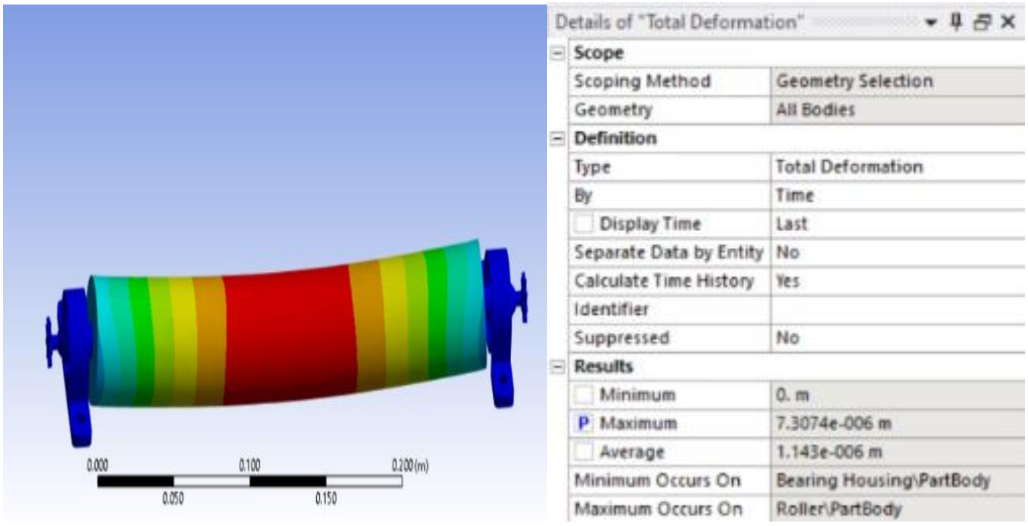


Figure 4.22: Total Deformation Result of Roller.

Figure 4.23: Equivalent Stress Result of Roller.

The studied Omni Wheel and Roller components undergo a comprehensive thermal and static structure analysis using ANSYS software, which provides a detailed view of the Omni Wheel and Roller components structural integrity behavior. Combined studies allow identification possible problems and optimization opportunities by allowing a comprehensive assessment of both mechanical stresses.

4.2.5 Fabrication of Omnidirectional Conveyor.

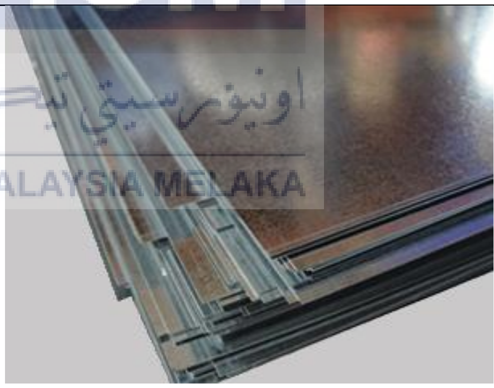
This section will discuss about the fabrication process to produce the Omnidirectional Conveyor product. It consists of three major fabrication aspects, including mechanical to produce the physical body, and electrical to supply the power.

4.2.5.1 Mechanical Fabrication Process.

4.2.5.1.1 Obtain the Raw Materials.

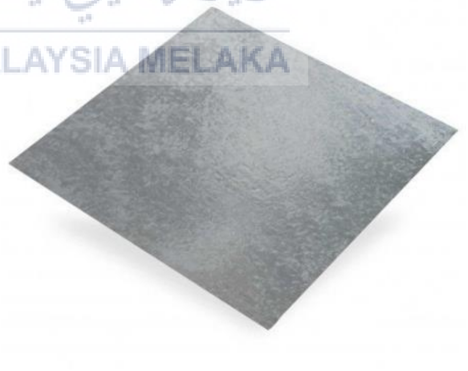
This sub-section will discuss about obtaining the raw materials process that will be used to fabricate the Omnidirectional Conveyor product.

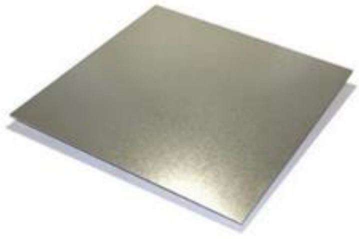
Table 4.8: Obtaining the raw materials process.

No.	Component (mm)	Dimension (mm)	Quantity	Description (mm)
1.	Galvanized Iron (GI) Plate (1.5mm) (Body)	1000 x 500	1	 Take the GI plate (1.5mm) at the CNC Lab

2.	Galvanized Iron (GI) Plate (3mm) (omni plate)	310 x 250	1	 Take the GI plate (3mm) at the CNC Lab
3.	Acrylic (3mm)	600 x 200	1	 Buy the Acrylic (3mm) at the Shopee
4.	Hollow Mild Steel (20 x 20)	L x 4000	1	 Buy the Hollow Mild Steel (20 x 20) at the Hardware

5.	Rod stainless steel (D x 8mm)	L x 250	4	 Buy the Rod stainless steel (D x 8mm) at the Shopee
6.	Mild steel plate (4.5mm)	450 x 250	1	 Take the Mild steel plate (4.5mm) at the CNC Lab
7.	PLA (D x 6mm)	L x 500m	60	 Take the PLA (D x 1.2mm) at the 3D printing Lab

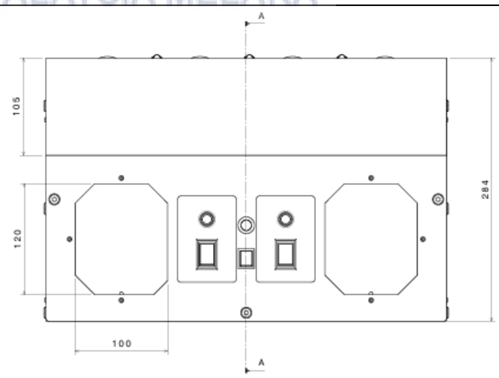
8.	Stainless steel pipe (D x 50mm)	L x 250	4	 Buy the Stainless steel pipe (D x 50mm) at the Shopee
9.	Chain 25H	L x 500	4	 Buy the Chain 25H at the Shopee
10.	Galvanized Iron (GI) Plate (1mm) (washer)	50 x 100	1	 Take the GI plate (1mm) at the CNC Lab

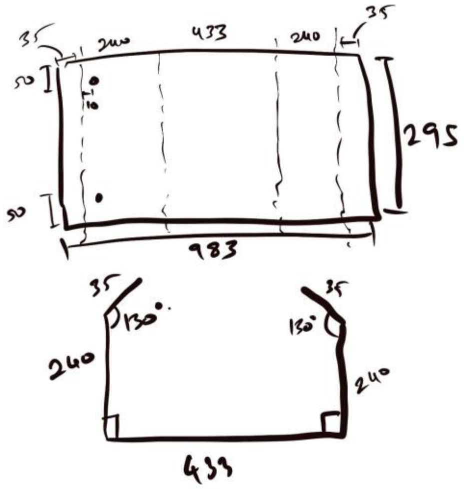
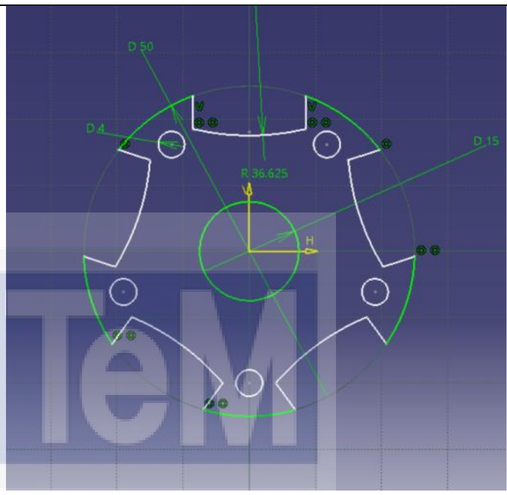
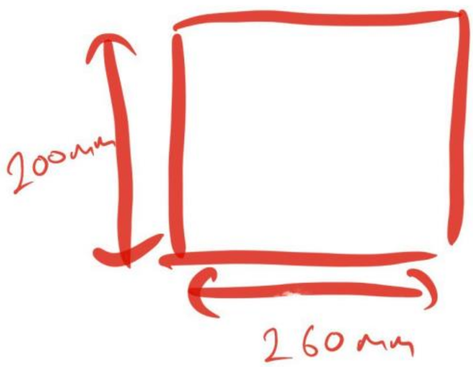
11.	Galvanized Iron (GI) Plate (1.5mm) (roller)	120 x 220	1	 Take the GI plate (1.5mm) at the CNC Lab

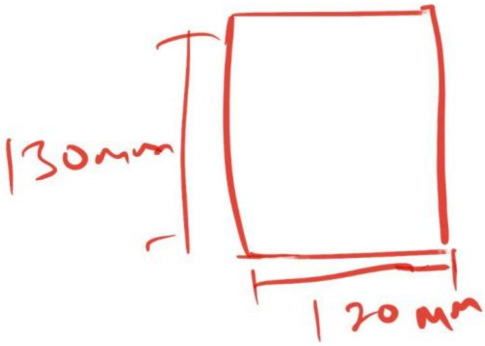
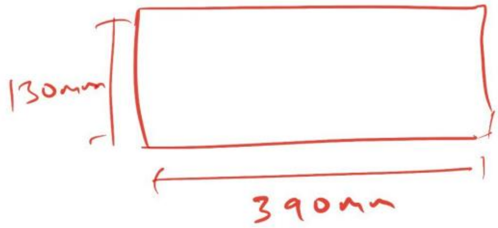
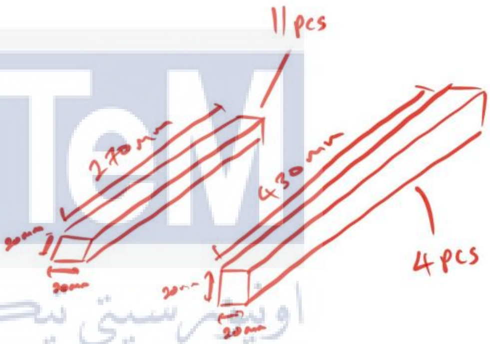
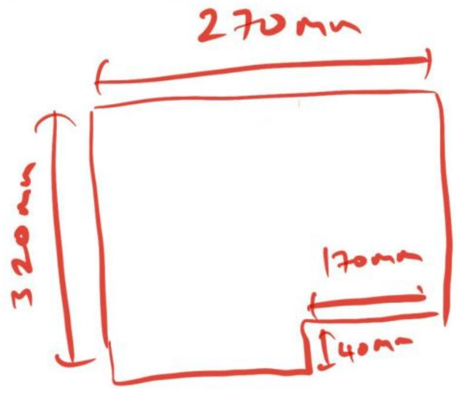
4.2.5.1.2 Measuring.

This sub-section will discuss about the measuring process to fabricate the Omnidirectional Conveyor product according to the engineering drawing.

Table 4.9: Measuring process.

No.	Component (mm)	Dimension (mm)	Quantity	Description (mm)
1.	Front and back body	433 x 340	2	

<table>
<tr><td>2.</td><td>Side body</td><td>983 x 295</td><td>1</td><td>
</td></tr>
<tr><td>3.</td><td>Omni wheel</td><td>D x 50</td><td>24</td><td>
</td></tr>
<tr><td>4.</td><td>Roller</td><td>L x 250
D x 50</td><td>4</td><td>
</td></tr>
<tr><td>5.</td><td>Acrylic side body</td><td>200 x 260</td><td>2</td><td>
</td></tr>
</table>

6.	Acrylic front body	130 x 120	2	
7.	Acrylic back body	130 x 390	1	
8.	Frame body	30 x 270	11	
		30 x 430	4	
9.	Plate omni	270 x 320	1	

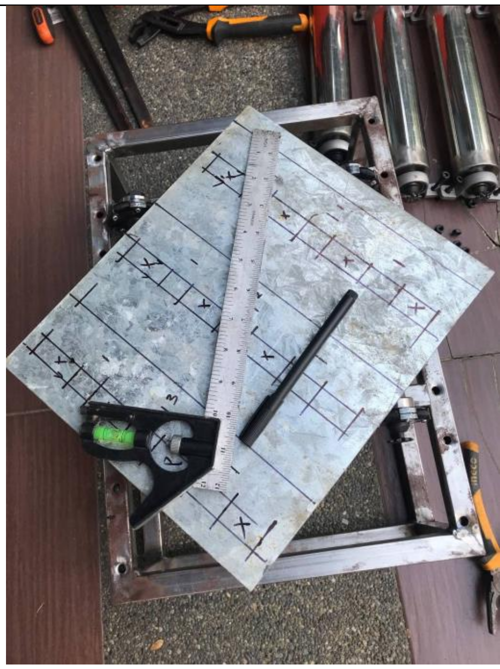
4.2.5.1.3 Cutting, drilling, and 3D printing.

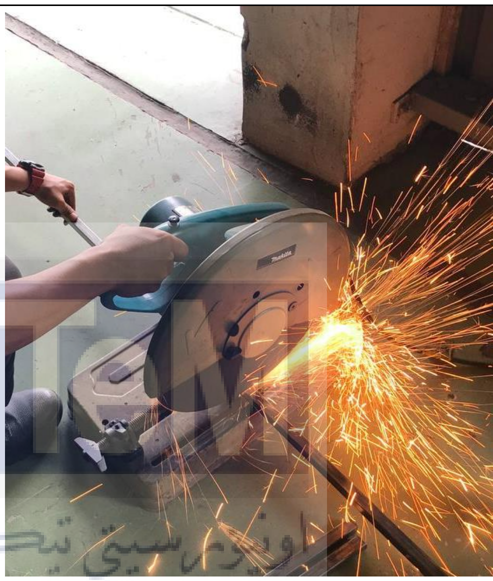
This sub-section will discuss about the cutting process to fabricate the Omnidirectional Conveyor product using the proper equipment and tools.

Table 4.10: The cutting process by using suitable equipment and tools.

No.	Component (mm)	Dimension (mm)	Quantity	Description (mm)
Laser cutting				
1.	Galvanized Iron (GI) Plate (1.5mm) (body)	433 x 340 983 x 295	2 1	 Cutting the GI plate at the laser cutting lab
2.	Mild steel plate (4.5mm) (omni wheel)	D x 50	24	 Cutting the omni plate at the laser cutting lab

3.	Galvanized Iron (GI) Plate (1mm) (washer)	D x 18	12	 Cutting the washer plate at the laser cutting lab
4.	Galvanized Iron (GI) Plate (1.5mm) (roller)	D x 50	8	 Cutting the roller plate at the laser cutting lab
Grinding				

1.	Galvanized Iron (GI) Plate (3mm) (omni plate)	270 x 320	1	 Cutting the omni plate using grinder at home town.
2.	Acrylic (3mm)	200 x 260	2	 Cutting the acrylic using grinder at home town.
		130 x 120	2	
		130 x 390	1	
3.	Hollow Mild	30 x 270	11	

	Steel (20 x 20)	30 x 430	4	 Cutting the hollow using grinder at process lab.
4.	Rod stainless steel (D x 8mm)	L x 250	4	 Cutting the rod using chop saw at process lab.

5.	Stainless steel pipe (D x 50mm)	L x 250 D x 50	4	 Cutting the stainless steel pipe using chop saw at home town.
6.	Chain 25H	L x 120	23	 Cutting the chain using grained and then punch the chain using hammer at home town.
Drilling				

1.	Hollow Mild Steel (20 x 20) (Body)	D x 6	16	 Drill the body using hand drill at process lab
2.	Galvanized Iron (GI) Plate (1.5mm) (roller)	D x 10	8	 Drill the side roller use drill press at home town

3.	Mild steel plate (4.5mm) (omni wheel)	D x 15	12	 Drill the omni wheel use drill press at home town
4.	Galvanized Iron (GI) Plate (3mm) (omni plate)	D x 8	28	 Drill the omnidirectional plate use drill press at home town

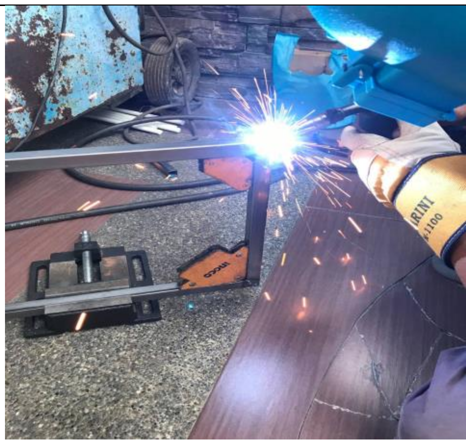
5.	PLA (D x 6mm)	D x 1.5	60	 Drill the omni PLA wheels using hand drill at home town
6.	Galvanized Iron (GI) Plate (1.5mm) (body)	D x 6	32	 Drill the body using hand drill at home town
3D printing				

1.	PLA (D x 1.2mm)	L x 500m	60	 3D printing the omni PLA wheels at the 3D printing lab

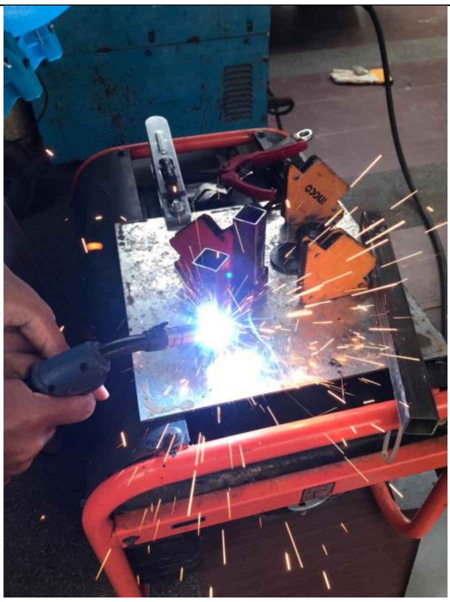
4.2.5.1.4 Joining and Shaping.

This sub-section will discuss about the joining and shaping process to fabricate the Omnidirectional Conveyor product using the proper equipment and tools.

Table 4.11: The joining and shaping process by using suitable equipment and tools.

No.	Component (mm)	Dimension (mm)	Quantity	Description (mm)
Welding				
1.	Hollow Mild Steel (20 x 20) (Body)	433 x 295 x 240	Body	 Welding the body using MIG welding at home town

2.	Stainless steel pipe (D x 50mm) & Galvanized Iron (GI) Plate (1.5mm) (roller)	D x 50	8	 Welding the roller using MIG welding at home town
3.	Rod stainless steel (D x 8mm)	L x 250	4	 Welding the lift rod using MIG welding at process lab
4.	Bearing stainless steel omni wheel (D x 30) & Galvanized Iron (GI) Plate (3mm) (omni plate)	D x 30	12	 Welding the bearing and omnidirectional plate using MIG welding at process lab

5.	Mild steel (100 x 50) (bracket motor)	100 x 50 x 80	2	 Welding the bracket motor using MIG welding at home town
6.	Bearing stainless steel omni wheel (D x 30)	D x 30	12	 Welding the bearing at hollow omnidirectional using MIG welding at process lab

7.	Hollow Mild Steel (20 x 20) (liner motor)	L x 295	2	 Welding the hollow mildsteel for liner motor using MIG welding at home town
		Banding		
1.	Galvanized Iron (GI) Plate (1.5mm) (body)	433 x 340	2	 Banding the front and back body using banding machine at laser cutting lab

2.	Galvanized Iron (GI) Plate (1.5mm) (body)	983 x 295	1	 Banding the side body using banding machine at laser cutting lab
		Rivet		
1.	Mild steel plate (4.5mm) (omni wheel)	D x 4	60	 Rivet the omni wheel using the rivet machine at home town

2.	Galvanized Iron (GI) Plate (1.5mm) (body)	D x 4	32	 Rivet the body and acrylic using the rivet machine at home town
		Sanding		
1.	Stainless steel pipe (D x 50mm) & Galvanized Iron (GI) Plate (1.5mm) (roller)	L x 250 D x 50	4	 Finishing the surface of roller using hand grinder at home town

2.	Hollow Mild Steel (20 x 20) (Body)	433 x 295 x 240	Body	 Finishing the surface of main body using hand grinder at process lab
3.	Mild steel plate (4.5mm) (omni wheel)	D x 50	12	 Finishing the surface of omni wheels using hand grinder at home town

4.2.5.1.5 Assembly.

All the physical components that were produced during the mechanical fabrication process were assembled according to the technical drawing. Figure 4.24 illustrates the Omnidirectional Conveyor product has successfully performed the mechanical fabrication process and assembly into a solid physical body.

Figure 4.24: The initial assembly of Omnidirectional Conveyor product.

Figure 4.25 show the prototype about the omni wheel assemble at omnidirectional plate.

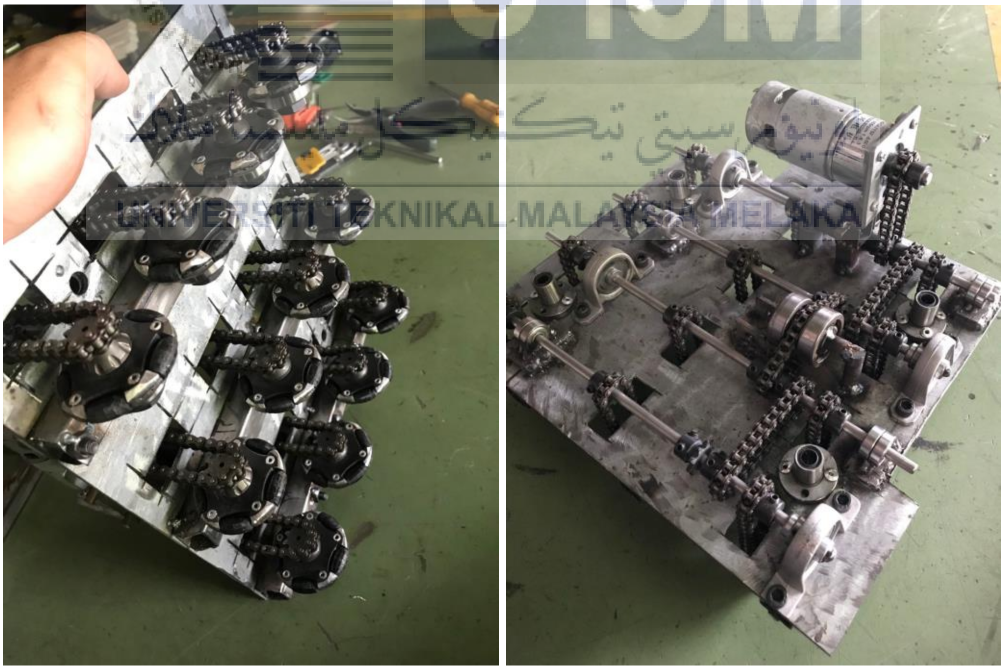


Figure 4.25: Prototye assembly Omnidirectional plate.

4.2.5.2 Electrical Fabrication Process.

This sub-section will discuss about the electrical fabrication process to produce the Omnidirectional Conveyor product regarding electrical aspects using the proper equipment and tools.

Table 4.12: Electrical fabrication process by using proper equipment and tools.

No.	Component	Details	Quantity	Picture
1.	Control speed	12V DC motor speed controller reversible switch	2	
2.	Converter AC to DC 10A	Power supply DC12V 10A transformer AC220V to DC12V converter	1	

3.	Wire	Mega PVC Cable 100% Pure Copper 2.5mm	1	
4.	Wire	2core, 15A Length: 1500mm Diameter: 1mm	1	
5.	Socket plug	Socket plug 13A 3 pin	1	
6.	DC motor 248rpm	12VDC, torque 10kgf.cm, 5.5A, 41.3W Diameter: 8mm	1	

		Length: 20mm		
7.	DC Motor 955rpm	12VDC, torque 10kgf.cm, 4.6A, 50.5W Diameter: 8mm Length: 20mm	1	
8.	12V Electric motor linear	DC gear push up down motion cylinder	1	
9.	LED	12.5cm 16.5cm 20.5cm 12v	2	

4.2.5.3 Final Assembly.

The fabricating of Omnidirectional Conveyor products has been achieved by performing the three major fabrication processes, including mechanical and electrical fabrication processes. The mechanical fabrication process was to produce the physical body, including measuring, cutting, joining, sanding, painting process, 3D printing etc. Next, the electrical fabrication process was to supply the optimum power energy into the product to the speed control motor roller and omni wheels. Figure 4.26 shows the final prototype of the Omnidirectional Conveyor product.

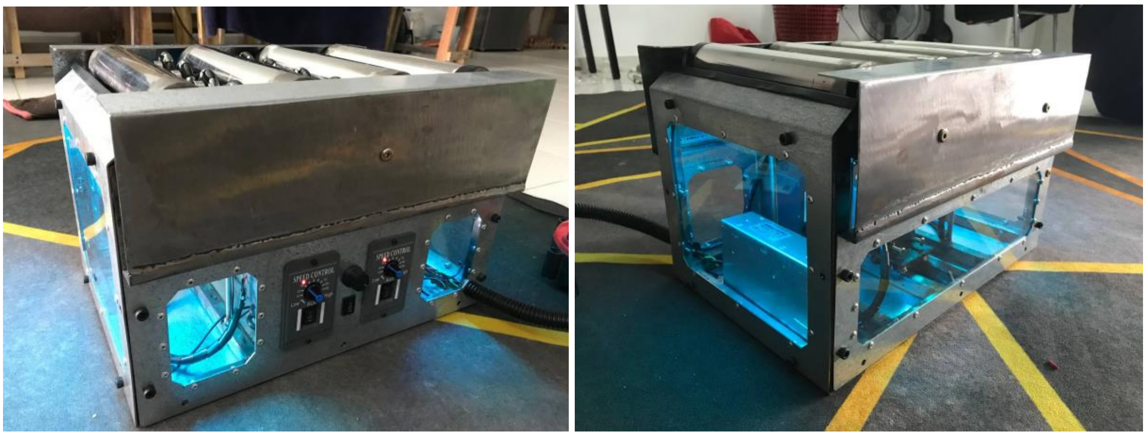


Figure 4.26: The final prototype of the Omnidirectional Conveyor product.

Figure 4.27 shows the speed control of roller and omni wheels with the various features, including an control linear electric DC motor at the middle speed control box.

Figure 4.27: The speed control box roller and omni wheels, along with the various features.

Figure 4.28 shows the assembly of electrical components into the Omnidirectional Conveyor product. The electrical components are installed according to the proper position to improve the wire management and product operation efficiency. At the same time, the DC motor for omni wheels and roller are installed in a main body likewise liner electric DC motor to ensure accessibility while performing the maintenance process.

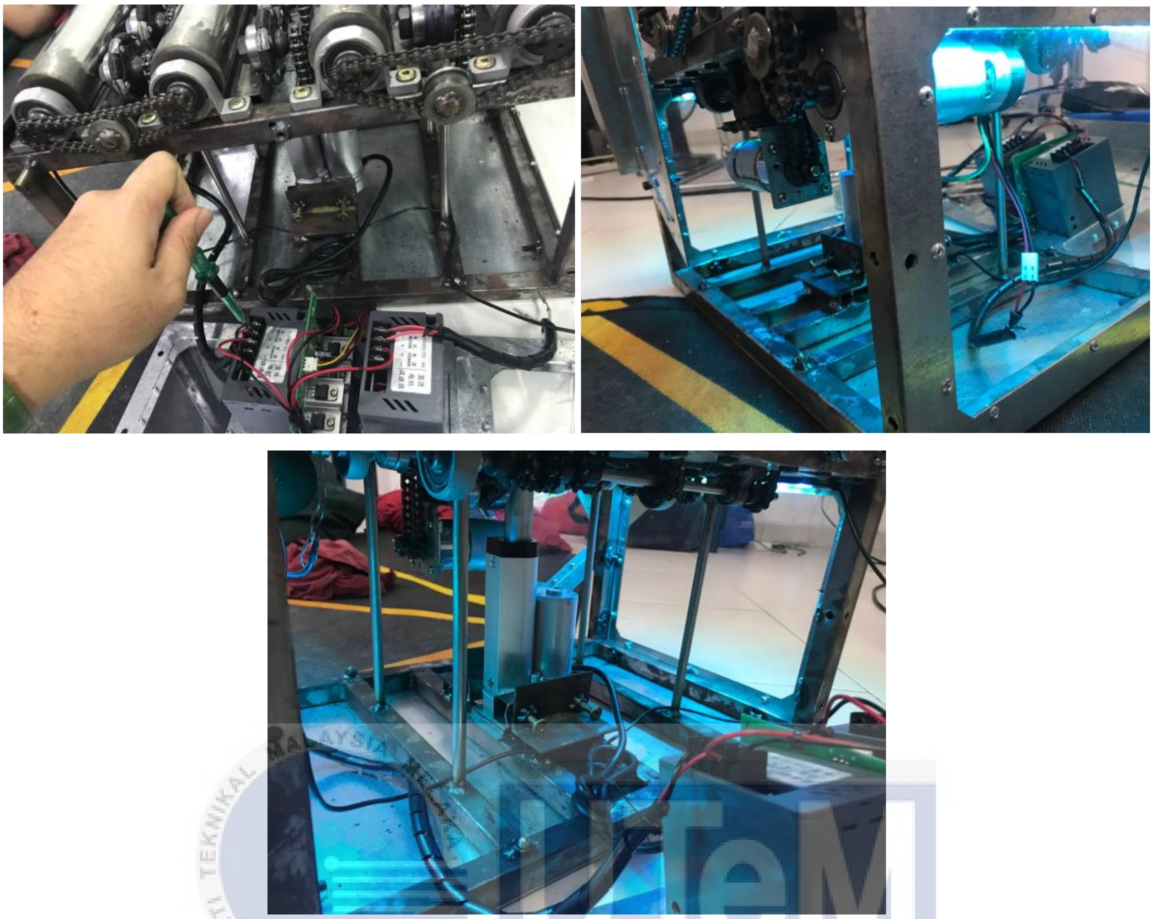


Figure 4.28: The assembly of electrical, DC motor, and liner electric DC motor components into the Omnidirectional Conveyor product.

Figure 4.29 shows the operation of the Omnidirectional Conveyor product to place the load on the conveyor and test run.

Figure 4.29: The omnidirectional Conveyor is in operation to place the load on the conveyor and test run.

Figure 4.30 illustrates the Bill of Materials (BOM), which consists of the significant components and materials used to produce the Omnidirectional Conveyor product. The Omnidirectional Conveyor prototype has been successfully produced according to the design requirements in the engineering drawing. To see the drawing more clearly, the drawing has been displayed in the Appendix C.

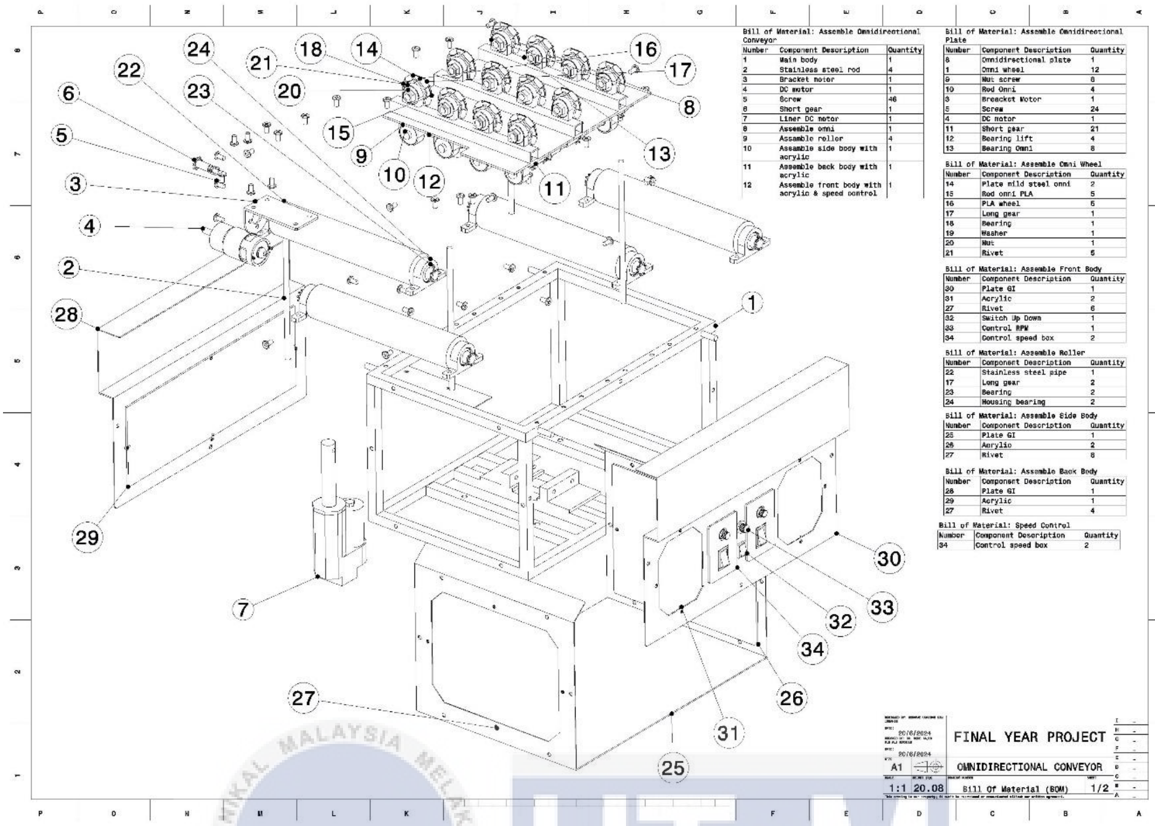


Figure 4.30: The Bill of Materials (BOM) to fabricate the Omnidirectional Conveyor product.

The Omnidirectional Conveyor product is supplied through a single-phase power supply (240V 50Hz) and controlled with a 13A switch plug to turn it on. Next, AC power converted to DC power using an AC to DC converter (12V 10A / 60W), and the power is distributed equally through the terminal solid state supply to DC load components such as speed controller to control the DC motor. Figure 4.31 depicts a schematic circuit diagram consisting of electrical components used to fabricate the Omnidirectional Conveyor product with wire connection. To see the drawing more clearly, the drawing has been displayed in the Appendix C.

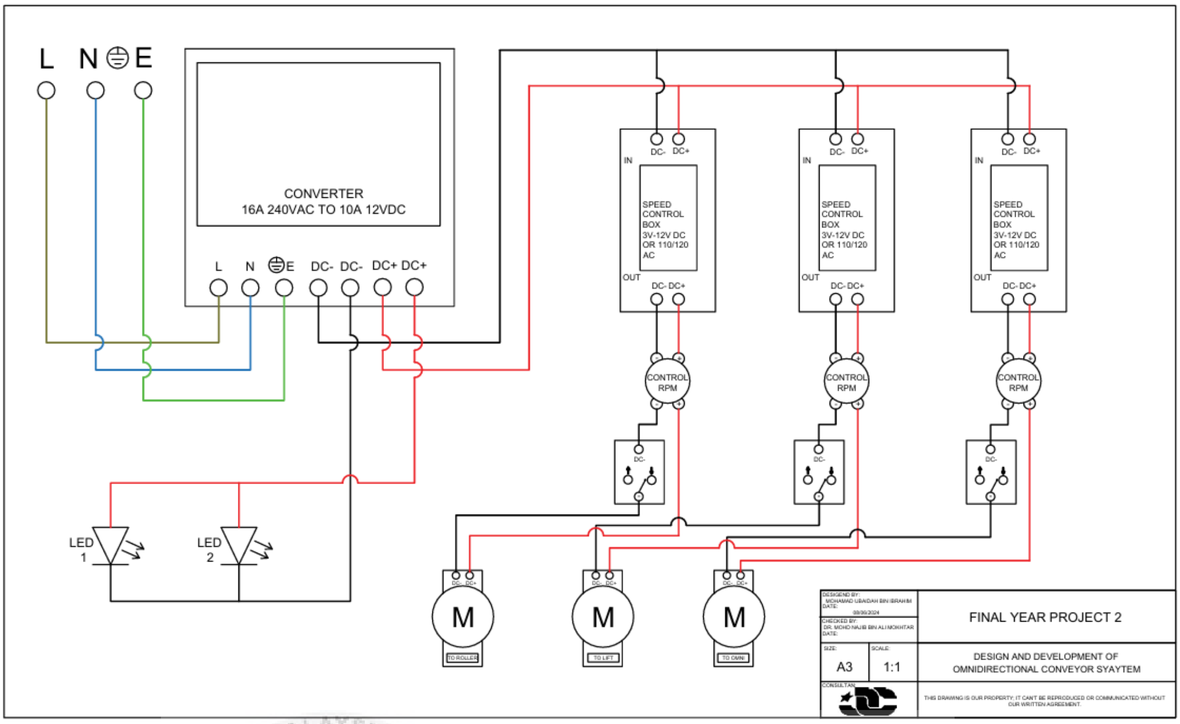


Figure 4.31: The schematic of the circuit diagram of the Omnidirectional Conveyor product.

4.2.6 Omnidirectional Conveyor Bill of Material (BOM).

Figure 4.32 illustrates the exploded view along with the bill of materials used to fabricate the Omnidirectional Conveyor product. To see the drawing more clearly, the drawing has been displayed in the Appendix C.

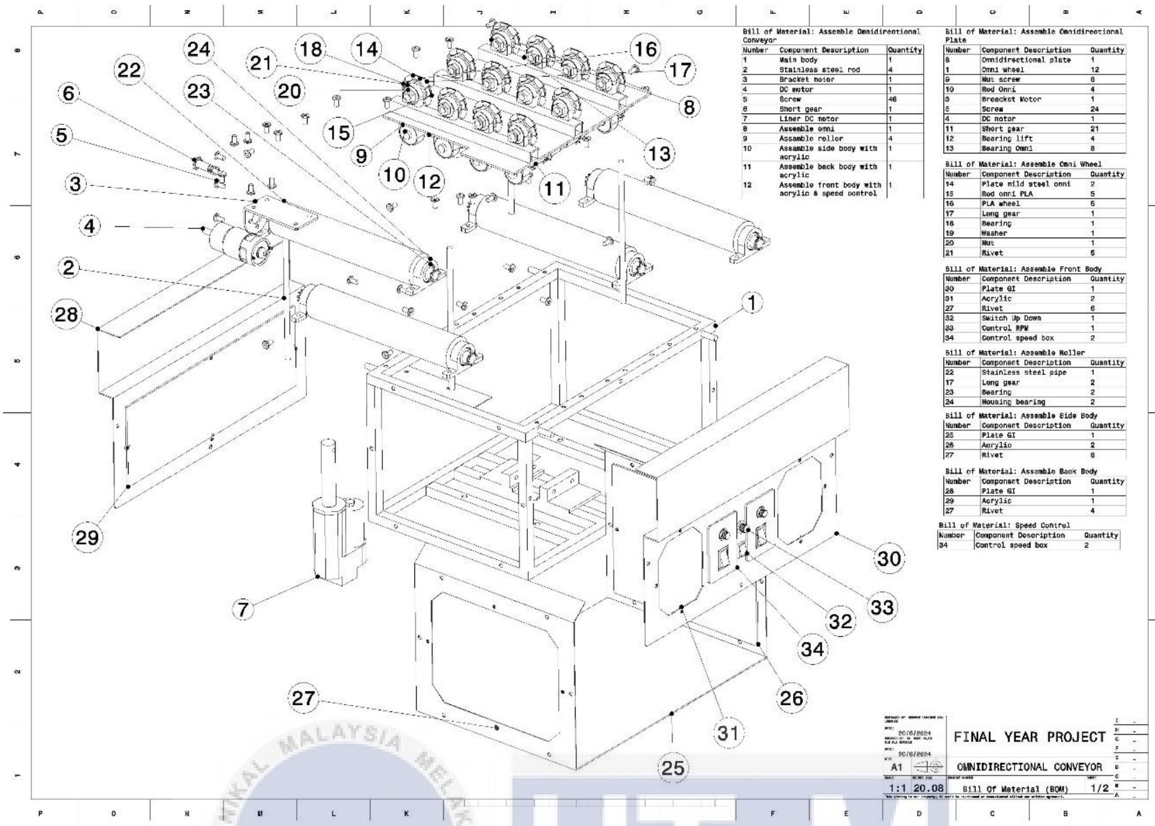


Figure 4.32: The Exploded View Omnidirectional Conveyor product with the Bill of Materials (BOM).

Figure 4.33 illustrates the exploded view along with the bill of materials used to fabricate the Omnidirectional Plate. To see the drawing more clearly, the drawing has been displayed in the Appendix C.

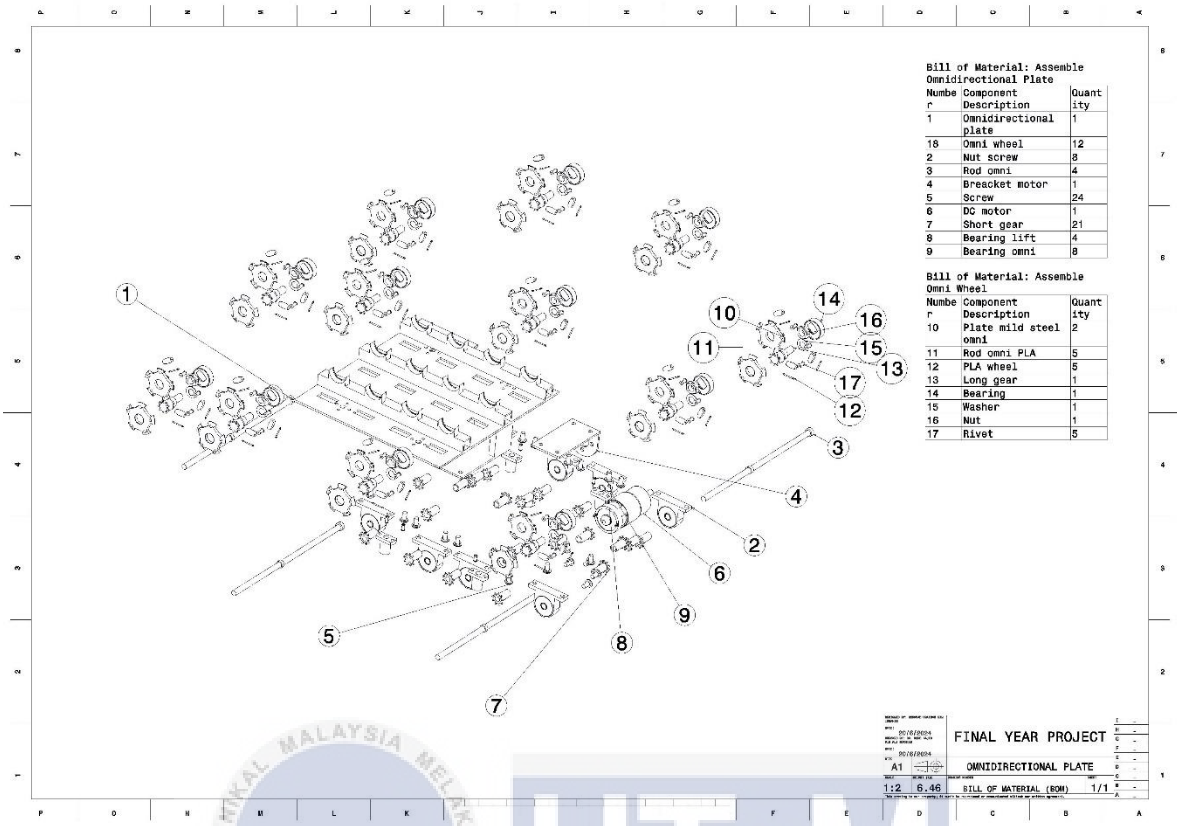


Figure 4.33: The Exploded View Omnidirectional Plate with the Bill of Materials (BOM).

Figure 4.34 illustrates the exploded view along with the bill of materials used to fabricate the Omni Wheel. To see the drawing more clearly, the drawing has been displayed in the Appendix C.

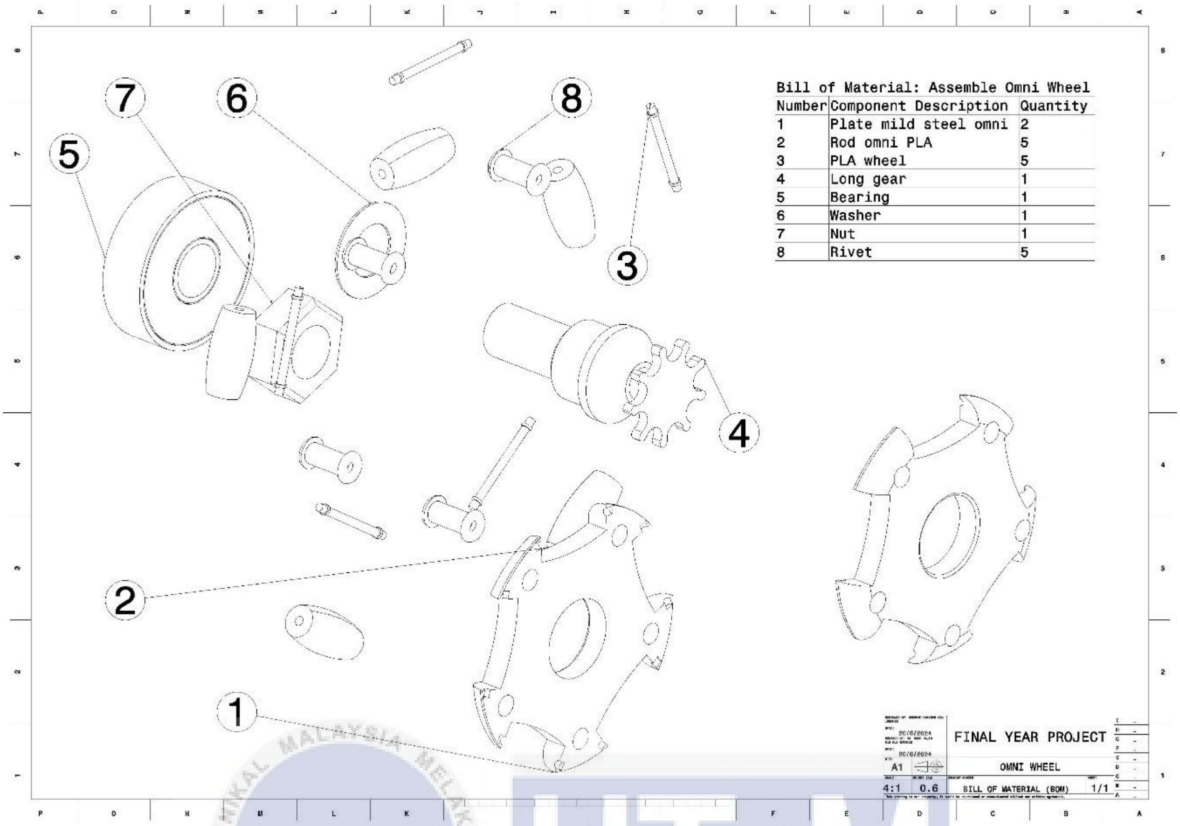


Figure 4.34: The Exploded View Omni Wheel with the Bill of Materials (BOM).

Figure 4.35 illustrates the exploded view along with the bill of materials used to fabricate the Roller. To see the drawing more clearly, the drawing has been displayed in the Appendix C.

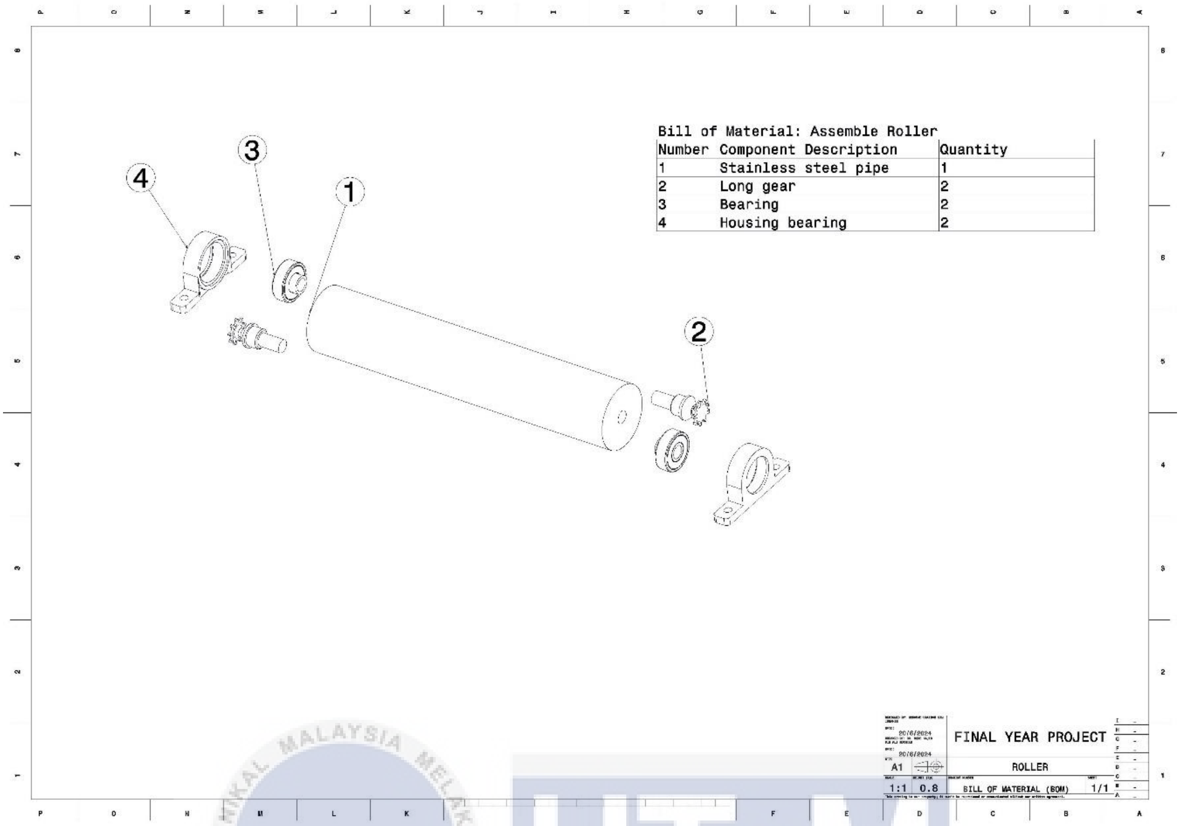


Figure 4.35: The Exploded View Roller with the Bill of Materials (BOM).

A Bill of Materials (BOM), frequently referred to as such, serves as a centralized repository of information outlining all assemblies, sub-assemblies, parts, and raw materials essential for the production of a single unit of the ultimate product. The provided bill of materials furnishes comprehensive information including the quantity, value, and product description of each constituent component. The components comprising the omnidirectional conveyor are enumerated in Table 4.13, located subsequently.

This section addresses the cost analysis, which involves determining the optimized market price of the product and enhancing the profit margin by minimizing overhead costs to achieve net revenue and significant profit. Conducting a cost analysis is crucial in product development as it helps reduce manufacturing expenses and prevents waste and losses by eliminating unnecessary components and processes. Consequently, several procedures must be undertaken in the cost analysis to yield more accurate and efficient outcomes. The table below provides a detailed cost breakdown structure of the components along with their total cost for fabricating the Omnidirectional Conveyor.

Table 4.13: Omnidirectional Conveyor Product Bill of Materials (BOM).

Part No.	Part Name	Details	Material	Quantity	Cost per Unit (RM)	Cost (RM)
1	Side body	Thickness: 1.5mm Length: 983x295mm	GI Plate	1	RM 20.00	RM 20.00
2	Front body	Thickness: 1.5mm Length: 430x350mm	GI Plate	1	RM 12.00	RM 12.00
3	Backward body	Thickness: 1.5mm Length: 430x350mm	GI Plate	1	RM 13.00	RM 13.00
4	Acrylic side body	Thickness: 3mm Length: 230x180mm	Acrylic	2	RM 6.00	RM 12.00
5	Acrylic front body	Thickness: 3mm Length: 100x70mm	Acrylic	2	RM 3.00	RM 6.00
6	Acrylic backward body	Thickness: 3mm Length: 370x100mm	Acrylic	1	RM 5.00	RM 5.00
7	Mild steel hollow	Thickness: 1mm Length: 20x4000mm	Mild steel	1	RM 25.00	RM 25.00
8	Stainless steel roller	Thickness: 1mm Length: 250mm Diameter: 50mm	Stainless steel	4	RM 10.00	RM 40.00
9	Omni wheel	Thickness: 4.5mm Diameter: 50mm	Mild steel & PLA	12	RM 8.00	RM 96.00
10	Plate omni	Thickness: 3mm Length: 310x250mm	GI plate	1	RM 8.00	RM 8.00
11	Bearing roller	Thickness: 10mm Inner diameter: 15mm Out diameter: 25mm	Stainless steel	8	RM 6.00	RM 48.00
12	Bearing omni	Thickness: 10mm	Stainless steel	12	RM 2.50	RM 30.00

		Inner diameter: 10mm Out diameter: 25mm				
13	Long gear	25H, 8teeh Length: 30mm	Mild steel	20	RM 9.00	RM 180.00
14	Short gear	25H, 8teeh Length: 20mm	Mild steel	21	RM 9.00	RM 189.00
15	Chain	25H Length: 500mm	Steel	5	RM 14.00	RM 70.00
16	Rod stainless steel	Length: 250mm Diameter: 8mm	Stainless steel	4	RM 3.80	RM 11.20
17	Bearing rod stainless steel	Thickness: 30mm Inner diameter: 8mm Out diameter: 18mm	Stainless steel	4	RM 5.50	RM 22.00
18	Screw	M12	Mild steel	39	RM 0.50	RM 19.50
19	Bolt nut omni	M12	Mild steel	12	RM 0.30	RM 3.60
20	Control speed	12V DC motor speed controller reversible switch	Plastic	3	RM 24.00	RM 72.00
21	Converter AC to DC 10A	Power supply DC12V 10A transformer AC220V to DC12V converter	Aluminium Alloy	1	RM 37.00	RM 37.00
22	DC motor 248rpm	12VDC, torque 10kgf.cm, 5.5A, 41.3W Diameter: 8mm Length: 20mm	Aluminium Alloy	1	RM 265.00	RM 265.00
23	DC Motor 955rpm	12VDC, torque 10kgf.cm, 4.6A, 50.5W Diameter: 8mm Length: 20mm	Aluminium Alloy	1	RM 95.00	RM 95.00
23	12V Electric motor linear	DC gear push up down motion cylinder	Aluminium Alloy	1	RM 100.00	RM 100.00

24	Wire	2core, 15A Length: 1500mm Diameter: 1mm	Cooper	1	RM 10.00	RM 10.00
					TOTAL	RM 1388.30

Based on the table presented above, the total cost for the components and parts required to fabricate the Omnidirectional Conveyor amounts to RM1388.30. This total cost encompasses all the components necessary to produce a single unit of the product.

4.3 Product testing and analysis

This section will discuss product testing procedures for load, speed and current on Omnidirectional Conveyors. Furthermore, it includes evaluating the product's performance regarding power and energy consumption.

4.3.1 Omnidirectional conveyor Load test.

Table 4.14 show about the Roller DC motor rpm and Currant for Low speed and High speed.

Table 4.14: The Roller DC motor rpm and Currant for Low speed and High speed

	Revolution per minute (rpm)	**Currant (Amp)**
Roller		
Low speed	**48**	**0.86**
High speed	**258**	**0.92**

Table 4.15 show about the Omni Wheel DC motor rpm and Currant for Low speed and High speed.

Table 4.15: The Omni Wheel DC motor rpm and Currant for Low speed and High speed

	Revolution per minute (rpm)	**Currant (Amp)**
Omni wheel		
Low speed	**240**	**3.61**
High speed	**661**	**4.33**

To estimate the power consumption (in Watts) at both the lowest and highest RPMs for the Omnidirectional Conveyor, we can utilize the power equation, which expresses the relationship between power (P), voltage (V), current (I), and the efficiency (η) of the motor. η is the efficiency of the motor (typically between 0.8 to 0.9). The general formula for calculating electrical power is:

$$P = V \times I \times \eta$$

Power consumption (in Watts) low speed roller calculation no load:

Voltage V = 12V

Ampere I = 0.86

Efficiency η = 0.8 (or 80%)

$$P = 12 \times 0.86 \times 0.8$$

$$P = 8.256W$$

Power consumption (in Watts) high speed roller calculation no load:

Voltage V = 12V

Ampere I = 0.92

Efficiency η = 0.8 (or 80%)

$$P = 12 \times 0.92 \times 0.8$$

$$P = 8.832W$$

Power consumption (in Watts) low speed omni wheels calculation no load:

Voltage V = 12V

Ampere I = 3.61

Efficiency η = 0.8 (or 80%)

$$P = 12 \times 3.61 \times 0.8$$

$$P = 34.656W$$

Power consumption (in Watts) high speed omni wheels calculation no load:

Voltage V = 12V

Ampere I = 4.33

Efficiency η = 0.8 (or 80%)

$$P = 12 \times 4.33 \times 0.8$$

$$P = 41.568W$$

Here, we observe that the Omni Wheels DC motor consumes 41.568W at high speed, whereas the DC roller motor consumes only 8.832W at high speed. These power consumption readings indicate the energy usage when no load is applied to the Omnidirectional Conveyor system.

When the power requirement of the motor and the supplied voltage are known, the current required can be calculated by factoring in the motor's efficiency. This can be applied to determine the current at both the lowest and highest RPMs. Here’s the process to isolate and calculate the current (I):

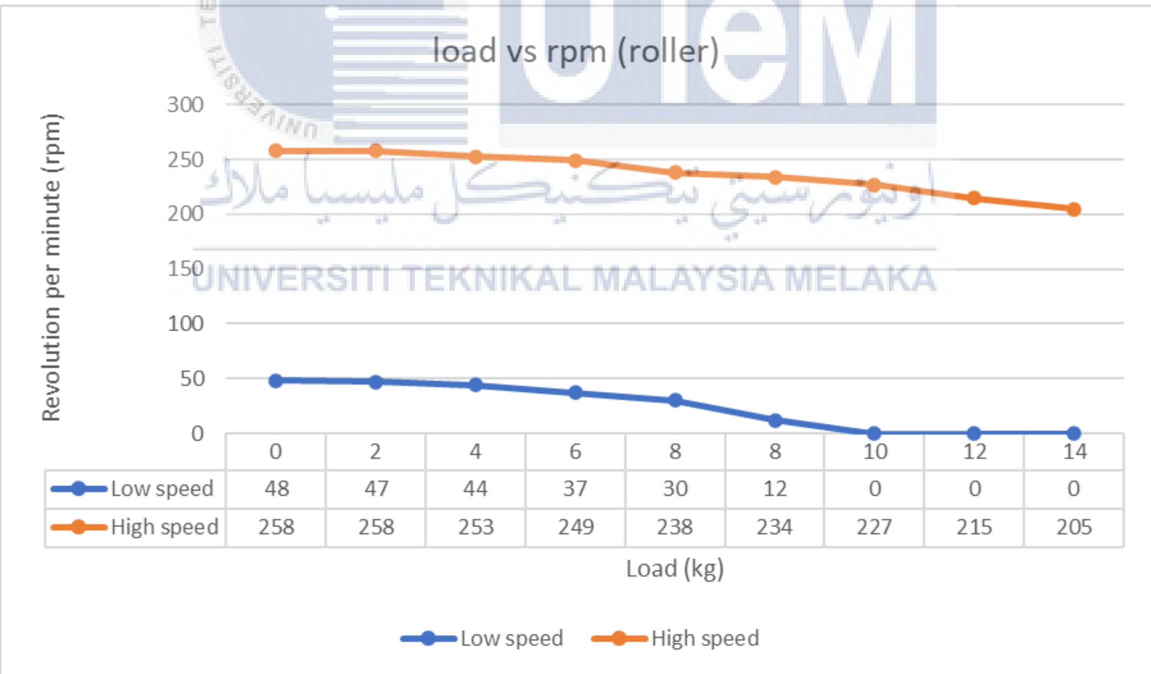
$$I = \frac{P}{V\ x\ \eta}$$

Table 4.16 show about the pass and non-pass applied the load at Omnidirectional Conveyor Product. This table show the high speed and low speed DC motor.

Table 4.16: omnidirectional conveyor load test.

Load (kg)	Roller		Omni wheel	
	Low speed	High speed	Low speed	High speed
2	✓	✓	✓	✓
4	✓	✓	✓	✓
6	✓	✓	✓	✓
8	✓	✓	✓	✓
10	X	✓	X	✓
12	X	✓	X	✓
14	X	✓	X	X

Figure 4.36 show the graph Load (kg) vs Speed Revolution per minute (rpm) for roller using the DC motor 248rpm.



	0	2	4	6	8	8	10	12	14
Low speed	48	47	44	37	30	12	0	0	0
High speed	258	258	253	249	238	234	227	215	205

Figure 4.36: The graph Load (kg) vs Speed Revolution per minute (rpm) for roller.

Figure 4.37 show the graph Load (kg) vs Speed Revolution per minute (rpm) for omni wheel using the DC motor 955rpm

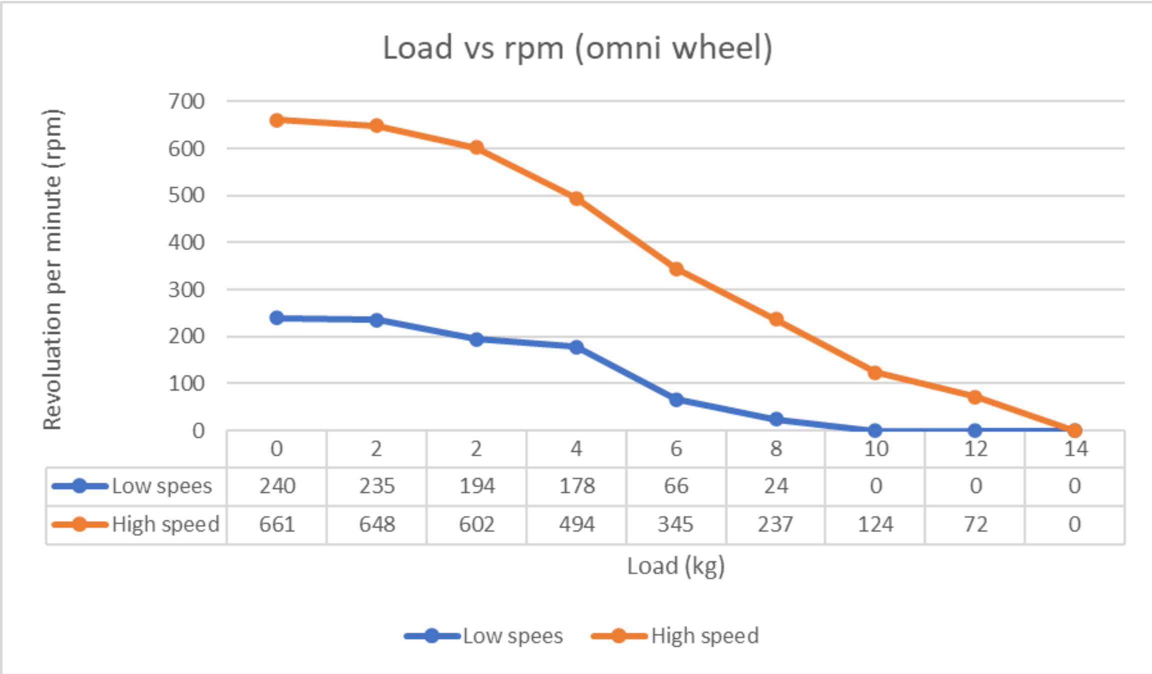


Figure 4.37: The graph Load (kg) vs Speed Revolution per minute (rpm) for omni wheel.

This figure 4.36 and 4.37 shows the results of the load placed on the omnidirectional conveyor product while the DC motor is running at high speed and low speed. Here shows, the DC roller motor in low speed where a load of 10kg is placed does not move, while in high speed it can move. In addition, the omni wheel of the DC motor in the low speed where the load of 10kg is placed does not move, while in the high speed load of 14kg the omni wheel of the new DC motor does not move.

4.3.2 Omnidirectional conveyor Load, speed, and currant test.

4.3.2.1 Load (kg) vs currant (Amp) for roller and omni wheel.

Figure 4.38 show the graph about Load (kg) vs currant (Amp) for roller.

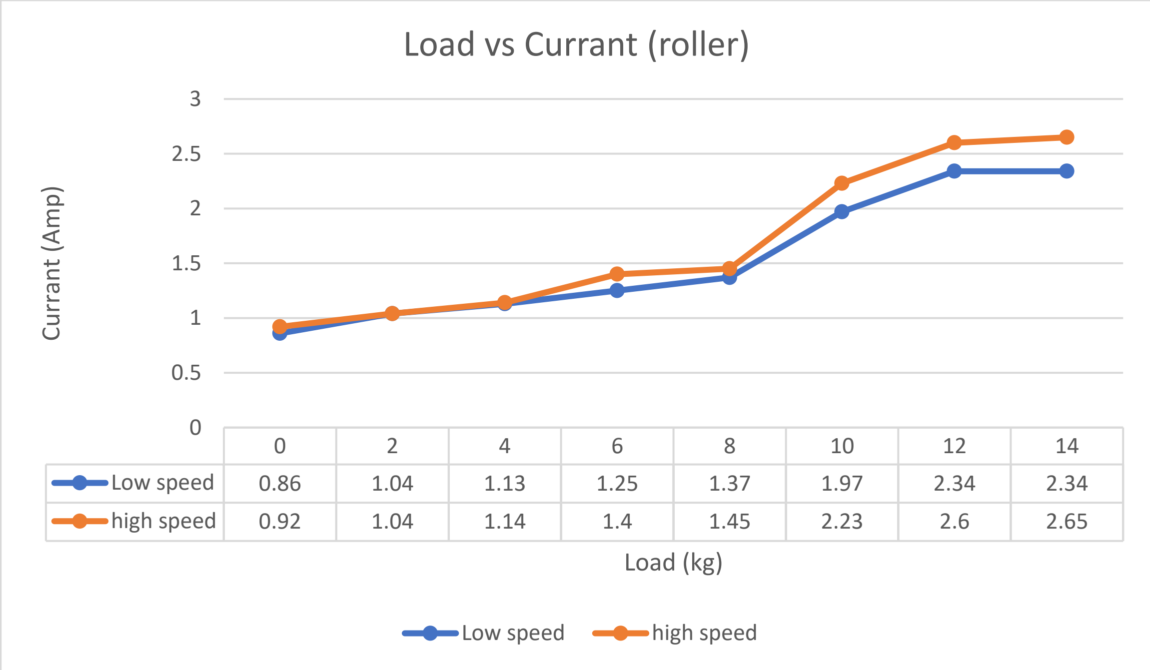


Figure 4.38: The graph Load (kg) vs currant (Amp) for roller.

The graph in figure 4.38 shows that as the load gets higher, the currant will increase. Here it is found that the rpm is at a low speed, the current maintains a load of 12kg and 14kg, this is because the roller does not move.

Figure 4.39 show the graph about Load (kg) vs currant (Amp) for omni wheel.

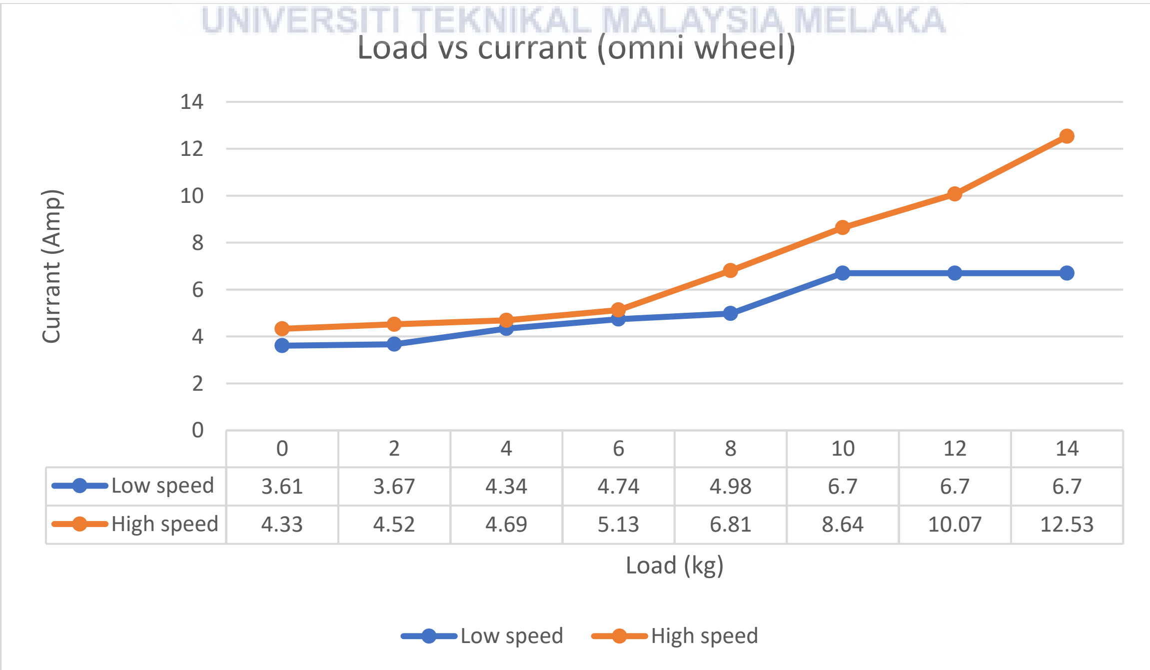


Figure 4.39: The graph about Load (kg) vs currant (Amp) for omni wheel.

The graph in figure 4.39 shows that as the load gets higher, the currant will increase. Here it is found that the rpm is at a low speed, the currant maintains a load of 10kg to 14kg, this is because the Omni Wheels does not move.

4.3.3 Check temperature DC motor.

Figure 4.40 shows the check temperature of the digital meter on the omni-wheel DC motor after all the tests. The current room temperature is 30.9°C. While the temperature of the DC omni wheel motor is 44.5°C after the DC omni wheel motor moves for 45 minutes.

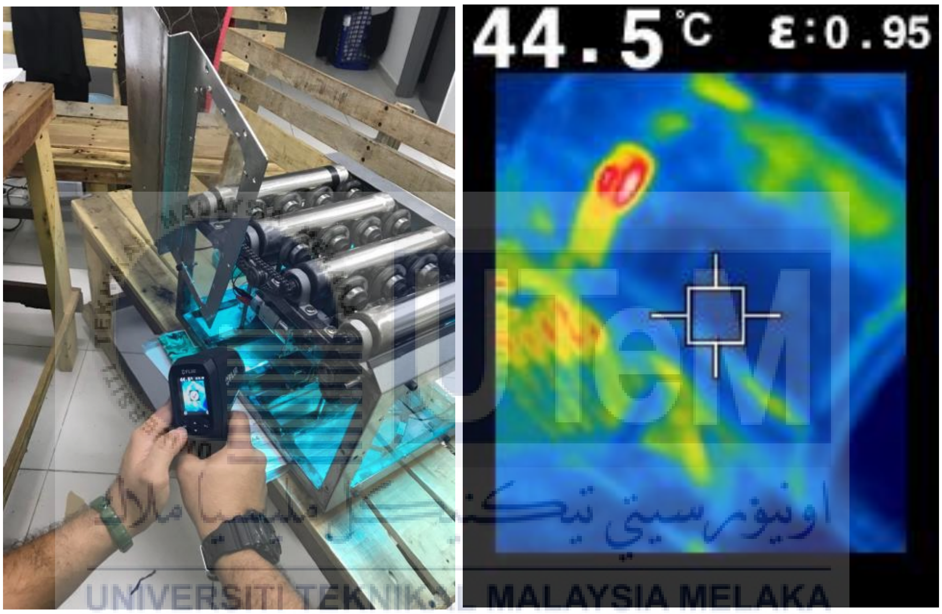


Figure 4.40: The digital meter temperature show the temperature DC motor omni wheel.

Figure 4.41 shows the check temperature of the digital meter on the roller DC motor after all the tests. The current room temperature is 30.9°C. While the temperature of the DC Roller motor is 41.1°C after the DC roller motor moves for 45 minutes.

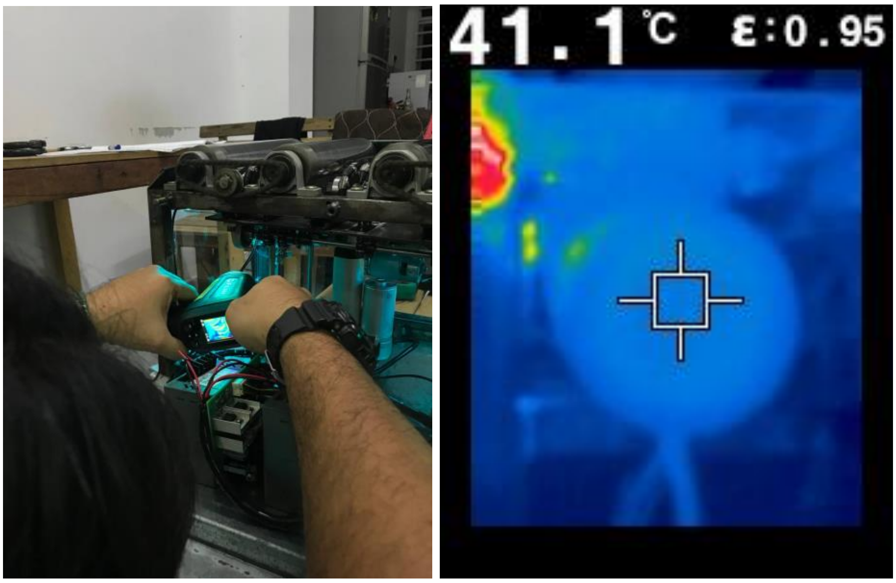


Figure 4.41: The digital meter temperature show the temperature DC motor roller.

4.4 Summary

The section on product testing and analysis for the omnidirectional conveyor system presents a thorough examination of the methodologies and outcomes related to load, speed, and current evaluations, alongside an assessment of power and energy consumption metrics. The load testing results, depicted in Figures 4.36 and 4.37, demonstrate that the DC roller motor is incapable of transporting a 10kg load at low speed, yet it is capable of doing so at high speed. Similarly, the DC motor omni wheel is ineffective in moving a 10kg load at low speed and also fails to transport a 14kg load at high speed. These findings underscore the motors' reliance on higher operational speeds to achieve load mobility.

Further analysis, as illustrated in Figures 4.38 and 4.39, reveals a proportional increase in current draw with increasing load. At low speed, the current stabilizes when handling loads of 12kg and 14kg for the roller and between 10kg and 14kg for the omni wheel. This stabilization is attributed to the motors' inability to move these loads at low speed, resulting in higher current consumption without corresponding movement.

Temperature assessments conducted post-testing, shown in Figures 4.40 and 4.41, indicate that after 45 minutes of continuous operation, the DC omni wheel motor's temperature rises to 44.5°C, compared to an ambient room temperature of 30.9°C. Similarly, the DC roller motor records a temperature of 41.1°C under the same conditions. These temperature increases provide insights into the thermal behavior of the motors during extended periods of operation, highlighting the thermal stress and the potential necessity for cooling mechanisms in prolonged usage scenarios. Overall, the tests offer a comprehensive evaluation of the performance, current draw, and thermal characteristics of the motors employed in the omnidirectional conveyor system, emphasizing their operational limits and efficiency.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction.

This chapter serves as the research study's and work's conclusion, with the main references for the findings' interpretation coming from the study's objective and scope. Additionally, suggestions for future work improvement are given.

5.2 Conclusion.

To sum up, the Omnidirectional Conveyor project endeavors to design and manufacture a highly effective and adaptable product. The design must be sophisticated yet accessible, suitable for various industrial applications, allowing for the transportation of packages in any direction, irrespective of their size and weight. The omnidirectional conveyor is required to be robust and durable, ensuring longevity and reliability. Cost management poses a significant challenge, especially due to the high expenses associated with components like the omni wheel. To mitigate this, the project incorporates custom fabrication of the omni wheels and other components, such as rollers, to better control costs.

Additionally, the importance of maintenance and serviceability is emphasized in this project. The design of the Omnidirectional Conveyor facilitates easy repair, disassembly, and installation on existing roller conveyors. This not only enhances usability but also contributes to cost efficiency by enabling existing roller conveyors to be upgraded with omnidirectional capabilities, thus extending their functional life without necessitating complete replacement.

Furthermore, to ensure the product's optimal performance, extensive structural testing was conducted using ANSYS software. The simulations revealed that the roller has a maximum load capacity of 20kg, while the omni wheel can support up to 10kg. These results affirm that the Omnidirectional Conveyor is highly efficient and capable of handling significant loads, making it an invaluable asset to industrial conveyor systems. The comprehensive testing and strategic design considerations guarantee that the product not only meets but surpasses operational requirements.

5.3 Recommendations.

At this point, it is recommended to upgrade the Omnidirectional Sender product in the future will be discussed as below:

i. Switch to a more powerful Motor to increase to lift higher loads.
ii. Add a control system to the Omnidirectional Conveyor product to move in various directions such as 45 degrees and be fully controlled by the system.

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Touching Point on Ground Outer Passive Wheel Inner Passive Wheel Axis of Rotation Fig. 3: The problem of Omni Wheel in Odometry. (n.d.).

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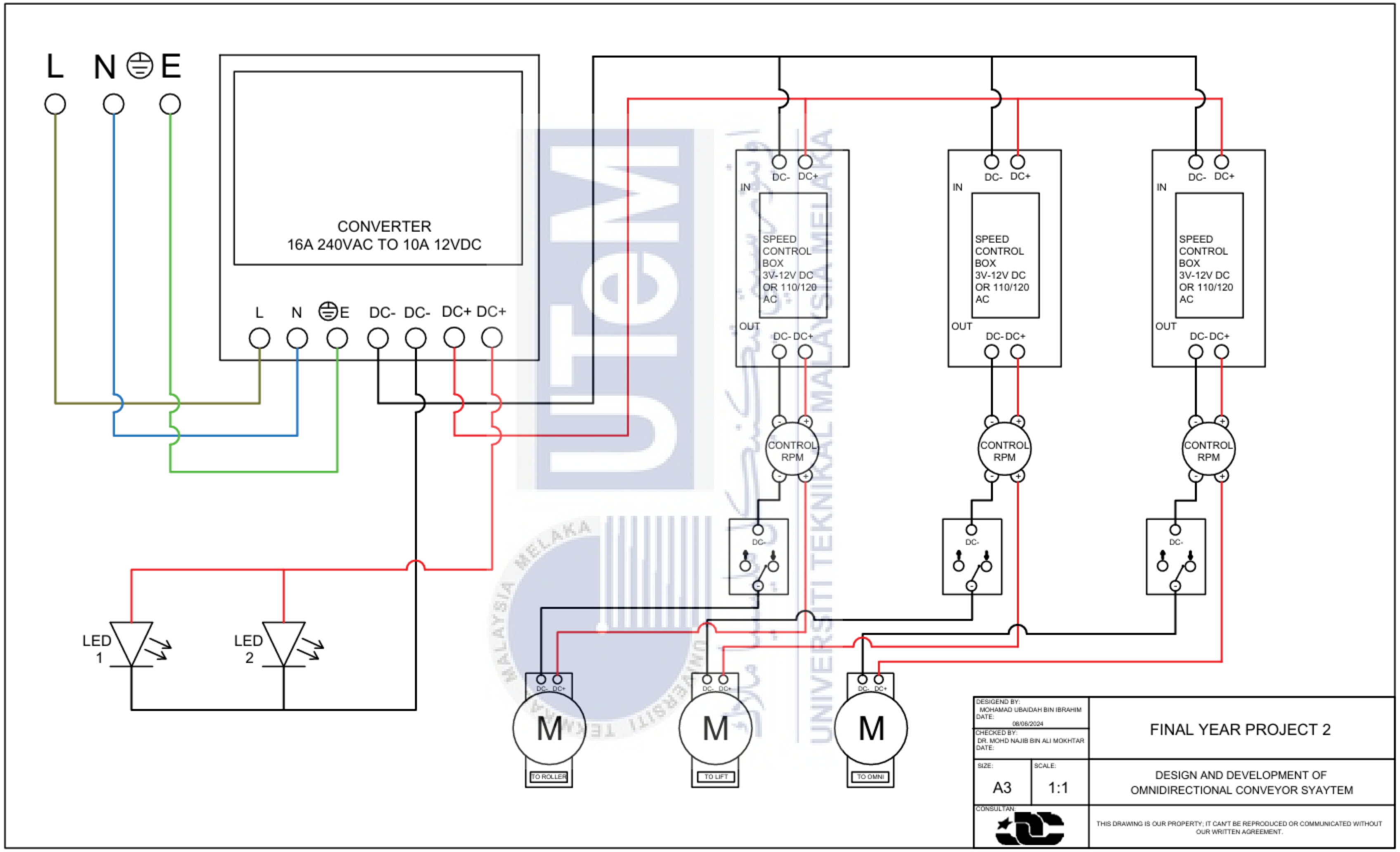
APPENDICES

Appendix A

Final Product.

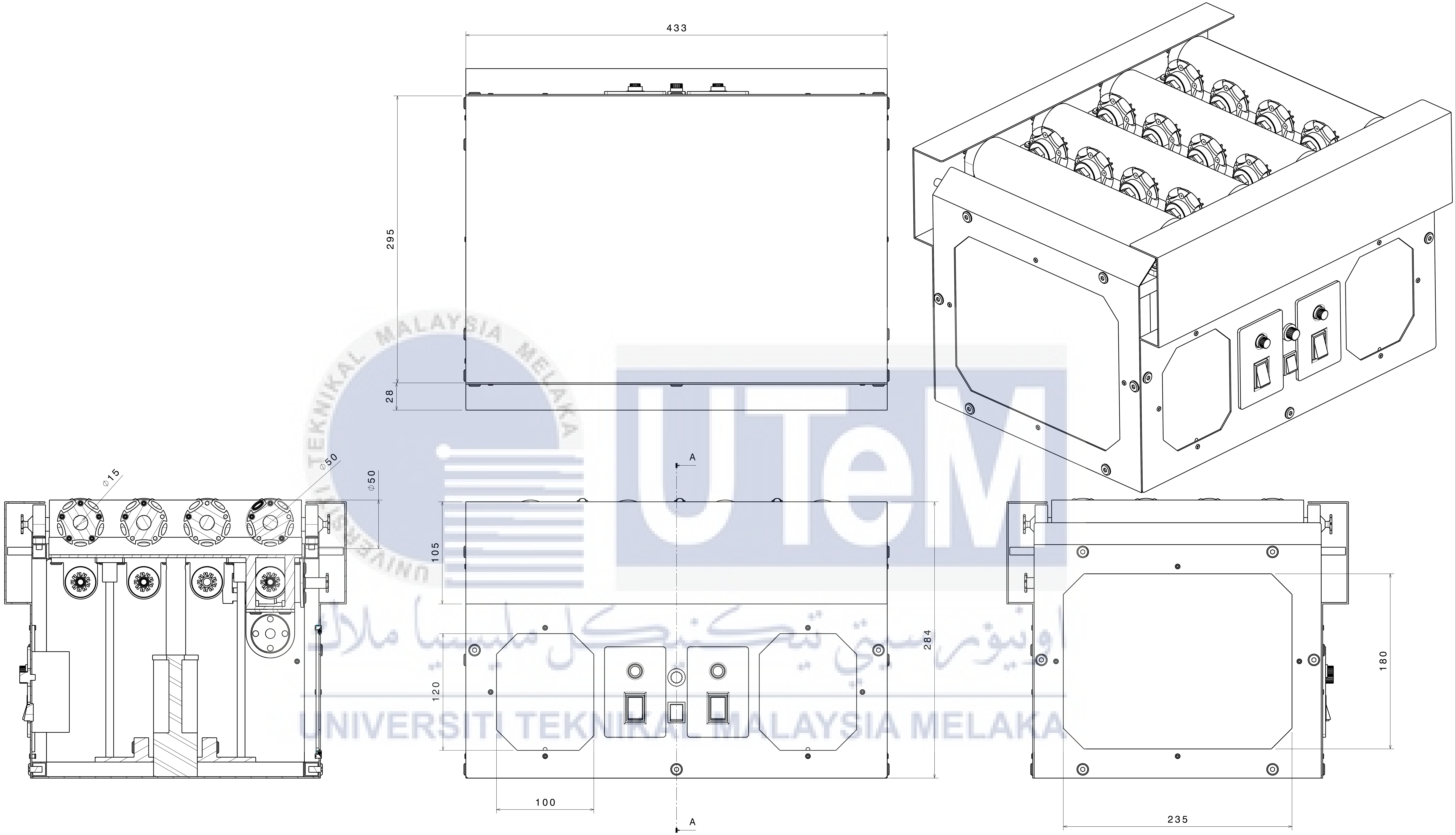
Appendix B

Schematic Circuit Diagram



Appendix C

Technical Drawing & Exploded View with Bill of Materials



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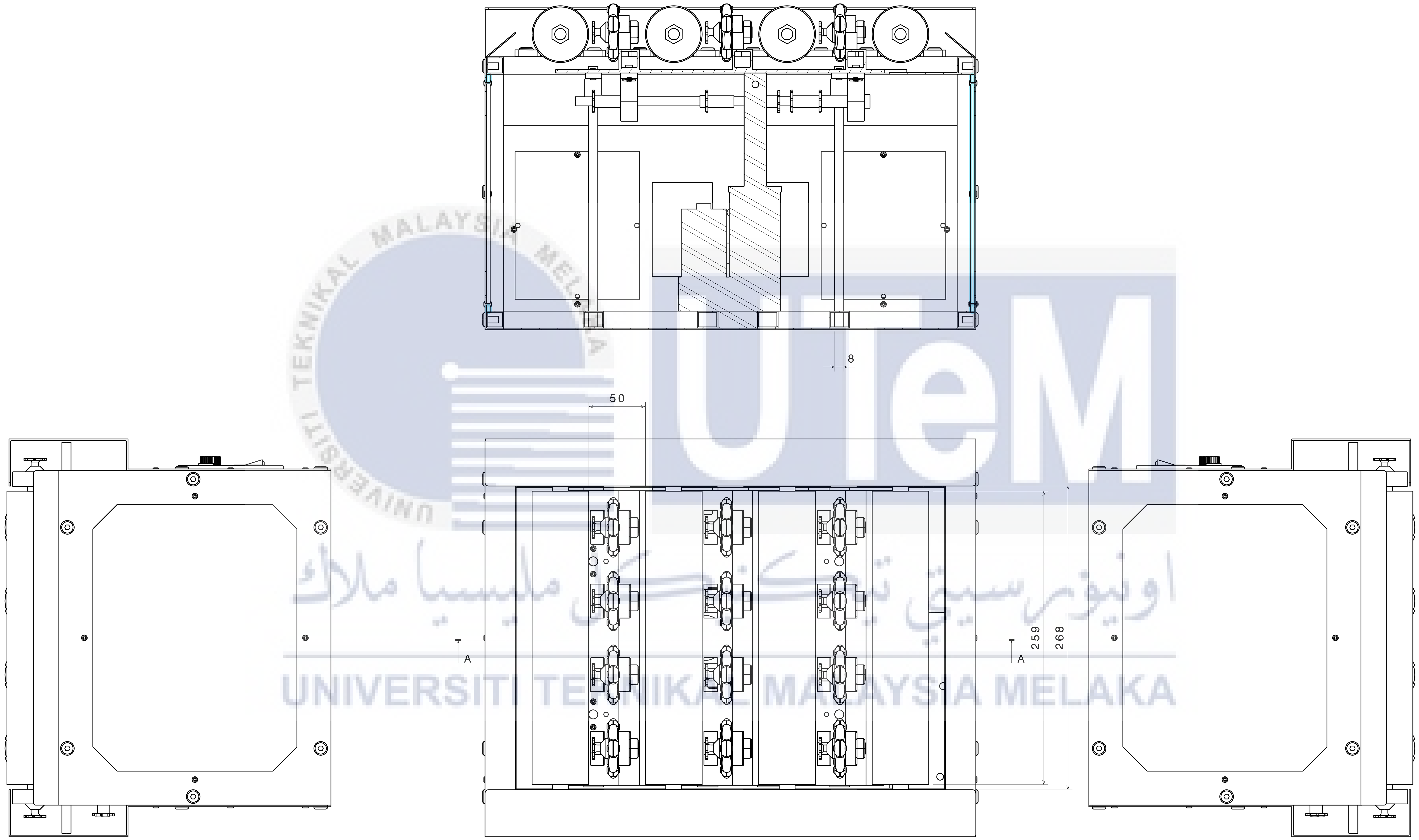
SIZE A1		OMNIDIRECTIONAL CONVEYOR	
SCALE 1:2	WEIGHT (kg) 20.08	DRAWING NUMBER Product1	SHEET 1/1

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



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SIZE A1		OMNIDIRECTIONAL CONVEYOR	
SCALE 1:2	WEIGHT (kg) 20.08	DRAWING NUMBER Product2	SHEET 1/1

I	_
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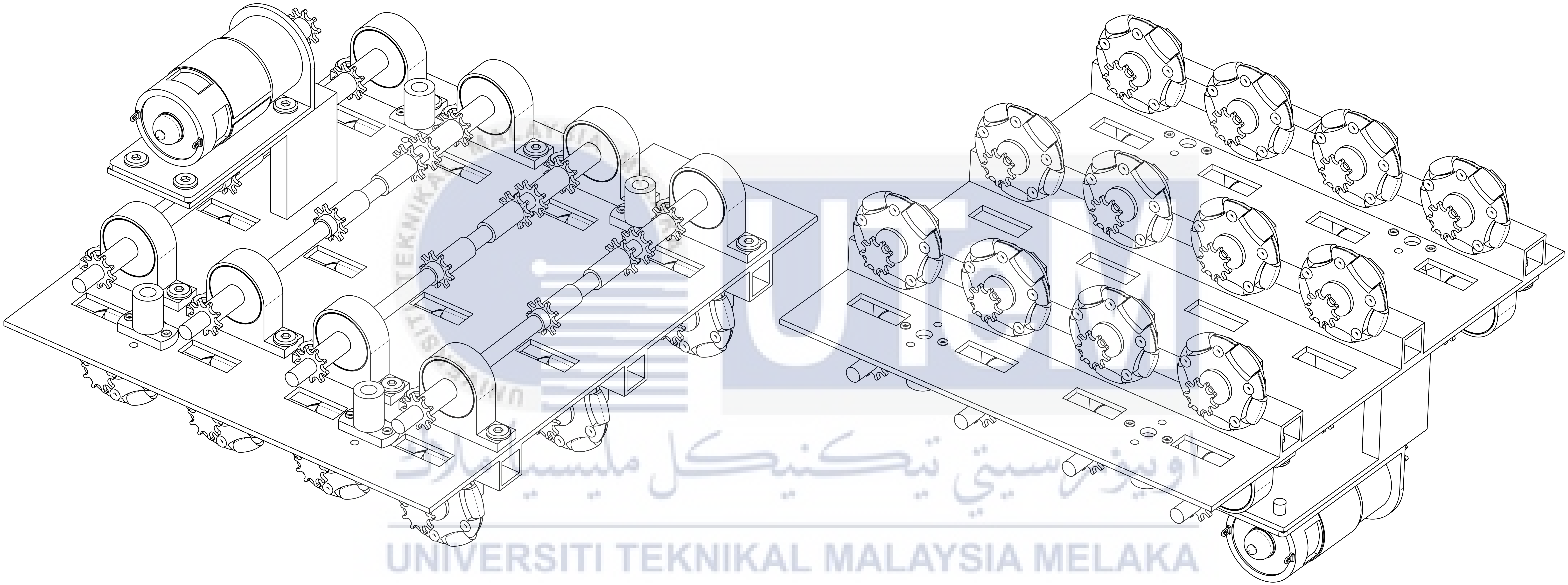
G	_
F	_
E	_
D	_
C	_
B	_
A	_



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CHECKED BY: DR. MOHD NAJIB BIN ALI MOKHTAR DATE: 20/6/2024			
SIZE A1		OMNIDIRECTIONAL CONVEYOR	
SCALE 1:1	WEIGHT (kg) 6.46	DRAWING NUMBER PRODUCT4	SHEET 1/1

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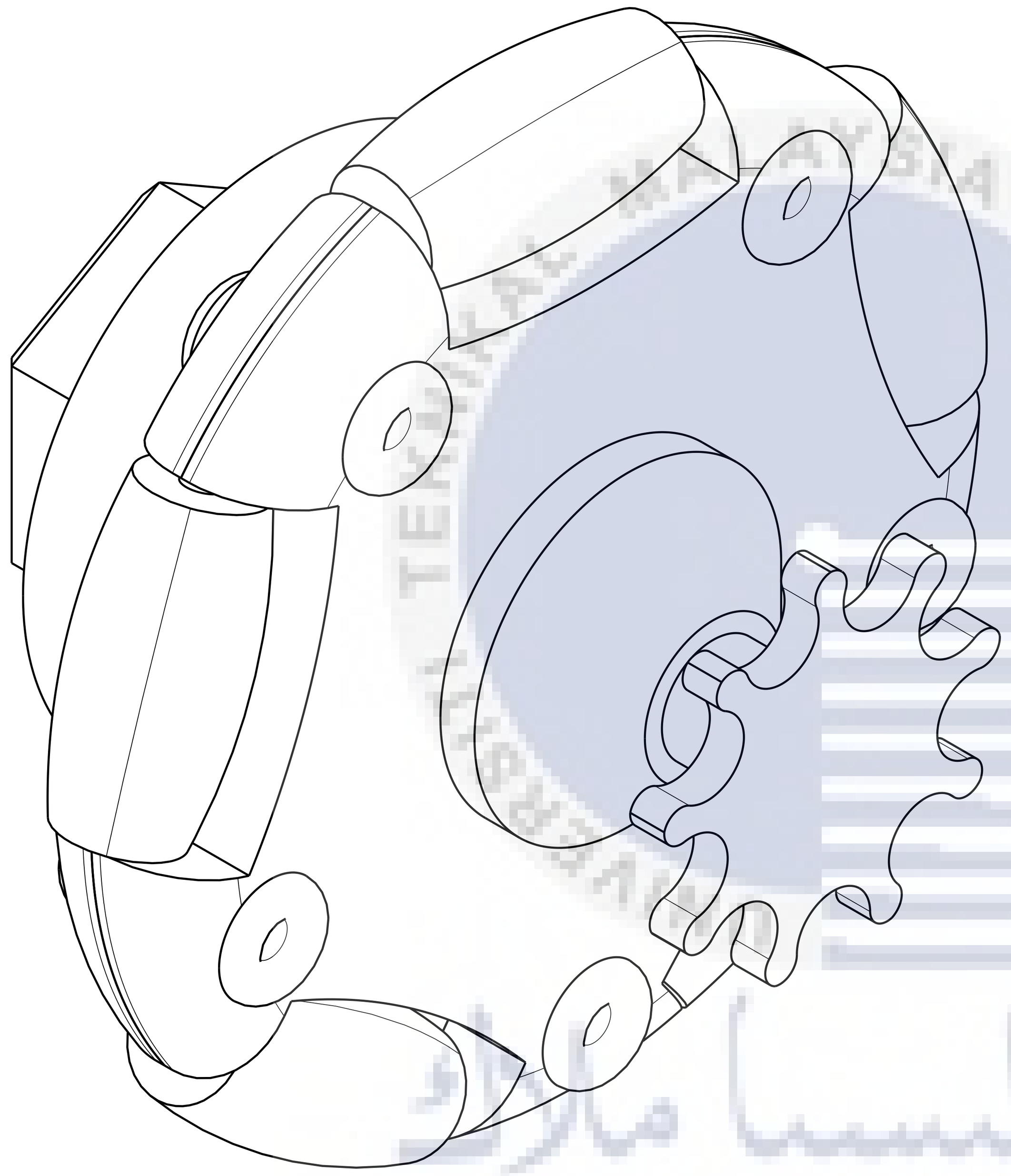
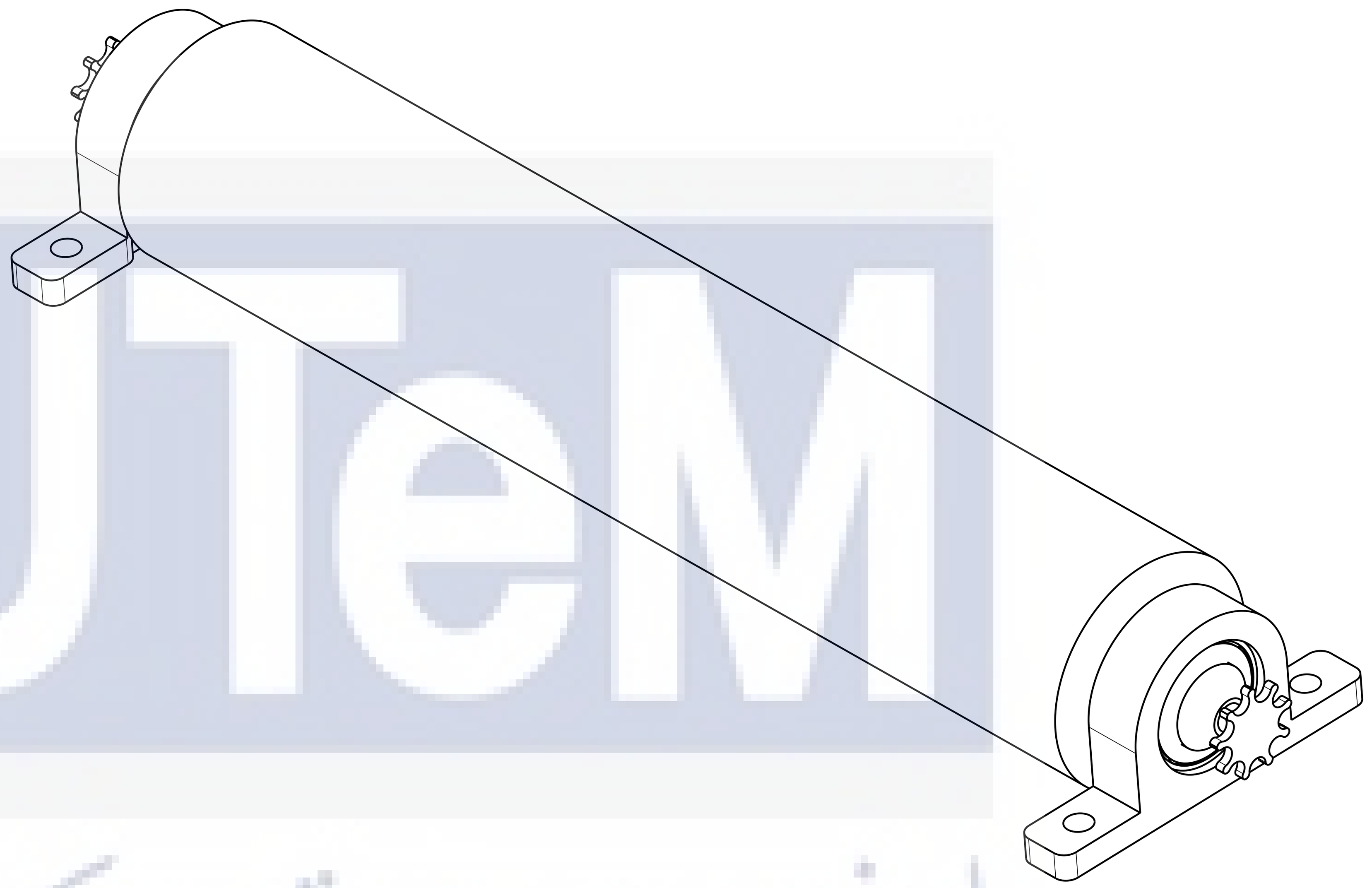
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



Isometric view omni wheel
Scale: 4:1



Isometric view roller
Scale: 1:1

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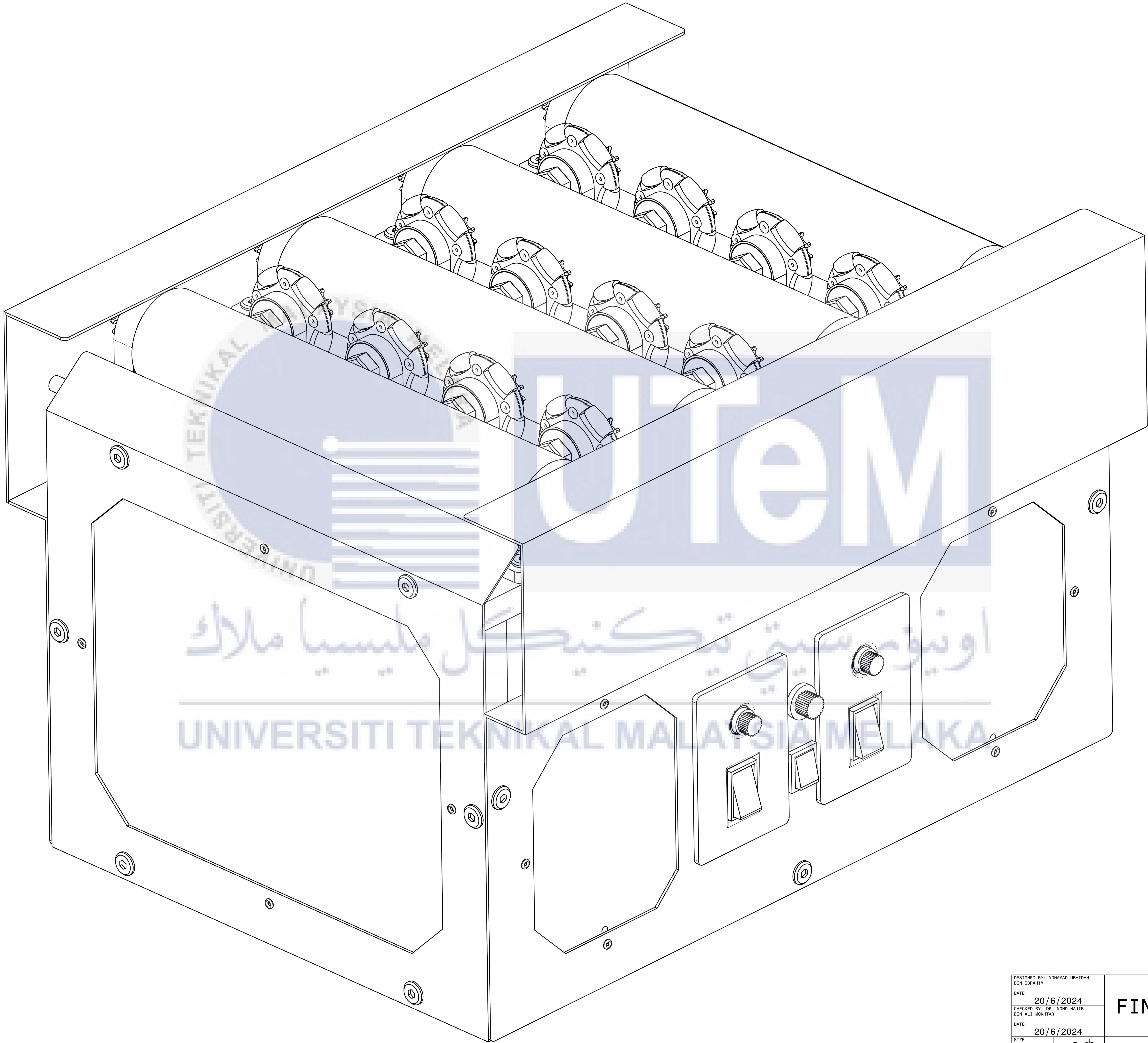
CHECKED BY: DR. MOHD NAJIB BIN ALI MOKHTAR DATE: 20/6/2024			
SIZE A1		OMNI WHEEL AND ROLLER	
SCALE 1:1	WEIGHT (kg) 1.16	DRAWING NUMBER Product5	SHEET 1/1



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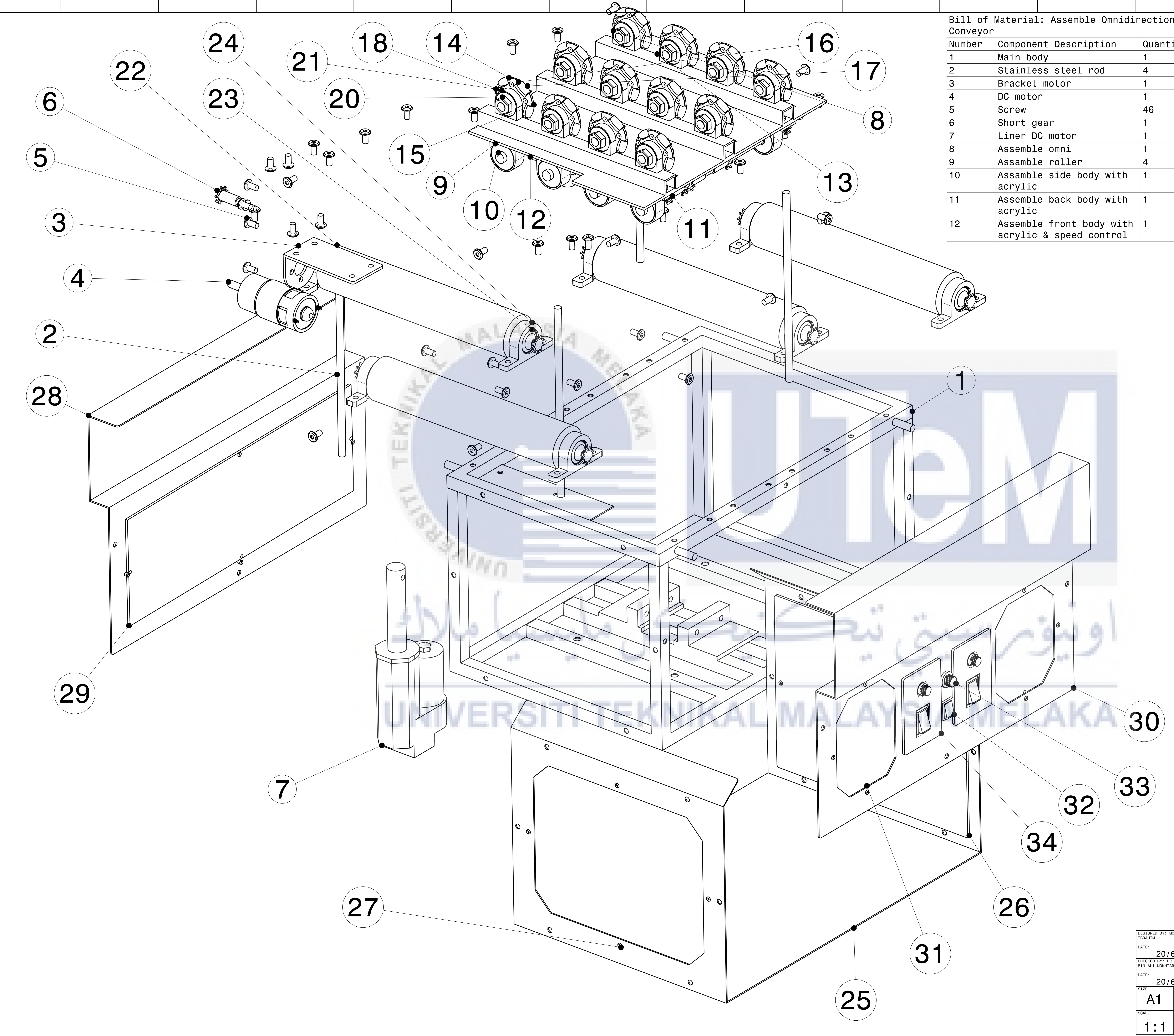
SIZE A1		OMNIDIRECTIONAL CONVEYOR	
SCALE 1:1	WEIGHT (kg) 20.08	DRAWING NUMBER Product3	SHEET 1/1



Bill of Material: Assemble Omnidirectional Conveyor

Number	Component Description	Quantity
1	Main body	1
2	Stainless steel rod	4
3	Bracket motor	1
4	DC motor	1
5	Screw	46
6	Short gear	1
7	Liner DC motor	1
8	Assemble omni	1
9	Assamble roller	4
10	Assemble side body with acrylic	1
11	Assemble back body with acrylic	1
12	Assemble front body with acrylic & speed control	1

Bill of Material: Assemble Omnidirectional Plate

Number	Component Description	Quantity
8	Omnidirectional plate	1
1	Omni wheel	12
9	Nut screw	8
10	Rod Omni	4
3	Breacket Motor	1
5	Screw	24
4	DC motor	1
11	Short gear	21
12	Bearing lift	4
13	Bearing Omni	8

Bill of Material: Assemble Omni Wheel

Number	Component Description	Quantity
14	Plate mild steel omni	2
15	Rod omni PLA	5
16	PLA wheel	5
17	Long gear	1
18	Bearing	1
19	Washer	1
20	Nut	1
21	Rivet	5

Bill of Material: Assemble Front Body

Number	Component Description	Quantity
30	Plate GI	1
31	Acrylic	2
27	Rivet	6
32	Switch Up Down	1
33	Control RPM	1
34	Control speed box	2

Bill of Material: Assemble Roller

Number	Component Description	Quantity
22	Stainless steel pipe	1
17	Long gear	2
23	Bearing	2
24	Housing bearing	2

Bill of Material: Assemble Side Body

Number	Component Description	Quantity
25	Plate GI	1
26	Acrylic	2
27	Rivet	8

Bill of Material: Assemble Back Body

Number	Component Description	Quantity
28	Plate GI	1
29	Acrylic	1
27	Rivet	4

Bill of Material: Speed Control

Number	Component Description	Quantity
34	Control speed box	2

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CHECKED BY: DR. MOHD NAJIB BIN ALI MOKHTAR
DATE: 20/6/2024

FINAL YEAR PROJECT

OMNIDIRECTIONAL CONVEYOR

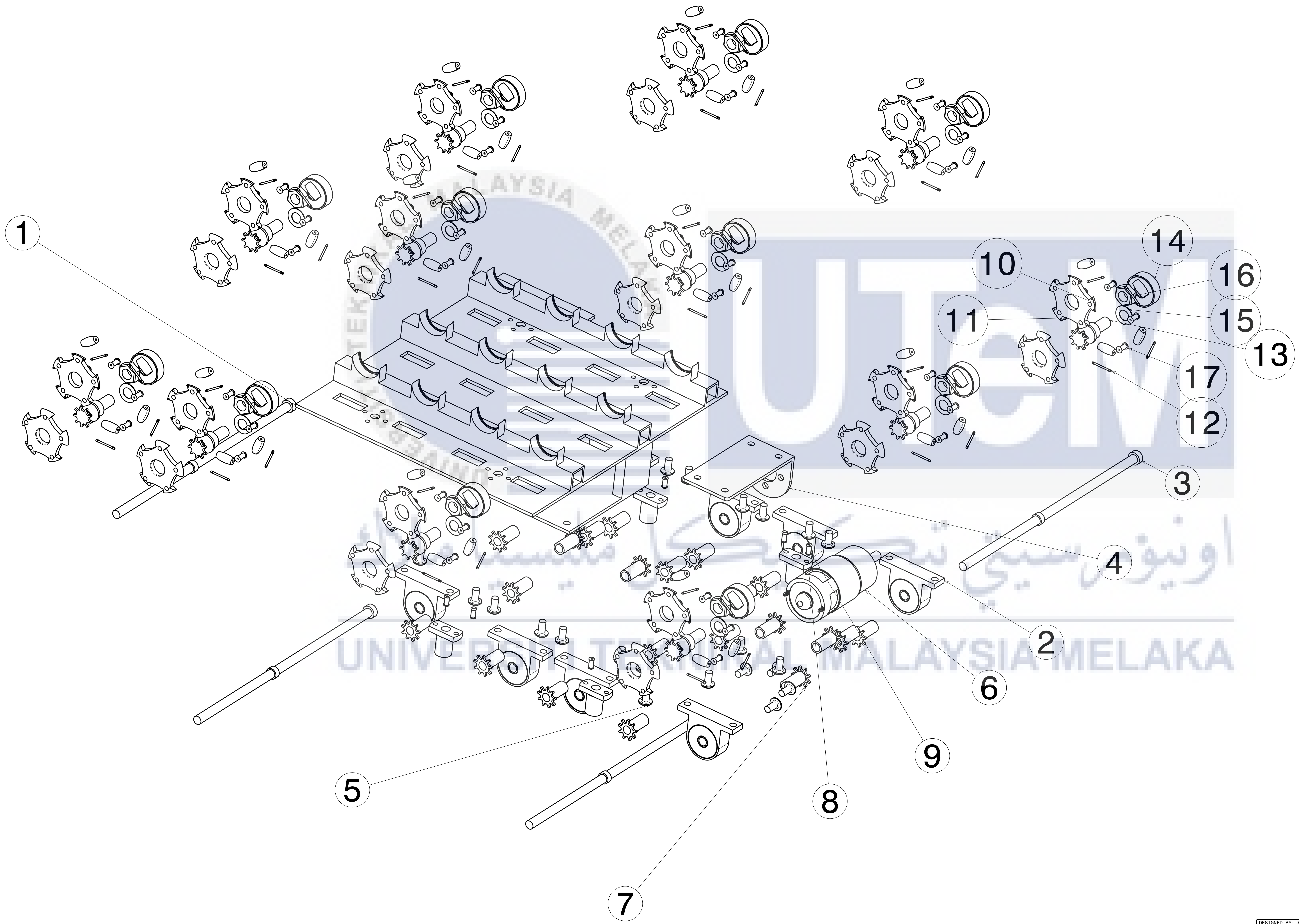
SIZE: A1

SCALE: 1:1

WEIGHT (kg): 20.08

DRAWING NUMBER: Bill Of Material (BOM)

SHEET: 1/2



Bill of Material: Assemble Omnidirectional Plate

Number	Component Description	Quantity
1	Omnidirectional plate	1
18	Omni wheel	12
2	Nut screw	8
3	Rod omni	4
4	Breacket motor	1
5	Screw	24
6	DC motor	1
7	Short gear	21
8	Bearing lift	4
9	Bearing omni	8

Bill of Material: Assemble Omni Wheel

Number	Component Description	Quantity
10	Plate mild steel omni	2
11	Rod omni PLA	5
12	PLA wheel	5
13	Long gear	1
14	Bearing	1
15	Washer	1
16	Nut	1
17	Rivet	5

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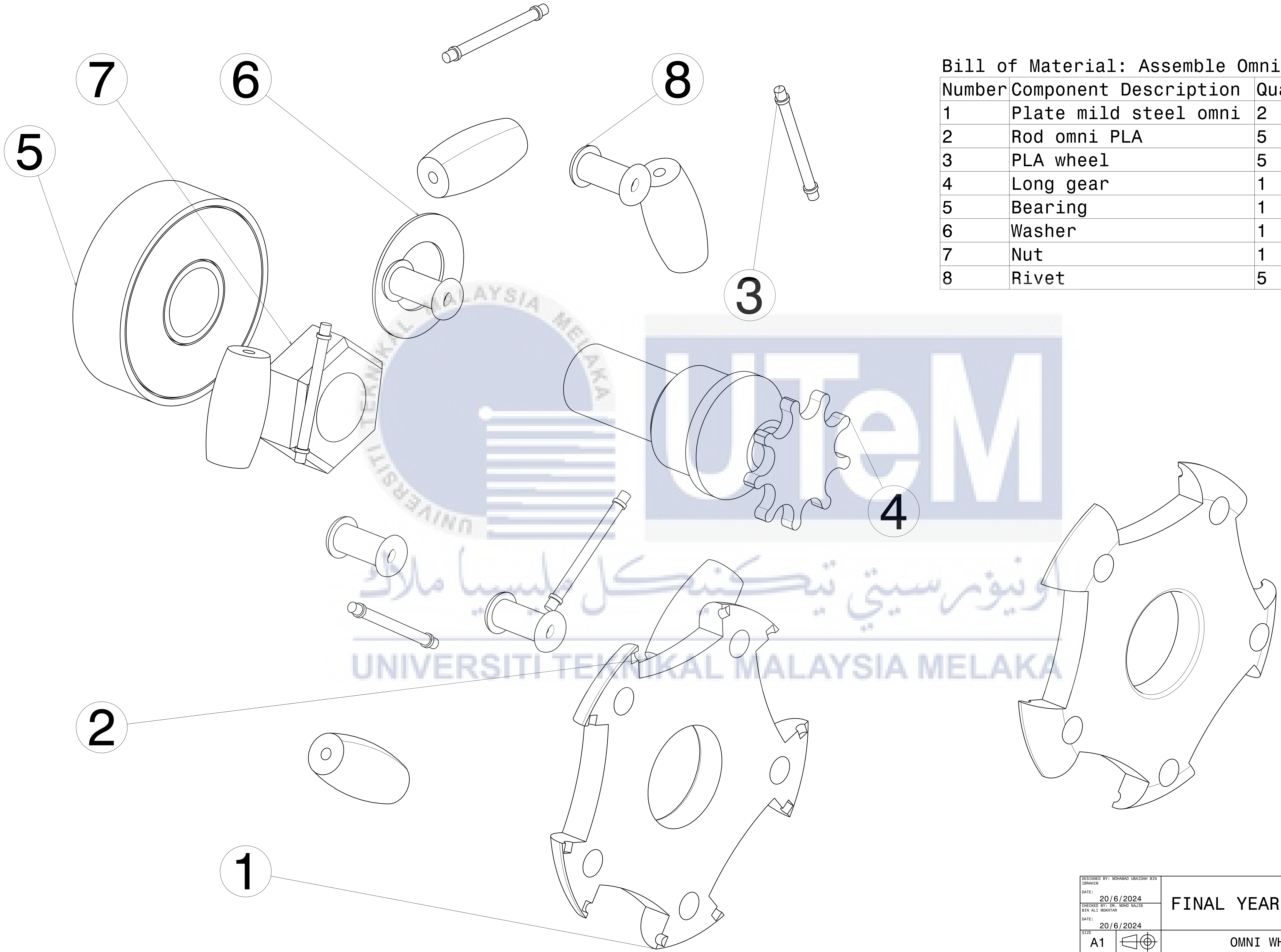
SIZE A1	OMNIDIRECTIONAL PLATE	
SCALE 1:2 / WEIGHT (kg) 6.46	DRAWING NUMBER BILL OF MATERIAL (BOM)	SHEET 1/1



Bill of Material: Assemble Omni Wheel

Number	Component Description	Quantity
1	Plate mild steel omni	2
2	Rod omni PLA	5
3	PLA wheel	5
4	Long gear	1
5	Bearing	1
6	Washer	1
7	Nut	1
8	Rivet	5

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DATE: 20/6/2024

FINAL YEAR PROJECT

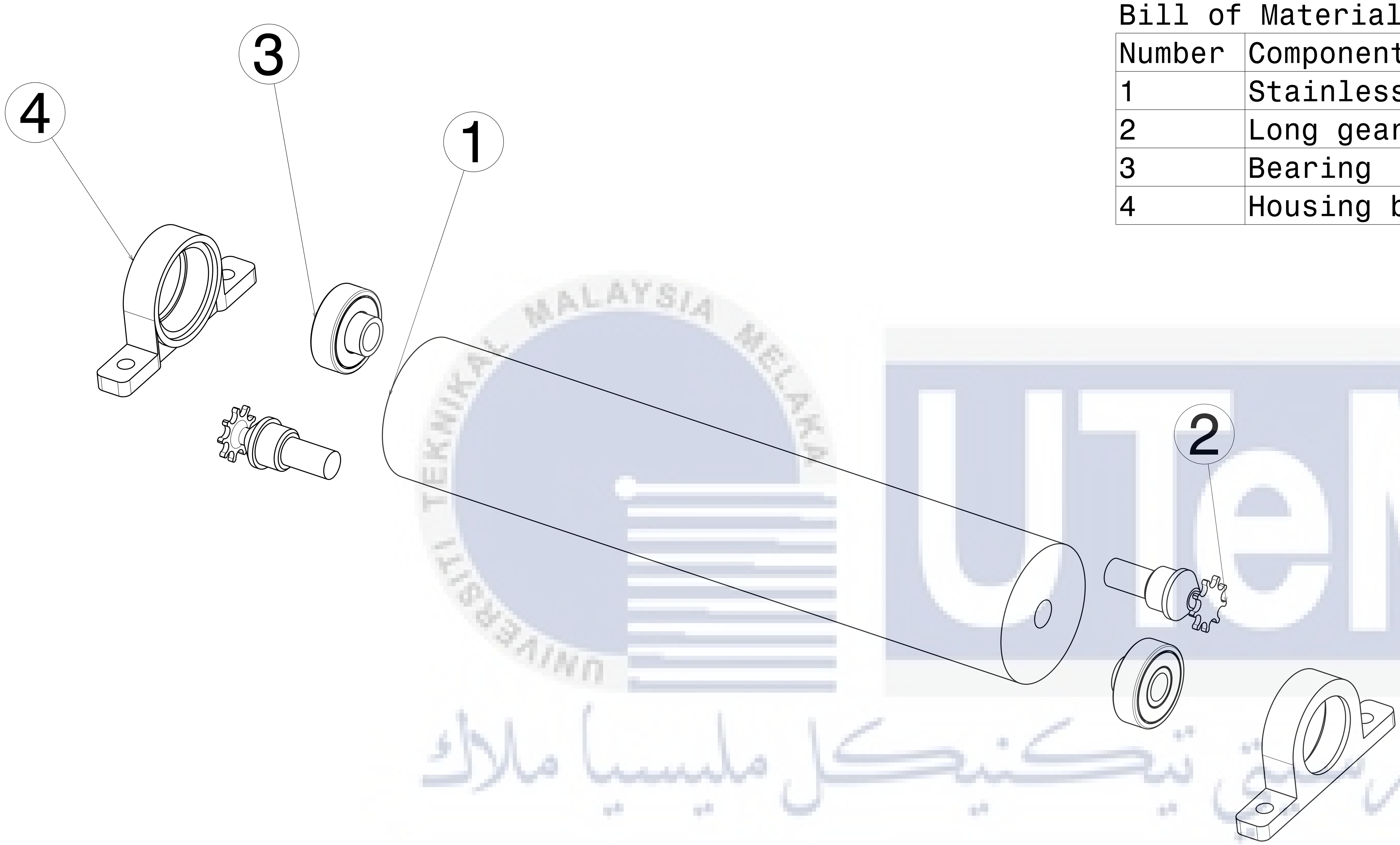
SIZE A1

OMNI WHEEL

SCALE 4:1 | WEIGHT (kg) 0.6 | DRAWING NUMBER BILL OF MATERIAL (BOM) | SHEET 1/1

Bill of Material: Assemble Roller

Number	Component Description	Quantity
1	Stainless steel pipe	1
2	Long gear	2
3	Bearing	2
4	Housing bearing	2



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CHECKED BY: DR. MOHD NAJIB BIN ALI MOKHTAR DATE: 20/6/2024				
SIZE A1		ROLLER		
SCALE 1:1	WEIGHT (kg) 0.8	DRAWING NUMBER BILL OF MATERIAL (BOM)	SHEET 1/1	