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Design and Fabricate of Lifting Equipment for Workshop

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ABSTRACT

For movement, protection, storage, and control during the manufacturing, warehousing, and disposal processes, a material handling system is employed. There have been some concerns related to manual handling of heavy items in the workshop. The main problem workers who manually handle large objects run the danger of suffering from threats to their productivity and health and safety at work. Lifting and transferring big objects can be exhausting and challenging, and doing so might cause workers to get injured or experience contact stress. Research on lifting equipment for the workplace is important since it can lower injuries and boost productivity. By using lifting equipment, workers can prevent sprains, fractures, and musculoskeletal problems. Make the lifting equipment specific to the workplace. There will be workers who can lift more than others. Before introducing new concepts, items must be evaluated in terms of their design and functionality against those already available on the market. The lifting equipment currently in use lacks features that are both ecologically friendly and effective for workers. The project's objective is to design, develop, and construct specialized lifting equipment that can effectively and safely meet the particular lifting needs of the workshop. The notion of designing with scale, function, and safety in mind is part of the design concept. This study used Software Inventor 2021 to examine the reliability and usefulness of a product's frame. A safe maximum load capacity of 100 kg was identified using finite element analysis. For weights that exceed 100 kg by 50 kg, the safety factor increased to 15, and the minimum displacement was 0.007405 mm. This confirmed to the frame's fit for its intended purpose. But a 200 kg load showed notable displacement (0.1017 mm) and a significantly reduced safety factor (5.61), exceeding allowable safety limits. As such, it was decided that the frame was not acceptable for loads heavier than 150 kg. The outcomes of the study for lifting equipment, which provides a different approach to help with the safe and efficient handling of heavy objects. Then, in accordance with the design parameters, the entire product was assembled by welding, drilling, and cutting components, verifying correct integration and functionality.

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1.0 INTRODUCTION

There are numerous lifting devices available, each with a unique purpose. It's important to choose the right device for the job since it can help avoid problems and accidents that aren't meant to happen. Designing and building lifting equipment that the workshop can employ for a range of purposes is therefore essential. By offering work platforms, lifting equipment facilitates the simple access to tight spaces and the movement of heavy components inside. Equipment for lifting helps to maximize worker performance. According to Bin Ren et al. (2023) [1], the assessment model based on subjective and objective correlation was equally capable of identifying the degree of risk associated with various handling tasks. The lifting equipment that is frequently available in the neighborhood is big, heavy, and occasionally inappropriate for the task at hand. Since the survey's validity and reliability have been examined and published, a valid and reliable usability survey questionnaire was employed in this investigation [2].

Despite several earlier studies showing that ergonomic material handling equipment can lower musculoskeletal biomechanical risk factors [3][4][5][30]. This idea aims to solve the problem of some workers and places with varied heights or spaces finding it difficult to move heavy objects around the workshop [6]. Workers usually use a large forklift, a pallet jack, or their own ability to carry heavy things. People commonly move huge objects incorrectly in industrial and warehouse settings, which leads to a high frequency of injuries and problems. Furthermore, it is difficult and impractical to shift the lifting tools that are already in use in industry. The building's employees are likewise susceptible to injury, as seen by their complaints of weariness and pains.

A single product that meets worker needs must be developed in order to address this problem. In order to make sure the aids are appropriate for the jobs, it is evident that the first step in the design criteria for manual handling equipment (MHE) should be gaining an understanding of the user usability requirements [7]. This lifting equipment differs from lifting equipment that was previously utilized in business, but it has been innovatively designed to make it easier to use and more beneficial. Workers at the workshop had to carry and move large objects on a regular basis as part of manual handling tasks. Even if the corporation has provided heavy-lifting equipment (such a forklift), many parts and tools remain too heavy for the equipment to lift. It's because of how big they are and how much space they have in the workshop.

Lack of specialized lifting equipment for large components makes it challenging to finish repairs in a timely manner and has a detrimental effect on combat capability [8]. The purpose of lifting equipment is to address the deficiency of effective and customized lifting solutions in the workshop setting, which compromises worker safety, productivity, and versatility in handling materials and equipment. In order to rank the lifting devices from most appropriate to least convenient, they are also compared based on economy and ecological [9][10][11].

In order to improve overall efficiency and guarantee the safety of both staff and equipment, the project entails designing, developing, and building specialized lifting equipment that can safely and effectively satisfy the unique lifting needs of the workshop. A wide range of factors are taken into consideration when developing lifting equipment for a workshop. The object or objects being lifted, which may include a person or persons, is referred to as a load [1]. Design Considerations: Creating robust, long-lasting, and user-friendly lifting equipment is the main objective. Weight capacity is one of the most important factors to take into account in this situation. The equipment must be able to safely lift the intended weight while taking into account both the maximum and average loads it may experience [12][13][14].

Finding the required lifting height and range of motion to suit different jobs and workspace constraints is important. According to workplace ergonomic principles (WEP), workplace design should take employees' skills and limitations into account [15]. This will improve performance and productivity by fostering excellent musculoskeletal health [16]. When choosing materials, look for ones that are lightweight for convenience of use, robust enough to support the weight, and resilient to deterioration. A useful tool for the ergonomic examination and assessment of working postures is the Ovako Working Posture Analyzing System (OWAS) [17][18].

In order to prevent tipping or swaying during the lifting process, the design should guarantee stability and balance. A broad foundation, counterweights, or other stabilizing elements might be used in this [19]. On the basis of Wurzelbacher et al.'s study [20], more research is required to determine whether ergonomic engineering solutions are beneficial. Operation ease: The apparatus should have simple controls and clear instructions, making it simple to operate. The degree of specialized vehicles, such as universal, well-known, and high-efficiency vehicles that can accomplish many duties concurrently, is closely correlated with the level of complex mechanization and automation of loading, unloading, transportation, and warehousing in industrial sectors [21]. Aspects like as crank mechanics, handle location, locking systems, and safety measures should all be taken into account. After the original design is finished, testing and analysis are necessary [22][23]. Testing and performance analysis are essential to make sure it fulfils the required requirements. This can be achieved by physically testing the equipment by building a prototype and testing it while lifting varied weights and simulating various lifting circumstances.

The next step is software simulation. To simulate the lifting action and examine stress distribution, material behavior, and potential weaknesses, use engineering software such as Inventor 2021 [24]. The production process's material flow, which consists of distinct technological processes and work areas, is represented by a simulation model [25][26]. Using stress analysis and test data, failure analysis can be used to pinpoint possible weaknesses and areas in need of improvement. Fabrication: The final design is prepared for fabrication following effective testing and refinement. The equipment components may be assembled using bolting or welding, and various joining techniques may be employed based on the design and materials. To obtain the required dimensions and tolerances, some pieces may need to be precisely machined or cut. To stop rust and improve the equipment's appearance, paint or polish it with a protective coating.

The particular parameters of lifting equipment are determined by the purpose and use of the device. The weight capacity range of 100 to 200 kg accommodates a range of lifting jobs, from light machinery components to heavy tools and materials. Here is a breakdown of the aforementioned criteria. To reach shelves, platforms, or do overhead maintenance, one can access most workshop chores with a lifting height range of 1 to 2 m. With a width range of 0.5 to 1.5 m, the equipment may be moved around obstacles and into various working locations with flexibility.

It is possible to create lifting equipment that is safe, dependable, and easy to operate while also fulfilling the equipment's unique requirements by giving careful consideration to these design elements, testing protocols, and fabrication methods [27][28]. Therefore, the project's objective is to design, develop, and construct specialized lifting equipment that can effectively and safely meet the workshop's particular lifting requirements.

2.0 EXPERIMENTAL PROCEDURE

2.1 Design Concept by Sketching

Three proposed designs are presented in Figure 1. The design idea for 1 (a) design Concept 1 assumes that the weight that each of the three conceptions is capable of supporting is equal. Concept 1 uses a hydraulic or gear-driven lifting system. The handle's height can be changed to suit the user's comfort level. The space where the items are kept, however, is ineffective since it is hard to load and unload the goods because of their shape—it is merely a compartment—and because there is not a sturdy support to hold the weight.

The second design concept (Figure 1 (b)) is enhanced from the first concept by changing the place where the goods are placed to 2 straight iron rods equipped with wheels to facilitate loading and unloading of goods. The system used is a chain system. the handle is adjustable and there is a lock on the top tire for safety purposes. The final design, represented by the third concept in Figure 1 (c), is relatively close to what is currently on the market but has been updated for greater functionality. However, the handle has been modified so that it can be adjusted to the user's comfort level. To make the process of loading and unloading items easier, wheels are positioned where the equipment is loaded and a chain system is used to raise and lower the equipment. The width of the equipment may also be modified. Design concept 2 has been selected as the project's primary concept for the finale. All of the components based on the morphological chart and advancements from the current equipment will be included in this design.

(a) (b) (c)

Figure 1: Design Concept: (a) Design Concept 1, (b) Design Concept 2, and (c) Design Concept 3

2.2 Select the Drawing

Selecting the drawing from the options that best meets the desired goal requires careful observation and study. evaluating a number of factors to ensure that the chosen graphic effectively conveys the idea. In order to make an informed decision, it's also necessary to understand the drawing's intended use, be it for construction, production, or visualization.

2.3 Tool and Materials Preparation

Setting up the appropriate equipment and supplies is the first step in any task or operation that calls for their use. It comprises assembling, preparing, and arranging every piece of equipment, material, and tool required to do the task safely and successfully. When everything is prepared, it is all readily available, which reduces downtime and process disruptions. This means checking and maintaining the instruments to make sure they are operating correctly and, if necessary, sharpening or changing worn-out parts. Furthermore, maintaining an adequate quantity of resources and arranging them neatly promotes effective workflow and lowers the chance of errors or delays.

2.4 Searching the Part Process

"Searching the part process" refers to the systematic and efficient process of identifying the parts or components required for a specific project or task. This process usually entails determining which materials—digital or physical—are required, and then locating them through a range of resources, such as online directories, catalogues, supplier networks, or real storage facilities. Finding the parts that best satisfy the specifications, quality benchmarks, and budgetary constraints is the aim. With the help of careful research and possibility analysis, the best project components can be selected [29]. Effective part searching also helps the current task or project succeed overall and be completed on time by expediting the purchasing process and saving time.

2.5 Machining Process

During the machining process, material must be removed in order to achieve the desired form, size, and surface polish for a workpiece. Drills, lathes, milling machines, grinders, and other devices are examples of cutting tools used in machining activities. There are several factors that determine the optimal machining method, including the kind of material, component complexity, tolerances, and production volume.

2.6 Checking Process

A crucial step in quality control and assurance is the checking process, which entails closely examining the manufactured or assembled items to ensure they meet all applicable standards and specifications. The dimensions, functionalities, use, and general performance of the product need to be thoroughly inspected and confirmed. numerous tools and techniques for testing. Finding any errors, discrepancies, or deviations from the specifications is made easier by the checking process, which makes it possible to make any required adjustments, changes, or rejections.

3.0 RESULTS AND CONCLUSIONS

The final design concept was reproduced using 3D drawings and an exploded view of the object using Autodesk Inventor 2021. The strength frame structure of the design had been evaluated using the strength analysis method. The strength analysis tools of Inventor 2021 were used to analyze the design of the frame section. The various loads were applied to the product. In linear static analysis, applied forces and displacements have a linear relationship. When stresses remain within the linear elastic range of the material being used, this has shown to be helpful in real-world applications for structural problems.

3.1 3D CAD Modelling

To create the 3D parts of the hoisting equipment, Autodesk Inventor was utilized. The bill of materials (BOM) and an exploded viewpoint were shown in Figure 2.

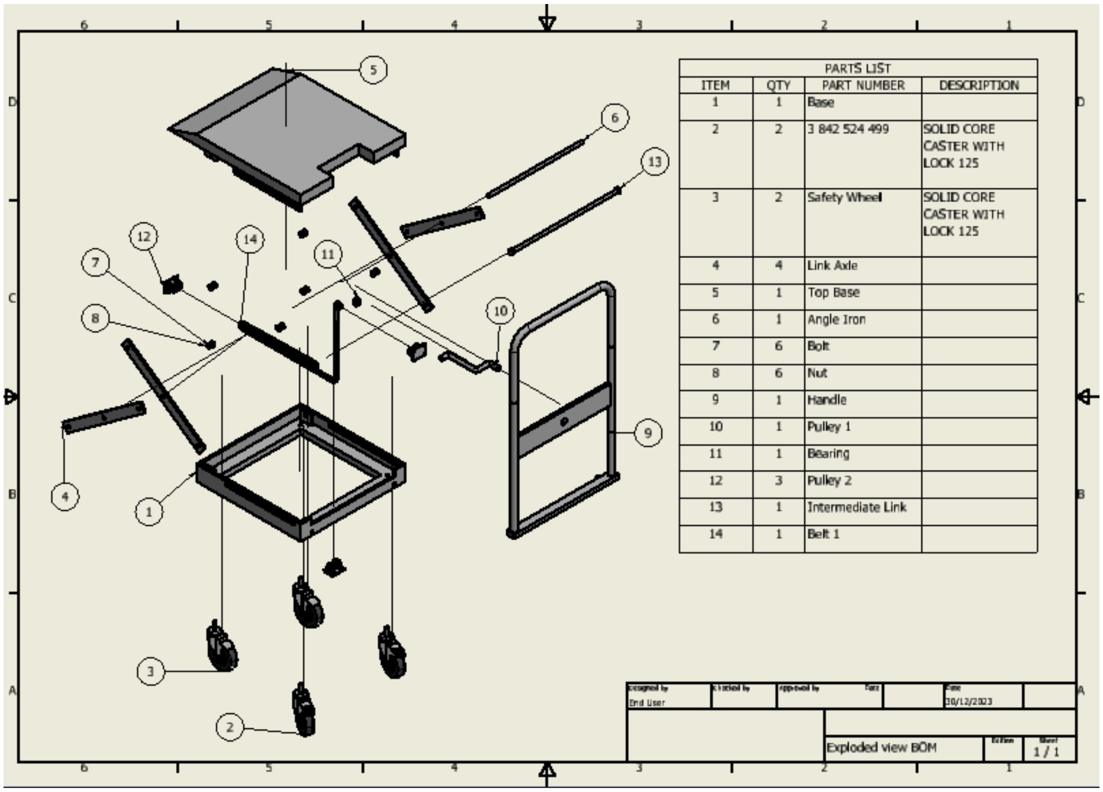


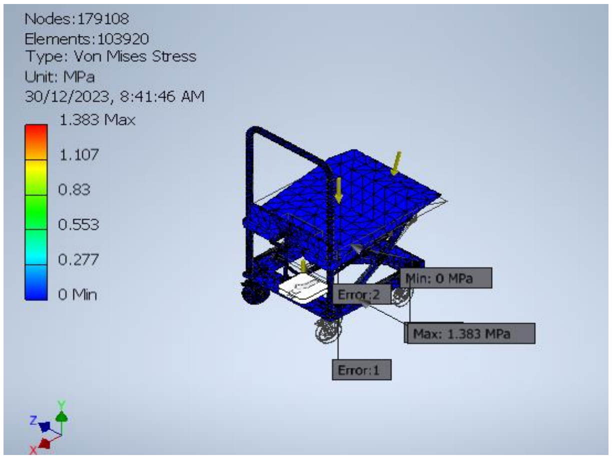
Figure 2: Exploded View and Bill of Material (BOM) for lifting equipment

According to Figure 3, which is displayed below, the maximum Von Mises Stress for 50 kg of angle iron steel analysis is 1.38 MPa, while it is 15.64 MPa for 100 kg and 36.93 MPa for 200 kg. Table 1 below compares the Maximum Von Mises Stress for loads weighing 50 kg, 100 kg, and 200 kg. These are the maximum Von Mises Stress levels predicted by the application. Yield strength is the amount of stress that could permanently deform a material. The material will return to its original shape if the stress level is less than the yield point; if it is greater than the yield point, the deformation will be permanent and the material won't regain its original shape.

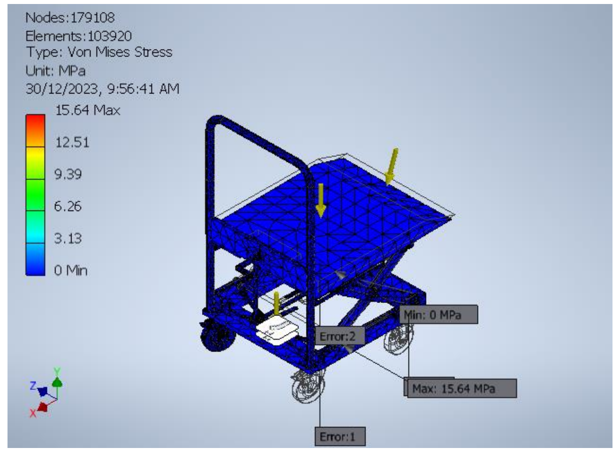
Table 1: Comparison of Maximum Von Mises Stress at different load

Loads (kg)	50	100	200
Maximum value (MPa)	1.38	15.64	36.93

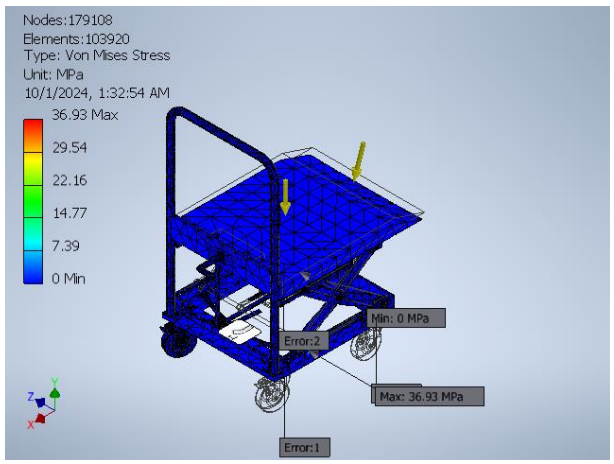
The greatest Von Mises Stress value for a 100 kg load is 15.64 MPa, while the lowest value is 1.38 MPa for a 50 kg weight. For both loads, the von Mises stress value is still lower than the yield strength. The highest pressure of 36.93 MPa is achieved with a 200 kg load. Strength is the maximum load a material can support before failing. The criterion used in design is yield strength, not ultimate tensile strength. Yield strength is the amount of load a material can withstand before undergoing plastic deformation. This suggests that, if the load remains below the yield strength, the material can return to its initial state. The model may demonstrate that the structure is deflecting logically by animating for each load. Usually, when loads and supports are applied wrongly, unusual behaviour results.



(a)

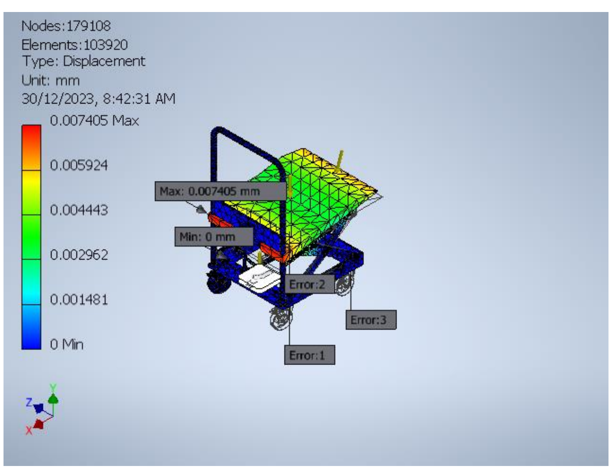


(b)

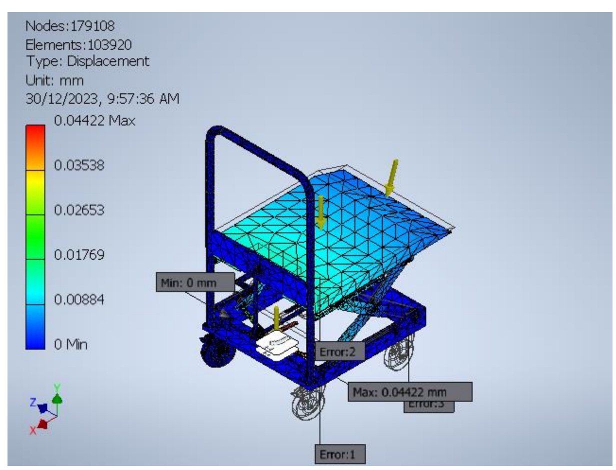


(c)

Figure 3: The maximum value of Von Mises Stress for angle iron steel: (a) 50 kg, (b) 100 kg, and (c) 200 kg



(a)



(b)

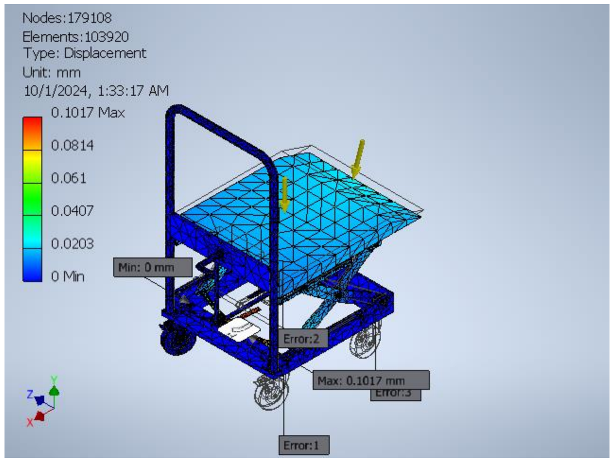
(c) 

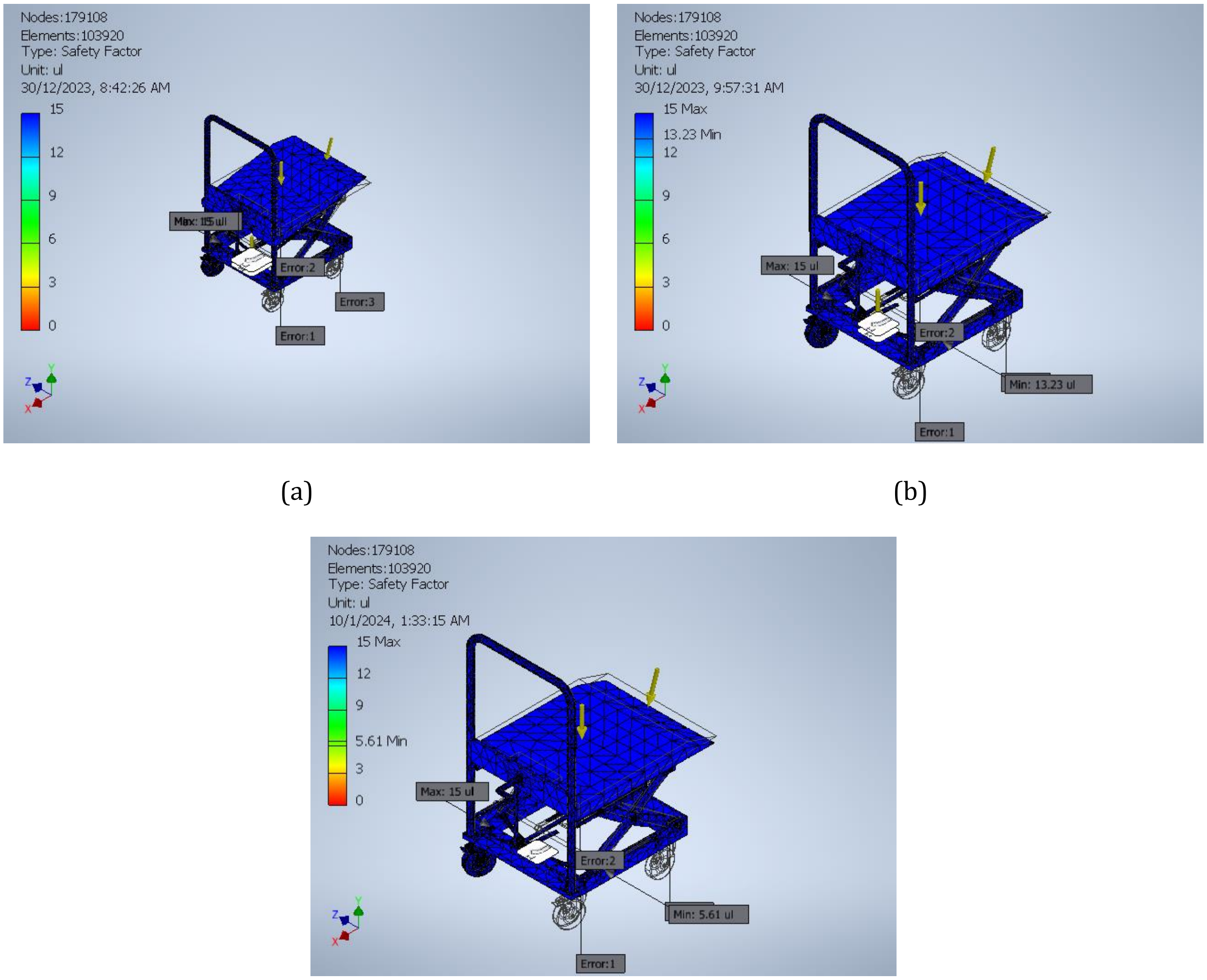
Figure 4: The maximum value of displacement: (a) 50 kg, (b) 100 kg, and (c) 200 kg

The maximum displacement value when using 50 kg is 0.007405 mm, as shown in Figure 4(a) above. The maximum displacement value while using 100 kg load is 0.04422 mm, as shown in Figure 4(b). The maximum displacement value of 0.1017 mm for 200 kg is displayed in Figure 4(c). In this examination, a force of 50 kg creates very little displacement on the material, whereas a force of 200 kg causes a significant displacement, indicating the extent of deformation from the original shape. Table 2 below illustrates how the software anticipated a different maximum displacement value, with a little movement of 0.007405 mm for a 50 kg load, 0.04422 mm for a 100 kg load, and 0.1017 mm for a 200 kg load in the red area.

Table 2: Comparison of displacement at the different load

Loads (kg)	50	100	200
Displacement (mm)	0.007405	0.04422	0.1017

Figure 5 shows that the lowest displacement value (0.007405 mm) is for a 50 kg weight; the next biggest displacement value (0.04422 mm) is for a 100 kg load; and the largest displacement value (0.1017 mm) is for a 200 kg load. This displacement value shows the amount of stretching that occurs when something is loaded. The location and degree of bend ability, as well as the force necessary to bend a part a specific distance, were determined using the deformation results. The deformation values for 200 kg were rather high, while they were relatively low for 50 kg and 100 kg. When the Von Mises stress value is less than the tension or yield strength of the material, elastic deformation occurs. Figure 5 illustrates that the factor of safety minimum for a 50 kg weight is 15. The value is positive and save because it is more than 1. Figure 5 (b) illustrates the minimal value of the safety factor for 100 kg, whereas Figure 5 (c) shows the value of 5.61 for 200 kg. Although it is less than the safety factor 50 kg load, the value is still greater than 1. A load of 50 kg is 1.5–2.5 times stronger than a load of 100 kg or 200 kg. The material is virtually at yield if the factor of safety is 1.



(a) (b)

(c)

Figure 5: Safety factor for different load; (a) 50 kg, (b) 100 kg, and (c) 200 kg

Figure 5 shows that a load weighing 50 kg has the maximum factor of safety, which is 15, followed by a load weighing 100 kg, which is 13.23, and a load weighing 200 kg, which is 5.61. It is permissible to utilise loads 15 and 13.23. This is a result of the safety factor's usefulness and safety during use. However, a weight of 200 kg is unacceptable since it is in the lowest level and close to the safety factor value's red region. Table 3 show that the different value of minimum factor of safety was predicted by software and the value for 200 is the lowest than 100 kg load and 50 kg load which is 5.61 while for the others, higher which is 13.23 and 15.

Table 3: Comparison of Minimum Value for Factor of Safety at the different load

Load	50 kg	100 kg	200 kg
Factor of Safety	15	13.23	5.61

3.2 Fabrication Process

The lifting equipment frame's concept design and analysis are completed and finalised, and then the manufacturing process is started utilising the recommended design. The complete fabrication and assembly process was shown in the following figures. Cutting, welding, and drilling were the main procedures performed.

3.2.1 Cutting Process and Welding Process

Figure 6 illustrates the welding and cutting steps involved in the fabrication process. Angle iron is cut using a grinder machine during the part fabrication process in accordance with the specifications shown in the 2D model. Welding is the following process after all of the material has been trimmed to size. This product's frame will be welded together utilising MIG welding. The welded bottom base was displayed in Figure 6(b).

Other parts were welded as the process proceeded, as seen in Figure 6(c). Figure 6(d) depicts the lifting equipment's structure. At this point, every component has been adjusted and set in place one more time. The hoisting procedure is carried out using the hand winch. With a cable long enough to handle the height of the lifting equipment is this winch has a 600 lb lifting capacity.

3.2.2 Removing Rust Process and Painting Process

The procedure for eliminating rust from the steel surfaces prior to painting the part was illustrated in Figure 7(a). A grinder equipped with a steel wire brush was the tool utilised. This procedure was used to give the steel a flat surface in preparation for painting. The body frame that was painted in grey and black for the connection was displayed in Figure 7(b). It took some time for the heavy-duty, heavier oil paint to set after two coats were applied to the surface to stop rust.

(a) (b)

(c) (d)

Figure 6: (a) Cutting the Angle Iron, and (b) Welding process, (c) Fitting the wheel, and (d) Fabrication of final product

(a) (b)

Figure 7: Final touch up for lifting equipment (a) Rust removing process, and (b) Spraying the body structure

3.2.3 Final Product Assembly

All of the product's components, including the angle iron for the frame, hand winch, wheel, handle, pulley, and cable, are included in the assembly. By welding, every component was joined and put together. The completed product assembly, which serves as lifting equipment for heavy items in the workshop, was displayed in Figure 8. The link has a one-meter reach and is adjustable to different heights. The completed product assembly adds a trolley function as well. Additionally, the handle was fastened to the product. There is a safety function on the wheel and winch to stop accidents from happening. To stop the gear and cable from moving freely, the winch incorporates a gear lock feature. In order to keep the product from moving when lifting parts, the wheel contains locks and brakes.

Figure 8: Final Product Assembly

4.0 CONCLUSION

It is widely accepted that this multipurpose, easy-to-use equipment could eventually replace the lifting equipment already in use in workshops. The consumer can utilise the product as a trolley, lifter, and storage area, among other things. It manages to avoid the large and unduly heavy lifting equipment that is currently in use. Finally, the following can be concluded:

(i) The design, analysis, and fabrication of the lifting equipment for the workshop was successfully completed. The 2D design includes every need for the product and discreetly simplifies the other processes.

(ii) Software Inventor 2021 was used to inspect the product's frame. According to the analysis, the frame could safely handle a maximum weight of 100 kg. For loads over 100 kg, the displacement value was found to be 0.007405 mm, and the safety factor value was found to be 15. This suggests that the information is suitable, relevant, and safe to use. However, the 200 kg load is not appropriate due to the relatively high displacement value of 0.1017 mm and the 5.61 safety factor. This suggests that the information is suitable, relevant, and safe to use.

(iii) When each component is accurately integrated according to the drawing and functions as intended, the integration process from concepts to visualisation is completed. The three primary techniques that were employed were cutting, drilling, and welding.

(iv) By guaranteeing that there is little physical contact with heavy object, the prototype further enhanced the safety aspects of manual handling activities. Ultimately, the improved lifting equipment reduces the need to manually raise the heavy weight during the transfer procedure and permits a more ergonomic working posture for load transfers.

Author Contribution

M. Nur Irfan: Conceptualization, methodology, visualisation, writing, fabrication and testing. Alias Mohd: Conceptualization, methodology, investigation, visualisation, writing, supervision and editing. Zahari Deraman: Fabrication, supervision and testing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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