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Design, Analysis and Optimization Using Solidwork Simulation of Chair Ladder

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Abstract: Chair Ladder is the concept of combining a chair with a ladder in one. It can also help to save money, time, and energy. The construction of theChair Ladder can withstand a weight of 1500 N. The project involves two different object that is a chair. Its main characteristics are two pieces of sturdymaterial, linked at a 90 ° or slightly higher angle to each other, as the back andseat are typically attached to the four corners of the horizontal seat in turn to four legs or other parts of the underside of the seat attached to three legs or toa shaft around which a four-arm roller may be powerful enough to withstand the weight of a person sitting on the seat. Next, for climbing up or down, a ladder is a step consisting of two parallel members linked by rungs. It's an ascending stage that helps someone or something to scale the ladder. The simulation analysis is done using Solidwork software and tested using linear static analysis and drop test analysis. The result shown that the design can undergoes a force around 1500 N on its seat and step ladder without being broken. Therefore, this design can achieve the objective stated.

Keywords: Chair Ladder, Solidwork, Design, Simulation analysis, 1500 N

1. Introduction

It is the intention of the present invention to provide a combination of a chair ladder that is inexpensive to produce, convenient to use as a chair and to use as a ladder to climb to heights above the usual height of a chair seat. It can save money for individuals who have limited budgets. Instead of buying 2 things that can only do 1 thing each. It can help to savespace as well. Its architecture is based on the idea that at least two types of appearance and function must be involved in the chair ladder. It should have both an ordinary look and an altered appearance. Thus, by combining the chair and ladder, a Chair Ladder that can transformthe ladder solved the dilemma. It's designed based on the concept that the chair ladder must involve at least two forms of appearance and function. A chair design that can be used as a ladder made of hardwood materials able to take all stress and drop test conducted to validate its safety features.

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Chair Ladder is basically a chair and a ladder that had been combined into one without changingits purpose of use. The size of the chair ladder must also follow Malaysian adult body standardswith height (1.5 m - 1.8 m). Thus, it must be ergonomic to avoid the user uncomfortable while using it and to avoid backpain. Next, this design should also withstand a standard weight for Malaysian adult (<150 kg) [1].

Chair Ladder is designed based on the concept that the chair ladder must involve at least two forms of appearance and function. The design is suitable to place it near the kitchen, as someoneis cooking and waiting the food to be cooked. The chair ladder can transform into a ladder when someone want to take something higher above the ground. It can save cost for people who have small budgets. Instead of buying 2 items that each only can do 1 specific things, youcan buy one that only has one use.

2. Materials and Methods

The invention relates to furniture, and especially relates to a multifunctional ladder chair. Whenthe multifunctional ladder chair is used as a chair, inner tubes shrink in; and when the multifunctional ladder chair is used as a ladder, the inner tubes stretch. The multifunctional ladder chair having multiple functions saves the household expenditure, occupies small land, saves the raw materials of the society, and accords with low carbon and economy principles [2].

2.1 Type of Chair

Adirondack chair is an outdoor lounge chair with wide armrests, a tall, slatted back, and a seatthat is higher in the front than the back [3]. The first gaming chairs arrived in the mid-aughts, around 2006, with a company called DXRacer that originally manufactured seats for luxury sports cars. **S**upport the shoulders and back so you don't start feeling tired. The more support your muscles have on the back and shoulders, the more the chair pushes you straight [4]. Highchair is a piece of furniture used for feeding older babies and younger toddlers. The seat is raised a fair distance from the ground, so that a person of adult height may spoon-feed the childcomfortably from a standing position [5]. Kneeling Chair is a kind of sitting chair in a positionwith the thighs lowered from the vertical at an angle of about 60 ° to 70 °, with some of the body's weight supported by the shins. Forward sloping seat did effectively tip the pelvis forward, opening the angle between torso and thigh, and thereby correctly aligns the spine, indicating a more suitable position for long periods of sitting [6]. Ladderback Chair tend to have tall backs with two uprights. Between these two uprights exists multiple horizontal spindles or slats. The seat can be made of a variety of different materials. Originally most seats were constructed using cane or rush, whereas now, the seats tend to be made of wood [7]. Office Chair is a type of chair that is designed for use at a desk in an office. It is usually a swivel chair, with a set of wheels for mobility and adjustable height. Near the floor this leg spreads out into several smaller feet, which are often wheeled and called casters [8].

2.2 Type of Ladder

The Extension Ladder is a non-self-supporting portable ladder that is adjustable in length. It consists of two or more sections that travel in guides or brackets so arranged to permit length adjustment. It is intended for use by one person [9]. The Step ladder is a self-supportingportable ladder that is non-adjustable in length, with flat steps and a hinged design for ease ofstorage. Stepladders range in size from 4 ft. to 20 ft. in length along the side rail. Stepladders shorter than 4 ft. are considered Step Stools. The highest standing level on a step ladder is slightly more than 2 ft. from the top of the ladder. The highest standing level is required to bemarked on the specifications label on the side rail of the product [10]. A fixed ladder is a vertical ladder that is permanently placed onto a frame. Such ladders are mainly used for industrial purposes to reach the roofs or other structures. Fixed ladders are usually made of steel or aluminium but can also consist of reinforced polymers, stainless steel, galvanized hot dipped steel, or wood. Next, multi-purpose folding ladders A hugely popular range of multi- purpose articulating ladders featuring multi-position locking, hinged ladder sections allowing configuration of the ladder into a variety of shapes for true versatility. Any of these ladders will lock in 10 or more useful

positions and pack into a minimum room for storage. It's as safeas the step ladder. However, this type of ladder is heavy, and it makes it harder to bring it anywhere [11].

2.3 Study of Hinge

A hinge is a mechanical bearing that connects two solid objects, usually allows the two bodiesto move rotationally to angles of 180 degrees and greater without breaking [12]. Two objects connected by an ideal hinge rotate relative to each other about a fixed rotational axis: all othertranslations or rotations are prevented, and thus a hinge has one degree of freedom. Hinges maybe made of flexible material or of moving components. In biology, many joints function as hinges like the elbow joint.

2.4 Finite Element Analysis

The Finite element analysis (FEA) is a numerical method for solving problems of engineering and mathematical physics. It's very useful for problems with complicated geometries, loadings, and material properties where analytical solutions can be obtained. FEA is the method of using virtual simulation technology to test how a product design reacts to physical effects including bending, heat, vibration, fluid flow, and other impacts. With FEA simulation tools, you can evaluate designs early in the design cycle, determine what will cause premature failures, quickly explore design changes to reduce cost and weight, and determine the product's factor of safety.

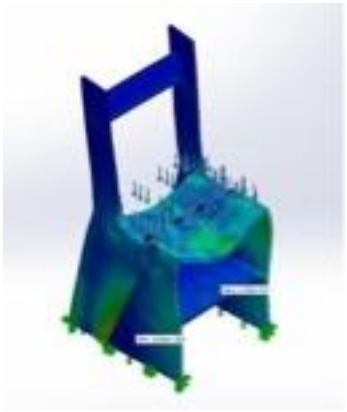


Figure 1: Finite Element Analysis

3. Methodology

The flow chart as shown in Figure 2 shows the overall process for the design and developmentof the chair ladder. The process starting by selecting the topic for the research study and proceed with the preliminary studies which are by reviewing the previous research papers andjournals, benchmarking the product in the market and make patent search that are connected tothe project. After the preliminary studies, the topic is selected and planned a Gantt chart to easefor the further process. After that, the design concept is made based on the material selection, calculation that are required and the simulation of the stress analysis.

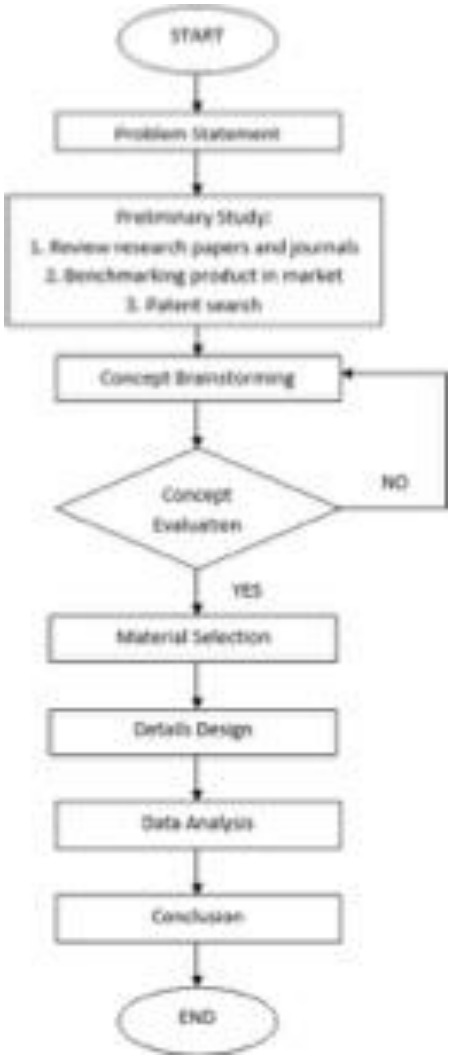


Figure 2: General Flow Chart FYP 1

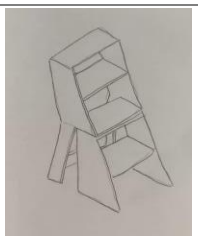
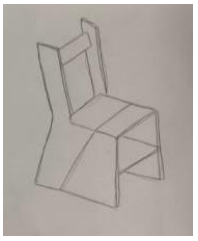
3.1 Product Sketching

Based on the Table 1, the Chair Ladder in the design A concept is having a hard time in fabricating it. This is because, it has a unique design at the leg of the chair. The curve leg designmakes it hard to fabricate than the other design that have straight leg. However, it is easier to lift as it has a less weight than the third design. Next, it also has a slight curve for the backrestas it can avoid the user from having a backpain while using it. Moreover, it is easy to transformthis Chair Ladder from a chair to a ladder.

The design B concept of the Chair Ladder is having a straight backrest, and this can cause the user having a trouble like backpain when using it. Next, it also only has a small area to sit on as it also can cause a backpain to the user. However, it is easier to lift as it has a less weight than the third design. Moreover, it also easy to transform this Chair Ladder from a chair to a ladder. Next, because of the simple design, it makes easier to fabricate the Chair Ladder with this design.

As for design C, it has the most advantages compare to other design concept which are the stepfor ladder is wider that can help in preventing injury while using it as a ladder. The wider the step, the more stable the user when using it. As can be seen, it has a simple design that makingit easier to fabricate it. Moreover, it is easy to transform this Chair Ladder from a chair to a ladder. Lastly, it also has a slight backwards for the backrest to avoid backpain. Though the design is simple, it still emphasizes the ergonomic in the design. However, the con for this design is it is a bit heavy to move around. Because of all the reasons above, the design C concept is selected.

Table 1: Sketching of Chair Ladder

Design	A	B	C
Chair			
Ladder			

3.2 Material Selection

Pine wood is medium-weight and relatively soft. Its strength and elasticity are good. As with other coniferous woods, the properties of the wood depend upon the density of the annual growth rings: The higher the proportion of summerwood, the heavier and harder the wood.

The heartwood has good natural durability except where it is in direct contact with earth or moisture. It has a high natural moisture content, which can lead to a blue staining of the woodthrough fungal infection. The colouring only affects the appearance, not the physical propertiesof the wood [13].

Wood is of course, a long-lasting and is the perfect choice for anyone looking for longevity from their furniture. Whether the option for hardwood or softwood there is an innate stability and reliability to a well-made wooden chair. This durability ensures that wooden furniture offers excellent value for money and should you ever want to sell a piece, solidly made. well-looked-after furniture can maintain its value over the years.

3.3 Selection of Hinge

Figure 3 show a butt/mortise hinge. When used on a cabinet or a room frame, the mortised hinge gives the cleanest final look. Mortising the hinge into the facial frame or jamb and creating a more compact fit between the ladder of the chair. A butt hinge is constructed of twomatching leaves of metal connected by a central pin and barrel system. The better the suit, themore professional the job is done. The inset cut for the hinge also holds the hardware hostage,so that it does not fall under the tension of movement when the chair is turned into a ladder. There are other advantages of mortising the hinge, other than the presence of the final hardwareinstall. For example, the edges of the hinge leaf are kept firmly in the wood of the pieces, preventing the hinge plates from twisting out of alignment under the weight of the chair ladder.

Figure 3: Hinge

3.4 Detail Design

The purpose of this project is to design a Chair Ladder that is a chair that can turn into a ladder.It requires human force to transform it from chair to ladder. However, the Chair Ladder is notsuitable used for long time. This means that it's not suitable for sitting for a long time on this chair. It is only suitable for use when you want to sit for a while. Next, it is also important thatthe product have a good durability. Figure 4 shows the detail drawing of the chosen design forproceed undergoing analysis simulation test

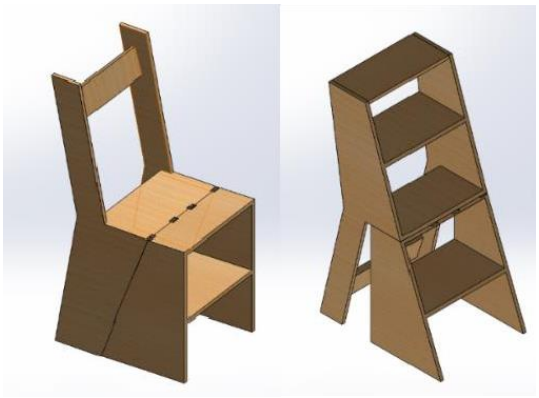


Figure 4: Detail Drawing of Chair Ladder Design A

4. Result and Analysis

Solidworks software to make a theoretical analysis of the durability of the Chair Ladder product that have been designed. Among the tests test to be performed are linear static analysisand drop test studies analysis. Table 2 shows the properties of Chair Ladder made of pine wood.

Table 2: Properties of Chair Ladder

Properties	Value
Yield Strength of Chair Ladder	2e+007 N/m^2
Force Applied (Newton)	1500N
Tensile Strength	7.23826e+008 N/m^2

Name	Type	Min	Max
Stress1 and strain	VON: von Mises Stress	0.000e+000N/mm^2 (MPa) Node: 1616	4.084e-001N/mm^2 (Mpa) Node: 660

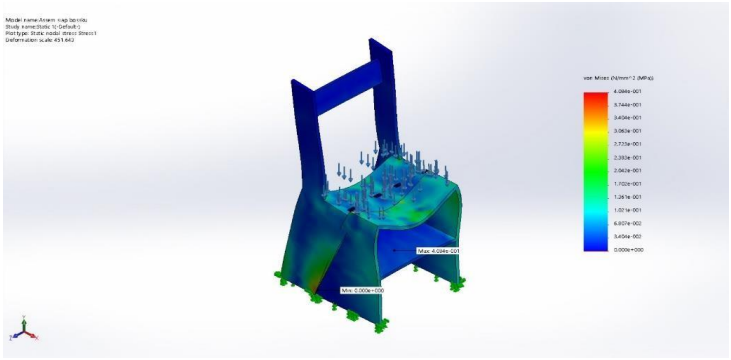


Figure 5: Linear Static Analysis Stress and Strain Chair

The stress analysis shown in Figure 5 is the value of maximum and minimum stress for Chair Ladder which acts on the seat. The maximum value for stress at the seat is 4.084e-001N/mm^2(MPa) and the minimum stress is 0.000e+000N/mm^2 (MPa) as shown in Table 3. Therefore,the Chair Ladder design value for maximum stress does not exceed their yield strength of material which is 2e+007 N/m^2.

The maximum value of the strain at the seat is 3.184e-004 and the minimum strain is 0.000e+000 as in Table 4. The maximum strain value occurs at the middle of the seat. Its showsthe elongation occurs when the seat is applying with the load. Since the value of strain not exceeding the value of tensile strength, the seat will not break or failure during the load.

Name	Type	Min	Max
Stress and Strain1	ESTRN: Equivalent Strain	6.363e-007 Element: 1263	1.454e-004 Element: 1194

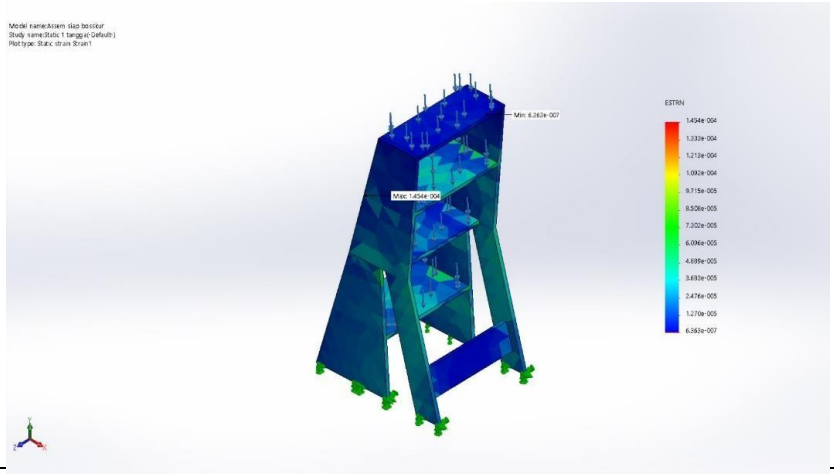


Figure 6: Linear Static Analysis Stress and Strain Ladder

The strain analysis shown in Figure 6 is the value of maximum and minimum strain for Chair Ladder which acts on the step of the ladder. The maximum value of the strain at the seat is 1.454e-004 and the minimum strain is 6.363e-007 as in Table 4. The maximum strain value occurs at the side of

every step. The maximum value for stress at the step is6.616e=003N/mm^2 (MPa) and the minimum stress is 1.492e-003N/mm^2 (MPa) as shown from Table 3. Therefore, the Chair Ladder design value for maximum stress does not exceed their yield strength of material which is 2e+007 N/m^2

Table 3: Stress on Chair and Ladder

Linear Static Analysis	N/m^2
Yield Strength	2.00E+07
Max Stress on Chair	408400
Min Stress on Chair	0.00E+00
Max Stress on step ladder	6616
Min Stress on step ladder	1492

Table 4: Strain on Chair and Ladder

Linear Static Analysis	N/m^2
Tensile Strength	7.23826e+008
Max Strain on Chair	2988000
Min Strain on Chair	1.405e-7
Max Strain on step ladder	1303000
Min Strain on step ladder	1.323e-9

Name	Type	Min	Max
Stress1 and strain	VON:von Mises Stress	1.405e-013N/mm^2(MPa) Node: 736	2.988e+000N/mm^2 (MPa) Node: 114

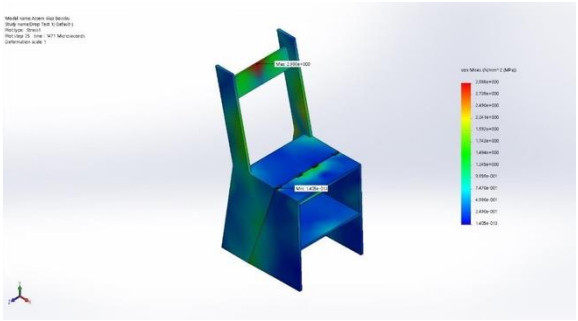


Figure 7: Studies Analysis Stress and Strain Chair

Name	Type	Min	Max
Stress1 and Strain	VON: von Mises Stress	1.323e-015N/mm^2 (MPa) Node: 246	1.303e+000N/mm^2(MPa) Node: 300

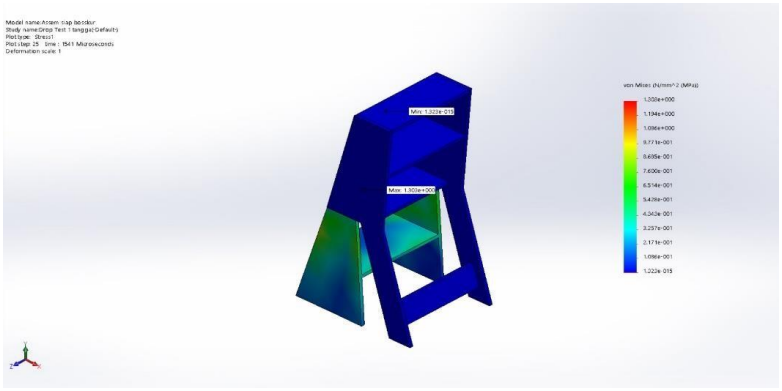


Figure 8: Studies Analysis Stress and Strain Ladder

The stress analysis shown in Figure 7 is the value of maximum and minimum stress for Chair Ladder which acts on the seat when dropped from height 1.5m. The maximum value for stressis at 2.988e+000N/mm^2 (MPa) and the minimum stress is 1.405e-013N/mm^2 (MPa).Therefore, the Chair Ladder design value for maximum stress does not exceed their yield strength of material which is 2e+007 N/m^2 as shown in Table 5.

This mean the seat of ChairLadder are not occurring break or failure when dropped from 1.5m height with gravity force 9.81 m/s^2. From Table 6, the maximum value of the strain at the seat is 1.065e-003 and the minimum strain is 1.159e-018. The maximum strain value occurs at the top of chair. Its showsthe elongation occurs when the chair is dropped from a height of 1.5m with gravity force 9.81 m/s^2. Since the value of strain not exceeding the value of tensile strength, the seat will not break or failure during the load implemented.

Table 5: Stress on Chair and Ladder

Drop Test Analysis	N/m^2
Yield Strength	2e+007
Max Stress on Chair	2988000
Min Stress on Chair	1.405e-7
Max Stress on step ladder	1303000
Min Stress on step ladder	1.323e-9

Table 6: Strain on Chair and Ladder

Drop Test Analysis	N/m^2
Tensile Strength	7.23826e+008
Max Strain on Chair	1.065e-003
Min Strain on Chair	1.159e-018
Max Strain on step ladder	4.910e-004
Min Strain on step ladder	4.049e-019

5. Conclusion

In conclusion, the overall objectives for this project were achieved successfully where a chair and a ladder are combined in one design. The reason of this is because, it can help in solving many problems such as limited space, energy waste and limited money. Besides, before detaildrawing in Solidwork, sketch drawing is done. This is to have some idea and measuring of theChair Ladder.

Moreover, linear static analysis and drop test analysis is run to the selected design. This is to determine the maximum stress and strain on the Chair Ladder. This is because, beforefabricating some design we need to know the performance of the object that needed to be fabricated. It is to avoid something wrong happen for example fabricating an object without knowing the performance may lead to waste of energy or waste of money as maybe the objectcannot become as desired. Hence, running a simulation test on the design in Solidwork softwaremay avoid unwanted events from happening.

Lastly, after the design is done at Solidwork, it can undergo the simulation analysis test. As what I have learned during my visit to Teaching factory UTHM, all the tests done at the factory is related to sustainability and performance of their product. Therefore, the simulationanalysis test been done in Solidwork is related to sustainability and performance of the chosendesign. As can be seen in chapter 4, the result shown that the chosen design of Chair Ladder issuccessful and safe to use as it can withstand a weight of 1500N (152.92 kg).

Acknowledgement

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