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Design of An Ergonomic Portable Fire Hose Roller: A Simulation Study

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Abstract: Firefighters are often exposed to hazards and involved in physical activities which can cause various ergonomic related problems. In this case, manually rolling the fire hose while maintaining an awkward posture for a long period caused back pain. Therefore, an ergonomic portable fire hose roller was proposed to help firefighters at Pagoh Fire Station, Johor to overcome ergonomic problems when rolling the fire hose. SolidWorks was used to design the fire hose roller and using ANSYS to assess the strength of the chosen material which was aluminium alloy. The simulation from ANSYS showed a bending occurred at the roller part after applying force. In conclusion, material selection and the design of the fire hose roller must be revised carefully. Further study can be carried out by more detailed design parameters and simulation process.

Keywords: Fire Hose Roller, Ergonomic Problems, Simulation

1. Introduction

This project is a continuous work from previous research of "Ergonomic and Manual Handling Workplace Improvement: A Case Study of Firemen at Pagoh" [5]. The main objective of this project is to design an ergonomic fire hose roller which is lightweight, save space and portable. Due to the compact design of a fire truck, the fire hose roller should not be too large. Besides, the fire hose roller should be lightweight and portable to reduce the amount of stress on the body when carrying it. Other than that, there are fire incidents that may be unreachable by the fire truck thus the portability of the fire hose roller is needed. An ergonomic design of the fire hose roller was proposed, together with the simulation by using SolidWorks software. The simulation had been done for evaluating its performance and data collection. Further modification in designing is expected after the simulation process.

Firefighters are often exposed to hazards and involved in physical activities which can cause various ergonomic related problems. In the fire ground, they connect hose lines, and position ladders at strategic positions to enable them to deliver water to the fire. These activities occasionally lead to accidents and injuries either from falls or hit by pressurized paraphernalia [1]. Specifically, when rolling the fire hose

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manually, they needed to bend forward using awkward posture while rolling the fire hose until finished. This can cause back pain as their body posture is in an awkward position for a long period [3]. Other than that, the fire truck has limited space as they are loaded with many types of equipment. Therefore, the size of the fire hose roller must not take too much space to be loaded into the fire truck. Other than that, the materials used must be lightweight and durable. Aluminium is suggested as the material to fabricate most of the parts of the hose roller. [2] and [4] stated that aluminium is lightweight, high strength and ductile which is good for the fabrication process. Its corrosion resistance makes it more reliable material for this project.

From previous research works, several designs of roller hose for firefighter had been proposed by previous authors ([4], [7], [8], [11], [12]; and [15]). However, much of the proposed designs are not suitable in term of usage and suitability in Malaysia. So, this project proposed a new design of fire hose rolling specifically use for the firefighter in Malaysia.

2. Literature review

2.1 Ergonomic Risk Factor

The ergonomic risk factor can contribute to the musculoskeletal disorder. Among the likely ergonomic risk causes of work-related musculoskeletal disorder (WMSD) are repetitive motion, awkward posture, forceful exertions, pressure points, and static postures [9]. Musculoskeletal disorders (MSD) is a high occurrence among firefighters because their work involves prolonged physical activity and a high physical burden [10].

2.2 Ergonomic Assessment

An ergonomic assessment is used to determine the level of ergonomic risk exposure faced by the firefighters caused by their work [1]. A questionnaire, observational method and technical measurement method were used to implement ergonomic risk factor [15]. Assessment such as FMEA and ERA were used by the previous researcher to evaluate ergonomic risks. By referring the previous research work, this project proposes an ergonomic design of fire hose roller for the firefighter. This is due to tough tasks and high risk of ergonomic assessment of firefighters [15].

2.3 Firefighters Working Background

Emergency workers such as firefighters are catalogued within the most demanding and injurious professions globally [9]. Fire station operation hours are divided into two shifts which are 12 hours shift and 24 hours shift. Work schedule on daytime duties included maintenance of vehicles and other firefighting and rescue equipment, paperwork, training for emergency service and actual performance of such services, sports, and drills [13]. Firefighters rescue victims and give emergency medical attention when needed, ventilate smoke-filled areas, and attempt to salvage the contents of buildings [2]. There are four types of hazards faced by the firefighters which are accident, physical, chemical and biology [2].

2.4 Previous Research Method

There were various methods used to collect data regarding risks that happen during the rolling and unrolling of fire hose carried by the firefighters. Table 1 shows the previous research methods and its findings.

Table 1: Previous research method

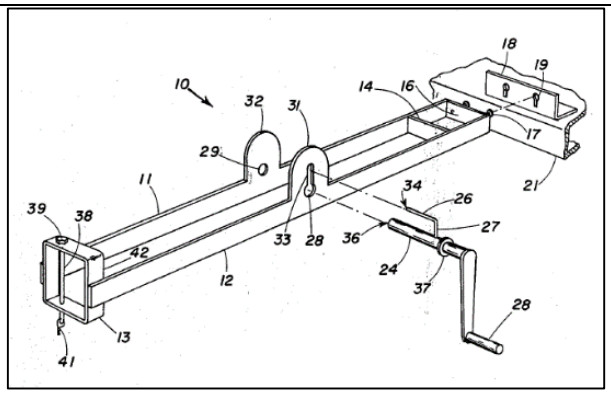
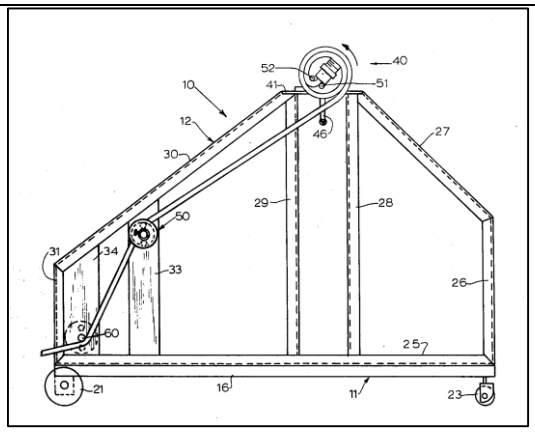
Author and Year Published	Method	Findings
[7]	National Institute of Occupational Safety	• Problem: Lifting the hose especially above the shoulder

	Health (NIOSH) lifting equation and Rapid Entire Body Assessment (REBA)	causes a huge amount of strain on the musculoskeletal system. • Solution: The height of the fire hose off the ground should be increased and reduce the amount of water in the hose to reduce its weight. Two roller devices were devised to eliminate the need to raise hose for drainage. They consist of squash and pinch rollers. • Problem: Rolling the hose caused strain on the lower back due to bending. • Solution: Proposed similar concept of roller to drain the hoses of excess water which can roll up the hose.
[1]	Cornell Musculoskeletal Questionnaire (CMQ) and Ergonomic Risk Assessment (ERA)	• Problems: Back pain problems were contributed mainly by awkward postures. The lower back had the highest percentage of pain experienced by the firefighters among other body parts such as shoulder, upper arm, thigh and knee. • Solution: Job rotation, fitness program and a mechanical tool were suggested to reduce the problem. Fire hose roller was suggested as the mechanical tool.
[15]	ERA and FMEA	• Problem: Back part of the body is the main risk injury. • Solution: A mechanical tool was proposed for the rolling process to reduce the ergonomic risk factor. The tool is fixed on the fire truck to reduce movement of the firefighters during rolling the fire hose. An automated process is applied so that the roller can roll the hose completely.

2.5 Previous Research Work on Fire Hose Roller

Previously, there were several designs of fire hose roller that had been fabricated. Table 2 shows previous research work on fire hose roller.

Table 2: previous Research Work on Fire Hose Roller

Author and Year Published	Description
[11]	 **Figure 1: Hose Roller** The hose roller is at a fixed position as the other end side of it is mounted on the fire truck. The opposite end is where the fire hose is inserted then rolled in the middle by the roller. When the hose is rolled, the shaft and pin are brought into keyed alignment with the opening in one of the sidewalls and the crank is removed, permitting the rolled hose to be lifted from the frame.
[12]	 **Figure 2: Fire Hose Winding Apparatus** The hose is directed to the reel past an idler roller and an adjustable hose guide assembly which serve to compress the hose and drain any water that may be present, and which also serve to align the hose with the tines so that it does not have to be straightened before the winding operation.

[5]

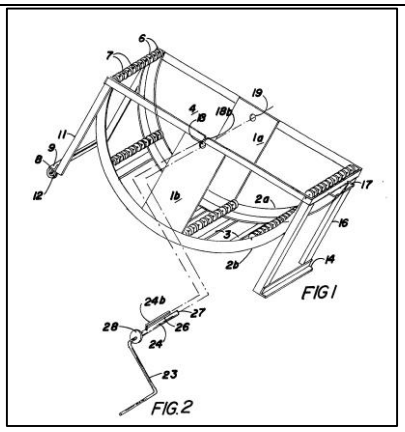


Figure 3: Firehose Reel and Transfer Device

This device is a straightforward design for rolling the fire hose as the hose is inserted directly into the roller guided by the reels on the wall. This device has rollers at the underside of the bracket for its movement. At the opposite end, a stabilizing bar is provided and is carried by arms.

[4]

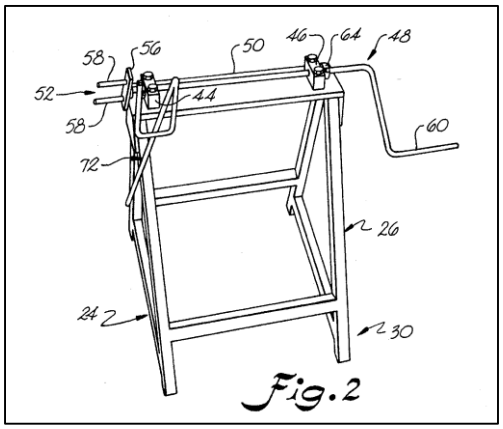


Figure 4: Fire Hose Winding

A self-supporting, stand-alone support structure is provided with an elongated crankshaft. One end of the crankshaft has a yoke for receipt of the hose couple while the other end is the handle for turning the yoke. A hose guide is provided upstream of the yoke to maintain the width of the hose when rolling it.

[8]

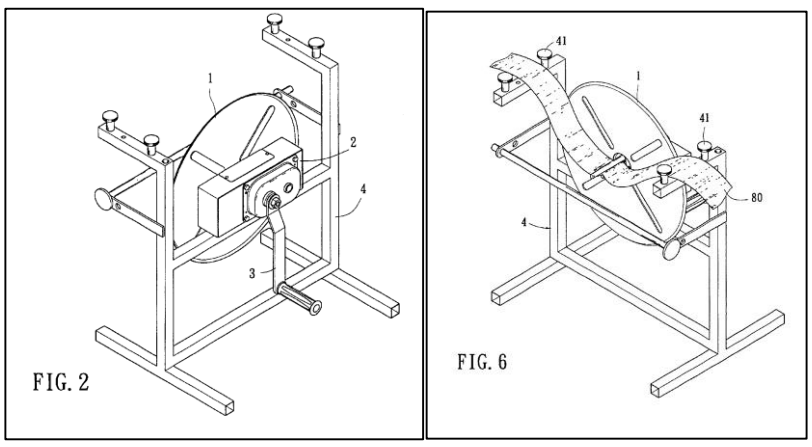


Figure 5 (a) and (b); Reeling Device for Fire Hoses (back) and (front)

This device includes a winch, a gearing kit that controls the winch and an operating handle for the winch and the structural rack to house all the above elements. The hose will be inserted as illustrated in the picture.

[7]

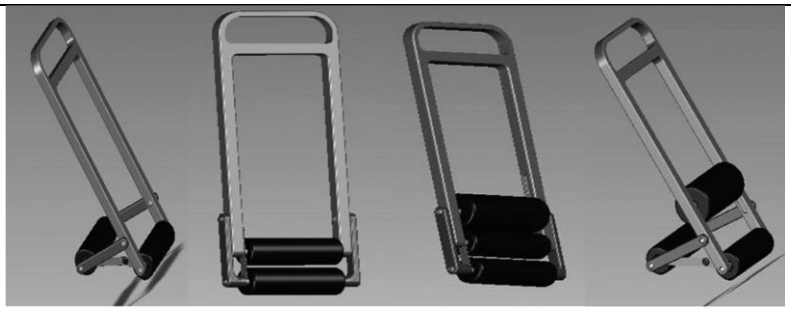


Figure 6: Squash and pinch rollers

These are two prototypes drawing of the squash and pinch rollers. They have fold-up feature like a folding chair to save space in the storage compartment of the fire truck. The squash and pinch rollers will provide force to remove excess water from the fire hose when the hose rolls through them.

3. Methodology

3.1 Flowchart

Figure 7 shows the flowchart of this project. A brainstorming session was done at Pagoh Fire Station where the firefighters demonstrated their previously made fire hose roller.

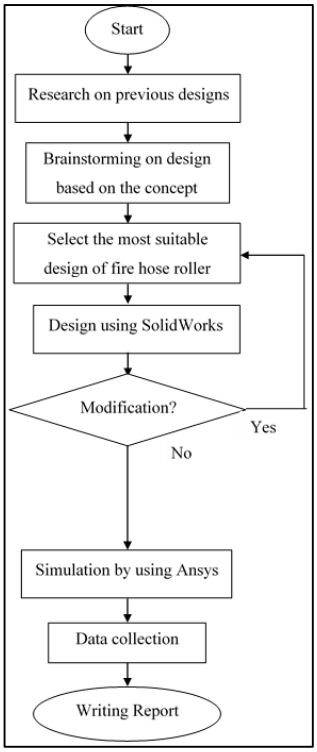


Figure 7: Flowchart

3.2 Brainstorming session

The brainstorming session was done at Pagoh Fire Station. Figure 8 shows the firefighters demonstrating their previously made fire hose roller. The fire hose roller's parts consist of steels from the used product of a bicycle such as a pedal. Figure 9 shows the previously proposed design of an ergonomic fire hose roller [14].

Figure 8: Pagoh Station's Fire hose roller

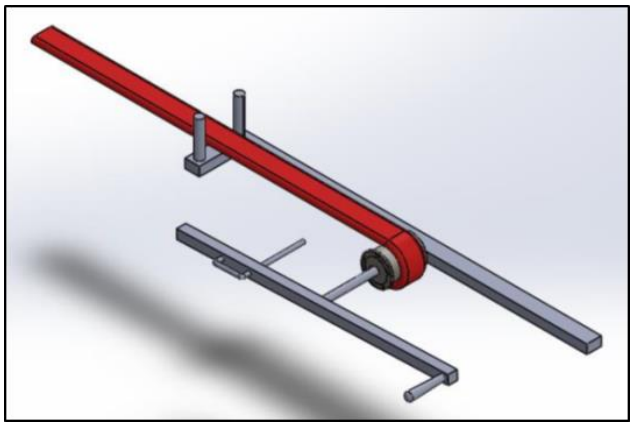


Figure 9: Previously proposed design [14]

3.3 SolidWorks

Using SolidWorks, the concept of the fire hose roller is designed. Some features used are such as an extruded boss, extruded cut and revolve boss. Each part of the hose roller was designed separately before being assembled into the final product. This design consists of a handle, main body, roller part, two wheels and connecting rod. The work concept of this design is that the fire hose will be inserted below the wheel connector and the nozzle will be placed on the roller part. Then, the fire hose roller will be tilted at a certain angle before being pushed forward. As the tool is pushed forward, the roller part and the connecting rod will rotate at the same time to roll up the fire hose.

3.4 Ansys

Finite Element Analysis or FEA is the simulation of a physical phenomenon using a numerical mathematic technique referred to as the Finite Element Method, or FEM [6]. The geometry is imported from SolidWorks, then the material is chosen from the library. Next step is to apply loads such as forces, moments or pressure and mesh on the model. After generating a mesh, every single point of the mesh will be calculated and then combined to make up the result for the structure.

4. Results and Discussion

4.1 Design

Figure 10 and Figure 11 shows the result of a fire hose roller design using SolidWorks software. The handle can be extended and collapsed.

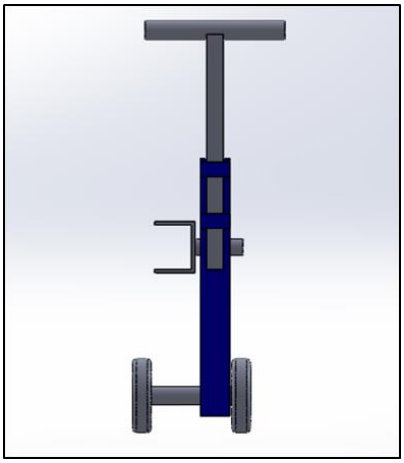


Figure 10: Fire hose roller when extended

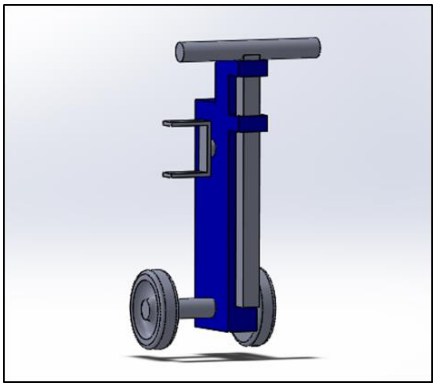


Figure 11: Fire hose roller when collapsed

4.2 Simulation

Figure 12 shows the mesh result of the design. The nodes can connect without any error. Therefore, the design is in a good condition.

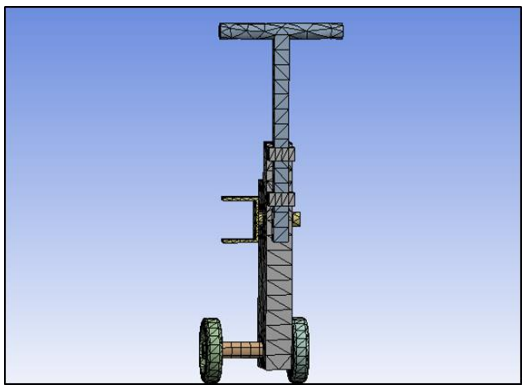


Figure 12: Mesh result

Figure 13 shows the result of total deformation when a force applied to the roller part. The roller part bent after a force was applied. The weight of fire hose was 15 kg as stated by the firefighters therefore the value was considered as the force.

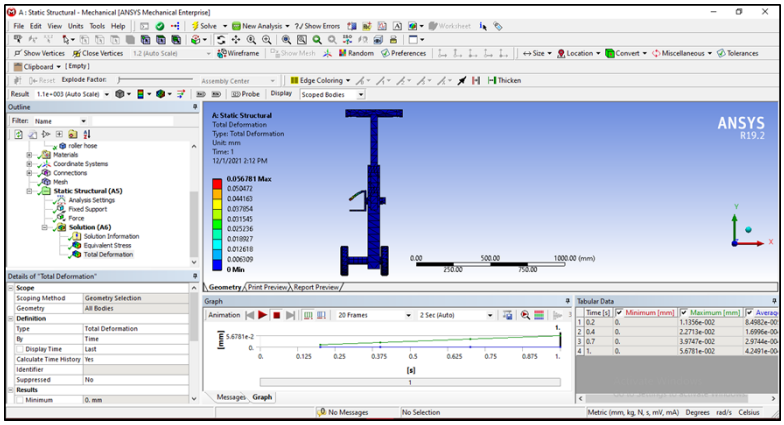


Figure 13: Total deformation result

4.3 Discussions

There was no error occurred in the design as shown by the mesh result. During the simulation process, there were no changes made in the parameters as they were set as the default program. After the simulation process, a bending occurred at the roller part due to force applied. Therefore, the parameters during simulation must be detailed to ensure more accurate data. Material selection and the design of the roller part also need to be revised carefully.

5. Conclusion

The objective of designing an ergonomic portable fire hose roller using SolidWorks was achieved. The strength of the fire hose roller was successfully assessed using Ansys software. A bending occurred at the roller part due to force applied. Material selection and simulation process should be more detailed to get a more accurate result.

A more detailed and guided simulation process should be done so that the design can be improved. Fabrication process should take place in the future study to help understand the mechanism of the fire hose roller to help the firefighters to overcome ergonomic problems.

Acknowledgement

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