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Design of Portable Hand Winch Tool for Stack Emission Monitoring Works

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Abstract: Winch is a mechanical apparatus utilized for either winding up or unwinding a rope or wire cable, which is connected to a load through a horizontally rotating drum. In traditional practice, winches were operated manually, relying on human labor. However, in modern times, winches are commonly powered by motors or hydraulics, as they provide substantial torque necessary for tasks involving heavy loads. Nonetheless, manual winches still exist and are suitable for lighter-load applications. During stack monitoring operations, industrial emission platforms like those found on boilers typically have a high height to perform related tasks, technicians must climb up these platforms using ladders and carry essential tools, often including a 90m rope. This process demands a considerable amount of energy and can quickly exhaust the technicians. By designing a suitable tool for this purpose, it is possible to enhance both the quality and safety of the working procedures. To design the machine, this project follows the George E. Dieter design process, which entails eight stages: problem definition, information gathering, concept generation, concept evaluation, product architecture, configuration design, parametric design, and detail design. The current patent and commercially available machines were consulted to come up with ideas and concepts for the machine. For the proposed design concept, engineering simulation and sustainability analysis are completed using SolidWorks software. The results based on SolidWorks show that the designed tool can handle the required load reliably and safely where the factor of safety (FOS) for casing and drum are 5.5 and 4.6 respectively.

Keywords: Hand Winch Tool, Product Design, Solidworks

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1. Introduction

A winch is a mechanical device which is used for winding up or winding out a rope or a wire cable which is attached to the load via a horizontal rotating drum. The most basic construction of a winch consists of a spool for winding rope and a hand crank for cranking the spool. Conventionally, the operation of winches is done with a motor or hydraulic nowadays as it produces high torque for specific tasks where a high load is involved. Manual winches which require human labour are still present, but they are for small load usage, as shown in Figure 1.

Figure 1: Workers lifting load manually

In Stack Monitoring works, stack platforms for industrial emissions such as boilers usually have a height of around 50m to 80m. A technician is required to climb onto a platform stack by ladder and carry the necessary tools for any related work and the most common one is a 90m rope. Whenever there is heavy lifting required such as installing a new dust or smoke sensor, most of the time a technician relies on a rope and pulls the new hardware tied to a rope by using a platform rail as a fulcrum as shown in Figure 1 above. This requires a tremendous amount of energy and causes a technician to wear out easily. By designing a suitable tool this can increase quality and safety in working procedures.

An extensive review and analysis of data collection procedures were done in order to guarantee project success. Research data is gathered from a variety of sources, including academic journals, online resources, and scholarly articles. The data offered is crucial for carrying out the project successfully. Data about relevant existing items used in the project, including both hardware and software components, will be gathered as part of this study.

2. Methodology

The design process methodology provides a structured approach for engineers and designers to develop and enhance product solutions. It involves sequential steps, guided by engineering techniques, to generate initial concepts and evolve the product to meet requirements. Following the framework by George E. Dieter, the design process includes three main phases: conceptual design, embodiment design, and detail design, as shown in Figure 2.

3. Results and Discussion

3.1 Component Decomposition Analysis

The purpose of component decomposition analysis is to outline the components and sub-components that together make up the product. Therefore, for a machine, each component will be separated into its major and minor components in that order as shown in Figure 3. This analysis may link or connect several parts to create a machine or product and some of the elements displayed in the component decomposition analysis, though, might not be chosen for idea selection.

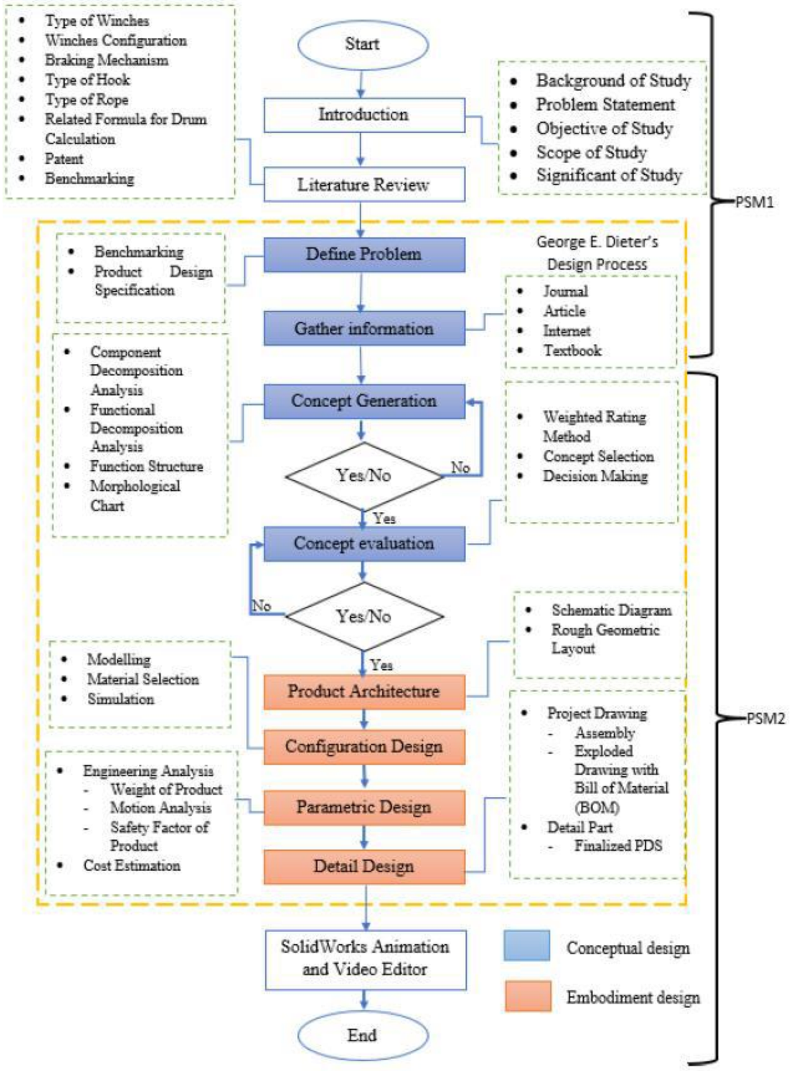


Figure 2: Flow Chart of Design Process

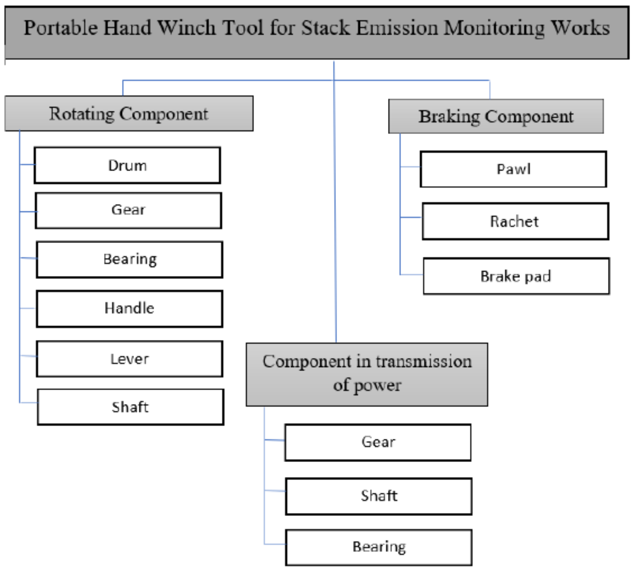


Figure 3: Components Decomposition of Product

3.2 Functional Decomposition Analysis

The shape of a product cannot yet be described by analysis of function decomposition, which is a function structure. This analysis will help in determining the relevant functions and areas where linkages between components may be appropriate, as in Table 1.

Table 1: Functional Decomposition Analysis

No	Component	Function
1	Handle	Act as hand placement to secure grip
2	Gear	Transfer the power to other parts
3	Lever	To move the rotating component in a circular motion
4	Drum	Winding rope and storing
5	Bearing	Reduce friction for shaft movement
6	Shaft	Act as a connection between drum and gear
7	Housing	To hold the component in the desired order
8	Bolt and screw	To hold and combine components in a machine

3.3 Product Sketching

A design concept sketch is supposed to show the visual appeal of a proposed product concept. Based on the final decision of the design concept, sketching allows designers to explore solutions to design challenges. Figure 4 shows the sketching of the proposed product concept.

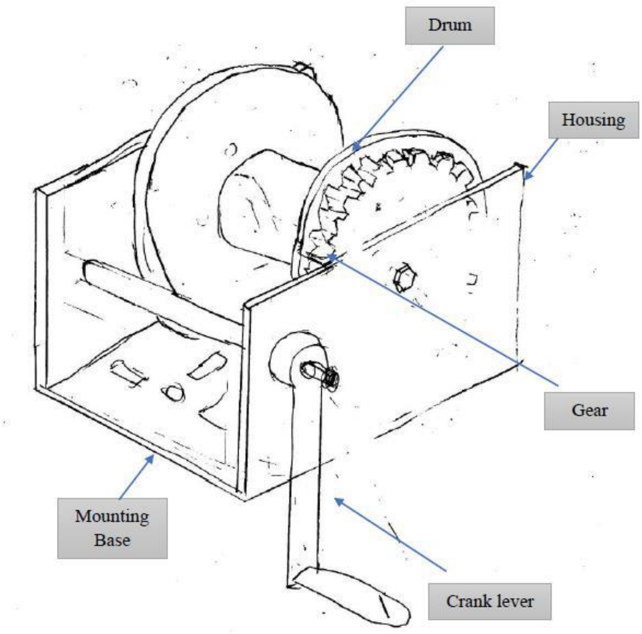


Figure 4: Sketching of the Product

3.4 Schematic Diagram of Winch

The schematic diagram will depict the fundamental elements required to produce a functional product design. The development of the schematic diagram begins with the function structure and concept outlined in the previous chapter. In the schematic diagram, energy and material traces were utilized. The level of detail depicted on the schematic should be determined with discretion. Figure 5 shows the schematic diagram of the winch.

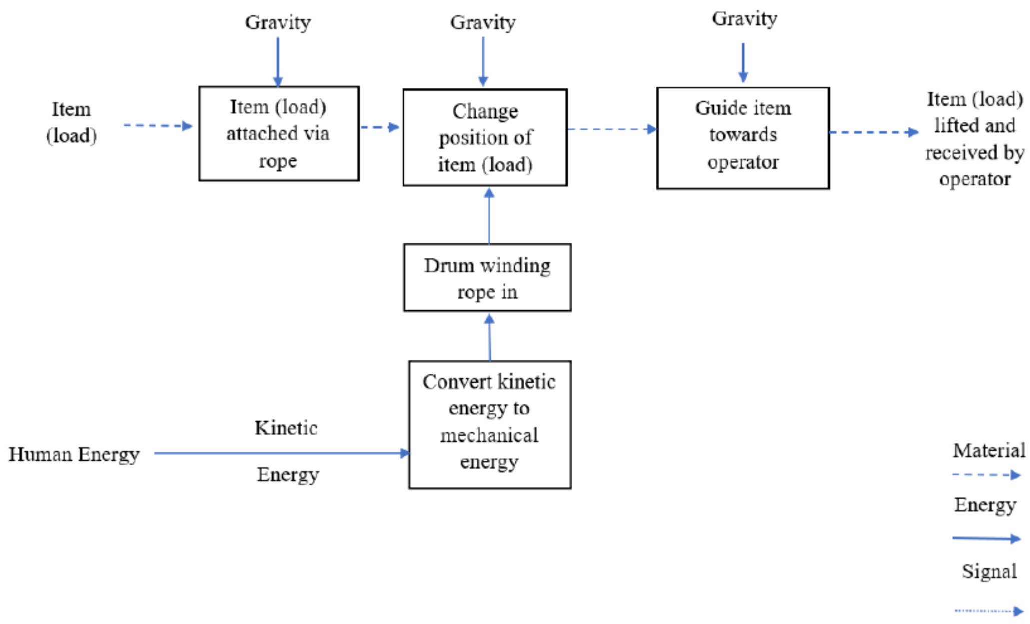


Figure 5: Schematic Diagram for Winch

3.5 Gear, shaft and bearing calculation

Gear calculations ensure efficient power transmission and reliability, optimizing performance. Shaft calculations determine dimensions and materials to withstand forces and prevent failures. Bearing calculations select the right type and size to minimize friction and ensure smooth rotation, enhancing efficiency and durability. Accurate calculations improve power transmission, structural integrity, and overall winch performance, reducing the risk of failures and downtime.

Table 2 shows the summarised data for gear analysis fundamentals. The value obtained is based on the required load to lift which is 150kg. The high value of DP (mm) and teeth, N needed to accommodate the size of the drum designed. The gear ratio, MG is 3 due to its torque conversion is desirable without sacrificing the gear speed, n (rpm).

Table 2: Gear analysis summary

Gear	Ratio, M_G	Teeth, N	Speed, n (rpm)	Torque, T (Nm)	D_P (mm)	Module, m	F^t	F^r	|F|
G1	3	20	40	200	60	3	1133.33	412.5	1206.07
G2	3	60	14	600	180	3	1111.1	404.4	1182

Tables 3 and 4 both show the shaft moment and force result being summarised from the bending moment diagram into table data. Each shaft moment and force is calculated by Z and Y plane reference. ΣMa(Nm) value is the total moment at the centre of the gear and Tm(Nm) is the torque experienced by the shaft.

Table 3: Gear shaft (G1) calculation result

Plane	V(N)	M(Nm)	ΣM_a(Nm)	T_m(Nm)
Z	303.3	7.58 (resultant)	10.27	100
	-101.1	25.78 (critical point)		
Y	832.32	6.94 (resultant)		
	-277.78	23.61 (critical point)		

Table 4: Gear shaft (G2) calculation result

Plane	V(N)	M(Nm)	ΣM_a(Nm)	T_m(Nm)
Z	309.4	2.57 (resultant)	7.53	34
	-103.1	8.76 (critical point)		
Y	850	7.08 (resultant)		
	-283.3	24.08 (critical point)		

Table 6 shows bearing analysis which involves bearing specifications, life cycle, and application factor. F_Y and F_Z values are obtained from Table 4 and Table 5 respectively. F_D stands for bearing desired radial load and C_{10}(kN) is bearing catalogue load rating while C_{10}(N) value is obtained from bearing analysis calculation.

Table 5: Bearing analysis result

Bearing	F_Y(N)	F_Z(N)	F_D(N)	N_d(rpm)	C_{10}(N)	C_{10}(kN)
A	832.32	303.3	885.86	14	2061.4	2.06
B	277.78	101.1	295.6	14	687.9	0.68
C	283.3	103.1	301.5	40	995.5	0.99

3.6 Static Simulation Analysis

A product is subjected to a thorough analysis known as static analysis to determine whether a component can be used safely. Since most of the shaft's applied force was concentrated on the winch case and drum, they will be considered a key component for this analysis. The total force is also considerably greater than the combined weight of the other assembled parts. So, it is preferable to set the stronger force as the acting force on the case and winch. SolidWorks 2022/2023 software will be used to perform a static analysis of the component.

Figure 6 shows Von Mises stress static simulations on the casing with the material specified as aluminium 6061. Hence, the maximum yield strength is 5.515e+07. Based on the results obtained from the figure above, the value for the Von Mises stress does not exceed the maximum yield strength.

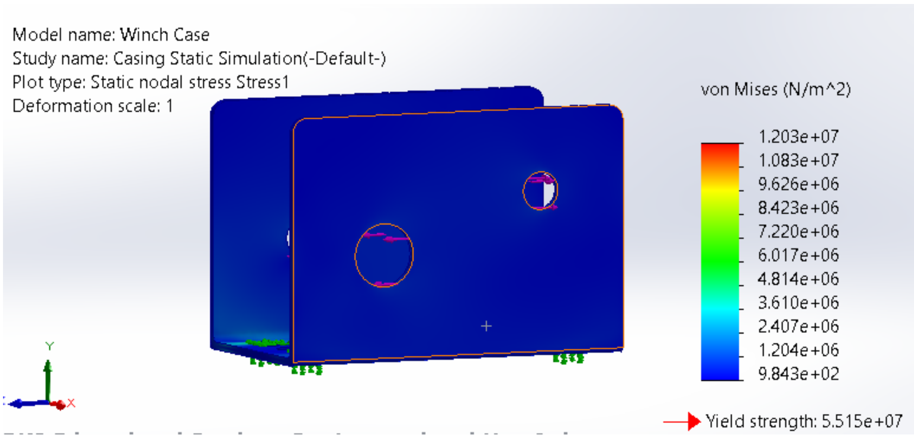


Figure 6: Results of Von Mises stress on the casing

Figure 7 shows Von Mises stress static simulations on the casing with the material specified as aluminium 6061. Hence, the maximum yield strength is 5.515e+07. Based on the results obtained from the figure above, the value for the Von Mises stress does not exceed the maximum yield strength.

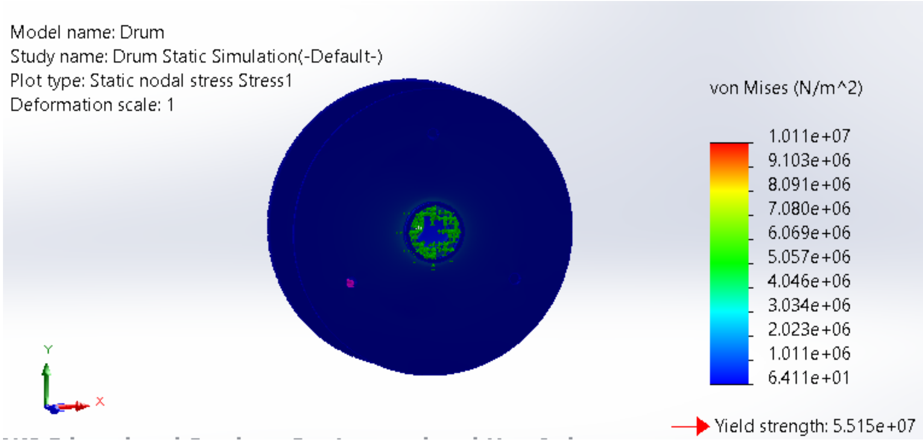


Figure 7: Results of Von Mises stress on the drum

Figures 8 and 9 show the static displacement analysis from both casing and drum respectively. Based on Figure 8, the maximum displacement is $3.232e\times{-02}mm$ while for Figure 9, the maximum displacement is $6.897e\times{-04}mm$ which will not affect the performance of both components as the deformation scale is only 1.

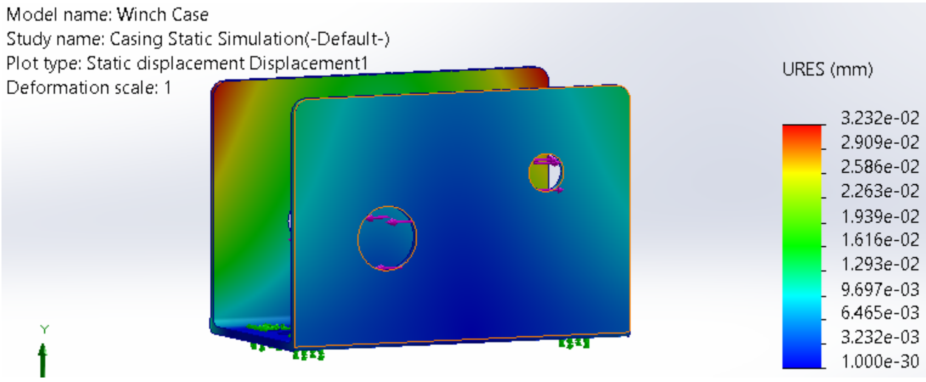


Figure 8: Static displacement analysis on the casing

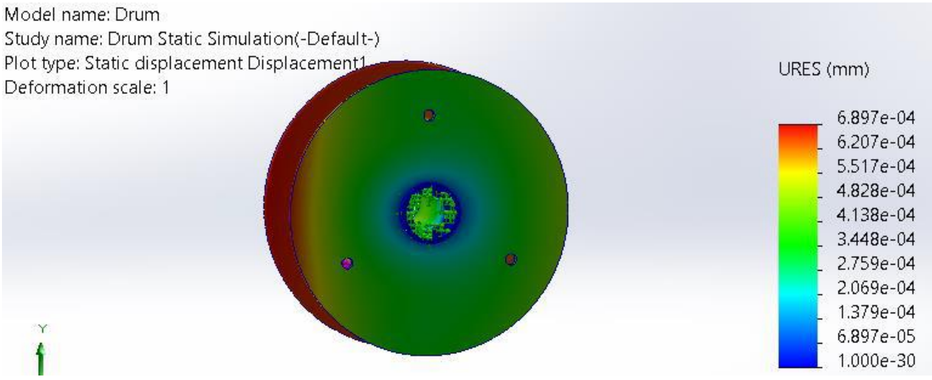


Figure 9: Static displacement analysis on the drum

Figures 10 and 11 both show the result for the Factor of Safety (FOS) for drum and casing respectively. For drum FOS as shown in Figure 10, the result value is 5.5 while for casing FOS shown in Figure 11, the result value is 4.6. Each result exceeds 1 hence the component will not fail, and it is considered safe within the industry standard. Results were achieved using the largest lift force that could be considered, which is 150 kg. However, most of the weight to be lifted rarely exceeds 80 kg in real-world situations where the application is made.

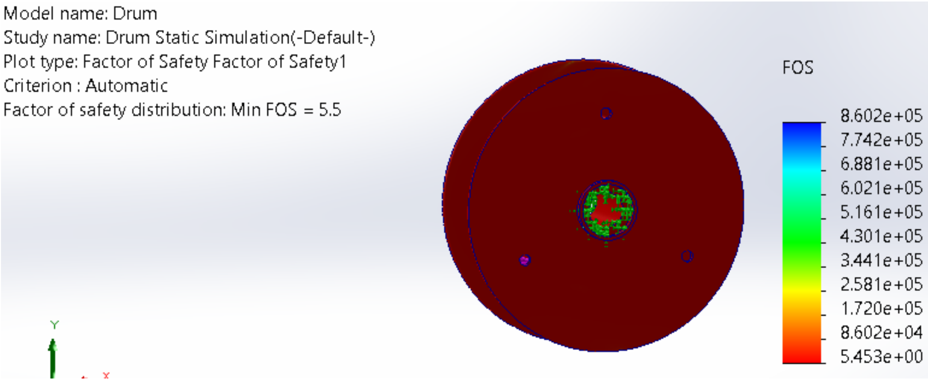


Figure 10: Result for the factor of safety on the drum

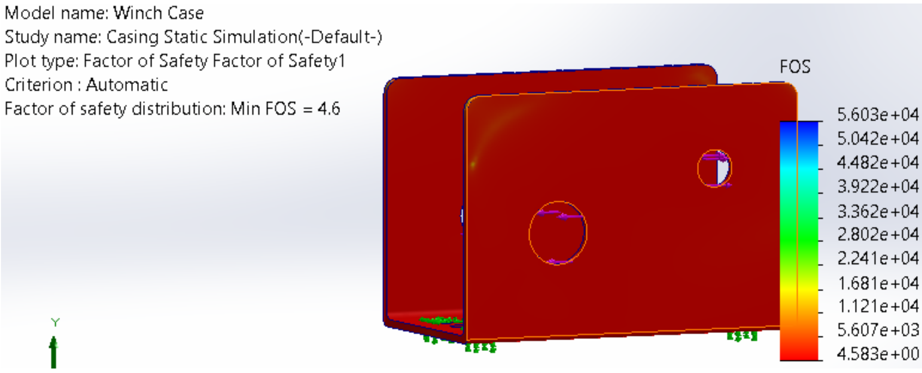
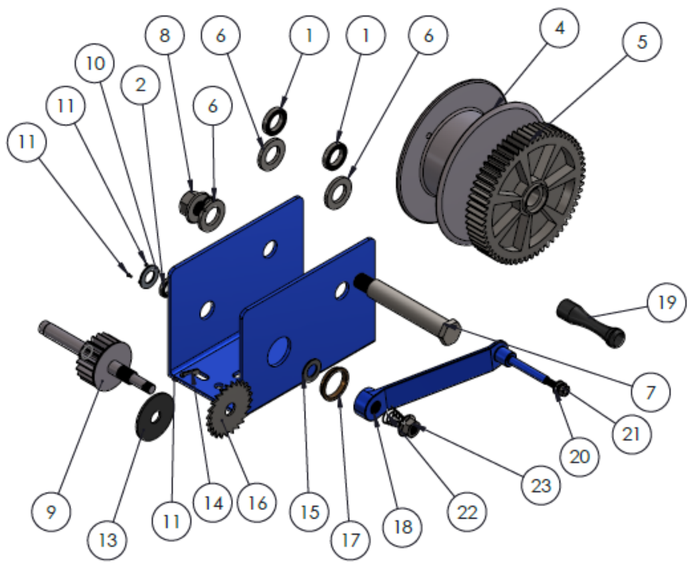


Figure 11: Result for the factor of safety on the casing

3.7 Exploded View

The main purpose of an exploded view graphic is to show the physical connections and interrelationships between different discrete pieces within a larger assembly. Visual representation of the physical arrangement of the dismantled parts would accurately portray the sequential progression involved in the process of developing the finished design product. The assembly worker's ability to assemble and install the product correctly is crucial. It is essential to include a Bill of Materials (BOM), shown in Figure 12, which serves as an exhaustive inventory or enumeration of the necessary components or goods that must be purchased.



ITEM NO.	PART NUMBER	QTY.
1	SKF - 61805 - 22,DE,AC,22_68	2
2	SKF - 61803 - 20,DE,AC,20_68	1
3	Winch Case	1
4	Drum	1
5	Metric - Spur gear 3M 60T 20PA 30FW --- S60N75H50L25N	1
6	B18.22M - Plain washer, 24 mm, narrow	3
7	Shaft drum	1
8	B18.2.2.4M - Hex flange nut, M20 x 2.5 --S	1
9	Metric - Spur gear 3M 20T 20PA 30FW --- S20O52H43L18N	1
10	Bearing holder	1
11	B18.6.7M - M2 x 0.4 x 5 Type I Cross Recessed PHMS --5N	3
12	B27.8M - 3FM1-18	1
13	Pad brake	1
14	Pawl	1
15	Pressure washer	1
16	Rachet	1
17	Bush	1
18	Lever	1
19	Lever handle	1
20	Lever handle washer	1
21	B18.2.2.4M - Hex flange nut, M8 x 1.25 --N	1
22	Lever spring	1
23	B18.2.2.4M - Hex flange nut, M14 x 2 --S	1

Figure 12: Exploded View of the Product

4. Conclusion

In summary, George E. Dieter's engineering design approach was effectively used to the design of the portable hand winch tool for stack emission monitoring works. This machine's design also effectively utilized the necessary calculations and analyses from the mechanical engineering degree. The machine's design may be fully created with the use of cutting-edge design software, such as SolidWorks, and an amazing simulation video, which considerably aids in our understanding of the machine's concept and operation.

Acknowledgement

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