Generator Rotor Extractor

MENG 3309 MSD REPORT

030-Group11

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We certify that the narrative, diagrams, figures, tables, calculations and analysis in this report are our own work.

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MECHANICAL ENGINEERING DEPARTMENT
HOUSTON ENGINEERING CENTER
COLLEGE OF ENGINEERING
THE UNIVERSITY OF TEXAS AT TYLER

Abstract

Turbine generators are machines that generate electricity by converting mechanical energy to electrical energy. They are comprised of two main components, a rotor and a stator unit. The rotor is covered in wires and is spun by mechanical energy inside a stator unit, which has wires coiled inside, creating an electric magnet. Over time of operation the generator's components wear and have to be serviced at a minimum three times a year. This becomes a problem because in order to access the components to service them the rotor must be extracted from the generator. In this proposal the rotor model that is tasked to be extracted is from CMT Machines and weights in at 129000 pounds. This proposal is about designing a process in which the rotor will be extracted using a guided rail system while being pulled by a winch. In order to achieve this, components were designed to distribute the load of the rotor among two support structures which are further divided into three components, a seat which supports the rotor, and two Hillman rollers which support the seat. The next step was to design a guided rail system in which the rollers would transition the rotor along a two channel rails, both placed on parallel to another. Next the device that will pull the rotor and supports will be a hydraulic winch model AQ-JM2 by Winch Machines. Finally, all these components will be held up by a Generator Field Support Platform made by MDA Turbines. Upon analysis of the components when placing the load of the rotor, the seat was found to have a safety factor of 15 with a displacement of 7.926E-5 inches. The rollers was then analyzed where each of the rolls had a safety factor of 15 and a displacement 1.851E-5 inches. The final analysis for this design was the winch which had a speed of 10.5 inches per second, torque 237741 lbf*in, and 54 Horse Power, when extracting the load of the rotor and its support along the rail system The one component that can be modified however, in this proposal is the seat due to it having such a high safety factor it is unnecessary to have a design where too much material is used to achieve this outcome.

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Introduction

Generators

Turbine generators are devices that convert mechanical energy into electrical energy. The way this is accomplished is by using an electromagnet, a magnet produced by electricity. The main components of the generator that produce the electromagnet are the generator stator and the rotor. The stator unit is a stationary unit with insulated wires coiled around an internal cylinder contained within the unit. The rotor is comprised of wires coiled and placed on a shaft. The rotor turns within the stator unit producing the electromagnetic power.

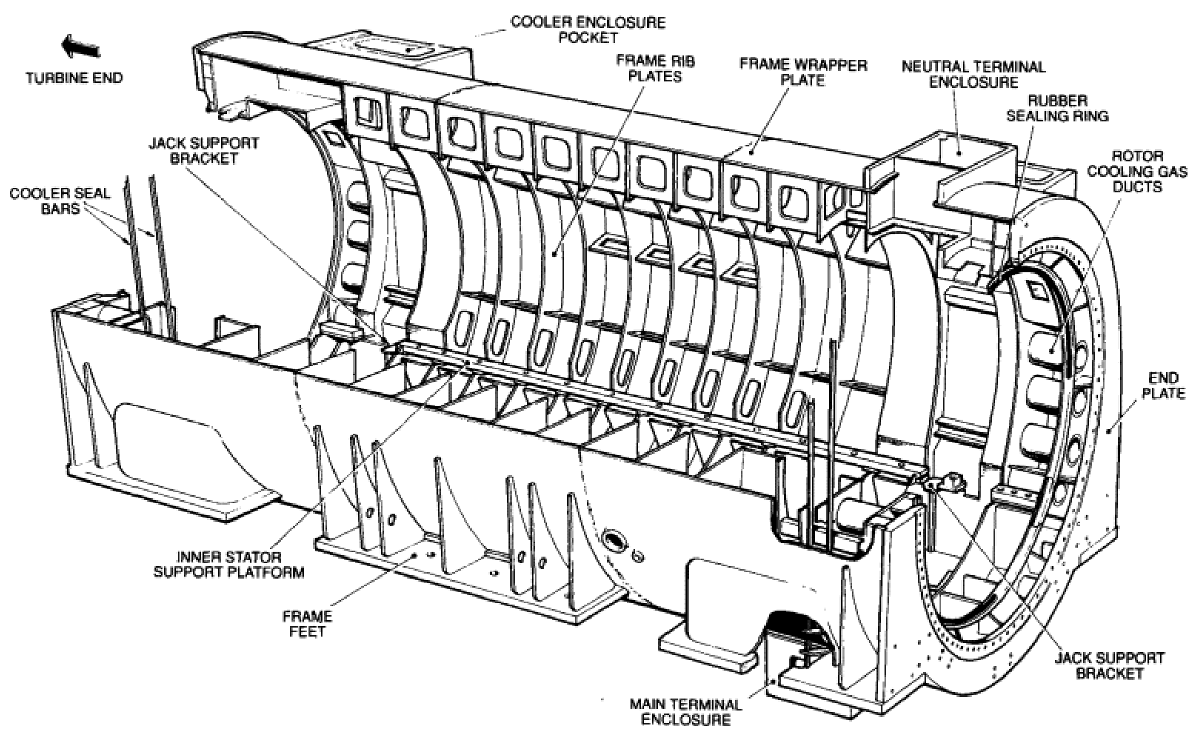


Fig 1. Depicts a diagram of a generator stator, which houses a rotor [1].

As shown in **Fig 1.** the stator is what houses the generator rotor, the rotor spins in the stator and induces a current to produce energy.

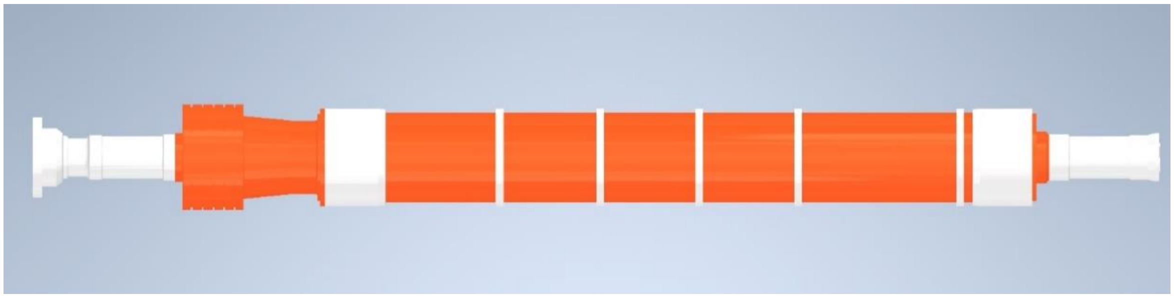


Fig 2. Generator rotor from City Machines Technology part number 98972-RGXLA [2].

As shown in **Fig 2.** a rotor shaft is selected and displayed above. This assembly is what would be housed in the stator when fully operational.

Rotor Maintenance

Overtime the rotor will need some maintenance and may even need to be replaced after the life cycle of the part comes to an end.

Fig 3. Image of rotor melted seat with melted insulated coiled wire taken from **Figure 2** "Ageing Generator Rotor: Refurbishment or Removal from Service?" [5].

Some of the common damages that can occur to a generator rotor are the coiled wires that can corroded from wear. As shown in **Fig 3.**, a rotor can experience burns cracks along with its components and even damage the stator unit inside when in operation. Due to the extensive components that can wear in a turbine generator, rotors need to be serviced at least three times a year. In order to do this the rotor must be taken out of the stator unit for it to be serviced. This process is known as generator rotor removal or extraction. Generator rotor extraction is done by a multi-step process in which multiple mechanisms work in tandem for the rotor to be extracted. The extraction is done by pulling the rotor from the generator's stator horizontally while it is suspended or held up from the bottom in pure translation. If the rotor is not removed in an extremely controlled fashion, and becomes imbalanced, the rotor can damage the generator stator.

Proposed Method

The motivation of this proposal is to find a way to optimize the process for extracting a rotor with a minimal cost, a verifiable factor of safety, and a projected life cycle. This can be achieved by comparing another process for rotor extraction to generator rotor extraction. The model for the assembly as shown in **Fig 2.** is what this proposal is challenged with removing from the stator unit.

In order to remove a rotor from a stator unit a method of extracting has been determined to be using a rail guided system. The rotor itself will be supported by structures that can support its weight while being rolled upon a rail. The rotor then will be pulled by a winch using a cable. The entire structure can then be supported by a platform which will be able to support the forces being enacted on the structure during the whole process.

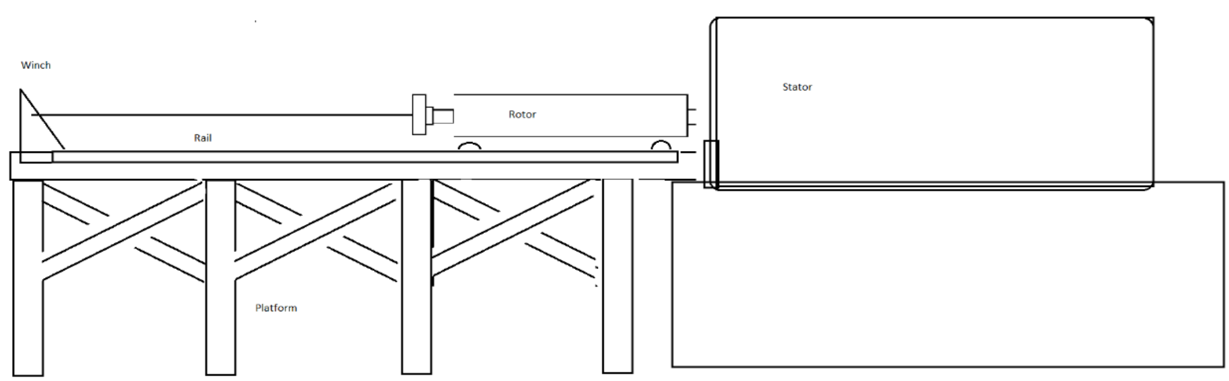


Fig. 3. Proposed Drawing.

Problem Statement

In designing the proposed design, the ideal process is putting together a detailed design that will help accomplish the goal of extracting a generator rotor from a stator unit. The following rotor as shown in **Fig 2.** from CMT is weighing in at approximately 129000 pounds, is what will be intended to be extracted for this design. The process in designing an extraction method that is proposed will present challenges. Such as when finding the distributed weight, the rollers will have to take from the rotor. Another challenge will be finding a cable winch that can pull the rotor including its supports. The guided railing system also will have to hold the weight of the rotor and support system. This rail then has to be placed on a platform that will keep the guided rail in its intended route, so it won't be displaced from the shear forces enacting on it by the rotor and the supports while it is being pulled by the winch.

Objectives

To minimize human error and unintentional damages to a rotor when being extracted; the process must be optimized with a mechanism to extract the generator rotor. The rotor assembly must be supported and guided as it is pulled at a safe rate for it to be extracted successfully.

In order to design the rotor extractor a similar method as shown in "Rotor Removal from Large Machines", a design of a rotor extractor can be made. The rotor extractor can be split into three components a guided rail, support structures, and a winch. The guided rail is for the extraction to occur with precision and not cause the rotor assembly to not damage itself or the stator. The support structures are to distribute the load of the assembly and move along the guided rail. Finally, the winch will use a cable that will pull the supports uniformly to ensure they move along the guided rail. Building on this the goal is to extract the rotor from its stator unit for 55 feet.

Preliminary Literature

In “Rotor Removal from Large Machines”, the process in removing a rotor is shown to be done by a mechanism that works by pulling a rotor out of its casing while resting on jacks guided along a determined path [3]. It begins by first pulling the rotor out of the casing slightly till it rests upon jacks that act as supports. The jacks are aligned to be positioned with the casing of the rotor so the transition will be smooth. The jacks then will move along the guided tracks for the extraction to be complete. This method helps show the type of supports that can be designed when moving the rotor from the stator unit.

In "Predictive Control of Hydraulic Winch Motion Control" hydraulic winches are used to pull large loads. However, it is stated due to the nonlinear way a load can be pulled when being dragged by a winch a guided rail system is necessary for the load to be transported in a linear fashion [4]. This will help with designing a guided rail which will keep the rotor and supports to be aligned with the winch.

Methodology.

When designing each component, a backwards approach is being taken by first designing supports which can hold the weight for the rotor and its dimensions. Next, a winch that can pull the weight of the rotor and the supports can be selected. Finally, the guided rail system with a platform can be then designed to hold the weight of the rotor, the supports, and a winch at the end.

Supports

The rotor that is most used has dimensions of half a meter in diameter while being 503 inches long and weights roughly 129000 pounds. Based on the dimensions stated a support to carry this rotor can be designed. The load of the rotor can be distributed between two supports. This means that the weight for each support will then be the total weight of the rotor and assembly divided by two giving the value 64500 pounds. The location of the supports will be placed along the assembly for it equal distribution of weight. The supports will be comprising of two components a seat in which the rotor rests on and two rollers where the seat can roll on.

When designing the seats, it is important to keep in mind where the seats will support the assembly. The seats must hold an approximate diameter of the rotor has a value of 41 inches. Another aspect of the seat will be to have two indentation on the bottom for the two rollers.

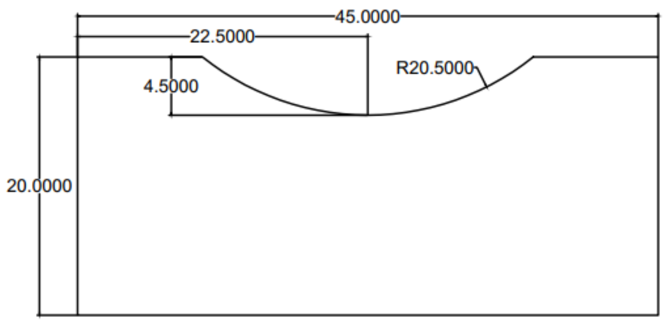


Fig 4. Shows the sketch of the seat.

As shown in **Fig 4.**, the seat dimensions are made to hold about 41 inches in diameter in rotor. The seat has been extruded to 18 inches and has slots on the bottom for the rollers. The total mass for the support is 3332 pounds.

The next component that has to be chosen is the rollers, which will be located on either side of the seat. The rollers are chosen from Hillman Rollers based on the weight that is being distributed on each roller. Since the Since the seat adds weight to the distribution along with the supported weight of the rotor assembly the total weight the rollers have to support is 67832 pounds. This means each roller will have to support about 33916 pounds. or about 17 us tons. In order for 17 us tons to be supported the Hillman Rollers 20 Ton Capacity T Style Roller 20-T (HIL20-T) is selected.

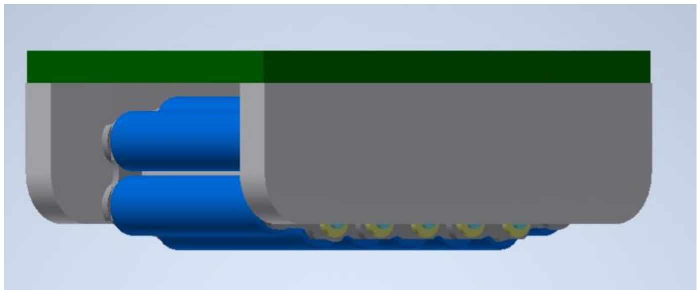


Fig 5. Shows the HIL20-T Roller which will attach to the seat.

Guided Rail System

After the Seat has been designed and the roller has been selected the next component for design is the guided rail. The guided rail is for the rollers to roll upon so the rotor assembly will be moved precisely and safely without being damaged or damaging the stator unit.

The first step is to design a rail with a length that will allow for the rotor to be completely situated on it when the extraction is complete and for room so personal can service it. Since the rotor is about 42 feet, a rail system that has the length of 60 feet is being designed. Another aspect is the channel dimensions of the rail, in which the rollers will move in. According to the Hilman official dimensions of HIL20-T Roller the width is about 6.5 inches and height is 3.75 inches. Due to this width the channel width of the rail is 6.5 inches with inner height of the channel 2.5 inches.

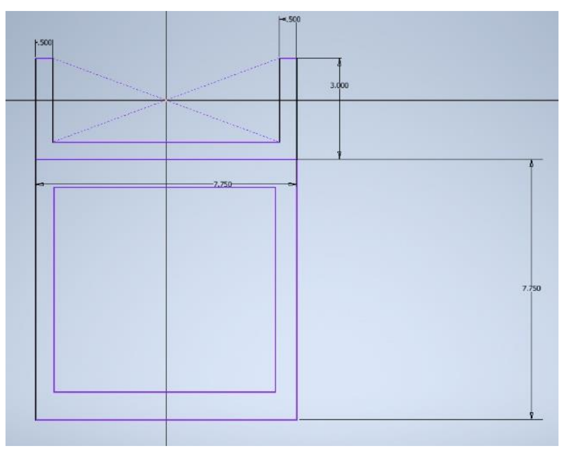
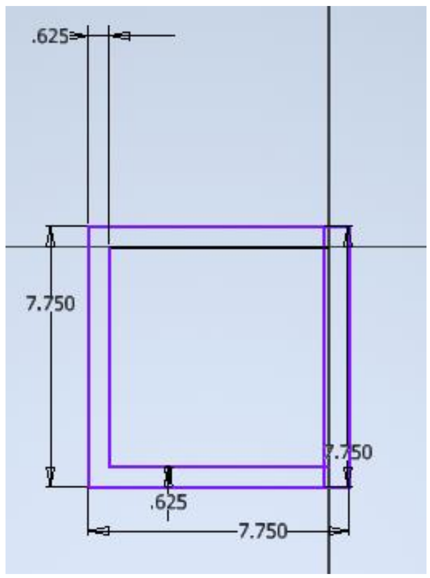


Fig 6. Shows the sketch of the guided rail component.

The guided rail as seen in **Fig 6.** has the length of 20 feet. Since the objective is to design a rail system that will extend to about 60 feet, three components will be used end to end to achieve the desired length. Also due to the distributed load of the rotor being divided on either side on rollers, there will be two sets of rails systems put about 20 inches apart. When all put together the 60 feet rail will have 13 sleepers placed 55 inches apart underneath the rail with following dimensions as shown below



Winch

In order to determine the winch that will be used to extract the rotor the horizontal force needed to pull the supports and the rotor itself on the guided rail system has to be first determined. The first step is to find the combined weight of the rotor and supports. There are 4 rollers being used in total each weighing at 47 pounds., giving a total weight of 188 pounds. There are two seats being used in the design each weighing at 3355 pounds. giving a total weight of 6670 pounds. All the support weight combined with the weight of the rotor, 129000 pounds., gives a value of 135870 pounds. Next using the friction coefficient for the steel being used on the rollers, .25, the determined force needed to pull the rotor with the supports come to a value of 33963 pounds or about 17 U.S. tons.

Fig 7. The AQ-JM2 series hydraulic pull winch.

As shown in **Fig 7.**, the winch, AQ-JM2, has been selected with a pull strength of 20 tons.

Platform

The platform has the length of 65 feet to contain the guided rail system and the winch which gives a total length of about 63 feet and a width of 5 feet. Based on the dimensions a truss system along with vertical beams are used to support the structure. These vertical support beams will be adjusted to level the platform to adhere to the height of the stator unit.

Fig 8. Shows Generator Field Support Platform from MDA turbines.

As shown in **Fig 8.** the support platform from MDA Turbines is chosen to be the platform for this proposal. The platform is able to hold the weight of the rotor, supports, rail guided system, and winch while still having enough structural integrity to withstand 30 miles per hour winds when in use. The platform length is 720 inches and is supported by 13 vertical beams spaced 55 inches apart.

Finally all the components can be assembled in the software inventor to show a simulated outcome of the proposed design.

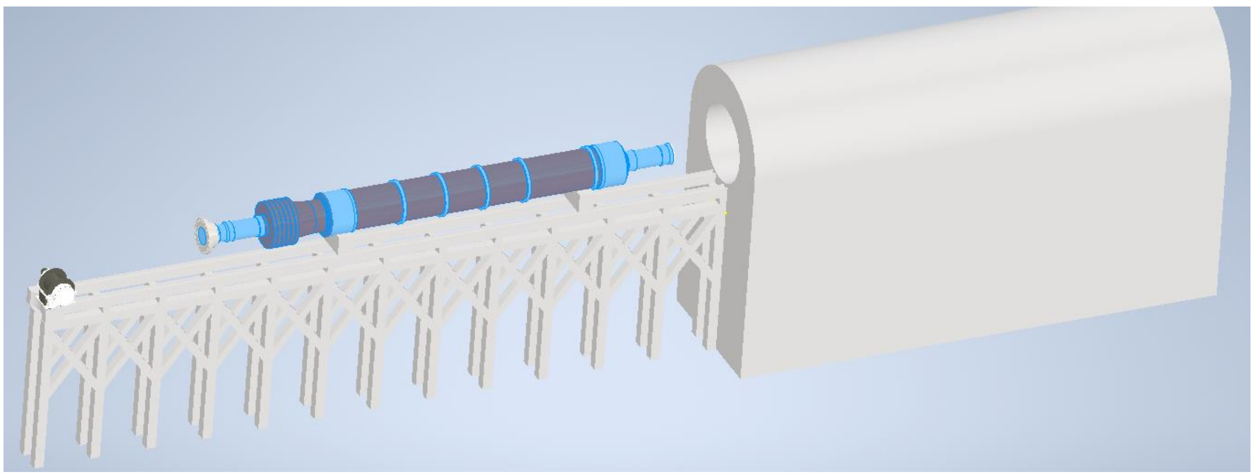


Fig 9. Shows the assembly of the proposed design on inventor.

Results and Discussion

Now the current design and its assembly is all put together, it is important to look at what results come from each component, which was specifically designed and not outsourced, when the load of the rotor is distributed.

The first validation that is needed to confirm whether or not the design can work is the seat component of the support system. The seat is placed under a force half of the weight of the rotor. This weight has been calculated to be about 64500 pounds. Using the inventors stress analysis tool, one can determine the safety factor, displacement due to deformation, and mass of the material being used of the component.

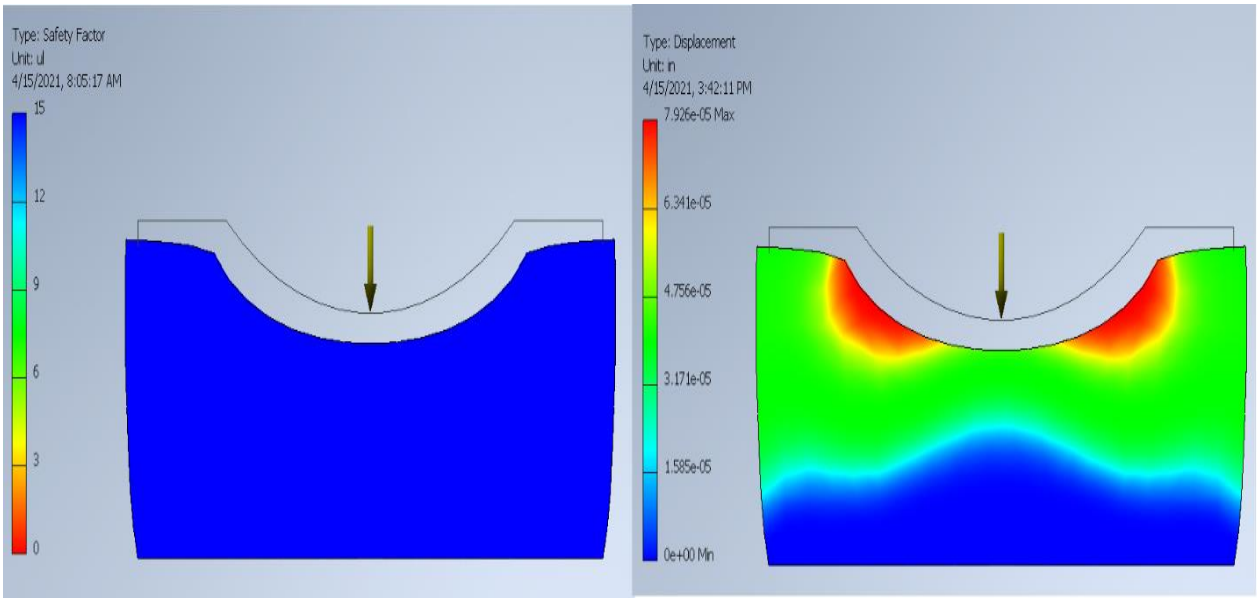


Fig. 10 Safety factor and Displacement due to deformation for the seat component.

From **Fig. 10** one can see the stress analysis that the seat went through. The displacement value was found to be 7.926E-5 inches when a load of 64500 pounds was placed on the seat. The safety factor was found to be 15 ul. From this analysis it can shown that seats component will be able to hold the distributed weight of the rotor.

The next component that can be analyzed is then rail system which can be determined based on the distributed load of the hillman roller, two of which will be situated under each seat. Each roller will have the distributed weight of half of the rotor and half of the seat, which is a load of 33916 pounds. The roller when in use has 5 rolls in contact with the surface of the rail allowing the load of 33916 pounds to be distributed among the 5 rolls. Each roll will therefore have to support the weight of 6783.2 pounds. Based on the dimensions of the roll as shown from the Hillman website, the diameter of the roll is 1.1875 inches and the length of the roll is 4 inches [8]. Each roll is made of high steel.

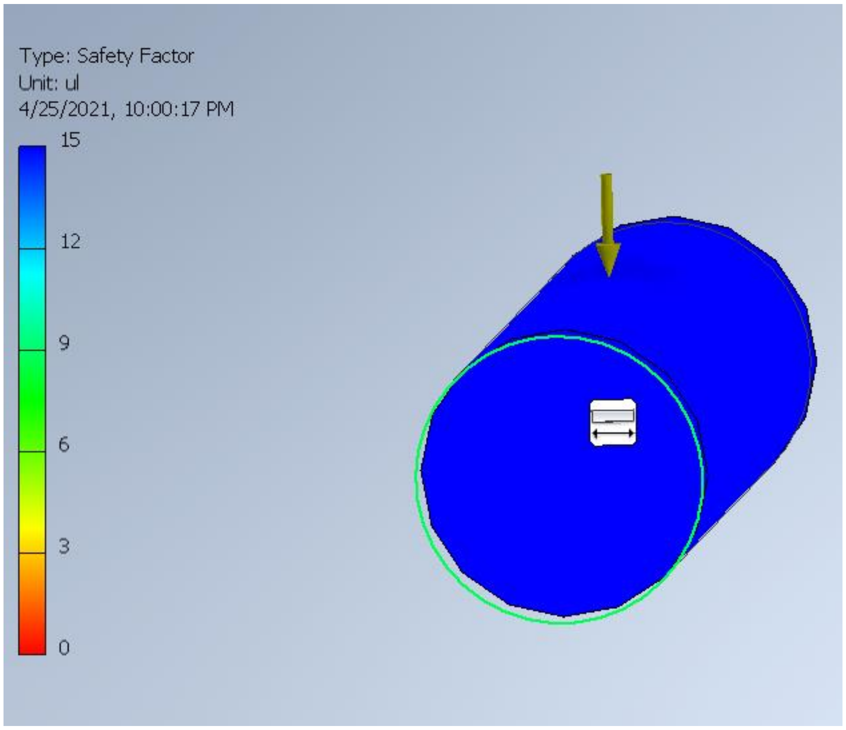


Fig. 11 Safety factor and Displacement due to deformation for the roll for roller component.

After using inventor stress analysis on the roll of the roller with 6873.2 pounds of force being placed on it, a safety factor of 15 was found while the displacement was 1.851E-5 inches. These values obtained from the analysis help determine that the HIL20-T Roller is able to support the distributed load while still functioning in the transition of the load.

The next analysis done is on the winch. The winch model is the AQ-JM2, the analysis of this component covers the speed and torque of the drum that pulls the cable with load of the rotor and supports system when moving along the rail system. The winch is rated to have a speed of 16 meters per minute which is 10.5 inches per second. Next based on the load that is pulled by the winch and the drum diameter to calculate torque. The drum is estimated to have diameter of .35 meters which is about 14 inches in diameter. The amount of force that is being pulled has already been calculated in the previous section to be 33963 pounds. When calculating torque the drum diameter which is 7 inches multiplied by 33963 pounds give a value of 237741 lb*in of torque. In order to find the amount of power that is being used in the process of extracting the rotor the following formula has to be used. As shown below

$$Power(HP) = \frac{Torque * speed(RPM)}{63{,}025} \qquad (1)$$

The speed for RPM can be found from the velocity at which the rotor will be extracted, 10.5 inches per second and diameter of the drum of the winch, 14 inches. This gives a value of 14.32 RPM. Using the previously stated formula above the power in horsepower is calculated to be about 54 horsepower when extracting the rotor from the stator unit.

Conclusion

In conclusion, the proposed design of a generator rotor extractor is successful based on the analysis done on each component that makes up the design. This is confirmed by the calculated and given information of each component's safety factor when placed under the load of the rotor, by CMT Machines, that is being extracted. The design makes sure to allow for the rotor to be supported by a seat and rollers which are to be extracted while being guided on a rail system and be pulled by a hydraulic winch, while the entire process is held by a generator support platform.

However, the analysis also showed how material was wasted for the seat structure that held the rotor. This is due to it having a large safety factor of 15 ul, which is shows that the same condition of the rotor being supported sufficiently can be achieved by scaling down the material being used for the design.

Another aspect of the design that can be modified for another environmental use is the rail system. Since the proposed design is meant for a particular extraction of a rotor from stator unit that is outside the rail system that was used was designed to be placed on a platform. However, if the design were to be modified where instead of a channel rail, a flat rail were used, the extraction can be used on ground level where the rail system was bolted to concrete. This is a method where a stator unit that is located indoors on ground level would be used

References

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Appendix

Appendix A

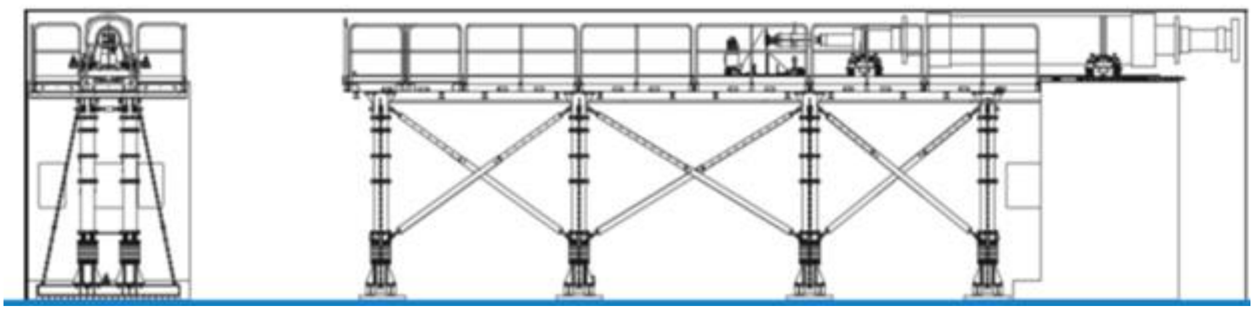

Fig 1. Shows the “Rotor Removal from Large Machines." diagram.

Appendix B

Writing Center Availability.

UT Tyler Writing Center: Appointment made successfully!

mohammed Waheed,

You have successfully made an appointment on Wednesday, April 21, 2021 between 9:00am and 10:00am. The appointment is with Autumn at UT Tyler Writing Center.

You can make, cancel, or modify appointments by logging into the scheduling system at uttyler.mywconline.com.

This e-mail was sent through the WCONLINE® scheduling and recordkeeping system. To opt out from receiving these types of messages in the future, log in to https://uttyler.mywconline.com

UT Tyler Writing Center

Welcome to WCONLINE 5! To get started, register for an account by clicking the link to the left.

uttyler.mywconline.com

and then select 'Update Profile & Email Options' from the welcome menu.

Appendix C

Work Hours of Participation

scaffolding 1									
	25-Feb	26-Feb	27-Feb	28-Feb	1-Mar	2-Mar	3-Mar	4-Mar	
Anishkumar Patel	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	
Mohammed Waheed	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	
David Rubio	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	
Luis Rosario	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	
Samuel Thompson	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	
scaffolding 2									
	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar	1-Apr	
Anishkumar Patel	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	
Mohammed Waheed	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	
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scaffolding 3									
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Samuel Thompson	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.
Final Draft									
	23-Apr	24-Apr	25-Apr						
Anishkumar Patel	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.						
Mohammed Waheed	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.						
David Rubio	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.						
Luis Rosario	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.						
Samuel Thom+B3:J36ps	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.	9:30 P.M.-10:30 P.M.						