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Design Optimization and Analysis of Remote Operated Rack in and Out Unit of Worm Gear

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Abstract: - Owing to safety regulations, electrical units like these must be kept 20 feet away. Additionally, because the electrical unit requires a constant power supply, a torque of more than 10 N-m is needed to withdraw the unit. The electrical unit that should be racked-out or racked-in into the panel should be easily removed or fitted with the rack-in/rack-out unit. The wheels of an LMV vehicle, such as a car or van, can likewise be changed using the same remote control unit. Many concepts have been developed to satisfy these demands. Units can be rotate in or out by turning a shaft in both CCW and CW directions. Use a torque of 10 N-M to rotate a shaft to rack in or rack out a unit. Rack-in/rack-out must be used remotely, at a distance of 20 feet. For every electrical unit, rack-in/rack-out must be completed in three seconds. The Worm-Worm gear unit looks to be the most distinct from the other concepts after applying SWOT analysis to investigate the aforementioned ideas. The Worm-Worm gear unit is primarily small in size, has a 1:20 gear ratio, multiplies 1 N-m torque to 10 N-m, and uses the same gear ratio to reduce high speed motor shaft to moderate speed.

Keywords: *Worm gear, Rack mechanism and LMV vehicle*

1. Introduction

Due to safety concerns in industries, many small and large scale businesses use rack in and rack out procedures for circuit breakers. However, doing so manually increases the risk of a short circuit, so in order to solve this issue, we are using worm gear for rack in and rack out, which allows us to operate from a distance of 20 feet. Two mounting studs on the secure connect unit door will be used to mount the remote racking unit. It is not recommended to do continuous CW/CCW operation more than twice. The torque required to operate the secure connect unit shaft is 100 Lbs-inch. Duty cycle: CW-CCW-CW. The secure connect unit shaft must be turned 90 degrees CW or CCW in three seconds. The remote operator shaft must align with the 2100 secure connect unit operating shaft in the same orientation. The shaft must rotate 90 degrees CW for connect and 90 degrees CCW for detach. The operational shaft will rotate in order to do this. Thus, the operational shaft should not be turned more than 90 degrees because doing so will harm the stab assembly. Therefore, a limit switch and stopper arrangement will be employed, and both the stopper and the limit arrangement's design must adhere to the criterion of preventing shaft over travel beyond 90 degrees. A step (flat surface) is necessary on the motor to assemble the coupler with set screw since the stepper motor shaft must be connected with the worm gear shaft via a coupler. Here, the red, green, and white cables are the ones that will mainly be used. To connect these cables to the 6 pin connector, they need to be crimped using a pin-type lug or terminal. The necessary cable length is 18 inches, the same as that of the power cable. The second are single-throated worm gears, in which the worm wheel is throated. "Design of mounting arrangement should have F.O.S 1.5 to keep design is safe and should be capable of handling axial load to avoid accidental release of the unit during operation". The last variety is worm gears with two throats, or double-throated gears. The maximum loading can be supported by this kind of gearing. An engulfing (hourglass) worm grows in diameter from its central region toward both ends and possesses one or more teeth. Worms that are totally enveloping and paired with enveloping worm gears make up double-enveloping worm gearing. Another name for it is globoid worm gearing. When the teeth of a left hand helical gear or left hand worm retract from the perspective of an observer gazing along the axis, they spin counterclockwise.

Energy Losses in Worm Gears

Energy losses from friction: The efficiency for worm gear is calculated similarly to the screw mechanism, when the worm is driving element. $\frac{\text{Tan}\gamma(1-f\text{Tan}\gamma)}{f+\text{Tan}\gamma}$

Worm Gear Design Parameters

A typical single reduction range for worm gears is 5:1 to 75-1. The ideal pitch line speed is up to 30 meters per second. Worm gear efficiency varies from 20% at the highest ratios to 98% at the lowest ratios. Worm boxes are made to disperse heat to the surrounding area because to the high frictional heat generation and lubrication is a necessary component. Worm gears are silent when they work. Higher ratio worm gears are by nature self-locking; while the worm can drive the gear, the gear cannot drive the worm. Worm gears can reduce speed by 50:1, but they cannot raise speed by 1:50. In practical terms, worms shouldn't be utilized as braking devices for safety-related systems, such as hoists. Worm gear backsliding can occur under certain material and operating conditions. The worm gear action is a slide action that causes large frictional losses. A ground-finished, case-hardened alloy steel worm and a phosphor bronze gear provide the perfect gear combination. For gears with relatively light loads, alternative combinations are employed.

A worm gear drive consists of two elements; driving element → Screw and Driven element → helical gear. The number of teeth on the worm gear and the number of starts on the worm define the velocity ratio. As the velocity ratio increases, the transmission of power diminishes. If a screw (worm) moves one groove in a linear direction in a single full revolution, it is said to have one start. If it advances two grooves (in a linear direction) in a single revolution, it is referred to as having two beginnings. In the animation above, the worm has four starts.

Problem Statement

Due to the years-long racking in and out of the circuit breaker, numerous workers have perished and had injuries from shock circuits that happened during racking. In addition, rebuilding it would have been an expensive endeavor. The problem of fire mishaps during racking in and out is resolved by this operated rack in and out development and structural analysis of the mast, which benefits the person in charge of the operation. The operation setup is highly portable, manageable, and simple to assemble.

2. Literature Review

The computation methods and mitigation technologies used to quantify and control arc flash hazards in industrial power systems. A review of analysis techniques compares algorithms used currently to determine incident energy. A presentation of cur- rent mitigation technologies identifies their advantages and disadvantages in the control of incident energy [1, 2, 3]. By incorporating reliability considerations in the system design and in the planning of system expansion, operation and maintenance the quality of supply can be improved. To obtain useful results from system reliability assessments, reasonable values of component reliability parameters need to be used. However, the required accuracy of the reliability data depends on the purpose of the assessment [4,5]. Arc flash mitigation uses modified electrical equipment, protective device set- tings, and work rules to restrict worker exposure to high energy levels. These modifications reduce the required level of PPE. The goal of arc flash analysis and mitigation is to provide a safe work environment while operating and maintaining industrial electrical systems with minimal disruption [6, 7, 8]. To analyse back to the fewest number or, preferably, to one center of gravity, Clausewitz outlined two aspects important when attempting to isolate a single center of gravity. The first was to examine the distribution of political power [9]. Rack & pinion steering systems can be located either on the bottom side of the frame, on the topside of the rear A-frame between the transmission and firewall, or on the topside front of the frame. When removing the rack & pinion, the wheels should always are facing straight ahead and the steering wheel held in place [10, 11,12]. To gauge the opportunities and barriers to optical interconnect adoption in emerging markets through an analysis of first phase interviews with professionals working in the datacom, automobile, consumer hand-held device industries, primarily concerned with investigating further the influence that power and performance concerns have on optical interconnect adoption in HPC data centres. a set of policy recommendations based on the results from the data centre cost model [13, 14, 15, 16]. The 90 volt motors are performance matched for continuous service over a 60:1 speed range. All have constant torque throughout the speed range when powered by a full-wave, unfiltered SCR-type 115 volt input adjustable speed control having a typical form factor of 1.3 to 1.4. The low voltage motors are also performance matched for continuous duty. Motors are designed for battery power or can be used with a low voltage controller with form factor up to 1.05 [17, 18, 19]. Distribution system component failure rates and repair times, based on operational experience that can be useful in distribution system reliability studies [20, 21]. In radial systems, fault current magnitudes diminish as the fault location moves further from the source. System designers achieve protection coordination by selecting devices that have time-current characteristics that intentionally introduce delay in device operation, the fault current decay in a radial system as a function of distance from a source [22, 23]. Selecting higher PPE categories that over-protect dress these hazards and give guidelines for computing incident energy, selecting personal protective equipment, and labeling equipment to alert workers of arc flash dangers [24, 25].

3. Methodology

Material Selection

Selection of materials depends on any considerations, which can in general be categorized as cost and performance. The material properties used throughout the study, these properties for Bronze and ASTM Steel.

a) Material Properties (Bronze)

- Young’s Modulus= 96-120 Gpa
- Poisson’s Ratio= 0.34

b) Material Properties (ASTM Steel)

- Young’s Modulus= 200 Gpa
- Poisson’s Ratio= 0.30

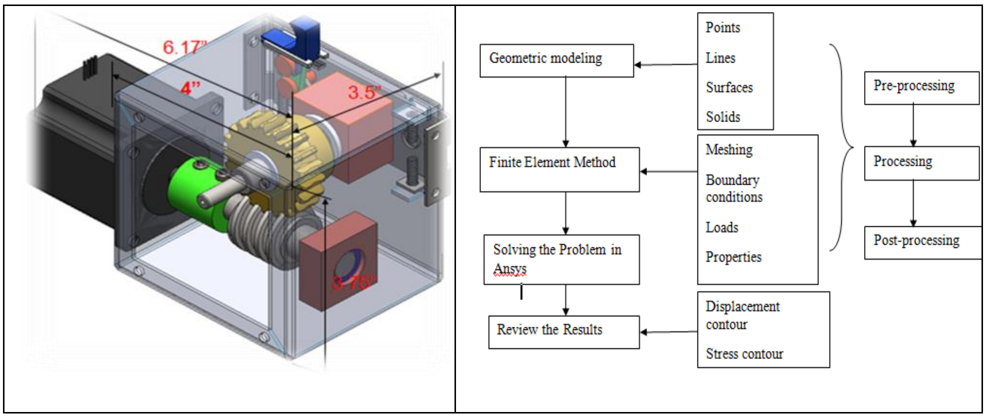

Figure 1: Worm-Worm Gear Proposed concepts with Methodology of study

Modeling with parameter

The worm and worm gear was solved by using analysis software each and every has to be individually drawn and to be assembled and standard gear dimensions should be taken and to be assembled. As all the details required for solving this problem are not available appropriate assumptions are made wherever required to simplify the problem. To simplify the problem the assumptions are made.

Table 1: Parameter of conceptual design model

Parameter	Worm-worm gear concept	Push-pull concept	Rack-pinion actuator concept	Ratchet pawl concept
Weight	3kg	3.5kg	5kg	4.3kg
Speed	5 Rps	2 Rps	3 Rps	3Rps
Cost	12,500	10000	16,000	12,000
Mounting method	adjustable	fixed	fixed	fixed

Selection of Gear Set

The worm and worm gear was solved by using analysis software each and every has to be individually drawn and to be assembled and standard gear dimensions

Table 2: Standard parameter of Gear Set

a. Shaft has to be rotated 90° (cw/ccw)	g. The worm & worm gear reduction ratio is 20:1
b. Timing: 3 Sec, hence the speed is 5rpm	h. Therefore, the speed of worm is (15 X 20) = 300rpm.
c. O/P Torque = 100 in-lbf	i. Torque required is (150/20) = 7.5 in-lbfor 120 in-oz.
d. Including safety factor, shaft speed 15rpm.	j. Max. Co-efficient of friction= 0.05
e. Including safety factor, Torque 150 in-lbf	k. Worm lead angle= 4°46”
f. The speed of worm gear will be 15 rpm.	l. η= 60% (For safety we take 50%)

If the motor provides a min. of 7.5 in-lbf torques, then with the current worm and worm wheel drive, the output torque will be 150 in-lbf.

If the motor provides a min. of 7.5in-lbftorque, if we required 100 in-lbf as output, with the current worm and worm wheel drive, the output torque will be 150 in-lbf. Suppose if we need 100 in-lbf as output. we will get 7.5 in-lbf torque from stepper motor shaft so the selected gear is 1:20 then 7.5 in-lbf is converted as150 in-lbf and gear losses is considered and gear loss is 0.75% den 150*0.75 and we will get 112.5 in-lbf torque so required torque is 100 in –lbf torque

Table 3: Torsional and Bending stress on the Worn Shaft and Gear Shaft

TORSIONAL STRESS ON THE WORM SHAFT				FORMULA	TORSIONAL STRESS ON THE WORM GEAR SHAFT			
DIAMETER OF WORM SHAFT	d_w	0.475	in	$I_p = \pi d^4/32$	AVERAGE DIAMETER OF WORM GEAR SHAFT	d_{avg}	0.385	in
RADIUS OF WORM SHAFT	r_w	0.237	in	$\tau = (T*r)/I_p$	RADIUS OF WORM GEAR SHAFT	r_g	0.1923	in
POLAR MOMENT OF INERTIA	I_p	0.005	In^4		POLAR MOMENT OF INERTIA	I_p	0.002	In^4
SHEAR STRESS IN THE SHAFT	τ_w	832	psi		OUTPUT TORQUE	T_O	100	In lbs
					SHEAR STRESS IN THE SHAFT	τ_g	8929	psi

BENDING STRESS ON THE WORM SHAFT				FORMULA	BENDING STRESS ON THE WORM GEAR SHAFT			
DIAMETER OF WORM SHAFT(MIN)	d_w	0.475	in	$I = \pi d^4/64$	DIAMETER OF WORM GEAR SHAFT	d_g	0.5	in
RADIUS OF WORM SHAFT	r_w	0.237	in	$\sigma = (M*r)/I$	RADIUS OF WORM GEAR SHAFT	r_g	0.25	in
MOMENT OF INERTIA	I	0.002	In^4		POLAR MOMENT OF INERTIA	I	0.003 068	In^4
MAX BENDING MOMENT	M	44.54	In lbs		MAX BENDING MOMENT	M	207.49	In lbs
BENDING STRESS IN THE SHAFT	σ_w	4,234	psi		BENDING STRESS IN THE SHAFT	σ_g	16,908	psi

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Analysis

The finite element method is a numerical technique for solving engineering problems. It is most powerful analysis tool used to solve simple to complicated problems. The pre-processing stage involves the preparation of nodal co-ordinates & its connectivity, meshing the model, load & boundary conditions and material information for finite element models carried in ANSYS.

The purpose of the discretization is twofold. The first is to capture the underlying geometry of the component accurately. The second is to capture the deformations and the underlying strain distributions. Features like fillets, notches and keyways need a higher level of discretization. This is because the strain distributions in these features have very high strain and deformation gradients. The above two tasks are accomplished by using nodes and elements.

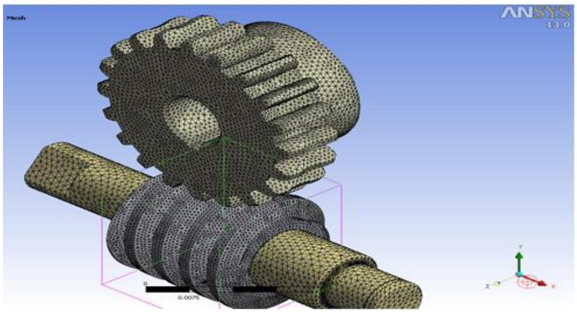

Figure 2: Meshing of a Gear

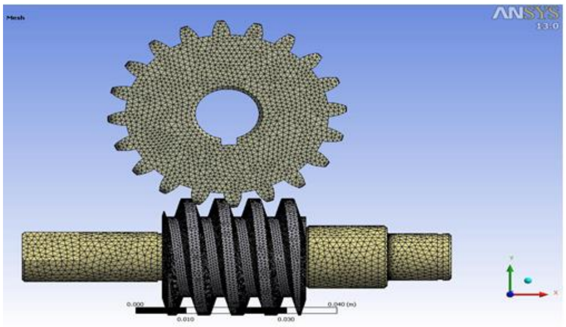

Figure 3: Load distribution

We want to apply upward force on the gear. To initialize a pressure load, in the Environment menu bar select lines Force. Therefore, the total pressure load applied from the bottom of the surface of gear. When the surfaces have been selected, press Geometry Apply in the Details window. Next, select Define By Components. Define the Y Component as load. We are now ready to set up the solution and solve.

4. Results and Discussion

Number of Divisions; change the Number of Divisions to 40. Also, create another Edge Sizing, and this time, select the 2 edges at the very front and very back of the gear,

Stress Analysis

In the solution sub menu, select Stress > Equivalent (von-misses). In the details pane, ensure Geometry is set to All Bodies. We are ready to solve the simulation.

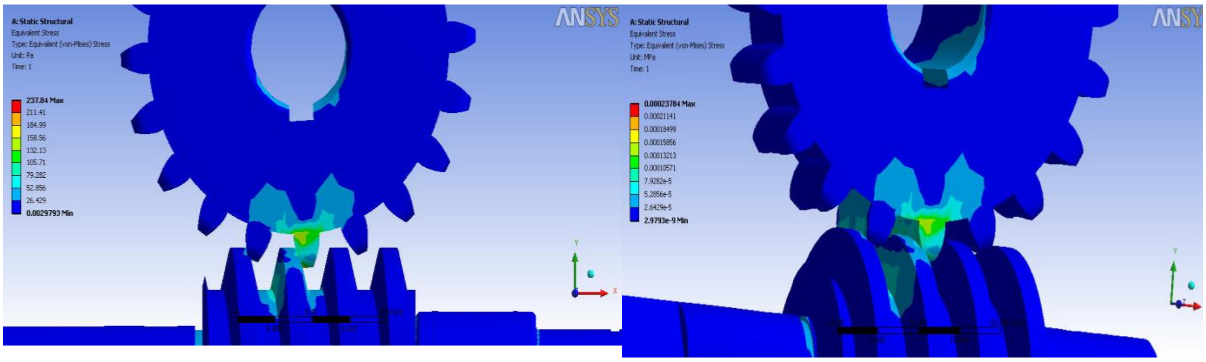

Figure 3: Equivalent stress of worm gear

Press solves. Here we can see the maximum and minimum equivalent stress. The Equivalent stress that takes place when load is applied on worm gear was shown in fig. 3.4. The maximum load of 100 Pascal is applied and maximum Equivalent stress of gear was 237.84 pa.

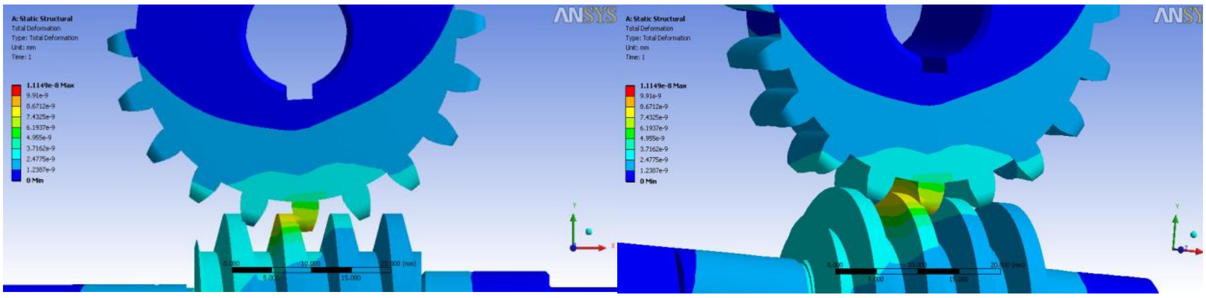

Figure 4: Deformation of Worm Gear

The deformation that takes place when load is applied on worm gear was shown in fig. 3.3. The maximum load of 100 Pascal is applied and maximum deformation of gear was 1.1149e-8 mm.

Conclusions

By the past many years due to this racking in and out of the circuit breaker many workers were dead and many were injured by the shock circuit occurred while racking and secondary its waste of money to rebuild it. By this operated rack in and out development and structural analysis of mast it helps to solve the problem of fire accidents during racking in and out so it help the person who is controlling the operation the operation setup is very portable and easy to handle and easy to construct. It plays a major role in safety purpose and the operated can operated from 20 feet distance so maximum there will not be any chance of occurring shock circuit else it happens the operated will be safe at the other end

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