A Review on Design and Optimization with Structural Behavior Analysis of Central Drum in Mine Hoist

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Abstract— This work gives optimised solution to make feasible hoisting application in heavy lifting and passing in coal and minerals mines. Rotary drum to be optimised with putting same diameter as required. Design is planned with casting stiffening links patterned circularly in round drum to form complete hollow drum, its replacing side disc of drum to make lightweight, loading condition is put by considering maximum loads. Drum behaviour is analysed in ansys tool in variations of degree of rotation from 0 to 360 degree. Finally conclusion will be opting to make optimisation feasible or not. We form few variants in design and compare results with each other. Finally the best drum design is found and from results it's found feasible in working also in manufacturability.

Keywords Introduction— Mine hoist, Central hub, Weldment structure, manufacturability and installation feasibility.

INTRODUCTION

Hoist by definition means to haul or to raise an object to higher altitudes. Hoists are mechanical or electromechanical devices used to move an object from one point to another, which would be otherwise physically challenging. The object can be raised, lowered or moved depending on the necessity. The hoist work on the basic principle of balance of forces where an equal and opposite force is applied on the load force. The applied force can be reduced by using a pulley system.

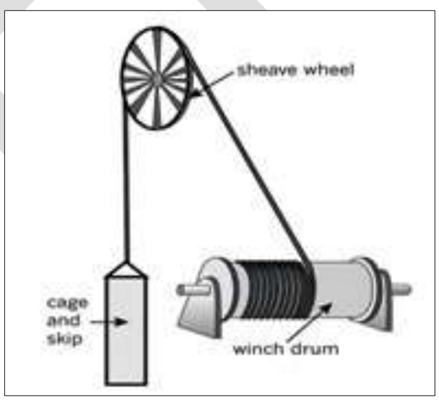


Fig.: - Mine Hoist

In underground mining a hoist or winder is used to raise and lower conveyances within the mine shaft. Modern hoists are normally powered using electric motors. Drum hoists are the most common type of hoist used. When using a drum hoist the hoisting cable is wound around the drum when the conveyance is lifted. Single-drum hoists can be used in smaller applications. Drum hoists are mounted on concrete within a hoist room, the hoisting ropes run from the drum, up to the top of the head frame, over a sheave wheel and down where they connect to the conveyance (cage or skip).

LITERATURE REVIEW

For this study, Observations are focused on existing system. The literature survey has been pioneered effort in this regard. Various machine design concepts and CAD/CAE concepts from literatures help to establish comparative study between existing and new experimentation. The terminologies referred from literatures for designing are discussed as follows:

WANG Jiu-feng, XU Gui-yun, ZHU Jia-zhou, YANG Yan-chu, in their paper named as, "*Parametric Design and Finite Element Analysis of Main Shaft of Hoister Based on Pro/E*", advanced parametric design method which realized in the process of modelling of main shaft of hoister was deal. Using the interface technology between Pro/E and ANSYS software, the simulation analysis of stress status of the main shaft of hoister designed in Pro/E under a certain load is made. The adoption of this method will dramatically shorten the development cycle and cut down the design costs. Otherwise the research method will reference value to gear model library development and to the optimization design of the main shaft of hoister [1].

LUO Jiman, XING Yan, LIU Dajiang and YUAN Ye, in their paper, "*Modal Analysis of Mast of Builder's Hoist Based on ANSYS*", For the purpose of researching the factors which affect the dynamic characteristic of mast of builder's hoist and analyzing the impact of different factors over system security, the authors of the paper applied the finite element method to build the model and made the modal analysis for mast which was installed with various installation distances or under different working conditions[2].

Yang Yuanfan, in the paper named as, "*The Study on Mechanical Reliability Design Method and Its Application*", Through the study on mechanical reliability design and combination with the structure of mine hoist, it is proposed that the crucial procedure of reliability design's application into mine hoist is as to ascertain the statistics of the relevant parameters, then to set up the failure mathematical model, and finally the reliability design can be operated [3].

J.J. Taljaard and J.D. Stephenson, in the paper named as, "*State-of-art shaft system as applied to Palaborwa underground mining project*", The design of a 30,000 ton per day underground mine at Phalaborwa presented many and various challenges to the owner and the design team. Using modern best and proven practice, innovative engineering, extensive test work and verification by worldwide experts these challenges were met head on and overcome. The state-of-the-art system will be in operation by the end of the year 2000 [4].

Shuang Chen and Shen Guo, in their paper named as, "*Stress Analysis of the Mine Hoist Spindle Based on ANSYS*", In this paper, the three dimensional modeling of 2JK mine hoist spindle was established by using Pro/ E according to given data. Then the model was inputted into the finite element analysis in ANSYS, the stress distribution of the spindle was obtained, strength check of the dangerous section was made at the same time, which provides an accurate and reliable theoretical basis for improving the spindle structural design [5].

HuYong and HuJiQuan, in their paper named as, "*Mechanical Analysis and Experimental Research of Parallel Grooved Drum Multi-layer Winding System*", in the present design criterion of multi-layer winding drum, multi-layer winding coefficient is chosen according to the number of wire rope layers. However, the actual wire rope arrangement on the drum and the elastic property of wire rope also play decisive roles in determining the multi-layer winding coefficient value. Analyzing the actual stress of the drum accurately is the precondition of ensuring the drums safety and reliability for meeting the lightweight design requirements [6].

PROBLEM IDENTIFICATIONS: -

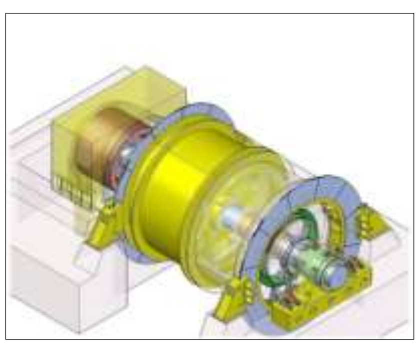
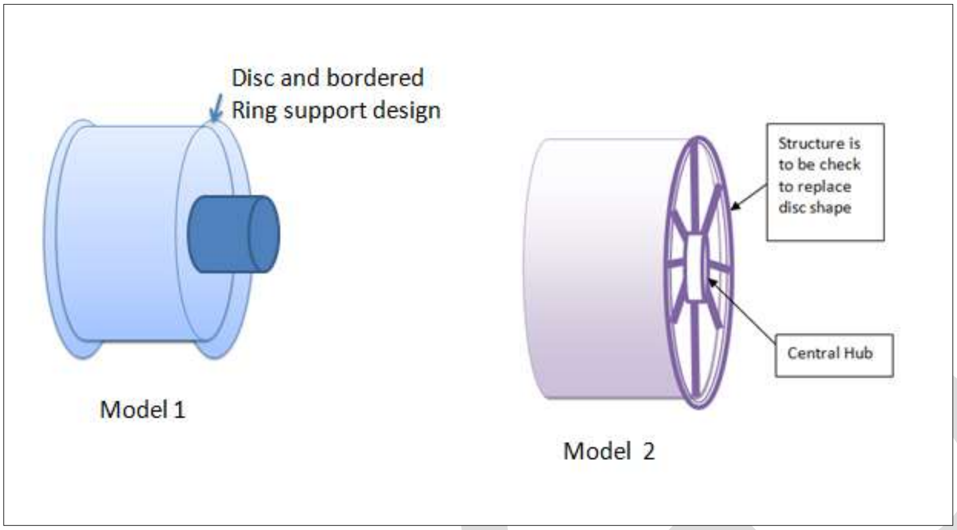


Fig.:- Closed Disc drum

1. Heavy drum difficult for commissioning and manufacturing in single body. Central hub is too heavy for making drive hold to rotate full body with loads.
2. Optimisation can be formed in drum structure to make it little lightweight without affecting its strength.

METHODOLOGY

Comparison in two models: -



Model 1: - Closed Disc Drum Model 2: - Proposed Conceptual Model

INPUT: -

- Boundary conditions: Max. RPM 20
- Maximum Torque: 700 N-m
- Material: Cast iron / Carbon steel
- Technology of development: Weldment structure, Welding treatment, Sheet metal components.
- Optimized meshed drum body to be developed outer Dia. 1300 mm & Width =600 mm.

PARAMETERS FOR DESIGN CALCULATIONS

The shear stresses are induced in the shaft due to transmission of torque i.e. due to torsion loading. According to American Society of Mechanical Engineers (ASME) code for the design of transmission shaft the maximum permissible shear stress (τ) may be taken as 30% of the elastic limit (σ_{el}) in tension but not more than not more than 18% of ultimate tensile strength (σ_{ut})[7]. In other words,

$\tau = 0.3\ \sigma_{el}$ or $0.18\ \sigma_{ut}$

The shaft is subjected to twisting moment or torsion only, and then the diameter of the shaft may be obtained by using torsion equation.

$\frac{T}{j} = \frac{\tau}{R}$ .... (i)A

Where, T = torque acting on the shaft

j = polar moment of inertia

τ = torsion shear stress

R = Distance from neutral axis to outermost fibre

= D/2.... Where D is diameter of the shaft

We know that, for solid circular shaft, polar moment inertia (j) is given by,

$$j = \frac{\pi}{32} D^4$$

For rotating shafts, gradually applied or steady load, combined shock factor (K_t) and fatigue factor (K_m) are taken as 1[8].

Also from torsion rigidity equation we have,

$\theta = \frac{584TL}{GD^4}$ .... (ii)

Where, θ = angle of twist in degree

T = Torque, Nmm

L = length of shaft, mm

G = Modulus of rigidity, N/mm^2

D = Diameter of shaft, mm

*Let the angle of twist for the shaft 1degree i.e. $\theta = 1^0$

ROPE SPECIFICATION

Rope construction: 6 x 26 RRL (right regular lay) rope

Safety factor of rope = (Minimum breaking load) / Load applied

DRUM CALCULATIONS

1. **Diameter of drum**

   D_{drum} = (ratio between 20 to 25) x d_{rope}

2. **Groove radius,**

   r = 0.53 x d

3. **Groove diameter,**

   d = groove radius x 2

4. **Pitch diameter,**

   p = 2.065 x groove radius

5. **Groove depth**

   h = 0.374 x d

6. **Thickness**

   tx = P/kp

7. **Drum grooved length,L3**

   L3 = (n - 1)*P

8. **Drum un-grooved length,L1=L2**

   L1 = L2 = 1/2 diameter of hook + radius of rope

9. Factor of safety = 6

CAD Model

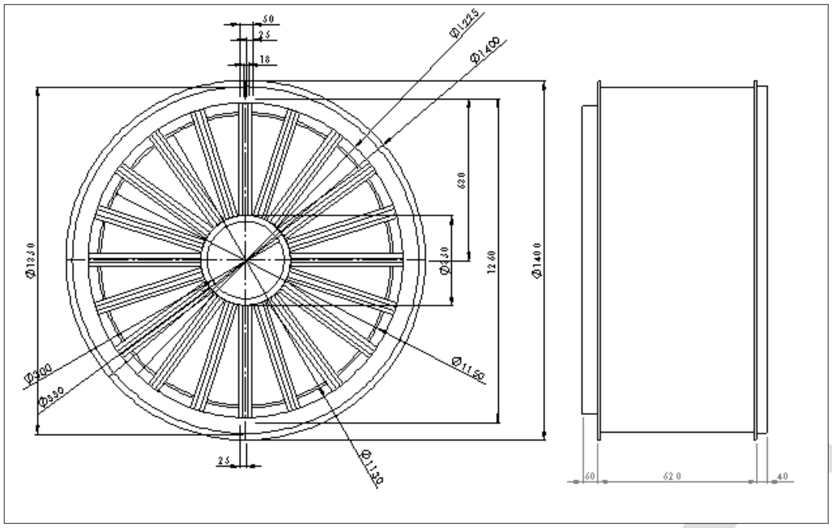


Fig.: - CAD Drawing

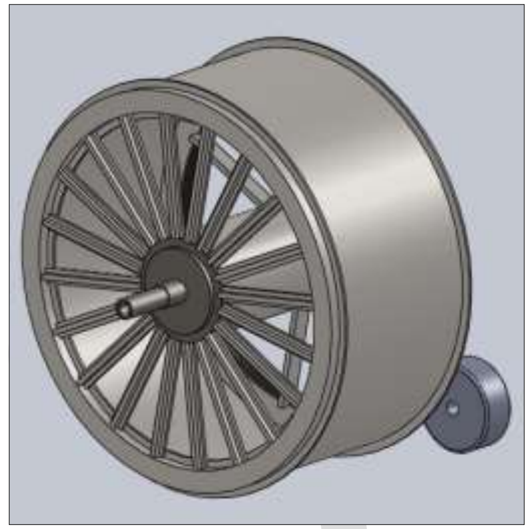


Fig.: - Axle Assembly

CAD Model is created by using Creo Parametric 2.0[9], [10] on which we can perform engineering analysis like finite element analysis. Finite Element Analysis of structural behavior can be done by using Ansys by applying various boundary conditions. Meshing is done by using 20 noded Solid95 elements [11], [12].

VALIDATION STAGES

- Mathematical calculations with structural behavior loads
- Optimization with material weight and feasible manufacturability.
- Validation with comparing different variants results.
- Solution and selection of best design amongst all variants and their respective results

CONCLUSION

This paper reviews the studies of Design and Optimization with Structural Behavior Analysis of Central Drum in Mine Hoist. The review finds that, the central drum in mine hoist is large and too heavy for commissioning and manufacturing in single body and for making drive hold to rotate full body with loads. The design and optimization with structural behavior analysis can give the new design which can reduce the weight of central drum. Design is planned with casting stiffening links patterned circularly in round drum to form complete hollow drum its replacing side disc of drum, which can make the system little light in weight without affecting its strength. Because of the reducing the weight of central drum, we can make it feasible to manufacture and installation.

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