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Design, Testing and Manufacturing of Decoiler Unit of a Semi-Automated Spooling Machine

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***ABSTRACT*:** *In a boiler cleaning equipment manufacturing unit, the need to spool the wire is quite essential. Ever since the development of wire rope, comprising multiple wire strands, spooling has presented technical challenges. In this paper, a small-scale automated wire spooling machine was designed, tested and fabricated. The machine will replace the current manual machine. The designed machine integrates mechanical, electrical and electronic components so as to automate it as much as possible. Space requirement of the semi-automatic spooling machine is considerably less too, hence improving the machine aesthetics. The spooling patterns are achieved by controlling separately the gear ratio of the reciprocator and speed of the decoiler assembly unit.*

Keywords - *Decoiler unit , Semi-automatic, Slip/Safety clutch, Solenoid operated brake, Spring steel wire.*

I. INTRODUCTION

The need for a semi-automatic spooling machine arises due to the high inefficiency of the current machine used. The accessories those are required for the cleaning of scales in boilers are made from processing of wires into different shapes. To convert a wire, wound and entangled, into a uniformly spaced and evenly distributed spool, alike, is difficult, indeed impossible using the presently operated machine. When wrapped in multiple layers, the upper layers have a tendency to crush the lower layers, while the lower layers have a tendency to pinch upper layers [1]. These problems were addressed by Frank L. LeBus Sr., a supplier of drilling equipment to the oilfields of Texas, USA, who in 1937, patented the use of a groove bar on hoisting drums to guide the spooling of rope. The rubbing of wire against wire also has a tendency to cause wear. The spooling of wire around the spools is currently done manually and thus makes it difficult to obtain a uniform pitch. The other problems faced by the presently operated machine are the size, wastage of manpower and also the risk of frequent breakage of the wire. The tremendous wastage of wire on account of breakage and in most cases unequally turned wire on the respective spool of the wire-rope machine makes reforms needed. The process of spooling is done initially by unwind the wire and to spool it with a uniform pitch and which requires manual operation. More than one number of persons are needed at the time of spooling and the reciprocating and braking have to be done manually. This causes wastage of man power. Also the numbers of turns obtained on the spool are not of the same value for two different spools. The reciprocating of the carriage is done manually and this causes irregular pitch, which may further lead to non-uniform spools. When the number of turns on the spool is not uniform, in further processes, more wastage of spooled wire takes place. Sometimes during the start of the spooling operation, jerks are induced in the decoiler, which in some cases induces stresses in the unspooled wire. If the stresses induced exceed the elastic limit [2], may be critical for further continuation. The present system does not accommodate for jerks and works on a rigidly fixed solid rod in the ground and also gives the wire tension so as to spool it well. Pilot studies were carried out, from which it was concluded that, using this technique the tension in the wire varies.

This paper is about the design, testing and fabrication of a decoiler unit of a semi-automatic spooling machine, which will enable the spooling of wires on the spool to give uniform pitch and accurate number of turns with least amount of supervision. Neal Rothwell gives more information about the technical methods of spooling [3]. The multilayer wire rope spooling system has undergone continuous refinement over the years and adapted for any application where long lengths of steel wire ropes [1] must be wrapped in multiple layers quickly and smoothly. The designed semi-automated spring steel wire spooling machine is an integration of mechanical, electrical, and electronics components. The spools are then used in a wire-rope making machine with the help of twelve to sixteen spools, four on each arrangement (disc) and then heated to allow fusion of wires. The semi-automatic spooling machine accommodates for jerks or over tensing by using a slip clutch. The machine consists of a decoiler unit, spooler unit, slip clutch, solenoid operated brake, springs and pulley arrangements and a reciprocating unit. To maximize the benefits of the Lebus grooving system, certain operating conditions are required.

II. SETUP OF THE DECOILER UNIT IN A SEMI-AUTOMATED SPOOLING MACHINE

Fig.1 Decoiler Unit during spooling

The decoiler unit is a critical module, that consists of disc or plate (designed for impact load of 1.5 times the wire bundle weight) on which the wire bundle is mounted- which is welded on the shaft and provides seating for the wire coil to be spooled as shown in Fig.1. The plate consists of slots to fit solid rods that are bolted and can be adjusted by nuts provided. This helps in keeping different diameters of coil in position and avoids play during decoiling. The rotation of the decoiler plate is caused by the pulling action of the motor-driven spooler shaft. As the decoiler plate rotates, the wire is unwound from one end. While loading there is a possibility that the entire load or weight of the wire is acted upon at one particular point. For that reason eight webs are provided on the bottom face. This helps the plate from withstanding cantilever type impact loading [4], tensional device[5]- which contains a band brake for increasing resistance to the pull, a single housing fitted with two bearing on either side and sealed with caps in the form of thin plates, all these put on a shaft made from carbon steel[6] and designed to sustain the loads(both torsional and compressive)[7]. Wire holder is used to hold the wire in place during pulling action.The double pulley with a groove setup generates rotary-to-linear motion [8] after the spooler unit is rotated by the motor. The wire is made to pass through a reciprocating unit mounted in between the two other units. The two pulley arrangement avoids wire from breaking by reducing the friction to a great extent.

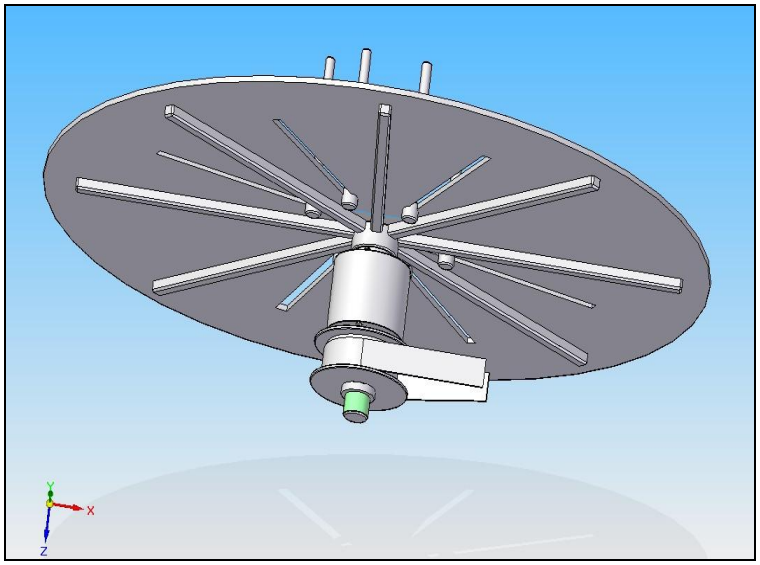

Fig. 2 Decoiler section assembly.

This decoiler unit is designed for the purpose of sustaining the load of the coiled wire bundle without deformation and rotates freely with the tension applied at the other end of the wire i.e. the spooled wire. In view of the above discussed purpose the shaft was designed with plain carbon steel [6]. This is held in place with two bearing, one being a taper roller bearing and the second a deep groove ball bearing at sufficient distance from each other [9]. The entire load (axial force) of the top assembly is taken by the inner race of the taper roller bearing. The plate attached is to accommodate the large wire diameter which is of thickness 8mm and diameter being 1100mm [10]. The solid rods move alone the slots shown in Fig. 2 and Fig.3. The wire to be spooled has high tensile strength [6] and is of grade 2 material. This allows it to withstand large amount of tensions at both the ends of the machine. The basis composition being [6]:

C - 0.70%-1.00%; Mn- 0.60%-0.80%; P- 0.035%; S- 0.040%.

Tests were carried out and results showed that the wire can sustain loads up to 4000N for a 1.8mm wire.

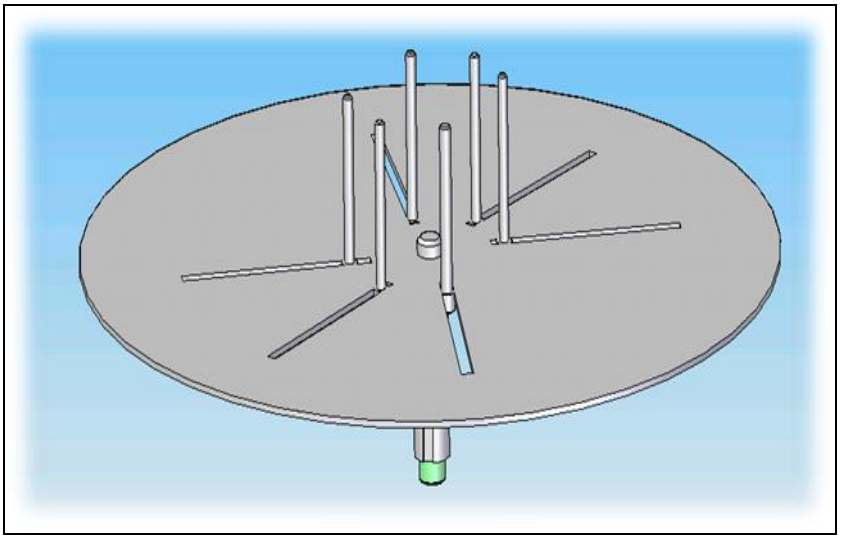

Fig.3 Decoiler shaft, plate and solid rods

III. VALIDATION

The ANSYS validation was done on the two critical components of the Decoiler unit i.e. Shaft and Decoiler plate. Maximum principal stress and total deformation was calculated to verify with the original values calculated and hence validate the design.

1. Shaft Analysis

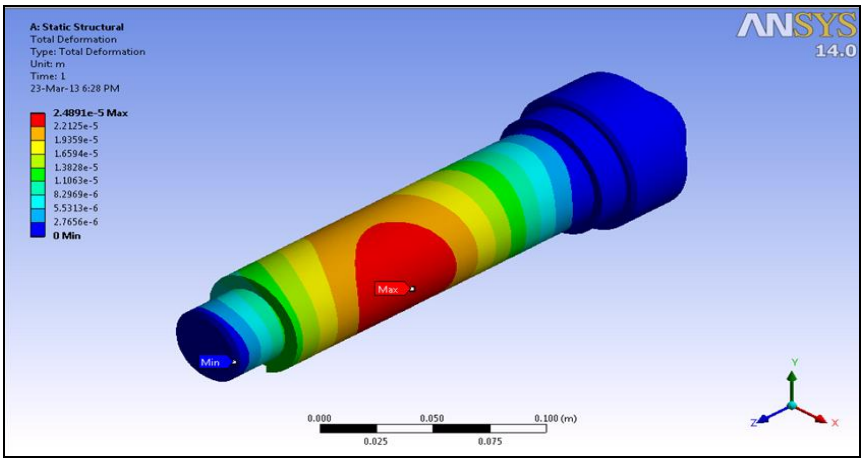

Fig. 4 Total deformation analysis of the shaft

Axial and Compressive force of 3000 N is subjected on the top of the shaft due to the weight of the Decoiler plate and coil placed on it. There is a constraint at the first step of the shaft which is in contact with the taper roller bearing. There are two moments; one is the braking which is applied on the lower half of the shaft and opposite pulling torque which is transferred from the plate to the top face of the shaft which are welded together. The Fig. 4 shows the result of the total deformation which will be induced in the shaft due to the above mentioned forces in the maximum possible stress condition. The maximum deflection of the shaft is 0.025 mm.

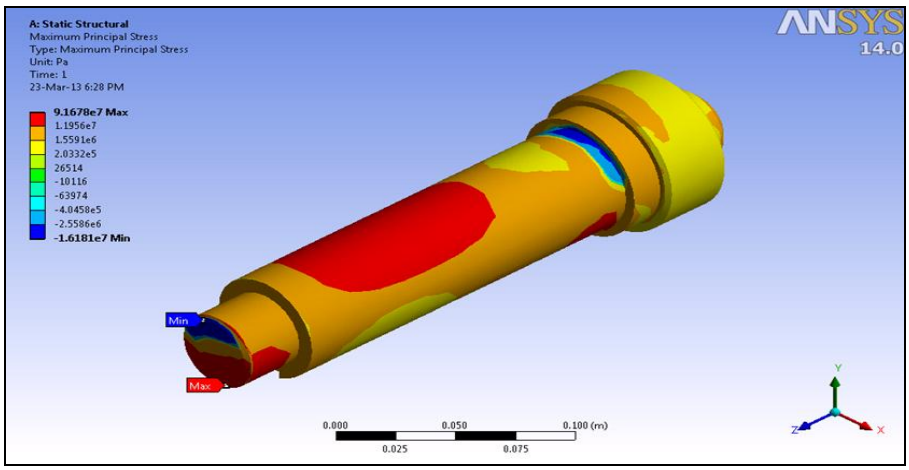

Fig. 5 Stress analysis of the shaft

The Fig. 4 shows the result of the maximum principal stress which will be induced in the shaft due to the above mentioned forces in the maximum possible stress condition. Maximum principal stress on the shaft is 91.68 N/mm^2.

2. Decoiler Plate Analysis

Validation on the decoiler plate was done for the impact loading. Force of 3000 N (actual force being 1800 N) is subjected at a point 10-15 % from the outer diameter.

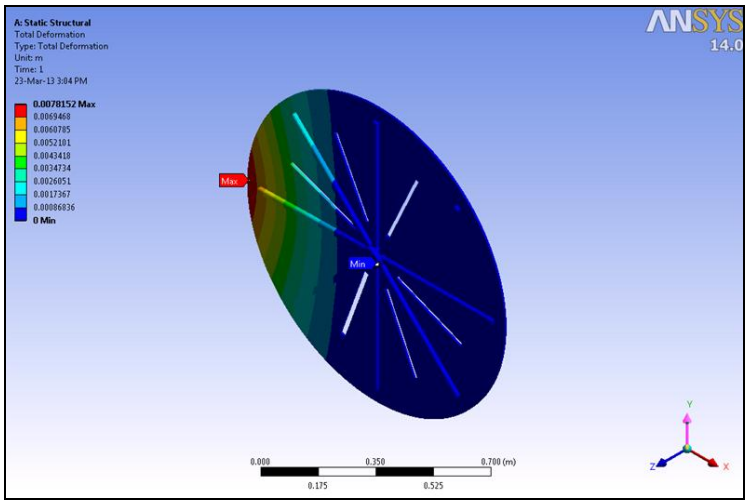

Fig. 6 Total deformation analysis of the plate

Fig.6 shows the total deformation which will be induced on the decoiler plate due to the above mentioned force in the maximum stress condition. Maximum deflection is 0.7mm. The Fig. 7 shows maximum principal stress which will be induced on the decoiler plate due to the above mentioned force in the maximum stress condition. Maximum principal stress is 144 N/mm^2.

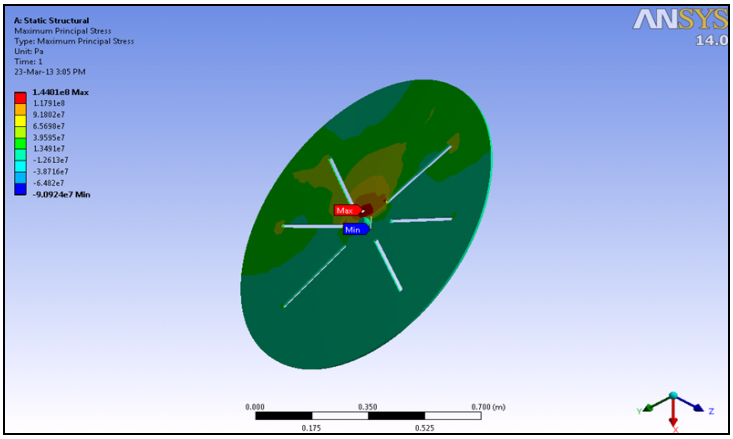

Fig. 7 Stress analysis of the plate

IV. CONCLUSION

The semi-automatic spooling machine helps in reducing the man power required. Initially reciprocating action was done manually, the semi-automatic spooling machine uses an automatic reciprocating unit due to which, the pitch on the spool is uniform and can be adjusted as per speed of reciprocator shaft. There is high tension in the wire, but due to the presence of a slip clutch, wire breakage is prevented. Work space which was 3.9 m^2 has been reduced to 2.8 m^2 hence making the complete system much more compact and saving floor area.The number of turns required on 1 spool is 6000. The speed at which the spooling takes place cannot be increased further as this would cause wire breakage incase the speed of pull is increased. Hence the one limitation it has is that the time required for one spool remains equal to the manual spooling machine. The present decoiler shaft has a small diameter of 30mm and a thin plate of 2-3mm. Thus, the deformation in the plate is high which causes wobbling and has the eccentric effect in induced.

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