Design, modification and analysis of 3 ton electrical overhead travelling crane rope drum

Dheeraj Thuniki1, Ravikiran MSSR1, Jayakiran Reddy Esanakula1* and Venkateswara Rao B2

1 Department of Mechanical Engineering, Sreenidhi Institute of Science and Technology, Hyderabad, India.
2 CMS of ES&F Department, Rashtriya Ispat Nigam Ltd, Visakhapatnam, India.

*ejkiran@gmail.com

Abstract. With the intention to enhance the electrical overhead travelling crane drum, the shaft in the drum was modified using reverse engineering technique. The stresses on drum were analysed using finite element method and the results are compared. The research provides a new idea for improving the stability and life of the drum. The proposed shaft is provided with the gear hub and gear sleeve in the place of traditional spline shaft to improve the life and efficiency.

1. Introduction
Cranes be allied to material handling equipment family which have wide applications in different fields of engineering. Cranes are industrial machines that are mainly used for moving of material in industrial environment, ware houses, storage areas, stock yards etc. Electrical overhead travelling (EOT) crane are used in the most of the industrial areas. These cranes are electrically operated by control pendant, remote pendant or from an operator cabin which is attached with the crane itself. It mainly works with the principle of hoist mechanism. Hoist is a device used for lifting or lowering a load by means of drum. It mainly consists of Motor, Electro-Magnetic Brake / Thruster brake, Gear box, Drum, Rope.

2. Literature review
EOT is commonly used overhead crane which consists of parallel runways. In order to enhance the EOT crane performance, various researchers have debated and research on different failures of EOT crane. One of them is Qiyu Li [1] who analysed the stability of crane lifting drum and conclude that theirs is an accurate approach as it is close to the actual stresses and it could be used while designing the crane drum. Similarly, Jun Shu [2] carried out buckling analysis on crane drum using Ansys software and proposed an approach to carry out the analysis using the software. Sarang Mangalekar [3] proposed the new design for reducing the weight of the crane drum by replacing the side disc with arm type structure. In the process of examining the dynamics of the crane's overhead, Marijonas [4] analyses the overhead of the crane while it is under operation and were able to obtain the real dynamics and their behaviour are attained. Similarly, various researchers' tried to develop an automatic design system to obtain the better design. Among them, the design improvement of various mechanical components like Universal Coupling [5], Spur Gear [6, 7], Industrial battery Stack [8], IC Engine Connecting Rod [9, 10], different nuts, bolts and bearings [11, 12], were presented. In the
same way, the generic process of improving the existing design is presented in various research papers [13-17]. Along these lines, many researches tried to improve the existing components of the crane drum but, as per the industry norms, the cost for the same is very high. Hence, in this paper, the authors tried to modify the existing crane drum components as it leads to less in cost as well. One of the primary causes for the breakdown of crane is the failure of the shaft or its interconnected components. But, on observation, it was found that failure of the shaft is the main reason for the breakdown. Hence, this paper concentrated on enhancing the existing 3 ton EOT crane drum shaft. In this paper, author modified the design of shaft which connects the rope drum and the gear box without affecting the internal and external diameter of drum and gear box.

Fig. 1 shows the existing spline shaft in an EOT crane in a steel manufacturing plant and its dimensions are shown in fig. 2. Fig. 3 shows the detailed dimensions of the break drum. But, with the existing design the problem is that it is getting failed when it is fully loaded ie. 3 ton. Hence, there is a need in the industry to do the modifications for the existing shaft.

![Figure 1: Existing spline shaft](image1)

![Figure 2: Detail drawing of existing spline shaft](image2)

![Figure 3: Detail drawing of existing Rope drum with units in mm.](image3)

In the process of changing the design, authors considered following three cases

Case 1: The spline shaft design is modified by replacing the spline with key way.
Case 2: The spline shaft design is modified by replacing the spline with modified spline.
Case 3: Considering all the above cases and shaft design is modified by providing internal and external gears to the shaft and rope drum.

3. Design and modelling:
In this section, the design and modelling of the modified shaft is presented as per the considered cases.

3.1. Case 1:
By considering the working condition of the shaft in the crane, the spline shaft is replaced with key way which is shown in fig. 4. This replacement was carried out by considering the industry requirements along with the available resources in the industry. The shaft dimensions are modified from ø 42mm to ø 45mm. Similarly, the length of shaft is modified from 60 mm to 93 mm keeping the
material same. Fig. 5 shows the detailed dimensions of shaft with keyway. Fig. 6 and fig. 7 shows the
details about the key. The remaining parts of the assembly like Hub and sleeve are shown in the fig. 8
to fig. 11. The assembled rope drum with the modifications is shown in fig. 12. Its cross section and its
details are shown in fig. 13 and fig. 14 respectively.
In the figure 14, part 1 is drum, part 2 is sleeve, part 3 is hub, part 4 is plate, part 5 is rear hub, part 6 is plate, part 7 is rib and part 8 is shaft.

3.2. Case2:
In this case, the spline shaft is replaced with modified spline. The shaft dimensions are modified from ø 42mm to ø 45mm. Similarly, the length of shaft is modified from 60 mm to 93 mm keeping the material same. Fig. 15 shows the modified spline shaft and its dimensional details are shown in fig. 16. This spline shaft is fit into hub which is connected to rope drum. The hub is shown in the fig. 17 and its dimensional details are given in the fig. 18. The assembled rope drum with the modifications as per case 2 is shown in fig. 19. Its cross section and its details are shown in fig. 20 and fig. 21 respectively.
In the figure 21, part 1 is drum, part 2 is hub, part 3 is plate, part 4 is rear hub, part 5 is plate, part 6 is rib and part 7 is shaft.

3.3. Case3:
In this case, the spline shaft is replaced with providing internal and external gears to the shaft and rope drum. The shaft dimensions are modified from ø 42mm to ø 45mm. Similarly the length of shaft is modified from 60 mm to 93 mm keeping the material same. Fig. 22 shows the modified spline shaft and its dimensional details are shown in fig. 23. This spline shaft is fit with the gear hub and sleeve with the help of the key. The fig. 24 and fig. 25 shows the gear hub and its dimensional details respectively. Similarly fig. 26 and fig. 27 shows the gear sleeve and its dimensional details respectively. The details about gear hub and gear sleeve are given in the table 1. The assembled rope drum with the modifications as per case 3 is shown in fig. 28. Its cross section and its details are shown in fig. 29 and fig. 30 respectively.
**Table 1.** Details of gear hub and gear sleeve.

| Description                  | Data  |
|------------------------------|-------|
| Type of gear                 | Hub   |
| Module                       | Spur  |
| No. of teeth                 | 3     |
| Pressure angle               | 48    |
| Reference circle diameter    | 144   |
| Tip circle diameter          | 150   |
| Root circle diameter         | 136.5 |
| Clearance                    | 0.75  |
| Sleeve                       |       |
| Module                       | 3     |
| No. of teeth                 | 48    |
| Pressure angle               | 20    |
| Reference circle diameter    | 144   |
| Tip circle diameter          | 137   |
| Root circle diameter         | 150   |
| Clearance                    | 0.75  |

**Figure 22:** modified spline shaft.

**Figure 23:** Detail drawing of modified shaft.

**Figure 24:** Gear hub

**Figure 25:** Detail drawing of Gear hub

**Figure 26:** Gear sleeve

**Figure 27:** Detail drawing of Gear Sleeve

**Figure 28:** Assembly of modified rope drum
4. Results and evaluation

The modified shaft in all the three cases is analysed using Ansys 18.1 software. The considered load applied on the drum is 3 ton in all the three cases which is the standard load as per the industry. The screenshots of the analysis part in the considered three cases are given below in this section and they can be seen in the fig. 31 to fig. 39. The shear stresses obtained in all the three cases are given below.

4.1. Case 1
On analysis, it is observed that, the minimum shear stress is 1.0866e-07 MPa and the maximum shear stress is 0.017398 MPa.

4.2. Case 2

On analysis, it is observed that, the minimum shear stress is 1.6998e-007 MPa and the maximum shear stress is 0.0022206 MPa. On compression, it is observed that the design in case 2 is better than the design in case 1 as the shear stress is low.

4.3. Case 3

On analysis, it is observed that, the minimum shear stress is 1.6998e-007 MPa and the maximum shear stress is 0.0022206 MPa. On compression, it is observed that the design in case 2 is better than the design in case 1 as the shear stress is low.
On analysis, it is observed that, the minimum shear stress is $5.5909 \times 10^{-9}$ MPa and the maximum shear stress is 0.00025395 MPa. On compression it is observed that the design in case 3 is better than the design in case 2 as the shear stress is low.

5. Conclusion
On analysis it is observed that, all the proposed alternatives in the three cases are found to be good, but it is observed that the shaft in case 3 is appeared to be better than the rest as the shear stress is less. Therefore, it can be concluded that the shaft in case 3 can suit better for the industrial applications. Hence, it can be understood that the shaft in case 3 is less prone to failure. Therefore, the shaft proposed in the case 3 can provide better efficiency under the given and industrial loads. As a whole, it can be concluded that the reverse engineering technique increased the lifespan of the shaft.

6. References

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