Reverse engineering technique for enhancing the EOT crane rope drum

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Abstract. EOT cranes are the widely used ones in the present day industry. In the process of maximizing the efficiency of EOT cranes, the industries are implementing different approaches. One among them is reverse engineering approach. This approach was recommended to improve the efficiency of the EOT crane drum shaft. The shape and size of the shaft were modified to meet the industry requirements. To improve the shaft loading capacity, life and efficiency, the proposed shaft is equipped with the gear hub and gear sleeve.

1. Introduction

Cranes are industrial machines that are primarily used for transportation of various materials in industrial environment. In most of the industries, electrical overhead travelling (EOT) or bridge crane are widely used. ‘Figure 1’ shows a 3 ton EOT crane which works on single girder. These cranes are electrically operated by control pendant, remote pendant or from an operator cabin. It mainly works with the principle of hoist mechanism. Hoist is a device used for lifting or lowering a load by means of drum which mainly consists of Motor, Electro-Magnetic Brake / Thruster brake, Gear box, Drum, Rope. ‘Figure 2’ shows various parts in a single girder EOT crane.

Figure 1. Single girder 3 ton EOT crane [Courtesy: www.Indiamart.com].
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.

‘Figure 3’ shows the existing spline shaft in an EOT crane in a steel manufacturing plant and its dimensions are shown in ‘figure 4’. ‘Figure 5’ 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 i.e. 3 ton. Hence, there is a need in the industry to do the modifications for the existing shaft.
3. Design and modelling:
In the process of enhancing the design of the shaft the authors considered following two cases.

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

Further, it is also taken into consideration that these modifications should not affect the interrelated components of the shaft.

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 ‘figure 6’. 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. ‘Figure 7’ shows the detailed dimensions of shaft with keyway. ‘Figure 8’ and ‘figure 9’ shows the details about the key. The remaining parts of the assembly like Hub and sleeve are shown in the ‘figure 10’ to ‘figure 13’ along with their detailed dimensions. The assembled rope drum with the modifications is shown in ‘figure 14’. Its cross section and its details are shown in ‘figure 15’ and ‘figure 16’ respectively. The maximum load that can be applied on the modified crane is 3 Ton, but, the advantage with this modification is improved life of it.
Figure 7. Detail drawing of modified shaft with key way

Figure 8. Key

Figure 9. Detail drawing of Key

Figure 10. Hub

Figure 11. Detail drawing of Hub

Figure 12. Sleeve

Figure 13. Detail drawing of Sleeve

Figure 14. Assembly of modified rope drum
In the ‘figure 16’, 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. Among these parts only drum, sleeve and hub are modified as the other parts not allowed the authors to modify because of the constraints in the industry environment.

3.2. Case2
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. ‘Figure 17’ shows the modified spline shaft and its dimensional details are shown in ‘figure 18’. This spline shaft is fit with the gear hub and sleeve with the help of the key. The ‘figure 19’ and ‘figure 20’ shows the gear hub and its dimensional details respectively. Similarly ‘figure 21’ and ‘figure 22’ 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 2 is shown in ‘figure 23’. Its cross section and its details are shown in ‘figure 24’ and ‘figure 25’ respectively.

Figure 15. Cross section view of modified rope drum

Figure 16. Detail drawing of modified rope drum

Figure 17. modified spline shaft.
Figure 18. Detail drawing of modified shaft.

Figure 19. Gear hub

Figure 20. Detail drawing of Gear hub

Figure 21. Gear sleeve

Figure 22. Detail drawing of Gear Sleeve

Table 1. Details of gear hub and gear sleeve.

| Description                  | Data       |
|------------------------------|------------|
|                              | Hub  | Sleeve |
| Type of gear                 | Spur  | Spur   |
| Module                       | 3     | 3      |
| No. of teeth                 | 48    | 48     |
| Pressure angle               | 20    | 20     |
| Reference circle diameter    | 144   | 144    |
| Tip circle diameter          | 150   | 137    |
| Root circle diameter         | 136.5 | 150    |
| Clearance                    | 0.75  | 0.75   |
In the ‘figure 30’, part 1 is shaft, part 2 is gear hub, part 3 is gear sleeve, part 4 is drum, part 5 is rear hub, part 6 is plate and part 7 is rib.

4. Results and evaluation
The modified shaft in the two cases is analysed using Ansys 18.1 software. The considered load applied on the drum is 3 ton and which is the standard load as per the industry. The screenshots of the analysis part in the considered two cases are given below in this section and they can be seen in the ‘figure 26’ to ‘figure 32’. The shear stresses obtained in these two cases are given below.

4.1. Case 1
4.2. Case 2

On analysis, it is observed that, the minimum shear stress is $1.0866 \times 10^{-7}$ MPa and the maximum shear stress is 0.017398 MPa.

Figure 26 Screenshot of finite element meshing of modified shaft in case 1.

Figure 27 Screenshot of load analysis on assembly in case 1.

Figure 28 Screenshot of load analysis on Key in case 1.

Figure 29. Screenshot of finite element meshing of modified shaft in case 2.
Figure 30. Analysis of case 3

Figure 31. proper view of gear hub

Figure 32. proper view of gear sleeve

On analysis, it is observed that, the minimum shear stress is 5.5909e-009 MPa and the maximum shear stress is 0.00025395 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.

5. Conclusion
On analysis it is observed that, all the two proposed alternatives are found to be good, but it is observed that the shaft in case 2 is appeared to be better than the shaft in case 1 as the shear stress is less. Therefore, it can be concluded that the shaft in case 2 can suit better for the industrial applications. Hence, it can be understood that the shaft in case 2 is less prone to failure. Therefore, the proposed shaft in the case 2 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.

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