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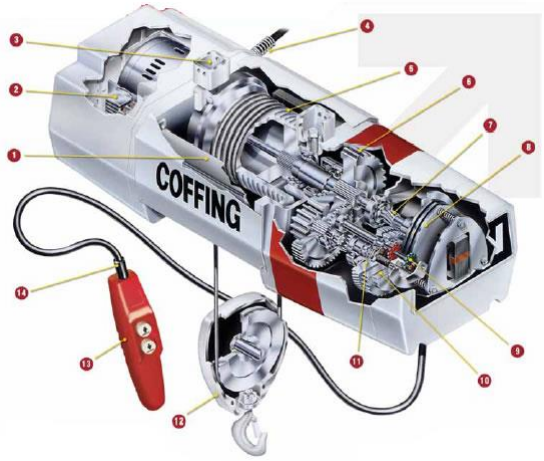
Failure Analysis Case Study

Failure Analysis of a Cable Puller due to torsional overload



Keywords: Cable Puller, Facture, Torsional stress

Material: AISI 1018 carbon steel

Introduction

A 'Powercat, Senior Mode Portable Cable Puller was submitted for failure analysis. The cable puller was located in an electrical closet just off an elevator reception area. This unit was installed to hoist an electrical cable, weighing 10.7 pounds per foot, to the 44th floor. As the cable neared the 44th floor a shaft failed, causing the cable to fall. A new shaft was installed and a new cable was being raised when the puller let go. The cable length was reported to be 570 feet, resulting in a load of 6,100 pounds being lifted. The cable puller was rated for a low pulling speed (6 fpm) at 5 tons(10,000 lbs.).Visual examination, Chemical, mechanical and metallographic analyses was performed on the submitted puller sections to look for root cause of the failure.

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Visual Examination

Fig 1 shows the gear arrangement to the drum containing the hoisting wire(1/2 inch dia.). Note that the drive shaft is bent which caused disengagement of the 4 inch diameter gear on the shaft from the drum gear. Fig 2 shows the shaft after removal from the unit. The shaft is obviously bent and fractured at the site of the inboard face of the small four inch gear. Note that there is severe torsional shear deformation in the bar in the area between the large drive gear (on the left in Fig. 1) and the 4 inch gear which drove the cable drum. This area experienced shear stress well in excess of the torsional yield strength of the shaft material.

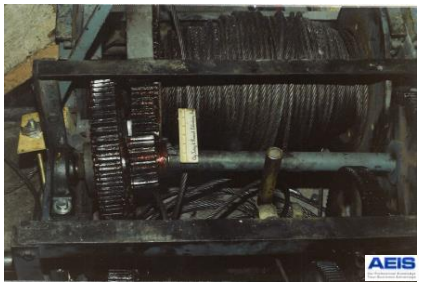

Fig 1 Gear disengagement caused by the bent drive shaft

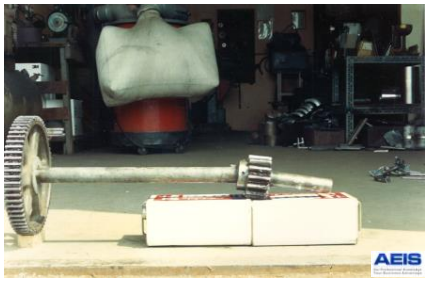

Fig 2 Bent and fractured drive shaft after removal from the unit

Note also that shear stresses in excess of the yield strength were also induced between the 4 Inch gear and the gear at the other end of the shaft (shown on the left in Figure 2). This is borne out by the bend at the end of the keyway in Figure 3. The fracture site in the shaft is also evident in this photograph. A series of punch marks were observed on the shaft surface. These were presumable placed there to assist in affixing the gear to the shaft. Fracture of the shaft took place through one of these punch mark. (Just below keyway, Figure 4). Fracture had begun through some of these marks which were further evidence of the high torsional stresses experienced by the shaft.

Fig 3 Fracture site at the end of keyway

Fig 4 Fracture begun through on of the punch marks

Chemical Analysis

A sample was cut from the end of the bar away from fracture site for chemical analysis. Result shows the material satisfied the requirement of AISI 1018 carbon steel.

	Result %	1018 required %
Carbon	0.18	0.15/0.20
Manganese	0.68	0.60/0.90
Phosphorus	0.013	0.035 Max
Sulphur	0.029	0.045 Max
Silicon	0.05	---
Chromium	<0.01	---
Nickel	0.02	---
Molybdenum	<0.01	---

Mechanical Test

Hardness test was conduct on a slice cut from the end of the bar nearest the fracture

	Near the surface	Near the core
Rockwell B	87-89	83-85

Microscopic Examination

Fig 5 showed microstructure of the slice from hardness test. The microstructure observed was that of a hot rolled mild steel bar which consisted of equiaxed ferrite plus pearlite.

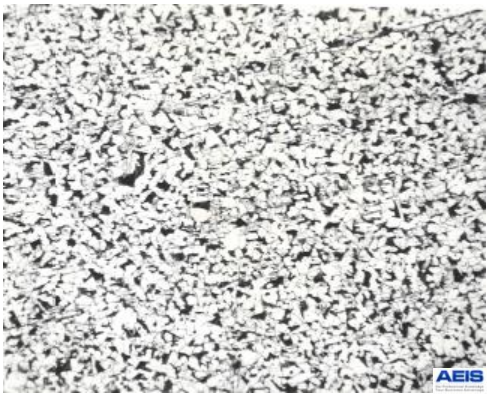

Fig 5 Microstructure of the fractured drive shaft X100

Discussion

There is no question that failure of the system was the direct result of torsional overload on the drive shaft. This overload between the four inch drive gear and the gears at either end of the shaft caused displacement and misalignment of the four inch gear relative to the cable drum gear. This caused the teeth on the four inch gear to ride up and onto the drum gears resulting in bending and fracture of the shaft and attendant gear teeth disengagement.

It's our opinion that the reason for the overload and resultant failure is that the shaft was undersigned. Assuming the reported load of 6,100pounds was being lifted at the time of the accident, this would result in a torsional shear stress of approximately 21,000psi on the shaft which is well above the shear yield stress of a soft(RB84/87), weak, 1018 plain carbon steel. Moreover, the presence of the keyway in the area of yielding and fracture would serve to further reduce the load bearing capacity of the shaft.

Also important to point out that if the cable puller had been used to lift its rated load at some time prior to this accident, that load would result in a shear stress approximately 34,400 psi and even with neglecting the effect the presence of a keyway, an event such as this would certainly have initiated failure.

Conclusion

Fracture and bent drive shaft of the cable puller is the result of torsional overload on the drive shaft. This torsional overload may be caused by undersigned shaft unit.