EXPERIMENTAL INVESTIGATION OF DISCARD CRITERIA OF ROTATION RESISTANT ROPES SUBJECTED TO BENDING OVER SHEAVE FATIGUE

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ABSTRACT

In this study, number of visible wire breaks and diameter reduction along discard lifetime of rotation resistant rope that has 39 strands have been measured in accordance with tensile load variations. Four different tensile loads and sheave with 250 mm in diameter have been adopted to attain comparable results. Bending over sheave fatigue test setup have been used in this study. Maximum reduction in diameter has been found by 1.80% at 25 kN tensile load. The number of wire breaks on visible wires is extremely important criteria in the inspection of wire ropes.
Keywords: wire rope, wire breaks, discard fatigue life

1. INTRODUCTION

Steel wire ropes are used in elevators, cranes, mine hoistings, bridges, offshore and aerial ropeway systems [1]. Steel wire ropes consist of large number of wires that spin or twisted to form a strand. A number of these strands are then twisted together to form rope. There are many different kind of rope constructions manufactured to perform varied duty expected from them. Traditionally, wire rope constructions are formed by parallel lay strands such as Filler, Warrington, Warrington-Seale, Seale, twisted around a fibre or steel core and multi layered rotation resistant rope constructions whose outer strand layers are closed opposite directions from inner strand layer is used to prevent untwisting while loads are carrying. Steel wire ropes are critical components in many engineering applications such as cranes, elevators, mine hoisting, bridges and offshore systems. Due to application area of steel wire ropes becomes vast there has been a great deal of interest in rope technology area. Mostly, steel wire ropes are subjected to fatigue since either loads carried by ropes fluctuate with time or repeated move on the sheaves in which the rope goes from straight to bent and back again as cranes. First issue is called as tension-tension fatigue where ropes experience to fluctuating tensile load. Second issue is called as bending over sheave fatigue where ropes experience to repeated bending combined with static tensile load. This paper deals with bending over sheave fatigue of steel wire ropes [2]. In the application area steel wire ropes are mostly subjected to bending over sheave fatigue since ropes are generally used as tension member together with sheaves. Rope moved over the sheaves goes from straight to bend when load is carried upward and bend to straight when load is taken down. Therefore in every cycle repeated bending over sheave causes bending over sheave fatigue [3]. One of the commonly used types of ropes in the cranes is multi-layered rotation resistant rope. In this study, rotation resistant rope with 39 strands (RRR) have been used to present in-situ measurement results of number of wire breaks and diameter reduction along the discard service lifetime of RRR.

2. BENDING OVER SHEAVE FATIGUE TEST MACHINE

In order to measure number of wire breaks and diameter reduction occurred on RRR four tests have been done in the Rope Technology Laboratory of Institute of Mechanical Handling and Logistics (Institut für Fördertechnik und Logistik (IFT), University of Stuttgart, Germany). Test machine used

in this study has been shown in Figure 1. Rope samples are connected between drive sheave (1) and test sheave (2) by means of lead casting end connections. Motor (3) gives the power on system. A leverage (4) and several weights are used to maintain a constant tensile load S on the test sheave to simulate actual operating conditions, in this manner static tensile load S can be applied to the rope tested permanently during the test. Actual rope bending over sheave fatigue occurs at contact length with rope that is certain 30·d length (d is a diameter of the rope) on test sheave [4].
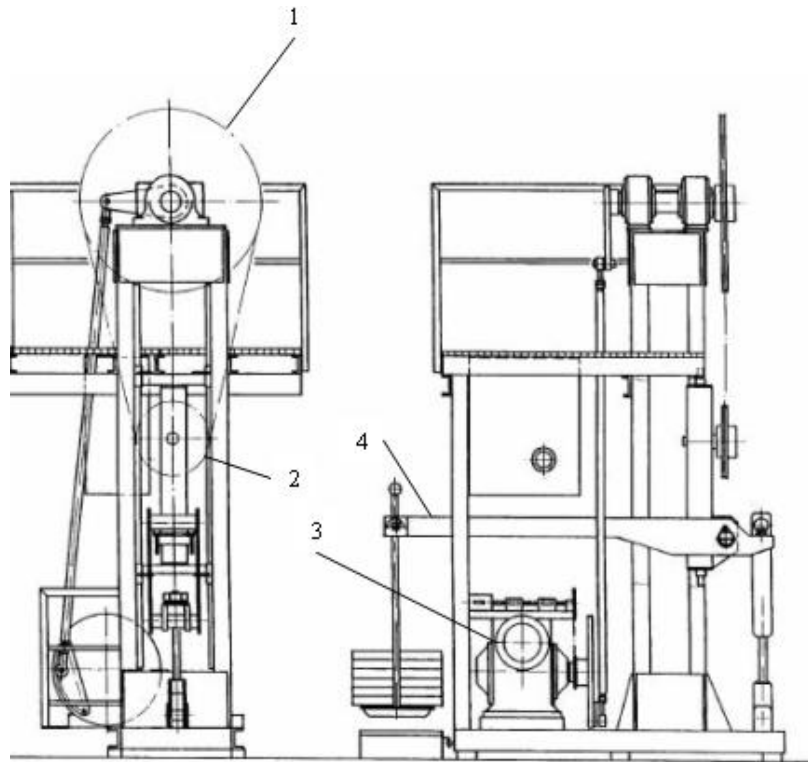

Figure 1. Bending over sheave fatigue test machine [2].
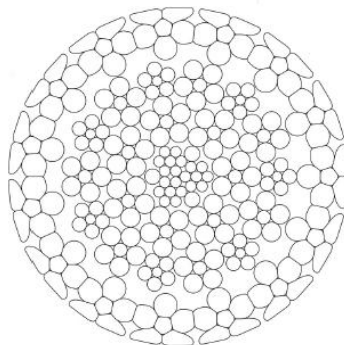

Figure 2. Cross sections of rotation resistant rope with 39 strands.

Table 1. Technical properties of rotation resistant rope with 39 strands.

Strand number	39
Wire number	241
Diameter	10 mm
Wire grade	1960 N/mm^2
Lay type	Right regular lay (sZ)
Filling factor	0.714
Minimum breaking load (MBL)	96.2 kN

3. INVESTIGATED STEEL WIRE ROPE

The steel wire rope used for this investigation is 10 mm in diameter. Rope sample used in this study is RRR with 39 strands Technical properties of RRR have been depicted in Table 1. Test rope has 15 outer strands for highest breaking load requirements. With only 5 outer wires per strand (plus one aluminium wire), it provides excellent abrasion resistant. Swage compaction applies an almost circular cross section to the rope and contributes to high running smoothness and proper pressure distribution on a sheave and a drum. This rope construction can be used as main and auxiliary hoist line for tower cranes, construction cranes and mobile cranes etc. Figure 2 shows cross section of RRR used in this study.

4. BENDING OVER SHEAVE FATIGUE TEST AND EXPERIMENTAL RESULTS

Inspection of steel wire ropes in service is extremely important phenomena. Degradations such as wire or strand breaks caused by fatigue reduction in rope diameter, internal or external corrosion and wear and heat damages deteriorate rope performance and those finally cause discard ropes from service. ISO 4309 [5] and DIN 15020-2 [6] standards present discard extent and value of degradations. According to those standards discard number of visible wire breaks is determined by number of load bearing wires in outer strands of rope, drive groups and lay type (regular lay or lang lay) as shown in Table 2. The wire rope such as RRR investigated in this study must be discarded from service at the latest when 2 wire breaks on the 6·d rope length or 4 wire breaks on the 30·d rope length (d is rope diameter). $1E_m$, $1D_m$, $1C_m$, $1B_m$ or $1A_m$ drive group is selected as application area of rope. In addition if the rotation resistant rope diameter has decreased by 3% or more in comparison with the nominal diameter, the wire rope must be discarded from service even if no wire breaks have been observed. Rope diameter is calculated by taking average of two perpendicular measurements from two different locations on rope length by rope calliper [7]. Bending over sheave fatigue tests have been performed by test rig depicted in Figure 1. Sheave with 250 mm in diameter has been mounted to the test rig.

Table 2. Number of visible wire breaks which justifies discarding [5].

Number of visible wire breaks

$1E_m$, $1D_m$, $1C_m$, $1B_m$, $1A_m$ Drive groups		2_m, 3_m, 4_m, 5_m Drive groups	
on a length of		on a length of	
6d	30d	6d	30d
2	4	4	8

d = Rope nominal diameter

Rope sample lengths became 1.45 m. Samples were made with lead casting cones moulded on each end and connected to backing rope in order to form a loop necessary for the test [8]. Author has conducted bending over sheave fatigue tests by using four static tensile loads that are 10 kN, 15 kN, 20 kN and 25 kN. Number of visible wire breaks and diameter reduction along discard lifetime of RRR have been in-situ measured in accordance with tensile load variations. Diameter variations in different two locations on wire rope samples, mean diameter, percent reduction in diameter and maximum wire breaks in the bending length has been presented considering certain tensile load, sheave diameter and bending cycles in Table 3. It can be seen from Table 3 that maximum reduction in diameter is 1.80% at 25 kN tensile load. Even this reduction is not enough to discard wire rope in service when reduction in diameter criteria is considered since percent reduction in rope diameter is 3% or more in the nominal diameter is discard criteria for rope investigated. In every experiment wire rope samples have been discarded by considering number of wire breaks since 2 wire breaks on the 6·d rope length or 4 wire breaks on the 30·d rope length are discard criteria for rope investigated.

Table 3. Experimental results

Tensile load (S) (*N*)	Sheave diameter (D) (*mm*)	Bending cycles	Diameter in first location (*mm*)	Diameter in second location (*mm*)	Mean diameter (*mm*)	Reduction in diameter (%)	Max. wire breaks	
							6·d	30·d
25	250	5000	d_1=9.95 d_2=9.88	d_1=9.95 d_2=9.83	9.90	1	1	2
25	250	discard cycle	d_1=9.86 d_2=9.77	d_1=9.88 d_2=9.79	9.82	1.80	3	6
20	250	5000	d_1=9.97 d_2=9.89	d_1=9.97 d_2=9.98	9.95	0.50	-	-
20	250	10000	d_1=9.82 d_2=9.84	d_1=9.90 d_2=9.91	9.86	1.40	1	2
20	250	discard cycle	d_1=9.82 d_2=9.84	d_1=9.90 d_2=9.91	9.86	1.40	2	5
15	250	5000	d_1=9.87 d_2=9.92	d_1=9.94 d_2=10	9.93	0.70	1	1
15	250	10000	d_1=9.80 d_2=9.96	d_1=9.88 d_2=9.89	9.88	1.20	1	1
15	250	discard cycle	d_1=9.80 d_2=9.96	d_1=9.88 d_2=9.89	9.88	1.20	3	5
10	250	5000	d_1=9.90 d_2=9.84	d_1=9.88 d_2=9.94	9.89	1.10	-	-
10	250	10000	d_1=9.91 d_2=9.83	d_1=9.96 d_2=9.86	9.89	1.10	-	-
10	250	discard cycle	d_1=9.85 d_2=9.87	d_1=9.82 d_2=9.86	9.85	1.50	4	6

5. CONCLUSIONS

In this study, number of visible wire breaks and diameter reduction along discard lifetime of rotation resistant rope that has 39 strands have been measured in accordance with tensile load variations. Four different tensile loads and sheave with 250 mm in diameter have been adopted to attain comparable results. Bending over sheave fatigue test setup has been used in this study. Maximum reduction in diameter has been found by 1.80% at 25 kN tensile load. In every experiment wire rope samples have been discarded by number of wire breaks. It can be concluded that number of wire breaks on visible wires is extremely important criteria in the inspection of wire ropes.

6. REFERENCES

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