TESTING THE DYNAMIC STRENGTH OFSUSPENSION LEVER OF MINE HOISTING EQUIPMENT

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ABSTRACT
Mine development imposes very high technical requirements of the mine hoisting equipment in terms of speed of transport. To meet these requirements it is necessary to properly design the structural elements of mine hoisting equipment which means that they must have the proper characteristics of the materials from which they are made such as mechanical properties.
The suspension lever is an important fixing part of mining installations export container. Since the suspension levers are exposed to dynamic loads during operation, one of the most important test is a determination of their dynamical strength.
This paper presents the determination of the dynamic strength of a new suspension lever and a suspension lever that has been in use for several years. Based on these parameters further working life of the suspension lever can be determined in order to increase the safety of the entire plant.

1. INTRODUCTION
The mine hoisting equipmentinstalled in the mine's export shafts has a key link between the production underground system and the surface facilities for mineral processing. The mine hoisting equipmentincludes the equipment and devices for transport in the mine shafts. The suspension lever is an important part of the connection equipment of the export vessels of the minehoisting equipment.
Suspension levers are in use for many years. For this reason, besides the selection of materials for the suspension levers, tests such as mechanical tests, testing of stresses that occur during operation, non-destructive testing, etc.are very important.
Mechanical testing gives a fuller insight into the condition of the exploited materials, and on the basis of tensile characteristics it is possible to assess the safety and further use of connecting accessoriesof export vessels as well as the decision forits replacement with the new one made of adequate material [1].
During exploitation, the greatest number of damage and failure of many parts and structures occurs as a result of fatigue. In this paper, a fatigue test of these elements is presented.

As the theoretical expression of the parameters of the real state of the structure and mechanism of mine hoisting equipmentdoes not provide a completely reliable approach, the need for experimental research is indicated. The most common goal of experimental research is to measure the real parameters of mine hoisting equipment(force, deformation, stress, oscillation time, damping, etc.) and to compare them with theoretical values obtained analytically or numerically.

The main objective of the experimental research is systematic testing of individual structural elements of the export container and fixingparts, during operation. The results of these tests can be used to determine the working life of this structural element.

As part of the experimental investigations, the paper investigates the fatigue testing of a new and used suspension levers.

2. EXPERIMENTAL TESTING

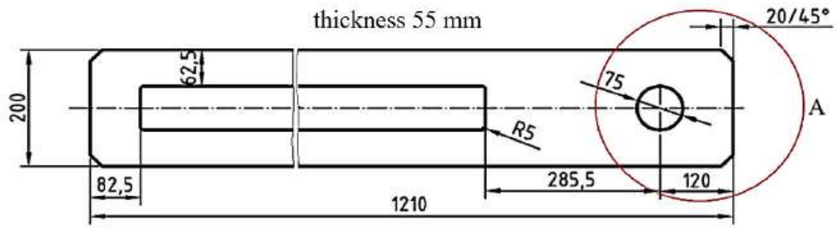
Fatigue is the appearance of gradual damage to the material due to the long-term effect of periodic dynamic loads or stresses [2].

The experimental fatigue tests were performed on a new suspension lever (N) and suspension lever that had been in service (E) for about 8 years.

The supplier of the material of the new suspension levers was the Steel "Smederevo" – Smederevo.Testing material wassteel grade S355JR according to EN standard supplied in the form of hot rolled sheets 55 mmin thickness.

According to the available technical documentation, the material of the old suspension levers was carbon structural steel grade Č0563 according to JUSC.B0.500 and S355J2G3 according to EN standard also in the form of hot rolled sheets 55 mm in thickness [1].Both grades of steel are almost with identical chemical composition and belong to structural steels with tensile strength (R_m) of 500 MPa to 700 MPa [3].

Figure 1 shows the layout of the connecting rod of suspension levers and the location of the samples for all mechanical tests(detail –A).



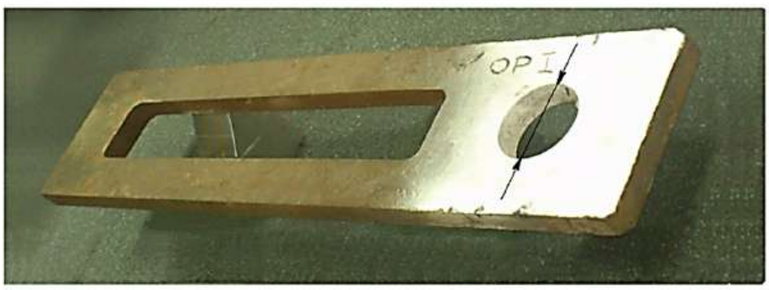


Figure 1. Schematic illustration of the suspension lever detailing the sampling point [1]

Tensile tests at room temperature were performed on both types of suspension levers, new and exploited material. Mechanical tests were performed on test samples prepared after determining the orientation of the grain in the sheet metal of which the suspension levers

were made.Orientation of the rolling of the sheet metal during its production is very significant during fabrication of fitting elements. The properties of rolling material in most metals are not always the same in all directions, and it can be observed that the grains in the microstructure are oriented in the direction of rolling, i.e. there is a degree of anisotropy. After determining the direction of rolling by metallographic method, test sampleswere taken in the direction of sheet metal rolling.
The mean values obtained by the tensile test for both of suspension levers are given in Table 1.

Table 1. Mean values of tensile tests of suspension levers [1]

Mark	Test temperature, °C	$R_{p0,2}$,MPa	R_m,MPa	A, %
N	20	404,0	550,6	30,5
E	20	363,7	537,7	29,2

From Table 1 is evident that the values of tensile properties of the new material (N) and exploited materialare differ, what is logical.Also, the values obtained by tensile testing, for both materials, are within the limits prescribed by the standardBAS EN 10002-1.

2.1. Dynamic testingat room temperature
Dinamic testing of the exploited and new material of the suspension levers are performed in order to obtain the points in the σ-N diagram (Stress-Number curve), for constructing the Wöhler curve and determining the dynamic strength R_d[2].
The test tubes are made according to ASTM E466 standard. Dynamictests were carried out at the Kemal Kapetanović Institute, University of Zenica, at room temperature (20 °C) on the high frequency pulsator "AMSLER" which have a range of unidirectional, sinusoidal dynamic load from –100 kN to +100 kN, Figure 2.

Figure 2. High-frequency pulsator "Amsler" for dynamic testing [3]

The mean stress and amplitudes stress were registered with an accuracy of ± 50 N. The achieved frequency ranged from 160 to 190 Hz, depending on the load sizes and the ratio of minimum and maximum load value(R ratio). At a load level lower than the flow stress the most common test is performed at a given force amplitude F_a. In order to evaluate more fully the behavior of the material under the action of dynamic loading, the thickness of the test tube as well as the thickness of the suspension leverwere considered. The dynamic test is performed with controled force and the ratio of minimum and maximum load R = 0,1, i.e. $F_{min} / F_{max} = 0,1$.
The aim of experimental dynamic tests is to determine the dynamic strength and to evaluate the behavior of specimens from suspension levers under dynamic load. Figure 3 provides a schematic illustration of the applied dynamic load.

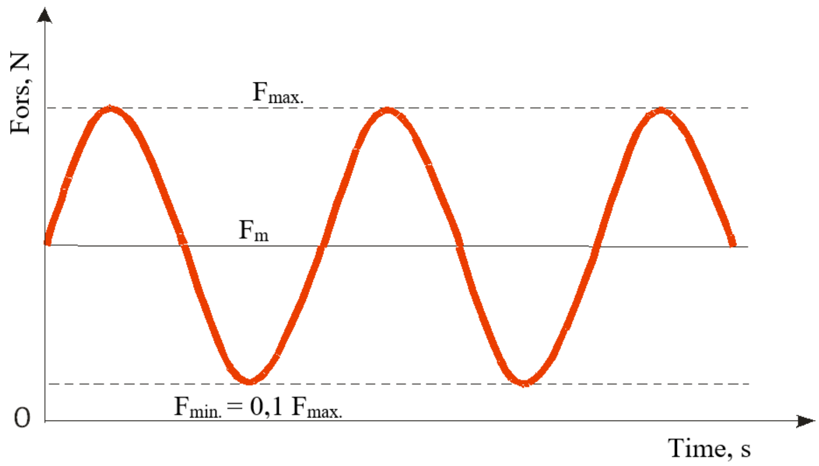


Figure 3. Positive unidirectional dynamic load used for fatigue test, R=0,1[1]

This test only determines the number of load-to-fracture changes at a constant-range load effect. The standard only requires information on the intensity of the stresses to which no fracture occurs after a number of cycles (typically between 10^6 and 10^8 cycles). Standard ASTM E468-15 defines the dynamic strength, $R_d = N_f$ after 10^7 cycles for steel materials [4].The results of fatigue testingon the 18 samples are presented in Tables 2 and 3.

Table 2. Results of dynamic testingon exploited (E) material

Mark	F_m, [N]	F_{min}, [N]	F_{max}, [N]	F_a, [N]	Stress σ, [MPa]	Number of cycles, *N*
DG-E-1	12272,7	2231,4	22314	10041,3	396,5	3,34 E+04
DG-E-2	12272,7	2231,4	22314	10041,3	396,5	4,05 E+04
DG-E-3	12272,7	2231,4	22314	10041,3	396,5	2,21 E+04
DG-E-4	10759,4	1956,26	19562,6	8803,2	350,4	1,54 E+05
DG-E-5	10759,4	1956,26	19562,6	8803,2	350,4	1,84 E+05
DG-E-6	10759,4	1956,26	19562,6	8803,2	350,4	2,01 E+05
DG-E-7	9990,31	1816,42	18164,2	8173,9	325,4	5,56E+05
DG-E-8	9990,31	1816,42	18164,2	8173,9	325,4	8,22E+05
DG-E-9	9990,31	1816,42	18164,2	8173,9	325,4	7,19E+05
DG-E-10	9236,92	1679,44	16794,4	7557,48	300,8	1,55E+06
DG-E-11	9236,92	1679,44	16794,4	7557,48	300,8	2,05E+06
DG-E-12	9236,92	1679,44	16794,4	7557,48	300,8	1,45E+06
DG-E-13	8605,08	1564,56	15645,6	7040,52	280,3	8,73E+06
DG-E-14	8605,08	1564,56	15645,6	7040,52	280,3	9,36E+06
DG-E-15	8605,08	1564,56	15645,6	7040,52	280,3	1,05E+07

DG-E-16	8156,94	1483,08	14830,8	6673,86	265,9	0,85E+07
DG-E-17	8156,94	1483,08	14830,8	6673,86	265,9	1,02E+07
DG-E-18	8156,94	1483,08	14830,8	6673,86	265,9	1,53E+07

Table 3. Results of dynamic testing on new (N) material

Mark	F_m, [N]	F_{min}, [N]	F_{max}, [N]	F_a, [N]	Stress σ, [MPa]	Number of cycles, *N*
DG-N-1	12290,3	2234,6	22346	10055,7	396,8	3,94 E+04
DG-N-2	12290,3	2234,6	22346	10055,7	396,8	5,06 E+04
DG-N-3	12290,3	2234,6	22346	10055,7	396,8	3,02 E+04
DG-N-4	10759,4	1956,26	19562,6	8803,2	365,2	1,54 E+05
DG-N-5	10759,4	1956,26	19562,6	8803,2	365,2	1,84 E+05
DG-N-6	10759,4	1956,26	19562,6	8803,2	365,2	2,01 E+05
DG-N-7	9990,31	1816,42	18164,2	8173,9	350,4	5,56E+05
DG-N-8	9990,31	1816,42	18164,2	8173,9	350,4	8,22E+05
DG-N-9	9990,31	1816,42	18164,2	8173,9	350,4	7,19E+05
DG-N-10	9236,92	1679,44	16794,4	7557,48	338,2	1,55E+06
DG-N-11	9236,92	1679,44	16794,4	7557,48	338,2	2,05E+06
DG-N-12	9236,92	1679,44	16794,4	7557,48	338,2	1,45E+06
DG-N-13	8605,08	1564,56	15645,6	7040,52	326,3	4,03E+06
DG-N-14	8605,08	1564,56	15645,6	7040,52	326,3	4,36E+06
DG-N-15	8605,08	1564,56	15645,6	7040,52	326,3	5,03E+06
DG-N-16	8156,94	1483,08	14830,8	6673,86	315,8	1,55E+07
DG-N-17	8156,94	1483,08	14830,8	6673,86	315,8	1,82E+07
DG-N-18	8156,94	1483,08	14830,8	6673,86	315,8	1,93E+07

Based on the obtained values given in Tables 2 and 3, diagrams σ-N were constructed and the dynamic strength was determined. Figures 4. and 5. give the obtained values of dynamic strength for the exploited and new material.

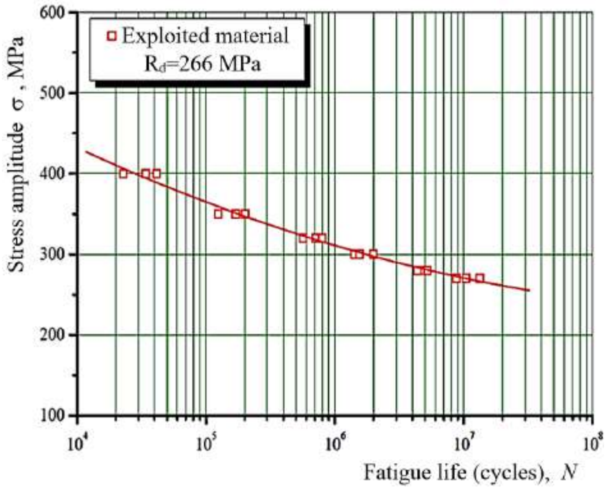


Figure 4. Diagram σ-N for exploited material(E) withR = 0,1

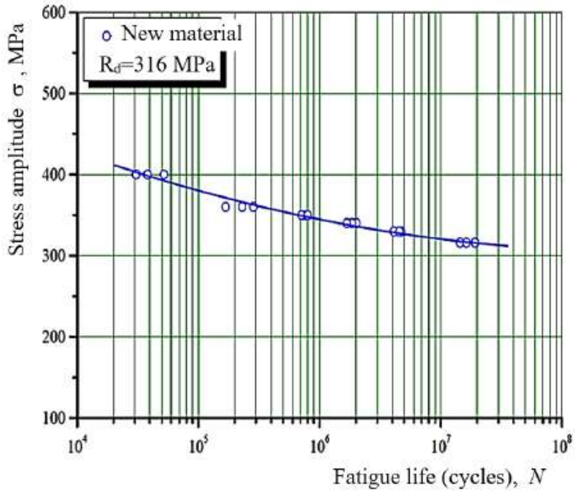


Figure 5. Diagram σ-N for new material (N) withR = 0,1

The obtained values of dynamic strength R_d at approximately 10^7 cycles are in the range for this type of material, i.e.for both samples. Namely, the dynamic strength of medium-strength steels for the fabrication of structural members of coupling accessories ranges from 0,7 to 0,8 of the yield stress. Therefore, minimum of the dynamic strength of the exploited material would be 254,59 MPa (= 0,7 x 363,7 MPa) to 290,96 MPa (= 0,8 x 363,7 MPa) and is still in the required range although closer to the lower value.After10^7 cycles approximately, the test resultsfor dynamic strength were 266 MPa for exploited material (E) and 316 MPa for new material (N).

3. CONCLUSIONS

- The suspension lever is an important part of fixing parts of mine installationsexport container, whose functionality and durability must be controlled continuously.
- One of the very important mechanical tests is the determination of the dynamic strength of a new suspension levers and a suspension levers in service, since these elements are mainly exposed to dynamic loads.
- The obtained values of dynamic strength R_d at approximately 10^7 cycles are in the range for this type of material, i.e. for both samples. After10^7 cycles approximately, the test resultsfor dynamic strength were 266 MPa for exploited material (E) and 316 MPa for new material (N).
- By comparing the test results after fatigue test of a new suspension leversand exploited ones the working life of these element can be predicted, taking into account the possible presence of failures, especially cracks. Specifically, above mentioned tests must be supplemented by tests related to fracture mechanics parameters under dynamic loads.
- It was also established that the fatigue test is very important for these elements, and that even after a long period in service suspension lever can have a value of dynamic strength within the required limits and remain in use with regular nondestructive testing.

4. LITERATURE

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