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Determination of the stress state of the hooklift superstructure for measured boundary conditions

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ABSTRACT: As part of the article, the research subject of the HKS12 hooklift is described. In the next section, it is presented how long-term measurements were carried out to determine the load distributions during the operation of the device. A model was built for strength calculations, which was then validated with the results obtained from strain gauge measurements. Based on the validated numerical model, FEM calculations were performed for the key load cases of the device. Based on the FEA results, locations requiring structural changes were identified..

KEY WORDS: finite element method, strain gauge measurements, FEM analysis, hooklift

1. Intorduction

Hooklifts are devices that combine two functions: lifting the load and unloading. These machines can carry the load in special containers designed for loading. The most common units have a lifting capacity of 20 tonnes, but there are also units on the market with lifting capacities of up to 50 tonnes. For private users, hookloaders with a lifting capacity of 7 or 12 tonnes are used.

Hooklifts are not included in standards or guidelines for strength calculations. A problem that arises with this type of equipment is determining the boundary conditions for strength calculations[1-2]. There is a lack of studies on what load values to take for adhesion and fatigue strength calculations[3]. This paper shows how these loads were measured, shows the results obtained from actual measurements and how the equivalent range of force variation on the hook was calculated. On the basis of the measurements, it is indicated which load cases are the most unfavourable and which should be used for the dimensioning of hook device structures [4].

2. Long-term measurements

In order to measure the strain of the hooklift as well as to measure the loads on the hooklift equipment during normal operation, a specially developed mobile measuring system was used, which allows remote connection via GSM. Ten strain gauge measuring points were mounted on the HKS-12. The measuring points were located at pre-selected locations. During the measurements, strains were measured at points T2, T3, T6, T7, system pressures at points T1-, T1+, T5, T8, T8+, and the hook force was measured at point T4.

Long-term tests of the HKS 12 hooklift carried out during 60 days of normal operation.

An example of the bending stresses on the hook arm (point T3) and the hydraulic pressure waveforms recorded at points T1 are shown in Figures 1 and Figure 2.

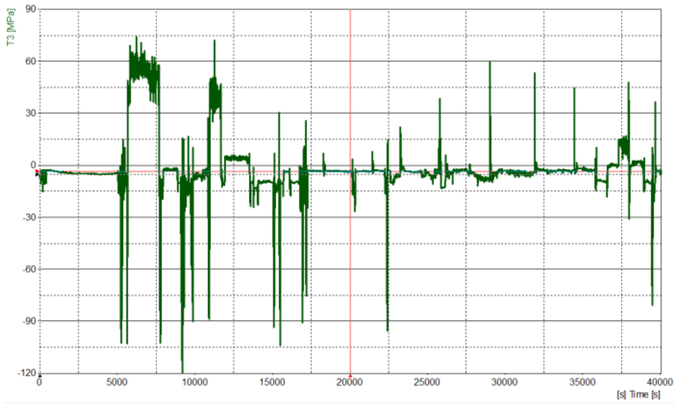

Fig. 1. Stress plot from the entire measuring day at point T3

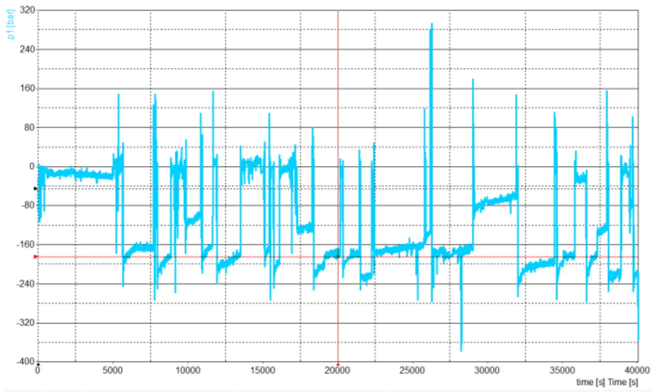

Fig. 2. Pressures from the whole measuring day at point T1

During the measurement period, N=1503 fatigue cycles were observed in the range above 5kN = approximately 12/7 * 3kN. Assuming an exponent m=3 as for the influence zones of welded joints, the equivalent range of variation of hook force was calculated for N=1503 specimens over the measurement period DFe = 23 kN. The ratio wDF = DFe / Fn = 23 / 60 = 0.38. The maximum weight of the container transported was approx. 14 tonnes (parameter mkd=14t), while the average weight of the container was approx. 12.5 tonnes (parameter mk=12.5 T). During the measurements, 265 containers were transported.

3. Strength calculations

To determine the fatigue condition of the load bearing structures of the hook device, 4 Load Cases (LC) were assumed:

- LC1 - lifting of the container just above the frame when the hook arm is shortest - - in this case there is an extremum of maximum force on the hook Fmax in the main fatigue cycle, with Fmax inducing a positive bending moment.
- LC2 - lift of the container just above the ground when the hook arm is at its shortest - - in this case there is an extremum of minimum force on the hook Fmin in the main fatigue cycle, with Fmin inducing a negative bending moment, figure 3.
- LC3 - lifting of the container just above the frame when the hook arm is the longest as for movement 2.
- LC4 - lifting the container above the ground to achieve vertical pocket alignment.

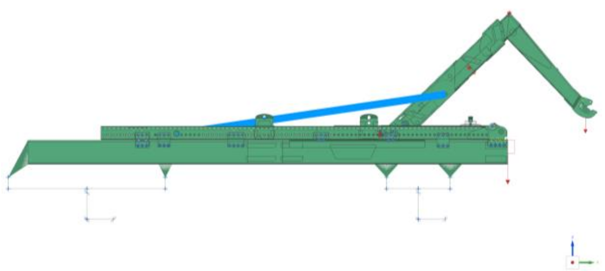

Fig. 3. Design position LC2

The results of the stresses according to the H-M hypothesis are presented in Figures 4 and figure 5 at level 50 - 237 MPa to show where the allowable stresses were exceeded. The exceedances occurred within the arm attachment of the actuator and at the locations where the outrigger is attached to the intermediate frame.

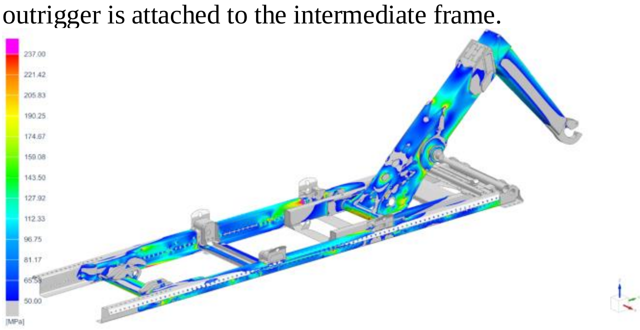

Fig 4. HM Stress levels [MPa] - general view LC2

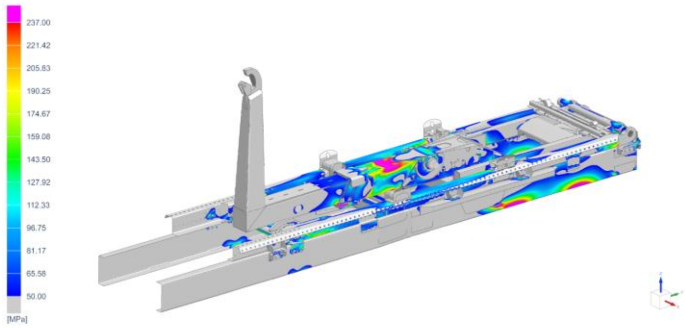

Fig 4. HM Stress levels [MPa] - general view LC3

4. Summary

Based on the analysis of the measurement data, the weights of the containers transported were determined. The data obtained showed that the hooklift equipment carried the majority of containers with weights less than the maximum possible. On the basis of a statistical analysis of the compiled results, it was noted that although the hooklift equipment carried fewer containers, the forces on the hook (necessary for further fatigue calculations) were significantly higher. This is due to the fact that the container may have been raised and lowered, or to loading problems.

On the basis of the measurements, 4 load cases used for the dimensioning of the load-bearing structure of the hook devices were determined, i.e. LC1, LC2, LC3 and LC4. On the basis of the results of the strength calculations, it can be concluded that there are cases where the allowable stresses are exceeded, but that these exceedances these occur in a small number of locations.

It was also noted that in most cases, simply changing the material used can result in the ad hoc strength condition of the allowable value being met.

Literature

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