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Original Research Article

The influence of superstructure vibrations on operational loads in the undercarriage of bulk material handling machine

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ABSTRACT

This article presents research on the correlation between vibrations of the ŁZKS 1600 stacker-reclaimer superstructure and the harmonic changes in loads in undercarriage supports. Investigations are focused on the change in center of gravity location caused by superstructure vibrations and its influence on loads acting on the elements of the undercarriage. The presented research and analysis of results indicate a clear correlation between dynamic behavior of the superstructure and the changes in loads acting on the undercarriage. It was shown that the harmonic nature of the changes in these loads is derived from the global vibrations of the superstructure, which cause a dynamic change in the position of the center of mass.

1. Introduction

Large-scale surface mining and material handling machines, such as excavators, stackers, and stackers-reclaimers, are characterized by a relatively small spacing between undercarriage supports in comparison to the size of their superstructure. In such machines, the superstructure is pivotally connected to an undercarriage, usually by means of a slewing bearing. Due to substantial changes in the configuration of the elements in these machines, during operation, the location of the horizontal center of gravity of the superstructure changes substantially relative to the diameter of the slewing bearing. Additional factors that influence the position of the resultant force exerted by the superstructure on the undercarriage include large excavation or loading forces, the mass of the transported material, and ground inclination.

The incorrect location of the superstructure's center of gravity may result in adverse consequences that affect the operating safety and durability of crucial elements in the machine's load-carrying structure. If the location of the center of gravity significantly deviates from the nominal values, the superstructure on the undercarriage, or even the entire machine, may lose stability. Smaller deviations accelerate the wear of the bearing raceway, and, in the case of bearings that transfer the tilting moment, cause overloading of the bolts that connect the bearing to the supporting elements. Therefore the location of the center of gravity of the superstructure or, less frequently, of the entire machine should be measured

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and validated in new or modernized machines, and, if need arises, the counterweight mass should be adjusted. Another reason for weighing is a significant decrease in the durability of the superstructure's slewing bearing. Detailed information about weighing and the misbalance influence on the structure is well described [1].

The center of gravity can be determined using different measurement methods. Most often the machine's superstructure is lifted on hydraulic actuators and the pressure in cylinders is measured directly with precision manometers or indirectly with the application of dynamometers. Another possibility involves is to place strain gauges on supports. Unfortunately, this method can only be used on unloaded support, e.g. during construction or modernization of the machine. In the case of rail-mounted machines the center of gravity can be determined by measuring the forces exerted on the rails [1–3].

The decision which method to choose depends on the size of the machine, the type of undercarriage and the technical possibilities. The abovementioned ratio between the changes in center of gravity location and the diameter of the slew bearing is reflected in the loads acting on the elements of the undercarriage. The influence of the dead loads and its static position is well documented. This article focuses on the change in center of gravity location caused by superstructure vibrations and its influence on loads acting on the elements of the undercarriage. This phenomenon can be observed during the weighing procedure, which records harmonic changes in load values in the supports. Their cyclic nature indicates that these changes are vibration-based and therefore it can be reasonably assumed that superstructure vibrations are the cause of the said cyclic changes in loads [4]. Refs. [5–7] describe in detail the characteristic normal mode shapes in superstructures of bucket wheel excavators. The mode shapes described in these works are global and cause global shifts in the superstructure's center of gravity location, and consequently in the loads transferred to the elements of the undercarriage. Therefore the changes in loads acting on the undercarriage are mainly caused by global vibrations of the superstructure. Research concerning this phenomenon is significant. The literature and calculation standards [8,9] do not take into account the variability of these loads in the context of fatigue strength of the load-carrying structure of the undercarriage. Only individual works [10,11] mention the harmonic changes in values of loads acting on the supports. However, they do not describe the possibility of using these loads during dimensioning of undercarriage elements. In practice, however, there are numerous instances of fatigue fractures in undercarriage elements, what is presented in works [12,13]. In the case of motor vehicles, papers can be found where full modal analyses were performed for undercarriage elements [14].

This article presents research on the correlation between vibrations of the ŁZKS 1600 stacker-reclaimer superstructure (Fig. 1) and the harmonic changes in loads in undercarriage supports. The ŁZKS stacker-reclaimer is a material handling [15,16] machine mounted on a rail undercarriage, which operates at the coal homogenization yard in the Bełchatów Coal Mine.

2. Measurement system

The measurement system was designed in a manner which allows for the analysis of the dependency between the global mode shapes of superstructure vibrations and the variability of loads transferred to the undercarriage (Fig. 2). An accelerometer (high sensitivity differential MEMS DC accelerometer: 200 mV/g, ±10 g, 0–1000 Hz) with magnetic mount was placed on the end of the bucket wheel boom (BWB) perpendicularly to the horizontal plane of the boom. The strain gauges were placed on two main frames of the support trucks (Fig. 3). The bending of these frames is directly correlated with the load transferred by the portal supports. A half-bridge strain gauge was mounted on the trolleys of each of the four supports. The abovementioned accelerometer measures vibration frequencies as low as 0 Hz. This is particularly significants in the case of large-scale machines whose main natural frequencies most often do not exceed the level of 1 Hz [17]. Additionally, the gauge can measure the constant component, owing to which the time-traces clearly show when the boom stopped moving (Fig. 4). This is also significant as it allows the analysis of only those segments of the time-trace that are stationary in character. Measurements were provided with LMS Scadas

Fig. 1 – ŁZKS 1600 Stacker-reclaimer.