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THE STRUCTURE FAILURE OF THE DISCHARGE BOOM OF BUCKET WHEEL EXCAVATOR C 700 S DUE TO DYNAMIC EFFECTS

LOM KONSTRUKCIJE STRELE ODLAGAČA ROTORNOG BAGERA C 700 S USLED DINAMIČKIH UTICAJA

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Keywords
- bucket wheel excavator
- structural failure
- dynamic behaviour

Abstract

During operation, the bucket wheel excavator (BWE) has developed bad dynamic behaviour, plastic deformation and structural failure. After performed experimental-numerical analysis, resonant dynamic behaviour of the discharge boom has been confirmed. Adding a new tension bar has increased the dynamic stiffness of the discharge boom, and so the resonant behaviour has also vanished.

The numerical model is carried out by finite element method and the experiment is carried out by measuring the vibration on a pre-determined number of characteristic locations. The experiment, among other things, has confirmed the results of the numerical analysis.

Ključne reči
- rotorni bager
- lom konstrukcije
- dinamičko ponašanje

Izvod

Tokom operacije, kod rotornog bagera (BWE) se razvilo nepovoljno dinamičko ponašanje, plastična deformacija i lom konstrukcije. Posle sprovedene eksperimentalne/numeričke analize, potvrđeno je rezonantno dinamičko ponašanje strele odlagača. Dodavanjem novog elementa (štapa) je povećana dinamička krutost strele odlagača, pa je došlo do poništavanja rezonantnog ponašanja.

Numerički model je urađen metodom konačnih elemenata i izveden je eksperiment, merenjem vibracija na unapred utvrđenom broju karakterističnih mesta. Eksperimentom, pored ostalog, su potvrđeni rezultati numeričke analize.

INTRODUCTION

The operation of the BWE (Bucket Wheel Excavator), Figure 1, is often tracked with a very bad dynamic behaviour of the discharge boom. In the case of C700 S BWE, bad dynamic behaviour is reinforced by the appearance of resonance, where the amplitude of oscillations reaches up to 60 cm. This has led to a deterioration (cracking phenomenon) of the elements of the discharge boom, Figure 2.

This is especially emphasized on the supporting structure of the lifting boom cylinder.

In order to find the cause for this behaviour, a detailed calculation is made, based on the previous experience, as described in /1-12/. It has included calculations with rough (reduced) and fine sub-structure models of the discharge boom and the whole excavator. Each substructure enters its behaviour in the whole system.

STATIC AND DYNAMIC ANALYSIS OF THE EXISTING BOOM STRUCTURE

The spatial linear model of the structure's radius is reduced to the plane model. The computational plane model shown in Figure 3 will give an answer to the behaviour of the boom in the plane.

The load is represented as the net weight boom and payloads as well as structural elements that are not present in the model. Supports are the two joints. The hydro cylinder is modelled by a beam element which is pivotally attached at both ends. The pylon is also pivotally attached to the beam and at the junction of the cylinder and tie rod. We can conclude that this structure consists of a beam element and three-rod (tie rod, the pylon and cylinder). The deformed structure of the boom is shown in Figure 4.

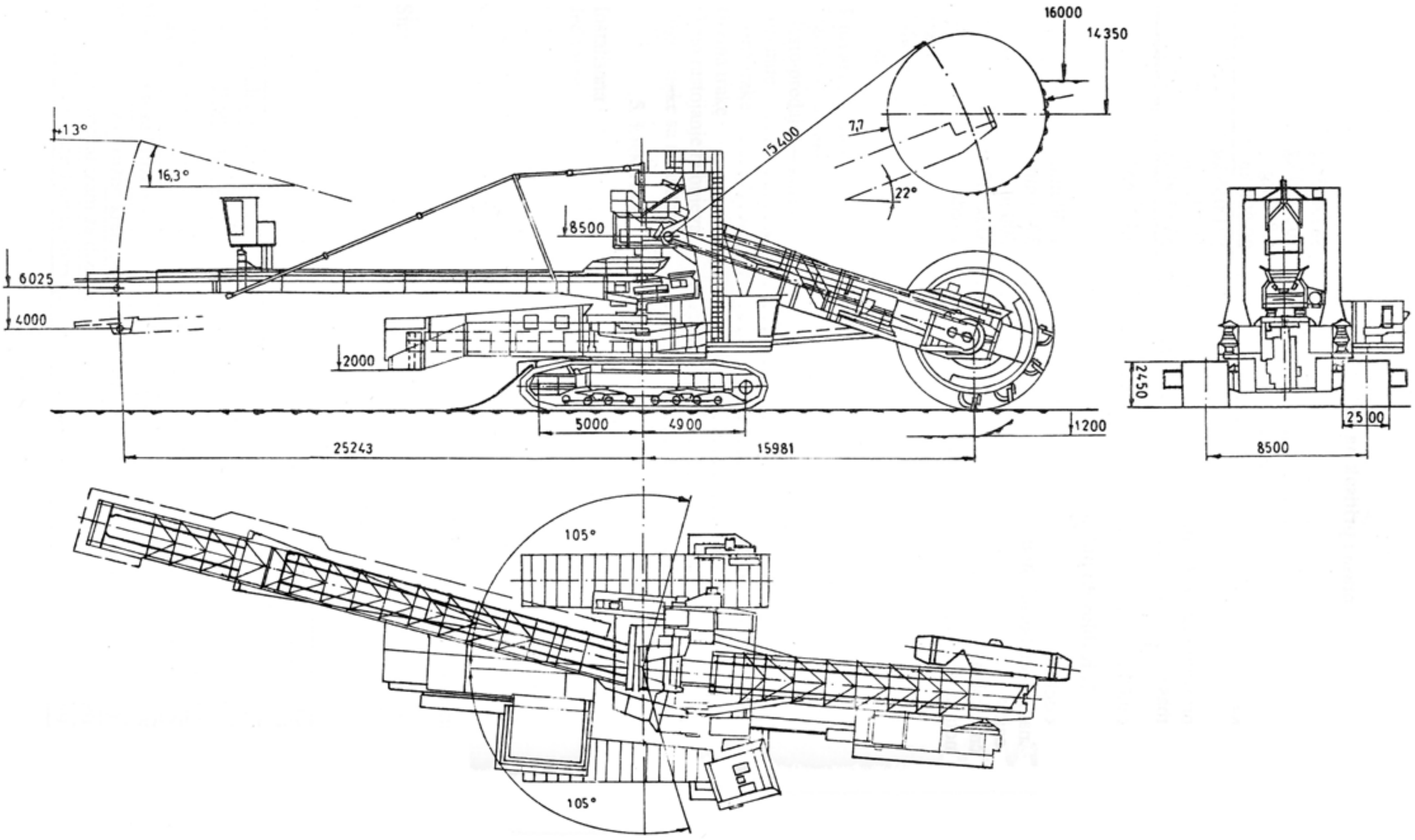


Figure 1. The Bucket Wheel Excavator C 700S – drafting overview.
Slika 1. Rotorni bager C 700S – pregled sklopa

Figure 2. Cracks on the mast of BWE.
Slika 2. Prsline na stubu BWE

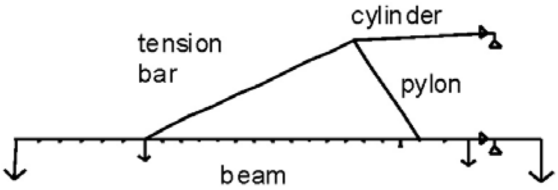


Figure 3. The computational plane model.
Slika 3. Proračunski ravanski model

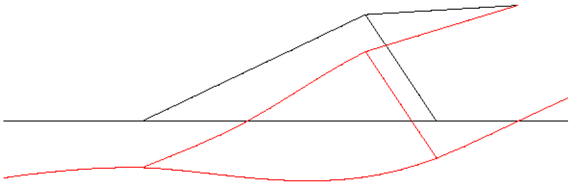


Figure 4. Deformed structure of the boom.
Slika 4. Deformisana konstrukcija strele

Dynamic analysis includes calculation of the first three undamped oscillations. The first four oscillations are shown in Figure 5. They also show the shape boom deformation for the case of resonance (overlap) with the excitation. The first three main types of oscillations are most important for consideration.

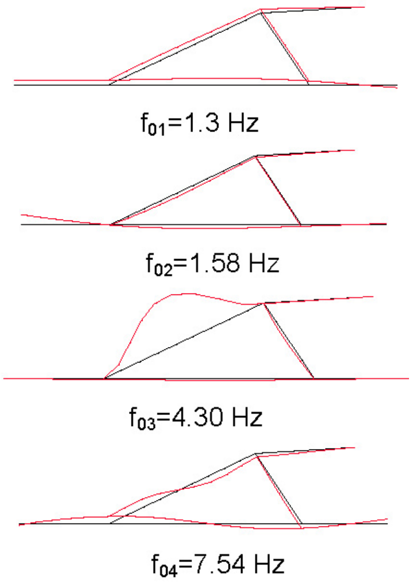


Figure 5. The first four oscillations.
Slika 5. Prve četiri oscilacije

The distribution of potential and kinetic energy to oscillations and substructures by the discharge boom is given in Table 1.

Table 1. Distribution of potential and kinetic energy to oscillations and substructures.
Tabela 1. Raspodela potencijalne i kinetičke energije na oscilacije i podstrukture.

	Potential / kinetic energy (%)	
	f_{01} = 1.3 Hz	f_{02} = 1.58 Hz
beam	80 / 35	90 / 16
tension rod	12 / 3	6 / 1
cylinder	8 / 0	4 / 0
pylon	0 / 0	0 / 0
external mass	62	73

Frequency characteristics of boom structure in the case of vertical excitation in the node that is connected to the tension rod, the pylon and the cylinder and the vertical response at the left end of the beam are given in Figure 6. *Comment*: a very large dynamic amplification factor and an unstable system.

The conclusion of calculations may be expressed:
- the first two frequencies are very low, very close to each other and match the static deformation,
- the dynamic amplification factor with 5% of damping is about 38 for the first and 30 second oscillation (too large), with a large imaginary part of the characteristics (unstable system) and,
- energies are dominant on the beam of the discharge boom and on external masses.

The basic element of dynamic optimisation is increasing the frequency and the distance between them.

On the basis of calculations, we can define the model variants that can lead to optimal solutions, and these are:
- remove the later added small house at the end of the boom (added mass),
- model with increased stiffness of the boom bending,
- model with a change in the position to do the pylon and the beam.

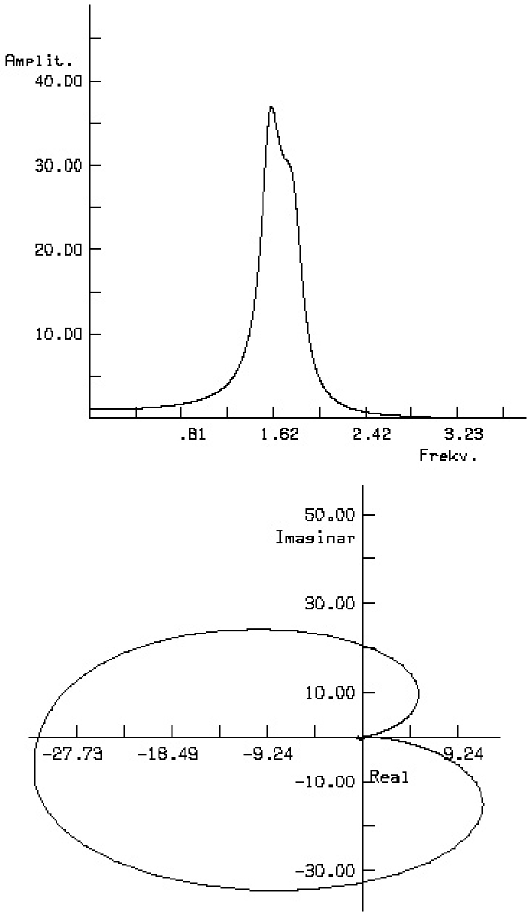


Figure 6. Frequency characteristics of boom structure.
Slika 6. Frekventne karakteristike konstrukcije strele

OPTIMISATION OF BOOM STRUCTURE

In order to obtain a model that largely fulfils the requirements, it is necessary to examine their effect on static and dynamic behaviour. Calculations of numerous variants must be made.

The geometry of the model variants are shown in Fig. 7.

Deformations of the model variant are shown in Fig. 8.

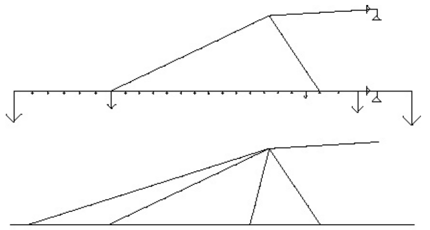
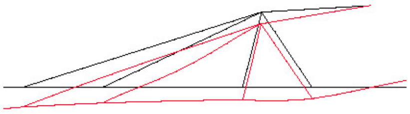
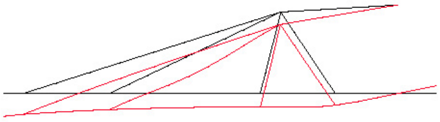


Figure 7. The geometry of the model variants.
Slika 7. Geometrija varijante modela



f_{max}=5.55 cm



f_{max}=5.15 cm

Figure 8. Deformation of the model variant.
Slika 8. Deformacija varijante modela

The deformation field indicates that the introduction of the new tension rod there was a drastic reduction of stress and its distribution on the beam.

CONCLUSION

Proposed are the following reconstructions of the discharge boom:

1) installation of two new tension rods, and
2) the removal of the small house for harmonisation of conveyor work.

As we can see in Figure 9, reconstruction is carried out successfully, according to research, as it is shortly shown above. There are no cracks at critical points.

Figure 9. BWE C700S after reconstruction with added new tension rods.
Slika 9. BWE C700S posle rekonstrukcije sa dodatnim novim zategnutim elementima (štapovima)

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