STRUCTURAL DYNAMIC MODIFICATION OF A TUBULAR COLLECTOR

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Abstract:

Dynamic modification of structures involves the transformation of an existing model in the new one, which has better behavior and higher accuracy in comparison with the existing. The main objective of a dynamic modification of the construction is to increase the first natural frequency, and that the gap between adjacent frequencies is as big as possible. This paper focuses on the improvement of dynamic characteristics of a tubular collector in one substation. It is shown how change of boundary conditions and the geometry of the cross section can improve dynamic characteristics of the structure. In this analysis the finite element method is used for calculating the natural frequencies, potential and kinetic energy in each node. In the particular case of a tube collector is confirmed once again, what was well known, that the change in the way of support (boundary conditions) is the most efficient way of dynamic modification. Additionally is shown one way to increase the dynamic stiffness while reducing the weight of the whole structure by choosing the right cross-section.

Key words: natural frequencies, potential and kinetic energy, boundary conditions, cross-section, finite element method

1. Introduction

The methodology of modification (reanalysis) of constructions is presented in [1], and includes the analysis of potential and kinetic energy in elements. It is shown how to deal with different cases of relations between potential and kinetic energy. Potential and kinetic energy are calculated using FEM software KOMIPS [2].

In [3] the authors deal with the problem of improving dynamic characteristics for a sub-structure of bucket wheel excavator, using methodology developed in [1], and gave several proposed modifications.

In [4] the authors applied procedure developed in [1] to deal with a problem of dynamic behavior of a wall side of a plastic container.

In this paper previously developed procedure is used to improve dynamic behavior of a tubular collector.

2. Dynamic modification of a tubular collector applying different boundary conditions

The existing tubular collector in the substation 400/110 kV is made of aluminum alloy AlSiMg9,5F22. Cross section of pipe is a ring bus Φ200 / 184mm, while the distance between two adjacent supports is 18m. The mass of the existing structure is 233kg.

For FEM calculations software KOMIPS is used. The structure is discretized into 10 beam elements (11 nodes connecting them).

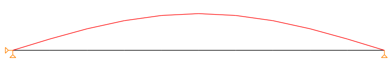
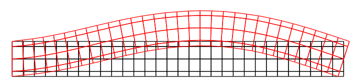
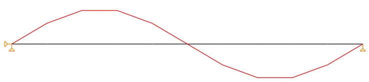
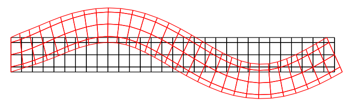
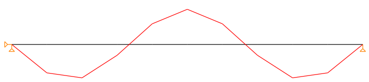
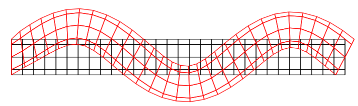
Forms of deformation	Forms of deformation, exaggerated case (beam is shorter, cross-section is larger)	Values of natural frequencies [Hz]
		f_1=1,67
		f_2=6,68
		f_3=15

Fig. 1. The first three oscillating modes, forms of deformation and natural frequencies, existing way of support (mobile and fixed support)

As can be seen the dynamic stiffness of the structure is small, since the first frequency is very low and close to 1.5 Hz (excitation due to wind), and the gap between adjacent frequencies is small.

Distribution of potential and kinetic energy in the nodes is shown.

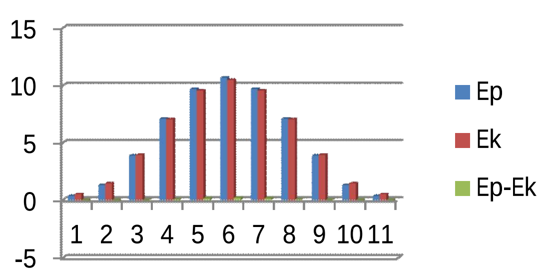


Fig. 2. Distribution of potential and kinetic energy in the nodes, existing way of support (mobile and fixed support), the first oscillating mode

Modified model 1

Instead hinged both ends of the tube collector are clamped, but temperature dilatation in the longitudinal direction must be provided, so one of the supports is plain wedged.

Form of deformation, the first oscillating mode	Values of natural frequencies [Hz]

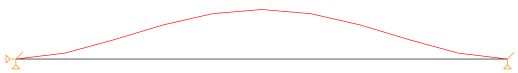
	f1=3,78 f2=10,42 f3=20,35

Fig. 3. Form of deformation for the first oscillating mode and natural frequencies for the first three oscillating modes, modified way of support (fixed and sliding wedged support)

Modified model 2

Compared to the previous example, instead of sliding wedged support, ordinary mobile support is used (the rotation of the mobile end of the beam is allowed).

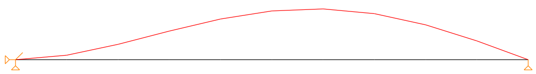
Form of deformation, the first oscillating mode	Values of natural frequencies [Hz]
	f1=2,61 f2=8,45 f3=17,58

Fig. 4. . Form of deformation for the first oscillating mode and natural frequencies for the first three oscillating modes, modified way of support (fixed wedged and ordinary mobile support)

The two proposed modified models have high dynamic stiffness as the first natural frequency of oscillation is quite high, and the gap between adjacent frequencies is large. Conditionally speaking preference may be given to the Modified model 2 because of the existing way of support. Pratcially, fixed support in the existing model can be easily converted to clamp (as shown in Fig. 5.), so Modified model 2 is taken as a good solution for a bad dynamic behavior.

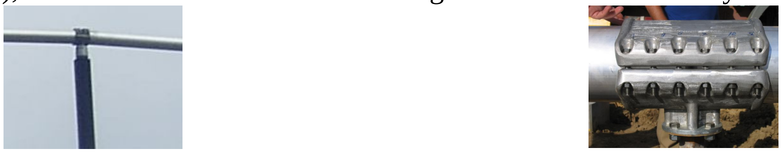


Fig. 5. Fixed support (photo on the left) is converted to clamp (photo on the right)

Here is shown how a small intervention in changing the way of support can improve dynamic rigidity of the system a lot.

Fig. 6. Inproved dynamic (and static) rigidity of the system by transforming fixed support into clamp

3. Dynamic modification of a tubular collector applying different boundary conditions

Modified model 3

Looking at Figure 2, the distribution of potential and kinetic energy in the nodes of the existing models of tubular collector, can be observed low level of potential and kinetic energy near the supports. These are those parts of the structure that are not sensitive to dynamic changes. Regarding the elements between them show a certain level of potential and kinetic energy, which means that these segments should increase rigidity, but so that the weight does not increase. For four elements in the middle of beam cross section is adopted Φ212 / 200mm, increasing the rigidity (greater distance of mass from the axis), while not increasing weight (reduced wall thickness). However, one should not expect much from this modification because the potential and kinetic energy, although higher than in the boundary elements, are relatively low.

Welded joint between segments Φ200 / Φ212 and 184mm / 200mm is performed per round Φ200mm.

Oscillating mode	Values of natural frequencies [Hz]
1	1,76
2	6,84
3	15,44

Table 1. Natural frequencies of annular beam with variable cross-section, existing way of support (mobile and fixed support)

Based on the previous calculation comparing the case with and without modifying cross-section, dynamic rigidity is slightly improved (1,76Hz), the weight has not increased (even decreased to 216kg). Taking into account that only a small modification in way of support can achieve great improvement (2,61Hz), this method of modification is not justified. Among other things, because the ejection of old and insertion (welding) new segments is too much intervention, and if you are willing to go to great intervention (replacing the existing tubes) would not be wrong to consider some aspects e.g. reducing the overall mass of the structure.

4. Dynamic modification of a tubular collector changing cross-section with decreasing mass of the whole system

Modified model 4

If the goal is to keep existing way of support, and to have a good dynamic behavior of Modified structure 2 (2,61Hz) while reducing the mass of the whole system, that leads to optimal cross-sectional shape. It could be a box cross-section (square bent sheet) external dimension 255mm and wall thickness of 2mm or annular cross-section Φ330 / 296mm. The box-cross section is used because of the smaller overall dimension.

Oscillating mode	Values of natural frequencies [Hz]
1	2,59
2	10,33
3	23,16

Table 2. Natural frequencies of box cross-section beam, existing way of support (mobile and fixed support)

Thus, compared to the existing tubular beam Φ200 / 184mm, this new box cross-section beam has the same static stiffness, significantly higher dynamic stiffness (it is set as a requirement at the beginning) and significantly lower mass (weight of existing is 233kg and new one 97kg).

5. Dynamic modification of tubular collector changing cross-section of the beam and the way of support, with the reduction of the mass

Modified model 5

This new box cross-section beam reduced weight, changing the way of support turning fixed support into clamp ensures that the first natural frequency is around 4Hz.

Oscillating mode	Values of natural frequencies [Hz]
1	4,04
2	13,05
3	27,1

Table 3. Natural frequencies of box cross-section beam, modified way of support (fixed wedged and ordinary mobile support)

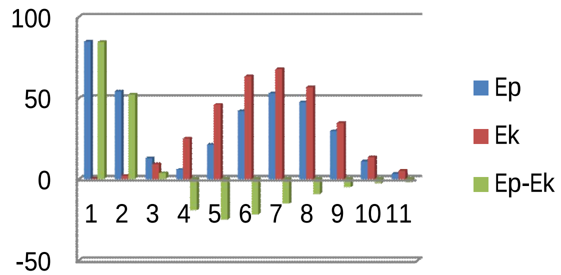


Fig. 8. Distribution of potential and kinetic energy in the nodes, box cross-section beam, modified way of support (fixed wedged and ordinary mobile support), the first oscillating mode

Modified model 6

Based on the above diagram the distribution of the kinetic and potential energy, can be observed that elements close to ordinary mobile support have low level of the kinetic and potential energy, so that these elements are not sensitive to changes. In elements close to clamp potential energy is dominant, so it is necessary to increase their rigidity, while in the other elements kinetic energy is dominant, so it is necessary to reduce their weight.

According to this, the first segment near clamp has a box cross-section outer dimension 259mm and wall thickness 2mm, thus increasing its rigidity. Other segments are box cross-section beams outer dimensions 255mm and wall thickness 1mm, which reduces their weight.

Oscillating mode	Values of natural frequencies [Hz]
1	4,4
2	13,95
3	28,38

Table 3. Natural frequencies of box cross-section beam with variable cross-section, modified way of support (fixed wedged and ordinary mobile support)

So compared to Modified model 5, first natural frequency is increased to 4,4Hz and the entire structure is lighter and has a mass of 53kg. However, compared to the previous structure under the action of static force this construction would have a 1,7 times greater deflections, so this is apparently unacceptable modification, but when you take into account the existing structure, this Modified model 6 has 1,3 times less deflections than the existing structure.

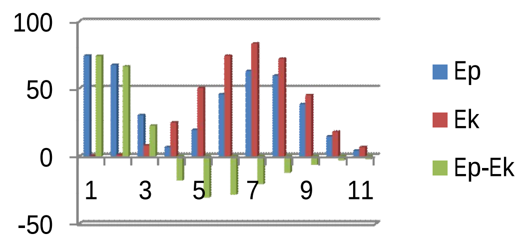


Fig. 9. Distribution of potential and kinetic energy in the nodes, box cross-section beam with variable cross-section, modified way of support (fixed wedged and ordinary mobile support), the first oscillating mode

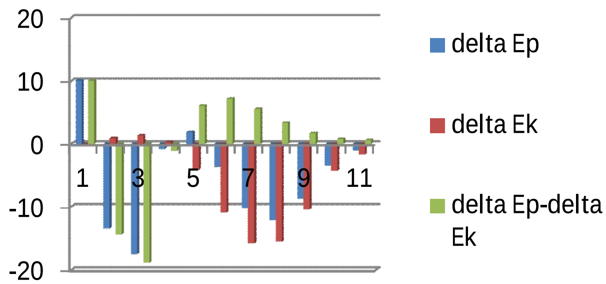


Fig. 10. Growth rate of potential and kinetic energy in the nodes for Modified model 5 and Modified model 6, the first oscillating mode

6. Conclusions

For a specific example of a tubular collector once again is confirmed what was well known, changing the way of support (boundary conditions) is the most efficient way of dynamic modification. Additionally, one way to increase the dynamic stiffness while reducing the weight of the whole structure by choosing the right cross-section is shown. Then based on distribution of kinetic and potential energy per segments of the structure is shown how to improve dynamical behavior of the structure by strengthening some segment, and weakening the others.

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