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# COMPUTER METHODS AS FASTENING FACTOR OF CONSTRUCTION DEVELOPMENT

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**Abstract** The development of new construction is fast due to using of computer methods especially Finite Element Method and simulation. The examples: high-reduced gear, piling-machine, light yacht and problem of structural damping are presented.

## Introduction

Considerable progress on development of new machines and vehicles is possible due to using computer methods, especially Finite Element Method and digital simulation. It is possible to fullfil general principles of design, formulated by Z. Osiński [1,2,3]. Many of problems realised during design of construction e.g. strength calculation, may be realised faster and more exactly, and it is possible to resign of many simplifying assumptions.

## 1. Design of new construction

Design of new construction must be realised according to general priciples of design, formulated by Z. Osiński [1,2,3]:

- *construction must be good,*
- *construction must be optimal.*

Moreover, construction must fullfil series of detailed principles of design, e.g. reliability and functionablity. Very important is economical evaluation of project - the method used to design gearbox is presented in work [5,6]. Handbooks [6,7] present the methods of design of power units: gearbox, brakes, clutches.

As an example is presented optimization of high-reduced gearbox. In particular two-stage planetary gear and differential planetary gear designed as in work by Maciejewski et al.[8] have been compared. The brief draft design was: gear ratio $i = 80$, transmitted power $N = 1$ kW, input rotational speed $n = 1500$ rpm.

The parameters of two-stage planetary gear were as follows:

| | | | |
|---|---|---|---|
| • number of teeth | $z_1 = 57$ | $z_2 = 198$ | $z_3 = 453$, |
| • normal modulus | $m_n = 0.5$ mm, | | |
| • width of the wheels: | | | |
| • I-st stage | $b_1 = 16$ mm | $b_2 = 16$ mm | $b_3 = 16$ mm, |
| • II-nd stage | $b_1 = 32$ mm | $b_2 = 32$ mm | $b_3 = 32$ mm, |
| • addendum modification | $x_1 = 0.425$ | $x_2 = 0.288$ | $x_3 = -1.003$, |

- 9 bearings on the planet gears axes.

The outline of the transmission is presented in Figure 1a.

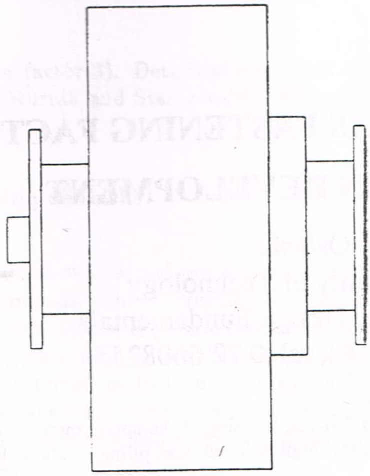

Fig. 1a.

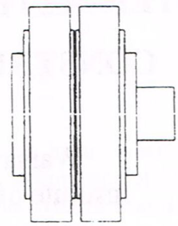

Fig. 1b.

The parameters of differential planetary gear were as follows:

- number of teeth $z_1 = 164$ $z_2 = 162$ $z_3 = 79$,
- normal modulus $m_n = 0.5$ mm,
- width of the wheels $b_1 = 26$ mm $b_2 = 26$ mm $b_3 = 53$ mm,
- 2 bearings on the planet gears axes.

The outline of the transmission is presented in Figure 1b.

Comparison of figures 1a and 1b clearly shows that differential planetary gear having similar parameters (gear ratio, mechanical efficiency) as two-stage planetary gear is significantly smaller, lighter and easier in manufacturing.

## 2. Strength calculations

Evaluation of stresses and straines of complex construction is possible, practically, only by FEM. As an example are presented stresses in tower of Piling-Machine PG-20 - Fig. 2 and Fig.3 (in critical zone). These results are obtained in work realised by order of *Road and Bridge Research Institute ( Warsaw)*. Another example are displacement in hull of light yacht - Fig.4 (these results are obtained by student M. Prugarewicz in diploma work).

## 3. Evaluation of machine's damping

Very important meaning have dynamic problems - protection of human from vibration and noise. Many publications by Z. Osiński [9,10] are devoted to problems of damping. The histeresis loop is proposed as a general description of damping [11]. Interesting, analitic resolving of free vibration of layered viscoelastic cantilever beam is presented in work [12].

Problem of damping in layred structures can be effectively analysed by FEM - an example is „floating floor" - Fig. 5

Continuous part discretisation has been carried out with the aid of ADINA program. Two dimensional net consisting of plane strain elements with 9 nodes has been created. The external layers have been divided onto 20×2 elements while the middle one onto 20×6 elements.

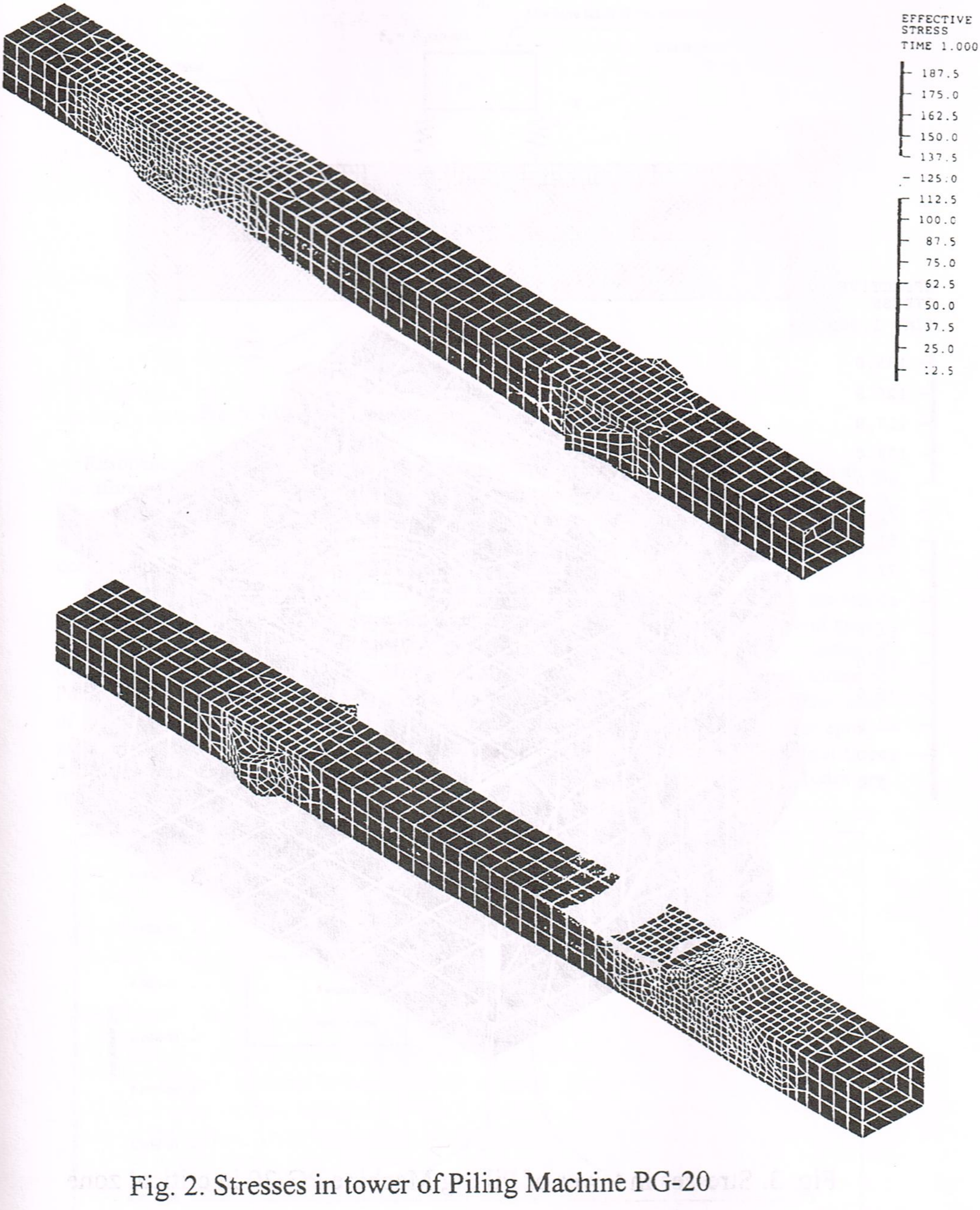


Fig. 2. Stresses in tower of Piling Machine PG-20

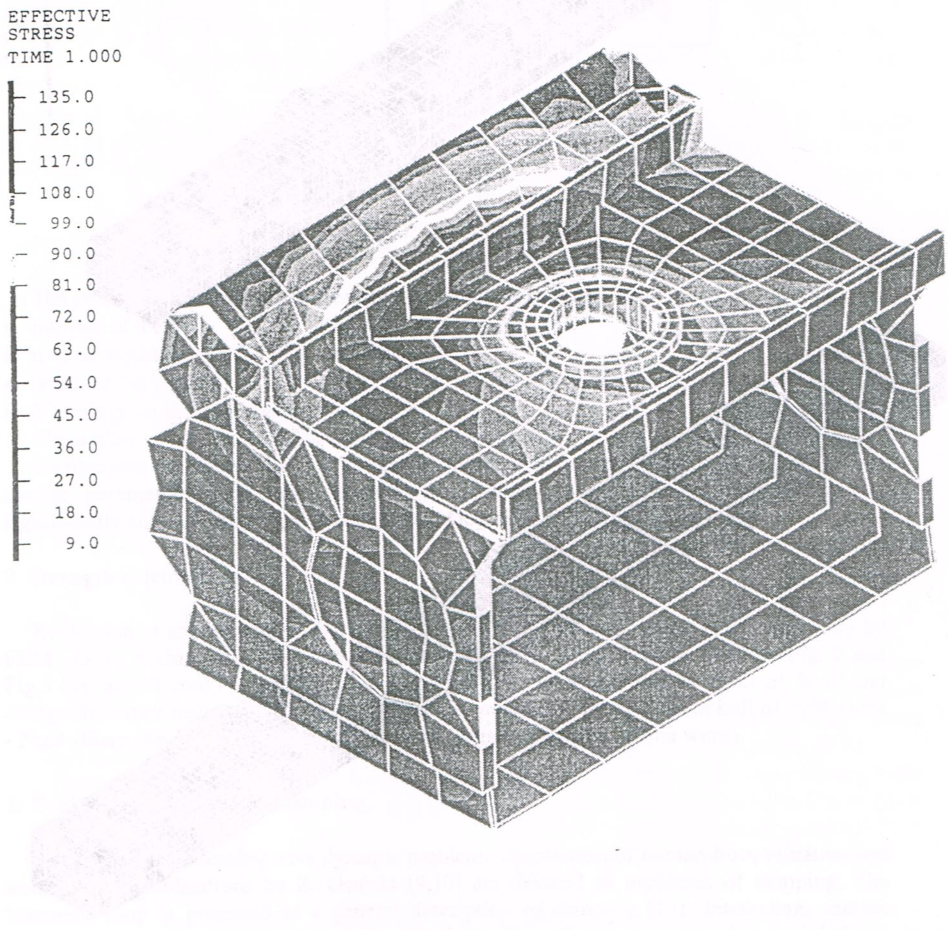


Fig. 3. Stresses in tower of Pilling Machine PG-20 in critical zone

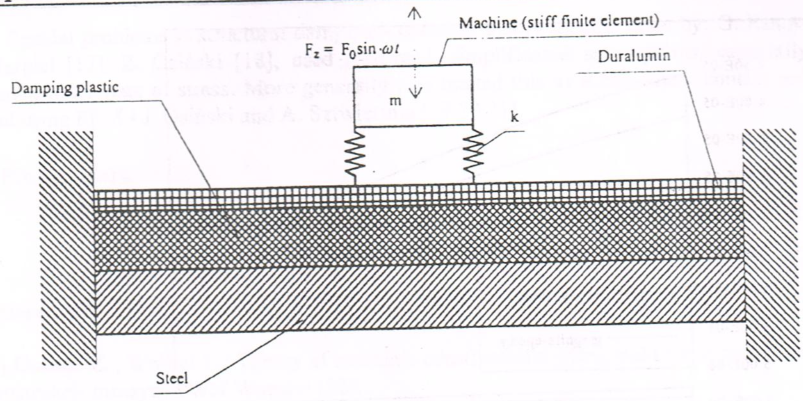


Fig. 5. Model of a machine connected to "floating floor"

Resonance curves in the range of first resonance have been determined for floor with all of the aforementioned materials. The stiff finite element has been excited harmonically with a force $F_0 = 5$ N (Fig. 5). The comparison of those curves is plotted in Fig. 6. Also the dependence of vibration amplitude on the distance from machine attachment has been considered. The results are plotted in Figures 6-7.

It can be seen that the resonance curves behaviour changes as various damping materials are used. Highest damping properties has damping plastic Paracril D then rubber and epoxy composite while the lowest ones of epoxy-graphite composite. The difference in properties of the last two materials is insignificant. On the other hand there is a significant disadvantage of Paracril D usage since the vibration amplitude is highest for this plastic (Fig. 7). It is the result of lower overall stiffness of two upper layers compared with the case of epoxy or epoxy-graphite composite. Thus the material that is best for vibration damping causes highest floor deflection and vibration amplitude values. For all other materials vibration amplitudes are smaller (Fig. 7).

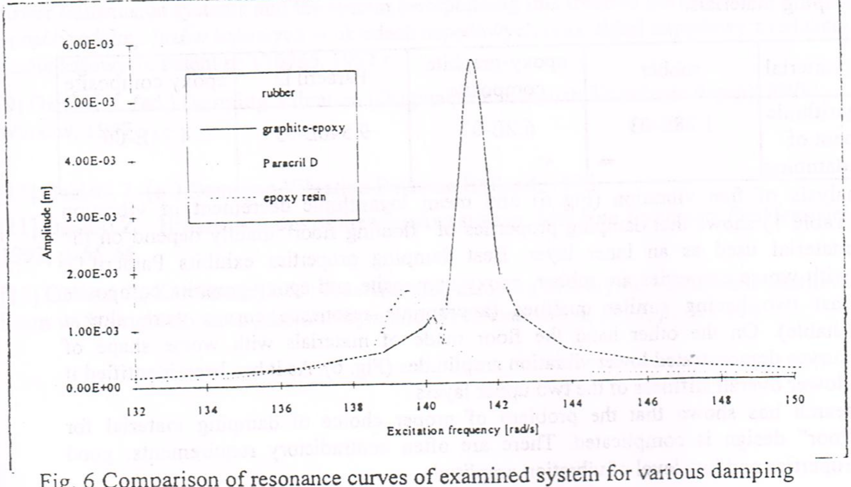


Fig. 6 Comparison of resonance curves of examined system for various damping materials in "floating floor"

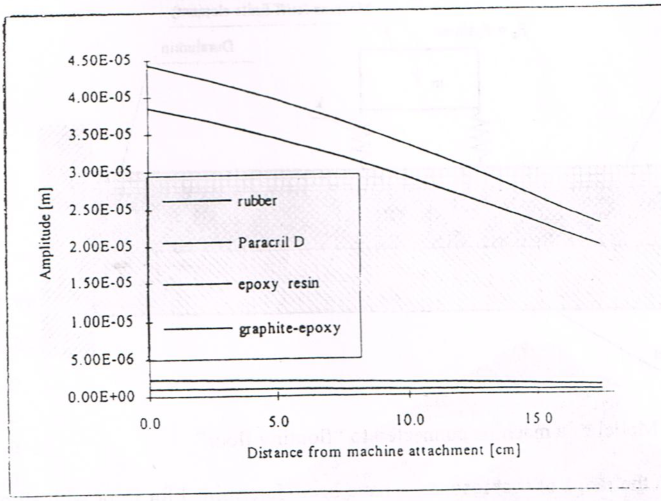


Fig. 7. Vibration amplitude of the "floating floor" points vs. the distance from machine attachment

Since the damping matrices were not diagonal for any of damping material the loss modules could not be computed. To judge the damping properties of various kinds of floors mean logarithmic decrement of vibration damping has been computed [13,14,15,16]. The time history for a certain time period of free vibration of stiff finite element after initial displacement by 0.5 mm in *z* direction (Fig. 5.) was calculated. Then it was possible to calculate mean logarithmic decrements of vibration damping presented in Table 1.

Table 1. The comparison of mean logarithmic decrements of vibration damping for floor with various damping materials.

| damping material | rubber | epoxy-graphite composite | Paracril D | epoxy composite |
|---|---|---|---|---|
| mean logarithmic decrement of vibration damping | 1.28E-03 | 6.2E-07 | 9.546E-03 | 4.74E-06 |

The analysis of free vibration (Fig. 6) and mean logarithmic decrement of vibration damping (Table 1) shows that damping properties of "floating floor" mainly depend on the damping material used as an inner layer. Best damping properties exhibits Paracril D. Materials with worse properties are rubber, epoxy composite and epoxy-graphite composite with the last two having similar qualities (appropriate resonance curves were almost indistinguishable). On the other hand the floor made of materials with worse shape of resonance curves demonstrated lower vibration amplitudes (Fig. 6). As it has been identified it was due to lower overall stiffness of the two upper layers.

The research has shown that the problem of proper choice of damping material for "floating floor" design is complicated. There are often contradictory requirements: good damping properties and low level of vibration amplitude.

Special problems is structural damping - classical theory of this, done by: G. Panowko, J. Giergiel [17], Z. Osiński [18], used restricted, simplificated assumptions, especially one-dimensional state of stress. More generally it is treated this as a non-linear contact problem, and using FEM - J. Osiński and A. Sztwiertnia [19,20,21].

**4. Final remark**

The development of new construction is fast due to using of *Finite Element Method.*

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