

CHAOTIC MOTION OF THE IMPACT FORCE GENERATOR

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Abstract

During the last years the interest of scientists in multibody mechanical systems in which the phenomenon of impact occurs has been still growing. In the present paper a principle of operation of the impact force generator being an element of the rotor of the heat exchanger has been presented. Step disturbances of the rotational velocity of the rotor caused by the generator are aimed at intensification of the heat exchange process.

Introduction

In numerous industrial machines the impact of their movable parts is either the basic principle of their operation or the effect which improves their operating efficiency. The classic examples of such machines or devices are: a pneumatic hammer, impact dampers, or heat exchangers [1]. One of the factors that contribute to intensification of the heat exchange process are disturbances in the rotational velocity of the rotor of the heat exchanger [2].

One of type of disturbances which can result in intensification of the heat exchange are step disturbances of the rotational velocity. The simplest way to generate such disturbances is to employ the phenomenon of impact which

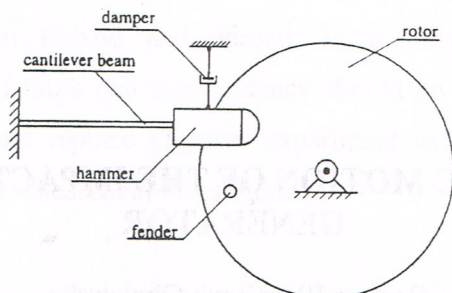


Figure 1. Schematic diagram of generator.

causes, according to the Newton's hypothesis, step variations of the velocity of the bodies impacting on each other.

Physical Model of the Generator

The object of considerations is a system composed of two main parts (Figure 1): a rotor equipped with a fender, driven by an electric engine, a hammer in the form of a cylinder with a semicircular end, mounted on the end of a cantilever beam. During the operation of the generator, the rotor fender impacts on the hammer, which causes vibrations of the hammer on one hand and the desired step variations of the rotational velocity of the rotor on the other hand. As the geometry of the generator is rather sophisticated, two various kinds of impacts occur during its operation: I - the fender collides with the cylindrical part of the hammer, II - the fender collides with the spherical part of the hammer. Equations of motion of the generator, and equations of impact have been presented in details in [3].

Influence of the Cantilever Beam Length on the System Operation

In order to evaluate the generator usefulness, the most important information is the average value of its angular velocity ω_a and the value of the velocity before the impact ω_{bi} and after the impact ω_{ai} .

Figure 2 presents a map of impacts for many generators which differ in the

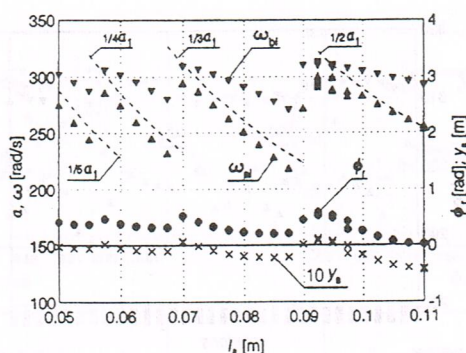


Figure 2. Impacts map for various l_s .

length of the cantilever beam l_s . The values of the angular velocity of the rotor before (ω_{bi}) and after (ω_{ai}) impacts and, additionally, the curves showing the values of the fractions of the basic frequency of free vibrations of the hammer: $1/2\alpha_1$, $1/3\alpha_1$, $1/4\alpha_1$ and $1/5\alpha_1$ have been shown on this map. In Here, a close relation between the variations of both the velocities ω_{ai} and ω_{bi} and the function of α_1 can be easily observed. For instance: when $l_s=0.07$ m, the rotor velocity ω_{bi} (close to its average angular velocity ω_a) is equal to approximately $1/3$ of the value of the basic frequency of free vibrations of the hammer α_1 . It means that the impact forcing of these vibrations has a subharmonic frequency.

An increase in the cantilever beam length causes of course a decrease in the value of $1/3\alpha_1$. Despite it, however, the hammer "wants" the impact forcing of its free vibrations to have a subharmonic character: the impacts are stronger and stronger, which, as a consequence, causes the diminishing of both ω_{bi} and ω_{ai} . This way of affecting the angular velocity by the hammer has been called the self synchronisation of the system. When l_s exceeds the value 0.0875 m, the conditions for easy generation of the hammer vibrations with the next subharmonic frequency $1/2\alpha_1$, arise and the situation repeats.

Regular and Irregular Motion

In the majority of cases presented in Figure 2, distinct, sharp contours of the markers can be seen. It means that the system motion is fully regular in these cases. In the vicinity of the first subharmonic resonance ($l_s = 0.0925$ m),

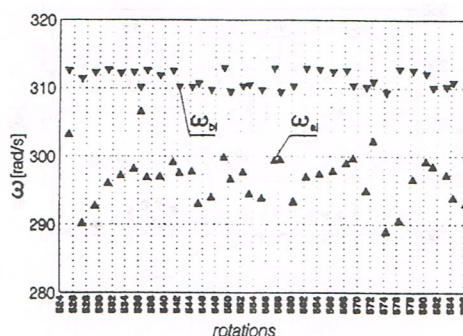


Figure 3. Global map of impacts; $l_s=0.0925$ m, $\Delta=\ln(1.5)$, $k=0.9$.

blurred columns of the markers can be seen, which indicates that the system motion has become irregular.

Figure 3 depicts a global map of impacts, on which it can be easily observed that the values of ω_{bi} and ω_{ai} during individual impacts are different, and, moreover, that impacts do not occur at all during some rotations of the rotor (e.g. rotation No. 526, 528, 530). In order to investigate the character of the system motion with $l_s=0.0925$ m in detail, maps of impacts showing the impacts occurring in the subsequent time intervals of the generator motion have also been drawn (Figure 4). As can be seen, despite the fact that the time passes, the motion does not become stable, and the motion assumes a chaotic character. Such a character of the motion is caused here by the occurrence of the impacts of the I and II kind and by the fact that the hammer and the fender often miss each other without impact.

Conclusions

The object of the numerical investigations presented here is a mechanical impact force generator. During the investigations it was found that in the majority of cases the system exhibited a regular motion. By a proper choice of the value of the basic frequency of free vibrations of the hammer it was possible to obtain desired changes both in the average rotational velocity of the generator rotor, and in the intensity of impacts. When the hammer is subject to the forcing close to the synchronic one, the motion of the system with the features of a chaotic motion can even occur.

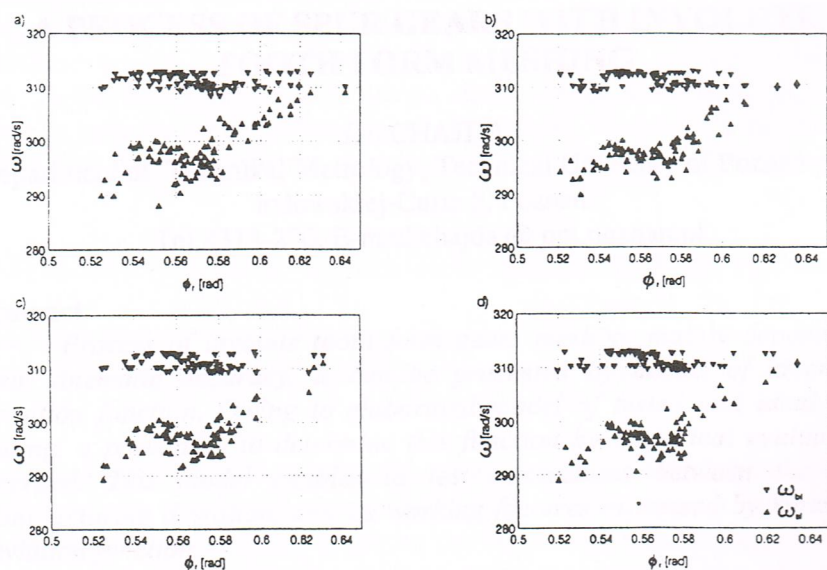


Figure 4. Local map of impacts; $l_s=0.0925$ m, $\Delta=\ln(1.5)$, $k=0.9$; a) $t=0-3$ s, b) $t=3-6$ s, c) $t=6-9$ s, a) $t=9-12$ s.

References

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