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THE EXPERIMENTAL INVESTIGATION OF AMPLITUDE – FREQUENCY CHARACTERISTICS OF CURRENT–CARRYING PLATES IN THE DIRECT MAGNETIC FIELD

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The bending waves of forced vibration of electro-conductive and ferromagnetic cantilever plates in direct magnetic field is experimentally considered. It is revealed that for the current–carrying plates, the character of the change in the frequency is essentially different from the analogical change in the same characteristics for the plate with no current. For the cantilever plates, the stability, depending on the influence of the magnetic field (MF), as well as on the quantity of the current and frequency of the forced vibration is investigated.

The experiments showed that for the plate placed in a longitudinal field, the increase of the magnetic field brings about an increase in the natural frequency. For the plate placed across the field, the increase of the magnetic field leads to the decrease in the natural frequency, and consequently to the loss of the stability, too. For the plate of comparatively average thickness, the dependency of the vibration frequency is of an experimental character. A point of minimum exists. The experimental character of the dependency “frequency – length of the wave MF” is also shown. It is also necessary to indicate that the character of the change in the frequency, depending on the current for the ferromagnetic plates is essentially different from the analogical dependecy for non- ferromagnetic current–carrying plates.

Keywords: magnetic field, frequency, characteristic, change.

Introduction. Theoretical investigations of the influence of the magnetic fields (MF) and currents on the behavior of plates have been considered in many works [1–13]. In these works, the stability of the plates are also studied. By application of hypothesis of non–deformable normal the linearizing equations, and the relations of magneto–elastic vibrations and stability of plates and shells are obtained [1,2,13]. The interaction of electro–conducting plates with direct MF in the space statement both theoretically and experimentally are investigated in [9]. It is shown that for large conductivity in a longitudinal field, two approaches give the same results, but in a transvere field, the yield is different. For the space statement, the longitudinal field leads to an increase in frequency, and the transvere field leads to a decrease in the frequency.

Aim of investigation. Numerous investigations of the influence of the MF and current have shown that the behavior of plates essentially depends on the relation of thickness of the plates and the length of the waves (from k_1h) where k_1 is the wave number in the direct axis; $Ox_1, 2h$ –the thickness of the plate [6,7,10-12].

For comparatively thick plates, the frequency of vibration, by increasing the MF, H_{01} increases. For very thin plates, by increasing the MF, H_{01} tends to zero. The following increase in H_{01} leads to an abrupt increase in the vibration frequency of the plates. For the plates with an average thickness, the dependence of the vibration frequency on H_{01} has an experimental character, – a point of minimum exists [13]. The experimental character of the dependence "frequency – MF – length of waves" is also shown in [3–5].

The abovementioned effects, i.e. the essential influence of MF on the amplitude – frequency characteristics of the console plate vibration both for aluminum and steel materials have been investigated experimentally in [4,5]. However, the mentioned experiments were made in the presence of MF only –without currents.

The impact of direct or alternating electrical currents on the behavior of the vibration of current–carrying plates, placed in a direct MF has been investigated theoretically in [6-8].

Method of investigation. The good of the present paper is the experimental investigation of bending waves of forced vibrations of electro-conductive and ferromagnetic cantilever plates in direct MF H_{01}, H_{02} or H_{03}.

Aluminum as an electro-conductive material and the steel current–carrying plates as a ferromagnetic material with different thicknesses were used. Plate 1 (Fig. 1) with length l, weight b and thickness $2h$ situated in the initial magnetic field H_{01}, H_{02} or H_{03} is loaded with an oscillating small force $P = P_0 \sin \omega t$ and is subjected to vibration. The direction of components of MF are indicated in Fig.1.

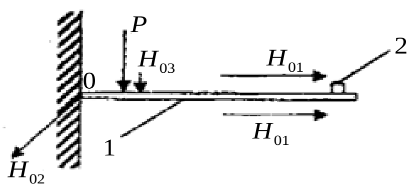


Fig.1. The diagram of the experiments

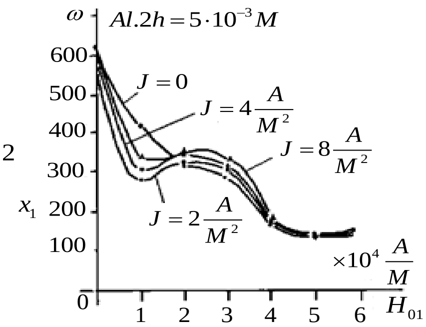
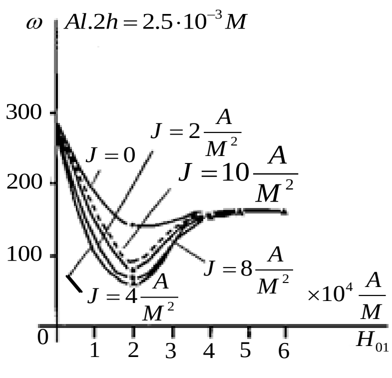


Fig.2. Dependece current of frequency on density



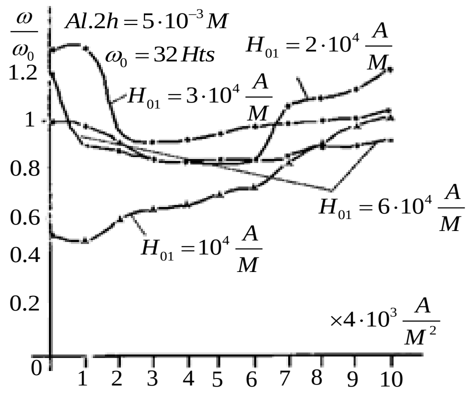


Fig.3. Dependence of frequency the relatively from current density

Fig.4. Dependence of the relatively frequency from current density

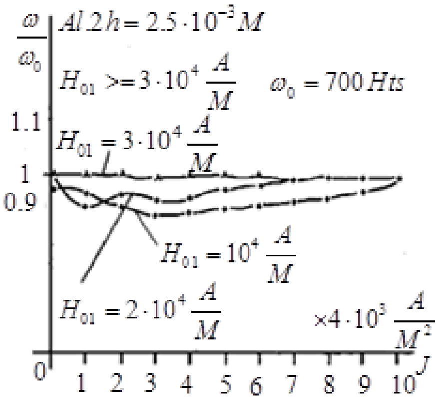


Fig. 5. Dependence of the relatively frequency from longitudinal MF

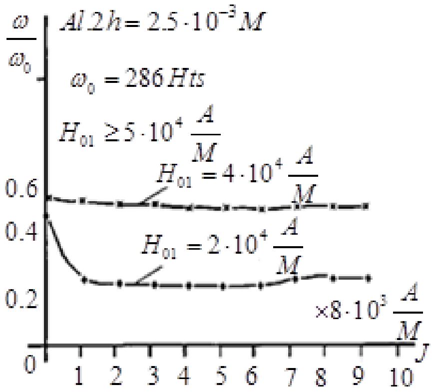
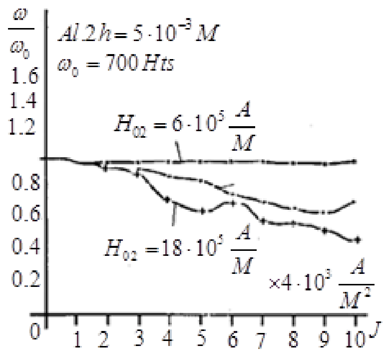


Fig. 6. Dependence of the relatively frequency from longitudinal MF

Signals obtained from the sensor element 2 (its weight is negligibly small with respect to the plates` weight), are given at the entrance into the amplifier of the oscillographs and into to the device, indicated the values of frequency, displacement, velocity and acceleration of the plates. The measurements of the abovementioned quantities are carried out at both the presence of MF and electrical currents, and the presence of MF and current separately, and at the absence of MF and currents.

The direct current I_{01} with density $I_{01}/2bt$ was conducted in the direction Ox_1.

By the change of frequency ω, the harmonics of vibrating plates were found. As P_0 is small, the sensitivity of the plates with respect to the change of MF and currents was relatively greater.



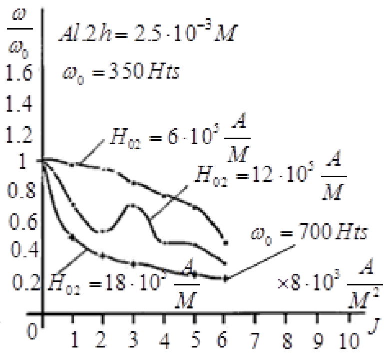
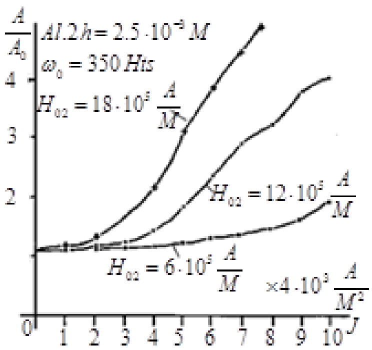


Fig. 7. Dependence of the relative frequency on longitudinal MF

Fig. 8. Dependence of the relative frequency on the longitudinal MF

The results of the experiment are presented in Fig.2–17. As it is shown, the graphs in Fig.2,3, for the fixed value of current, a significant change in frequency dependent on value of MF takes place.



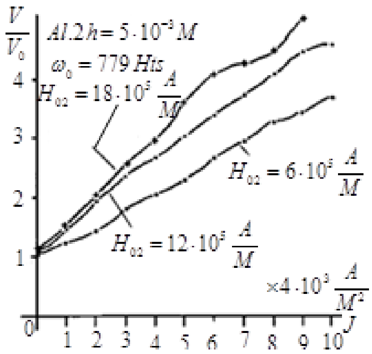
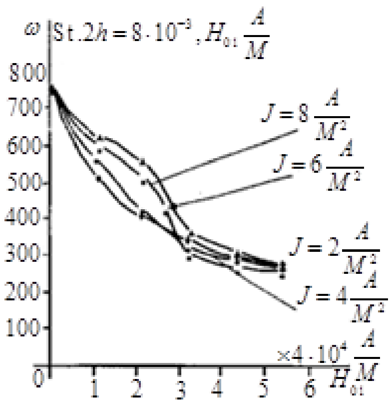


Fig. 9. Dependence of the relative amplitude on the current density

Fig. 10. Dependence of the relatively velocity of vibration on the cross–sectional MF

The change $\omega(I_0, H)$ has an experimental character. From Fig.4 it is seen, that the fixed value of the external MF H_{01} the increase of the current brings to the decrease of the frequency change.

The comparison of Fig.4 and Fig.5 indicates that in case of the same values of MF, the influence of the current decreases at the increase of harmonics. The result of the decrease by the plate thickness, the influence of the current becomes stable and for external MF $H_{01} \sim 5*10^4$ A/M, $\omega/\omega_0 \approx 0{,}54$ (Fig.6).



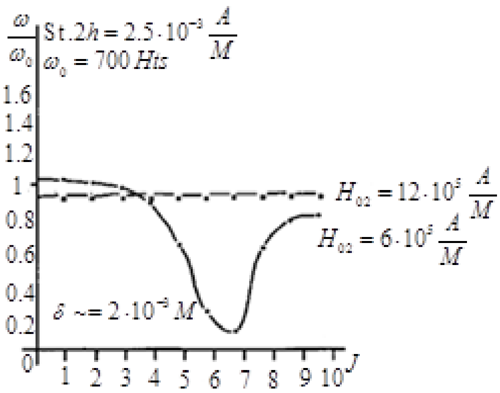
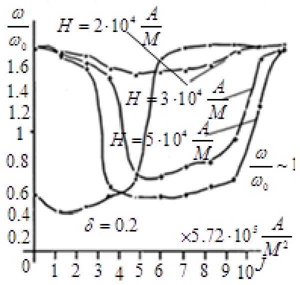


Fig. 11. Dependence of the frequency on the current density

Fig. 12. Dependence of the relative frequency on the current density in the cross–sectional MF

As it is shown by the experiment for materials with high conductivity, the change of $\omega/\omega_0, A/A_0$ (change in frequency and amplitude), the dependence on H_{01} and j (density of currents) becomes insignificant. In Fig.7–10 the dependences of the investigated quantities in field H_{02} are brought. As the plate has the least rigidity in this case, the changes of frequencies, amplitudes and velocities of vibration are more essential. As it is seen from the following formulae, obtained in [6-8]:

$$\frac{\omega}{\omega_0} = 1 - \frac{J_0^2}{J_*^2} \tag{1}$$



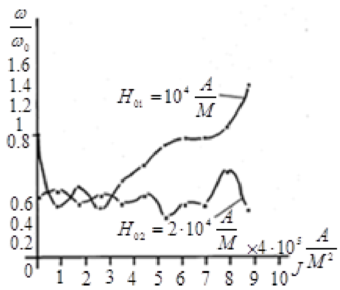


Fig. 13. Dependence of the relative frequency on the MF

Fig. 14. Dependence of the relative frequency on a diferent MF

(where J_*^2 is the critical value of the current for the which $\omega = 0$, ω_0 is the frequency of the plate in the case $J_* = 0$) the decrease of frequency has a monotonous character.

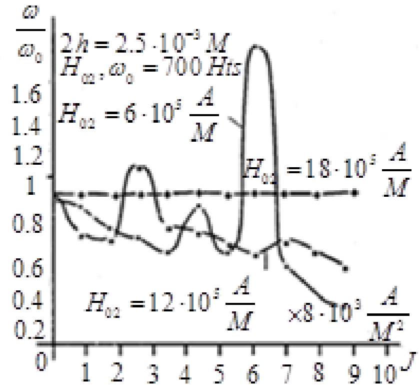


Fig. 15. Dependence of the relative frequency on diferent MF

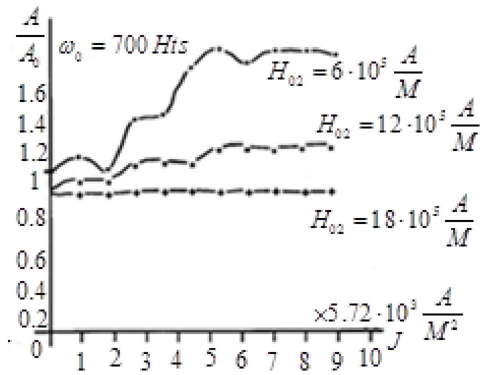


Fig. 16. Dependence of the relative amplitude on the current density

However, as it is shown by the experimental results obtained in this paper and in [10,11], the dependences of $\frac{\omega}{\omega_0}(J)$, $\frac{\omega}{\omega_0}(H)$ are vibratelly diminished. The experiments also show that for small frequencies $\sim \omega_0 = 300 \div 350$ Hts and for the value of the current density $\sim 1 \div 2 \cdot 4 \cdot 10^3 \frac{A}{M^2}$ a decrease in frequency takes place (Fig.4).

These results for small MF, when *j=0,* was also obtained in [10,11].

Analogical results for steel plates are introduced in Fig.11–17.

Using the calculation results of thickness of skin–layer δ for different frequencies and materials obtained in [14], the qualitative estimation for relation δ/h is indicated in the figures.

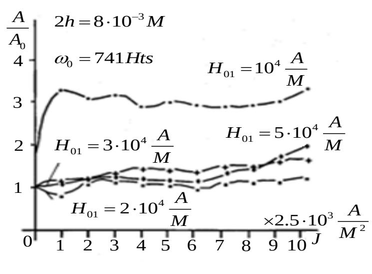


Fig.17. Dependence of the relative amplitude on the current density

Analaze of obtaining results. The graphs one can plot by analyzing the conclusions, that for the current–carrying plates, the character of the change of frequency is essentially different from analogical changes of the same characteristics for the plate with no current. It is also necessary to indicate that the character of the frequency change is dependent on the current for ferromagnetic plates are essentially different from the analogical dependence for non-ferromagnetic current–carrying plates. This phenomenon can explain that for ferromagnetic plates, beginning from the same value of MF magnetization and saturation of materials of plates takes place, consequently also the phenomenon of frequency change saturates.

Finally, it is necessary to indicate that the presence of the current essentially influences the character of the change $\omega(H)$, as it is clear from Fig.11.

Conclusion. For the current–carrying plates the character of the frequency change is essentially different from the analogical change of the same characteristics for the plate with no current. The character of the frequency change is dependent on the current for ferromagnetic plates is essentially different from the analogical dependence for non-ferromagnetic current–carrying plates. The obtained experimental results qualitatively describe the amplitude–frequency characteristics which coincide with the known theoretical results.

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ՀԱՍՏԱՏՈՒՆ ՄԱԳՆԻՍԱԿԱՆ ԴԱՇՏՈՒՄ ԳՏՆՎՈՂ ՀՈՍԱՆՔԱՏԱՐ ՍԱԼԻ ԼԱՅՆՈՒԹԱ-ՀԱՃԱԽԱՅԻՆ ԲՆՈՒԹԱԳՐԻՉՆԵՐԻ ՓՈՐՁԱՐԱՐԱԿԱՆ ՈՒՍՈՒՄՆԱՍԻՐՈՒԹՅՈՒՆԸ

Ա.Ա. Վանցյան

Ուսումնասիրվել են էլեկտրահաղորդիչ և ֆերոմագնիսական կոնսոլային սալերի հարկադրական ծռման ալիքները հաստատուն մագնիսական դաշտում։ Փորձարարական ճանապարհով ստացված է, որ հոսանքատար սալերի համար հաճախության փոփոխման բնութագիրն էապես տարբերվում է ոչ հոսանքատար սալերի համանման փոփոխություններից։

Ուսումնասիրված է մի ծայրում կոշտ ամրացված սալի կայունության հարցը՝ կախված ինչպես մագնիսական դաշտի ուղղությունից, այնպես էլ հոսանքի մեծությունից։ Ընդլայնական դաշտում սալի գտնվելու դեպքում դաշտի մեծացումը հանգեցնում է սեփական հաճախության փոքրացմանը, հետևաբար՝ նաև սալի կայունության կորստին։ Համեմատաբար միջին հաստությամբ սալերի դեպքում տատանման հաճախության կախվածությունը կրում է էքստրեմալ բնույթ. գոյություն ունի մինիմումի կետ։ Ցույց է տրված նաև «հաճախություն–ՄԴ ալիքի երկարություն» կախվածության էքստրեմալ բնութագիրը։ Փորձերը ցույց են տվել, որ երկայնական դաշտում գտնվող սալի դեպքում դաշտի մեծացումը հանգեցնում է սեփական հաճախության մեծացմանը։ Անհրաժեշտ է նաև նշել, որ հաճախության բնութագրիչների փոփոխությունը, կախված հոսանքից, ֆերոմագնիսական սալերի դեպքում էապես տարբերվում է ոչ ֆերոմագնիսական հոսանքատար սալերի համանման կախվածությունից:

Առանցքային բառեր. մագնիսական դաշտ, հաճախություն, բնութագրիչ, փոփոխություն:

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ АМПЛИТУДНО–ЧАСТОТНЫХ ХАРАКТЕРИСТИК ТОКОНЕСУЩИХ ПЛАСТИН, НАХОДЯЩИХСЯ В ПОСТОЯННОМ МАГНИТНОМ ПОЛЕ

А.А. Ванцян

Экспериментально исследованы изгибные волны вынужденных колебаний электропроводящих и ферромагнитных консольных пластин, находящихся в постоянном магнитном поле. Выявлено, что характер изменения частоты для токонесущих пластин существенно отличается от аналогичных изменений тех же характеристик пластин при отсутствии тока. Для консольной пластины изучен также вопрос устойчивости в зависимости от влияния магнитного поля, а также от величины тока и частоты вынужденных колебаний. Эксперименты показали, что для пластины, находящейся в продольном поле, увеличение магнитного поля приводит к увеличению собственной частоты. Для пластины, находящейся в поперечном поле, увеличение магнитного поля приводит к уменьшению собственной частоты, а следовательно, и к потере устойчивости. Для пластин сравнительно средней толщины зависимость частоты колебаний носит экспериментальный характер, существует точка минимума. Показан также экспериментальный характер зависимости ″частота–длина волны МП″. Необходимо отметить, что характер изменения частоты в зависимости от тока для ферромагнитных пластин существенно отличается от аналогичной зависимости для не-ферромагнитных токонесущих пластин.

Ключевые слова: магнитное поле, частота, характеристика, изменение.