THE EXPERIMENTAL INVESTIGATION OF AMPLITUDE – FREQUENCES CHARACTERISTICS OF CURRENT–CARRYING ELECTROCONDUCTING AND FERROMAGNETIC PLATES IN THE DIRECT MAGNETIC FIELD

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Abstract

The bending waves of forced vibration of electro conducting and ferromagnetic cantilever plates in direct magnetic field experimentally was considered. It is experimentally obtained, that for the current–carrying plates the character of change of frequency is essentially different from analogical change of the same characteristics for the plate, where the currents is absent. For the cantilever plates the stability, depending from the influence of the magnetic field (MF) and from the quantity of the current and frequency of the forced vibration was investigated.

The experiments showed, that for the plate placed in a longitudinal field, the increase of the magnetic field brings to the increase of the proper noun frequency. For the plate placed across the field, the increase of the magnetic field brings to the decrease of the proper noun frequency, consequently to the loss of stability too. For the plate comparatively with the middle thickness the extremely character depending on the vibration frequency takes place. The point of minimum exists. The extremely character depending on “frequency – length of wave MF” is also showed. It is also necessary to indicate that the character of change of frequency is dependent from the current, for ferromagnetic plates are essentially different from analogical dependents for non ferromagnetic current–carrying plates. The obtaining results one can opplicate in different regin sphere of the life. Particulary the results may be use in electrical machins, in communicatron, computers, flying machins.

Keywords: magnetic field, frequency, character, change.

INTRODUCCIÓN

The theoretical investigations of the influence of the magnetic fields (MF) and currents on the behavior of plates were considered in many works [1–13]. In these works the stability of the plates are also investigated. 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 longitudinal field two approaches give the same results, but in transvers field the yield different results. For the space statement, the longitudinal field leads to increasing of frequency, and transvers field leads to decreasing of frequency. Numerous investigations of influence of MF and current shown that the behavior of plates essentially depends on relation of thickness of plates and length of waves (from k_1h) where k_1 is waves number in direct of axis $Ox_1, 2h$ – thickness of plate [6,7,10,11,12].

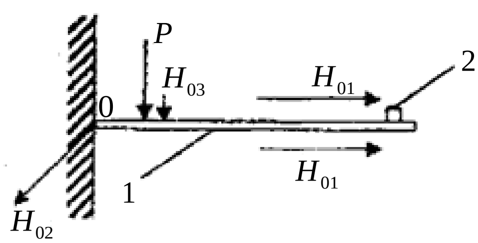
For the comparative thick plates the frequency of vibration, by increasing of MF H_{01} on larges. For the very thin plates by increasing of MF H_{01} the frequency of vibration decreasing, tends to zero. The following increase of H_{01} brings to abrupt increase of frequency of vibration of plates. For the plates with the "middle" thickness the dependence of frequency of vibration from H_{01} have extremely character, – the point of minimum exists [13]. Extremely character of dependence of "frequency – MF – length of waves" was showed also in [3–5].

Above mentioned effects i.e. the essential influence of MF on amplitude – frequency characteristics of vibration of console plates as for aluminum as for steel materials were investigated experimentally in [4,5]. However the mentioned experiments had been made in the presence of MF only –without currents.

The influence of direct or alternating electrical currents on the behavior of vibration of current–carrying plates, placing in direct MF was investigated theoretically in [6,7,8].

The aim of the present paper is the experimental investigation of bending waves of forced vibration of electro conducting and ferromagnetic cantilever plates in direct MF H_{01}, H_{02} or H_{03}.

The aluminum as electro conducting materials was used and the steel current–carrying plates were used as ferromagnetic with different thickness. The plate 1 (Fig. 1) with length l, weight b and thickness $2h$ situated in initial magnetic field H_{01}, H_{02} or H_{03} is loaded by 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.



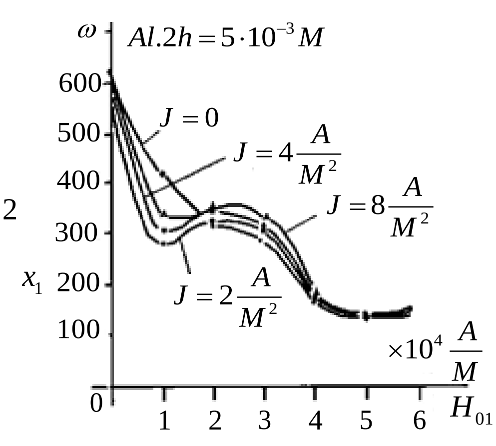
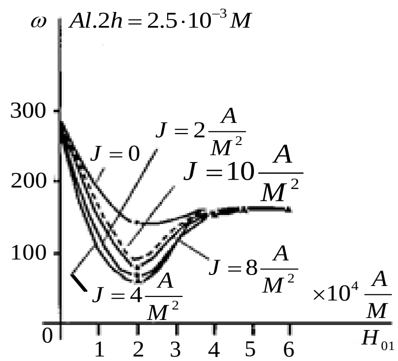


Fig.1 Principal scheme of the experiments Fig.2 Dependens of frequency from current density



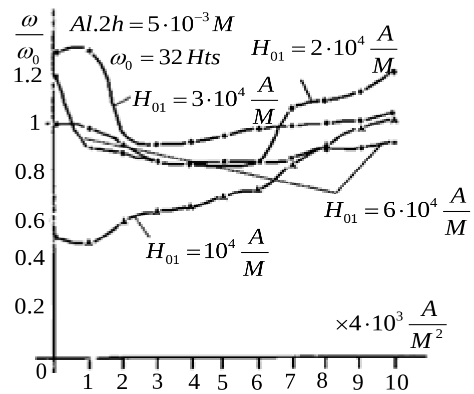
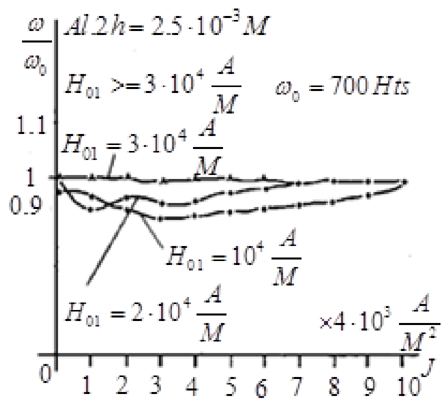


Fig.3 Dependens of frequency from current density

Fig.4 Dependence of the relatively frequency from current density



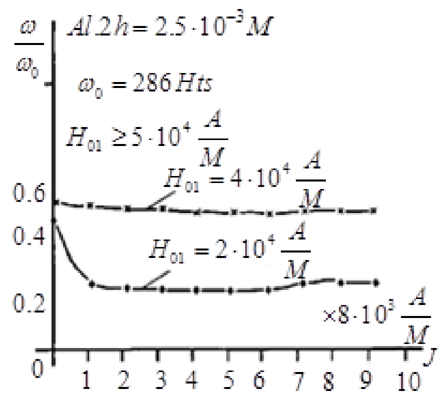


Fig. 5 Dependence of the relatively frequency from longitudinal MF

Fig. 6 Dependence of the relatively frequency from longitudinal MF

Signals obtained from the sensor element 2 (weight of it is negliclably small with respect to plates weight), are given at the entrance to the amplifier of the oscillographs and to the device, indicated the values of frequency, displacement, velocity and acceleration of plates. Measurements of the above mentioned quantities are carried out as at the presence of MF and electrical currents, as at the presence of MF and current separately, and at the absence of MF and currents.

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

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

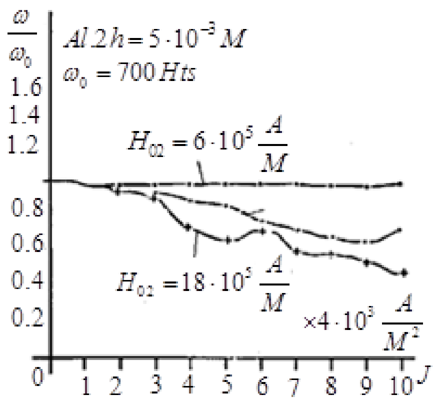


Fig. 7 Dependence of the relatively frequency from longitudinal MF

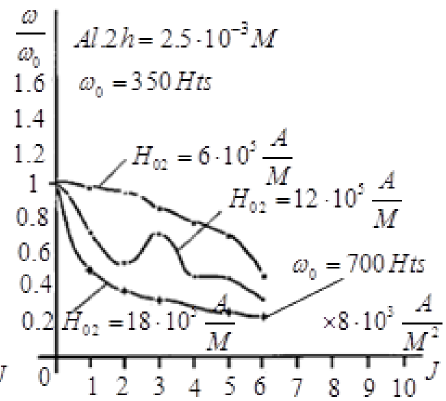


Fig. 8 Dependence of the relatively frequency from longitudinal MF

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

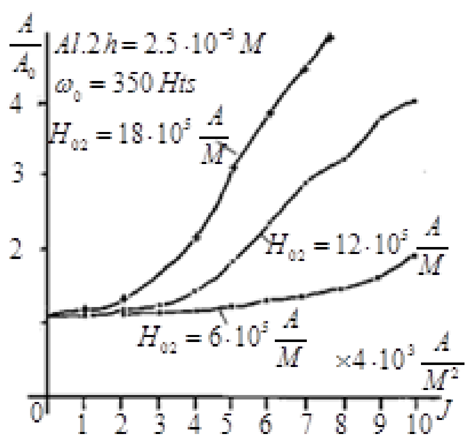


Fig. 9 Dependence of the relatively amplitude from current density

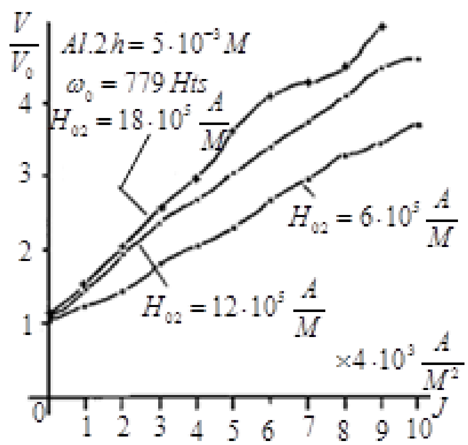


Fig. 10 Dependence of the relatively velocityof vibration from cross–sectional MF

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

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

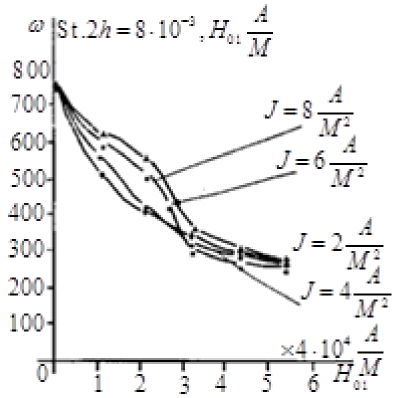


Fig. 11 Dependence of the frequency from current density

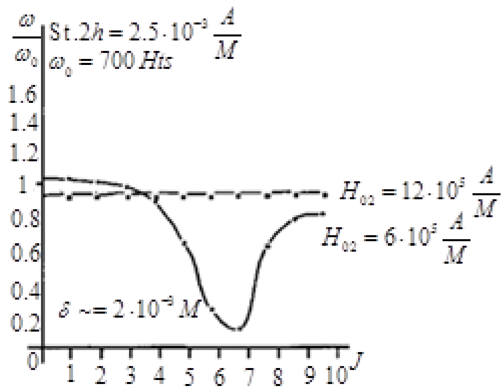
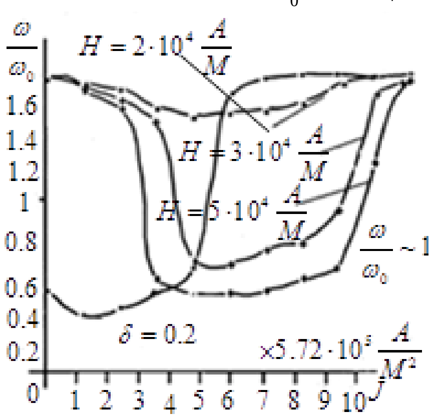


Fig. 12 Dependence of the relatively frequency from current density in the cross–sectional MF

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

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



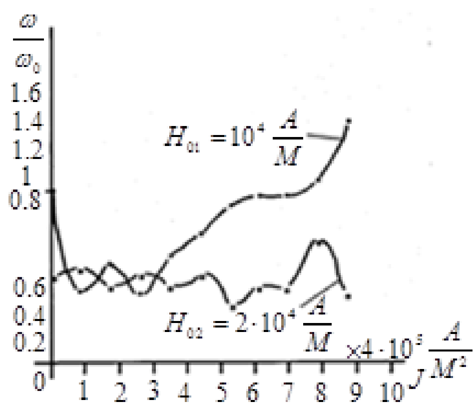


Fig. 13 Dependence of the relatively frequency from MF

Fig. 14 Dependence of the relatively frequency from diferent MF

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

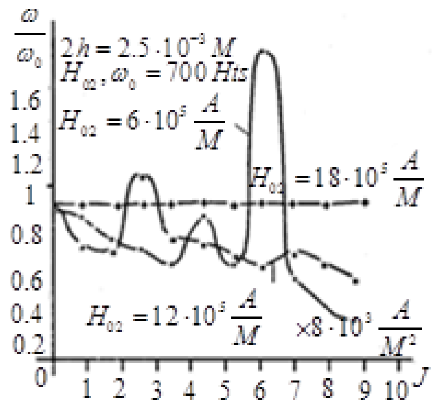


Fig. 15 Dependence of the relatively frequency from diferent MF

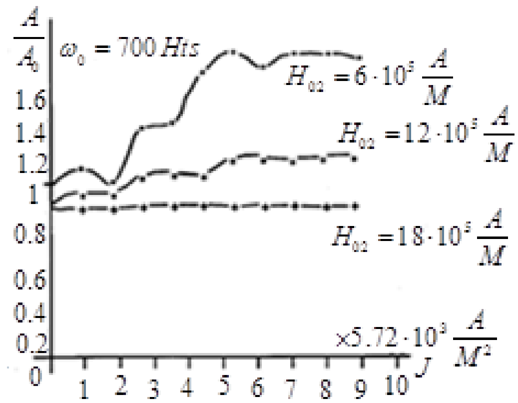


Fig. 16 Dependence of the relatively amplitude from current density

However, as it is shown by the experimental results, obtaining in this papers 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 $\sim\omega_0 = 300\div350$ Hts and for the value of current density $\sim1\div2\cdot4\cdot10^3\frac{A}{M^2}$ the decrease of 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 brought on Fig.11–17.

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

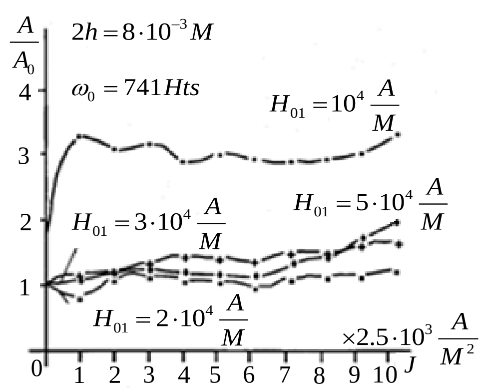


Fig.17 Dependence of the relatively amplitude from current density

The graphs one can come to with the help of analysis the conclusions, that for the current–carrying plates the character of change of frequency is essentially different from analogical changes of the same characteristics for the plate, where the currents is absent. It is also necessary to indicate that the character of change of frequency is dependent from the current, for ferromagnetic plates are essentially different from analogical dependents 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 on the character of change $\omega(H)$, as it is clear from Fig.11.

Conclusion. For the current–carrying plates the character of change of frequency is essentially different from analogical change of the same characteristics for the plate, where the currents is absent. The character of change of frequency, is dependent from the current, for ferromagnetic plates is essentially different from analogical dependents for non ferromagnetic current–carrying plates. The obtaining experimental results are qualitatively described the amplitude–frequency characteristics, which are coincides with the theoretical known results.

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