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Fig. 1

Figure 1: Fig. 1

Abstract

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ON THE INFLUENCE OF SURFACE IMPERFECTIONS ON THE PROPAGATION OF RAYLEIGH WAVES

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1. In connection with the many practical uses of surface Rayleigh waves (seismology, seismic prospecting, surface flaw detection, delay lines), the question of the influence of surface imperfections on the propagation of these waves is of substantial interest. It is known that various surface defects in the path of a Rayleigh wave lead to its attenuation, create a reflected Rayleigh wave, and also longitudinal and transverse waves scattered into the depth of the medium. In the present work the influence of isolated surface imperfections is investigated experimentally. Certain models of surface imperfections are considered, and the reflection of Rayleigh waves from these models and their passage through them are studied. As models of surface imperfections the following were chosen: a slit cut in the surface along which the Rayleigh wave propagates, a semicylindrical recess on the surface, and a wedge with different opening angles (Fig. 1). The first two models may represent defects of the crack and dent type; the last model may represent surface kinks; moreover, the faces of the wedge may be regarded as the side surfaces of defects whose depth is greater than the thickness of the localization layer of the Rayleigh wave. The investigations were carried out for the case in which the slit, the semicylindrical recess, and the edge of the wedge are perpendicular to the direction of propagation of the Rayleigh wave.

Fig. 1

2. The measurements were made in a pulsed regime at a frequency of 3 Mc/s; the pulse duration was 10 μsec. Rayleigh waves were excited on the flat side surfaces of rectangular metal rods. Excitation and reception of Rayleigh waves were carried out by the "plastic wedge" method described in work ([1]). A set of duralumin rods was available with slits and semicylindrical

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

recesses on the side surfaces, as well as a set of duralumin rods whose ends were cut at acute and obtuse angles to the axis. The side surfaces of all rods were carefully machined.

3. Figures 2–4 present the measurement results. Here the abscissas show, respectively: the wedge opening angle θ in degrees, the slit depth in wavelengths h/λ, and the ratio of the radius of the semicylindrical recess to the wavelength R/λ. The ordinates in each graph show the values of the reflection coefficient of Rayleigh waves from the corresponding model (A_{refl}), the coefficient of passage through it (A_{trans}), and also the quantity $A_{\text{refl}}^2 + A_{\text{trans}}^2$, representing the ratio of the total energy of the transmitted and reflected Rayleigh waves to the energy of the incident wave. A rigorous interpretation of the dependences obtained requires the solution of diffraction problems—

of Rayleigh waves on a wedge, a slit, and a semicylindrical recess, which is extremely difficult. We shall confine ourselves only to stating a number of experimental facts and explaining some features of the curves obtained.

First of all, let us note that the quantity $A_{\text{refl}}^2 + A_{\text{trans}}^2$ is always less than unity, i.e., part of the energy of the incident Rayleigh wave is always transformed into the energy of longitudinal and transverse waves scattered by the faces of the wedge, the slit, and the semicylindrical recess; moreover, the slit and a recess of radius $R > 0.25\lambda$ scatter most strongly. The transformation of the waves is connected with the fact that the combination of incident, reflected, and transmitted Rayleigh waves cannot satisfy the condition of absence of stresses on the faces of the wedge or slit and on the surface of the recess.

Fig. 2. Dependences $A_{\text{refl}}(\theta)$ (1), $A_{\text{trans}}(\theta)$ (2), and $A_{\text{refl}}^2(\theta) + A_{\text{trans}}^2(\theta)$ (3) for a wedge

Fig. 3. Dependences $A_{\text{refl}}(h/\lambda)$ (1), $A_{\text{trans}}(h/\lambda)$ (2), and $A_{\text{refl}}^2(h/\lambda) + A_{\text{trans}}^2(h/\lambda)$ (3) for a slit

From Fig. 2 for a duralumin wedge it is seen that the curves $A_{\text{refl}}(\theta)$ and $A_{\text{trans}}(\theta)$ have a number of clearly expressed maxima and minima; moreover, the maximum of the reflection coefficient, as a rule, corresponds to the minimum of the transmission coefficient, and conversely, with the exception of the case $\theta = 115^\circ$. The reflection and transmission coefficients never attain the values 1 and 0. As θ approaches 180°, $A_{\text{refl}} \to 0$, while $A_{\text{trans}} \to 1$. Similar curves for $A_{\text{refl}}(\theta)$ and $A_{\text{trans}}(\theta)$ are also obtained for a steel wedge; only the positions

Fig. 4

Figure 4: Fig. 4

of their maxima and minima are somewhat different. This makes it possible to suppose that for any other elastic wedge the qualitative character of the dependences under consideration will be the same.

The curves $A_{\mathrm{refl}}(h/\lambda)$ and $A_{\mathrm{trans}}(h/\lambda)$ for a slit (Fig. 3) show that as h/λ increases, the reflection coefficient, oscillating, increases, while the transmission coefficient, oscillating, decreases. The mean value A_{refl}, about which the oscillations occur, tends with increasing h/λ to the value of the reflection coefficient of a Rayleigh wave on a wedge with opening angle $\theta = 90^{\circ}$ (see Fig. 2). The transmission coefficient of a Rayleigh wave through a slit for $h/\lambda > 1.5$ ceases to depend on the depth of the slit. This is explained by the fact that for $h/\lambda > 1.5$ the depth of the slit becomes greater than the thickness of the surface layer in which the Rayleigh wave is localized, and Rayleigh–

wave passes through the slit, "descending" along one of its faces and "ascending" along the other.

The curves for a semicylindrical recess are presented in Fig. 4. Comparing them with the curves for a slit, one may note that, for identical depths of the slit and the recess such that h/λ, $R/\lambda < 0.4$, the shielding and reflecting abilities of the slit are greater than those of the recess. The maxima and minima of the curve $A_{\mathrm{refl}}(R/\lambda)$ are caused by interference of waves reflected from the two edges of the recess–the front and the rear. For a shallow recess ($R \ll \lambda$)

Fig. 4. Dependences of $A_{\mathrm{refl}}(R/\lambda)$ (1), $A_{\mathrm{trans}}(R/\lambda)$ (2), and $A_{\mathrm{refl}}(R/\lambda) + A^2_{\mathrm{trans}}(R/\lambda)$ (3) for a semicylindrical recess

the phase difference of these two reflections is equal to $8\pi R/\lambda$; therefore we have a minimum of A_{refl} at $R/\lambda \simeq 0.125$ and a maximum at $R/\lambda \simeq 0.250$. (We note that an analogous mechanism of reflection should occur for shallow recesses of any shape, for example, for a rectangular groove.) When the depth of the recess is of the order of λ and greater, the phase difference of the two reflections is determined by the number of half-waves fitting along the perimeter of the recess. These waves are an analogue of Rayleigh waves on the concave cylindrical surface of the recess. A theoretical study of them, carried out by us*, showed that they attenuate during propagation, and the more strongly the smaller kR is (k is the wave number of the Rayleigh waves). The velocity of these waves C' is always less than the velocity of Rayleigh waves. For large kR ($kR > 100$) the formula $C' = C(1 - B/kR)$ is valid, where B is a positive constant of the elastic medium, determined by the value of Poisson' s ratio. Estimating from this formula the approximate value of C' for the region $0.5 < R/\lambda < 1.1$, we obtain $C' = 0.6C$. From the distance between the maxima of $A_{\mathrm{refl}}(R/\lambda)$ in the region $0.5 < R/\lambda < 1.1$, one can determine the experimental value of C', which is equal to $0.8C$. The difference between these two values lies within the error given by the formula for C' in the region $0.5 < R/\lambda < 1.1$.

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* For more detail see (2).

Note: Figure translations are in progress. See original paper for figures.