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SHAKER WITH PLANE CIRCULAR MOTION OF THE TABLE: DESCRIPTION AND POLAR DIAGRAMS

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A new and simpler technique has been proposed [1, 2] for determining the transfer constant K_l of a transducer (vibration pickup) and the relative transverse transfer constant K_{rt} on a shaker with circular motion of the table.

At the center of the base 1 of the shaker (Fig. 1) is a post 2, which serves as the stem of a tuning fork. Attached to it is the mounting plate 3, which forms the base of the tuning fork; the latter is made of a thick-walled pipe section of height H with six slotted grooves. The lower unslotted part of the tuning-fork pipe 5 of height h is connected to the mounting plate 3. The ends of the resulting bracket-type bars 15-20, which have an almost-square cross section, are connected in two groups, forming the two branches of the tuning fork. The even ends of the bars 16, 18, 20 are welded together by means of the disk 21, which serves as the table of the shaker.

The odd ends of the bars 15, 17, 19 are joined concentrically in the same plane by means of the ring 9. The measurement head 10 with the pickups 11 and 12 are mounted on the shaker table 21. In order to balance the vibratory system the mass of the connecting ring 9 must be greater than the mass of the shaker table 21 by an amount equal to the mass of the measurement head 10 with the transducer.

A cylindrical shell 6 is mounted on the plate 3 outside the base of the tuning fork 5, and six electromagnets 7 are attached to it at the top, opposite each of the bars, which are fitted with armatures (not shown in Fig. 1). The shell 6 is mounted on the plate 3 by means of the flange 4. A second threaded lug 13 on the measurement head 10 is used to attach it to the shaker table 21 by means of the slip nut 14 at right angles.

The six electromagnets 7 are connected in opposite pairs to a three-phase network through three LATR balancers. Each phase or interphase voltage is connected to two diametrically opposite directions. In the rest state, the centers of gravity of the branches coincide. In the driven state, they move in circular paths.

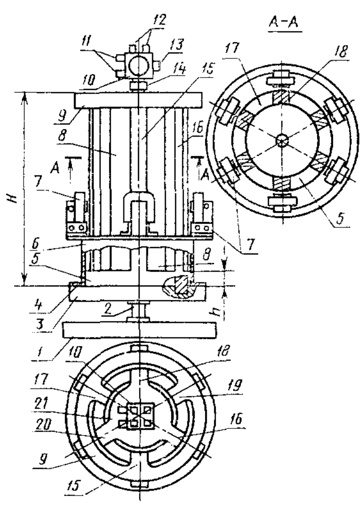

Fig. 1

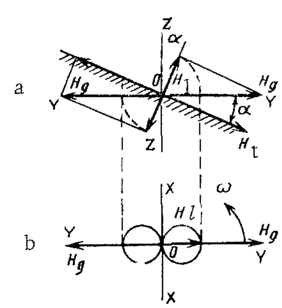

Fig. 2

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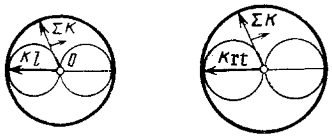
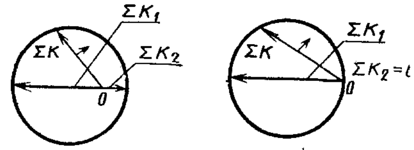


a b

Fig. 3



a b

Fig. 4

TABLE 1

α (β)	0,057° (3,4′)	0,29° (17,4′)	0,57° (35,1′)	1°09′	1°43′	2°17′	2°52′
K_l ; K_{rt} %	0,1	0,5	1,0	2,0	3,0	4,0	5,0

The plotting of the polar diagram of the longitudinal components of the shaker accelerations (Fig. 2) has the distinctive feature that their representation must be transferred from the vertical to the horizontal plane, i.e., this diagram must be oriented relative to the Z axis and related to the transducer diagram. Let the perpendicular dropped to the plane of the table deviate from the vertical (Z) axis of the shaker through an angle α (see Fig. 2a). When the shaker table moves in a circular path with an angular velocity ω, centrifugal accelerations H_g are developed in the horizontal (XY) plane (see Fig. 2b). The transverse accelerations acting in the plane of the table are $H_t = H_g \cos \alpha$. Acting in the vertical plane of the table is the longitudinal acceleration component $H_l = H_g \sin \alpha$. It acts in the plane of the transducer axis, which is perpendicular to the XY plane, at an angle α relative to the shaker axis.

In the well-known plotting of the polar diagram of K_{rt} [3] the transverse displacement component Δ of the shaker acting along the transducer axis is transferred to the perpendicular plane in the form of a circle. Analogously, we transfer both diameter vectors to the plane of the table, obtaining two contiguous circles of diameter H_l, which represent the directivity patterns of the longitudinal accelerations of the shaker. It is oriented with its maximum along the Y axis and is equal to zero along the X axis, because at this point the vectors $H_l = 0$. The ratio of the longitudinal to the transverse accelerations, which is determined by the angle α, is called the longitudinal acceleration coefficient of the shaker $K_l = H_l/H_t = \tan \alpha$. The ideal shaker would be one for which $\alpha = 0$, $H_l = 0$, and $k_l = 0$. We recall that the relative transverse sensitivity coefficient (transfer constant) K_{rt} of the transducer and its polar diagram are determined by the angle β between the transverse transfer vector F_t and the axial transfer vector F_a [1], and $K_{rt} = F_t/F_a = \tan \beta$.

To record the resultant diagram of the pickup with K_{rt} mounted along the axis of the shaker with K_l it is necessary to perform several measurements of the transverse accelerations of the pickup after each time it is turned on the shaker table around the Z axis through an angle φ, say every 30°. In this case the resultant vector of the polar diagram $\Sigma K = \bar{K}_{rt} + \bar{K}_l$ will be equal to the geometric sum of the principal vectors determined on the diameters of the transducer and shaker polar diagrams. The quantity ΣK is determined by the output voltage of the shaker transducer (driver).

The case in which the directivity pattern of the shaker is measured with an ideal pickup with $K_{rt} = 0$ is illustrated in Fig. 3a. Here the directivity pattern is determined solely by the longitudinal component of the shaker $\Sigma K = K_l$. The readings of the transducer will not change when it is rotated on the shaker table. The voltage vector U_l will move in a circle centered at the point 0.

The diagram plotted for an ideal shaker with $K_l = 0$ is shown in Fig. 3b. The resultant diagram $\Sigma K = K_{rt}$ in this case is determined by the shaker transducer. Its output value is also independent of the angle of rotation on the shaker table. A generalized directivity pattern for the general case $K_{rt} \neq K_l$, say $K_{rt} > K_l$, plotted on the path swept out by the resultant vectors ΣK as the angle φ is varied in the interval 0-360°, is shown in Fig. 4a.

In this case the output voltage vector ΣK also represents a circle with its pole at the point 0 rather than at the center. The tip of the output stress vector ΣK moves in a circle as the pickup is turned around the Z axis; it has two diametrically opposite points corresponding to two vectors: The large vector $\Sigma K_1 = K_{rt} + K_l$ and the small vector $\Sigma K_2 = K_{rt} - K_l$. The inclined vector ΣK corresponds to a vector that acquires different values as the pickup is turned through the angle φ.

By measuring the voltages corresponding to the vectors ΣK_1 and ΣK_2 it is possible to determine $K_{rt} = (\Sigma K_1 + \Sigma K_2)/2$; $K_l = (\Sigma K_1 - \Sigma K_2)/2$.

This method can be used to check out the correct operation of a shaker and to determine the errors of measurement of K_{rt} and K_l.

A special case of polar diagram of a vibration pickup on a circular shaker, namely when $K_{rt} = K_l$, is shown in Fig. 4b. The first vector, which is equal to the sum of the vectors, runs along the diameter of the diagram $\Sigma K_1 = 2K_{rt} = 2K_l$, and the second vector $\Sigma K_2 = K_{rt} - K_l = 0$. It follows from an analysis of the polar diagrams that the constants K_{rt} and K_l, as two components, uniquely determine the resultant polar diagram ΣK.

The most important conditions that must be met by the shaker for the minimization of errors are follows: perpendicularity of the shaker axis relative to the plane of the table; perpendicularity of the faces of the cubic measurement head and its threaded connections. Errors in the fabrication of the shaker induce an increase in the angle α and the formation of longitudinal components. It also follows from these conditions that the axis of the shaker must be coaxial or parallel with the axes of the measurement head in two positions. The additional error determined by K_l and K_{rt} as a function of α and β is given in Table 1.

The motion of the centers of gravity of the branches of the tuning fork resembles the orbit of the components of a double star.

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