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A Method of Determining Whether the Restoring Torque is Proportional to the Torsional Strain During the Vibration of a Torsion Pendulum

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A METHOD OF DETERMINING WHETHER THE RESTORING TORQUE IS PROPORTIONAL TO THE TORSIONAL STRAIN DURING THE VIBRATION OF A TORSION PENDULUM.

BY L. P. SIEG.

During some experiments on the elasticity of a certain type of wires the question arose as to whether the restoring torque, during the actual vibration of the system was at all times proportional to the torsional strain measured from the zero position. It is easy to determine the answer to this question in the case of a static twist of the wire, but there seemed at first to be an unsurmountable experimental difficulty in determining the answer for the case where the wire is actually vibrating.

The question was finally solved in two ways; one a direct method, and the other an indirect one. First as to the direct method. At the lower end of the wire tested, was fastened a light metal connecting frame and from the lower end of this frame was attached a steel wire. This steel wire was assumed to have regular elastic qualities. At the end of the steel wire was attached the vibrating mass, and on this mass was placed a mirror. Another mirror was attached to the frame connecting the two wires. These mirrors were adjusted so that they threw the focussed image of a pointer on a large 360° circular scale. Suppose for simplicity that the two mirrors are adjusted to read the same zero value when the wires are at rest. Call this reading, r. Now imagine the lower end of this compound pendulum to be twisted through some angle. The mirrors will now read different values. Let the reading of the lower mirror attached to the steel wire be r_1 and of that attached to the connecting frame be r_2. The two wires are twisted, and their twists act against each other. The twist of the steel wire will be $r_2—r_1$, while that of the tested wire will be $r_2—r$. Now if a series of values of the two twists is obtained one can plat a curve connecting the twist of the tested wire with that of the steel wire. Assuming that the restoring torque in the steel wire is at all times proportional to the twist, we have then a set of values for twist and restoring torque in the tested wire. By platting the above values one can readily determine if their relation is a linear one.

The question of technique at once arises, for it will be seen that in the above method a simultaneous reading of two separate spots of light must be taken. It was possible to do this at the turning points of the vibrations, by the close observation of two experimentors. In the intermediate positions of the spots of light their simultaneous positions were determined by taking an instantaneous photograph of the moving spots. A number of such plates were thus exposed, and afterwards a leisurely measurement of the positions was possible. It may be stated, that while no specific data are to be given in this paper, the above tests were applied to a wire which possessed such peculiar elastic properties as to lead one to suspect different conditions during vibration from the conditions existing at rest. The test, however, proved quite definitely that the law of proportionality held, at least within a very small per cent. So, while what was looked for did not materialize, at least the method was valuable in settling the question.

The indirect method is simpler in theory. If the above mentioned proportionality holds, the vibration of the pendulum, with the tested wire alone, should be simple harmonic, and the trace of the vibrating point if combined (at right angles) with uniform linear motion should give a sine curve. Photographic paper was placed around the drum of a chronograph, and the vibrating spot of light traced its record on the revolving drum in a darkened room. The developed paper, before being measured, had to be corrected in two particulars. In the first place the spot of light moved along the tangent instead of along the arc of a circle. After this correction was made, the correction for the decay in the amplitude of vibration had to be made. This was done by determining the logarithmic decrement, and by it, correcting all the ordinates of the curve that were used. As a result of one hundred and twenty measurements, it was found that the vibration of the pendulum was simple harmonic, from the fact that within the limits of error of the above measurements and reductions, the curve representing the vibrations was a sine curve. Thus the two methods were in agreement, and as a result one feels more confidence concerning the assumption of the elastic action of the steel wire under torsion.

