STRING UNDER INTERMITTENT IMPULSES AND EXPERIMENTAL VERIFICATION OF KAR'S THEORY OF INTERMITTENT ACTION

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ABSTRACT. Kar's theory of intermittent action as applied to bowed string by Biswas has been experimentally verified

The experiment consists of two parts :

(1) A string has been subjected to intermittent impulses at a point near one end by means of a toothed rubber wheel rotated by a motor, and the vibration recorded photographically by a Vibroscope It is observed that the trace on the photographic paper is a two-step Zig-zag

(2) Helmholtz's law of velocity of the bowed point has also been verified by photographically recording the vibration of the region struck by the wheel provided with a pin along its circumference fixed perpendicular to the plane of the wheel It is observed from the photo that the forward velocity of the region is equal to that of the wheel.

These two experiments therefore conclusively prove that the action of the bow and that of the toothed wheel are similar in nature

It was observed long ago by Helmholtz that when a string is bowed, not far from one end, the vibrations at any point can be represented by a simple two step zig-zag curve. He also showed that when the bow is moved perpendicularly on the string, the velocity of the bowed point in the upward direction is equal to that of the bow. He investigated the motion of the string by using a vibroscope and explained the action of the bow. Later on, Raman (1919) investigated the motion of the bowed string more exhaustively and was able to demonstrate the equality of the velocity of the bow with that of the bowed point. Kar's theory of intermittent action was applied to bowed string by Biswas who showed that if intermittent impulses of regular period be imparted to a string under tension, the motion of the string is the same as that given by Helmholtz. The present problem is therefore undertaken to verify experimentally the theory given by Biswas (1930). This theory clearly explains the action of the bow when it is moved perpendicularly across the string.

THE EXPERIMENTAL PORTION CONSISTS OF TWO PARTS

Part 1.—Intermittent impulses of regular period are imparted to the string under tension by using a toothed rubber wheel mounted on an axle which is held horizontally between two clamps. The wheel is set into rotation by means of a motor driven by a battery of constant e.m.f. The motion of any point of the string is recorded by using a vibroscope in the usual manner. It is observed that the trace of the motion on the photographic paper is a two step zig-zag curve.

Part 2.—The toothed wheel is provided with a pin along its circumference fixed perpendicularly to the plane of the wheel, rotated and allowed to strike the string. The simultaneous record of the motion of the wheel and that of the string is obtained photographically in the usual manner by means of the vibroscope.

INDEX OF PARTS OF THE APPARATUS USED

W—Rubber wheel.

S_1 and S_2—Wooden shutters.

M_1 and M_2—Metallic strips attached to the shutters S_1 and S_2.

S—Photographic slide.

C_1 and C_2—Clamps for holding the string.

T—Tension screw.

Q—Tilting screw

U—Wooden board to which the wheel is attached. It is hinged on one side and can be tilted by the screw Q.

L—Condensing lens.

A—Arc lamp.

M—Low horse power motor.

Rh—Rheostat.

Ws—Wooden stand for the wheel.

Is_1 and Is_2—Iron stands to which the clamps C_1 and C_2 are attached.

O_1 and O_2—Openings at the back of the vibroscope provided with black pieces of cloth.

Vs—Vibroscope stand.

V—Vibroscope.

P—Pan in which weights are placed.

B—Wooden board to which iron stands Is_1 and Is_2 are fixed.

R—Resistance for the arc lamp.

Wb—Wooden bar fixed at the top of the iron bars Is_1 and Is_2.

Wa—Pulley fixed to the axle.

*EXPERIMENTAL

Part 1

Method.—The string is held between two metallic jaws which are clamped to two iron bars Is_1 and Is_2 fixed to a wooden board B (Fig. 1). The vibroscope V

* This part is carried out by Mr. H. G. Mane alone.

fixed to a wooden stand Vs is placed just behind the string and parallel to it. The vibroscope is provided with two wooden shutters S_1 and S_2 which can be adjusted so as to form a very fine slit just behind a point of the string whose motion is to be recorded. A photographic slide S similar to the ordinary photographer's slide provided with two small metallic rollers at the bottom to minimise friction, runs between two grooves of the vibroscope. It is dragged along the grooves by a piece of string, one end of which is fixed to the slide. The string passes over a pulley and at the other end a pan P is attached to add weights.

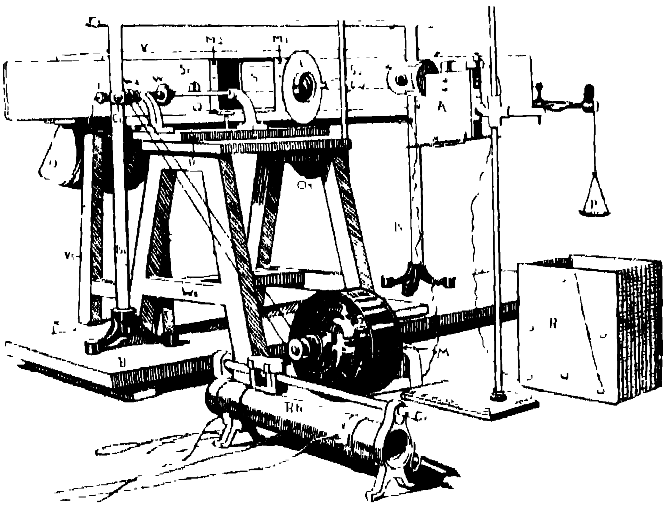


FIG. 1

The string is excited by a toothed rubber wheel W held between two metallic jaws. A small piece is first cut from a plane rubber sheet and is then cut on a lathe. The circumference is then divided into 32 equal parts (this number is found to be suitable with the material at hand) by means of a divider. The teeth are then cut by a razor blade. Great care must be taken while cutting the teeth as the length and the depth of each tooth must be the same. The teeth are then polished and any defect in them is removed by using a fine file.

The wheel is then mounted on an axle which is held horizontally between two clamps which are fixed to a wooden board. This board is hinged on one side to another wooden stand. At the unhinged edge there is a milled screw Q which is used for adjusting the pressure of the wheel on the string. The whole stand is then placed on the wooden board carrying the iron stands and the string.

To excite the string, the height of the string is adjusted and the clamps are fixed to the iron bars. The wheel is then fixed to the axle against the desired point of the string. To maintain the vibrations of the string, the speed and the pressure of the wheel are to be adjusted. The first is done by adjusting the current from the battery and the second by using the screw Q.

When the vibrations of the string are maintained, the shutters are arranged so as to form a very fine slit just behind the point whose motion is to be recorded.

The slit is illuminated by condensing the light from an arc lamp. The loaded photographic slide is then inserted into the vibroscope through the left hand opening, is opened inside the vibroscope and then released. The plate then runs through the grooves on account of the weights placed in the pan. In this way the motions of several points of the string are recorded photographically. The photographs are shown below :—

LENGTH OF THE STRING 60 CMS

Plate No.	Struck pt. distance from one end	Observed pt distance from the other end	Plate.
1	1/3	1/3	
2	13 cms	1/3	
3	1/5	1/5	
4	1/6	1/5	
5	1/6	1/4	
6	1/8	1/4	

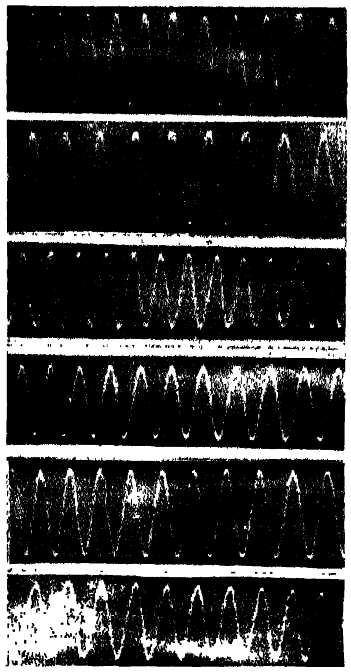


FIG. 2.

Part 2

To show the applicability of Helmholtz's law of velocity to the present case.

A thin pin is fixed to the rubber wheel against one of its teeth and perpendicular to the plane of the wheel. • The wheel is then fixed to the axle against the desired point of the string. The shutters are adjusted to form a fine slit just near the wheel. The slit is illuminated by the arc lamp and the vibrations of the string are maintained as explained previously and the photograph of the point struck by the wheel is taken. In this way several photographs of the motion of the wheel and that of the corresponding points of the string are taken.

It is observed that the record of the motion of the pin and that of the motion of the string are coincident. The photographs are shown below :—

LENGTH OF THE STRING 60 CMS

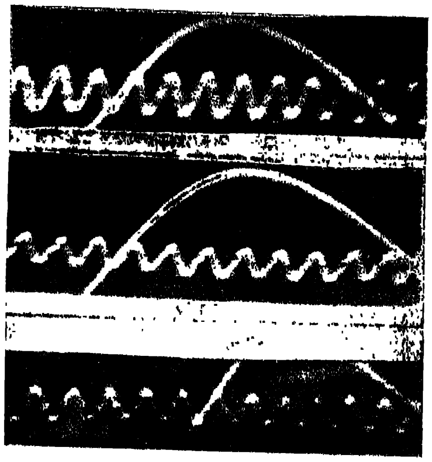
Plate No.	Struck pt. distance from one end.	Plate
1	1/4	
2	1/5	
3	1/6	

FIG. 3

CONCLUSION AND DISCUSSION

The photographs obtained in the two parts of the experimental portion show that Kar's theory of intermittent action as applied to the bowed string by Biswas is true. The action of the bow is similar to that of the wheel. When the wheel is rotating, the part of the string in contact with the wheel is carried along with the particular tooth in the forward direction, it then slips and begins to move in the downward direction till it is caught by the next tooth and the process is repeated. The investigations are being continued to solve other allied problems such as to find the relation between the upward and downward velocities and the position of the point of observation, etc.

Finally, we express our heartfelt thanks to Dr. Kar of Presidency College, Calcutta, for the kind interest he took in our investigations.

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