ON THE PREPARATION OF QUARTZ ULTRASONIC OSCILLATORS

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In certain problems connected with the detection of cavities under weirs it became necessary to generate powerful ultrasonic radiations in this Institute. The first important step in this connection was to prepare thick X-cut crystals from natural quartz; for firstly, these are costly to import and, secondly, due to war conditions they cannot be obtained in any reasonable period. A technique has, therefore, been developed to prepare the required crystals from natural ones.*

Geometry of the Crystal

A quartz crystal may roughly be said to be a hexagonal prism terminating at either end in apparent hexagonal pyramids. Fig. 1 shows a perfect left-handed crystal and Fig. 2 a right-handed one. The crystals possess

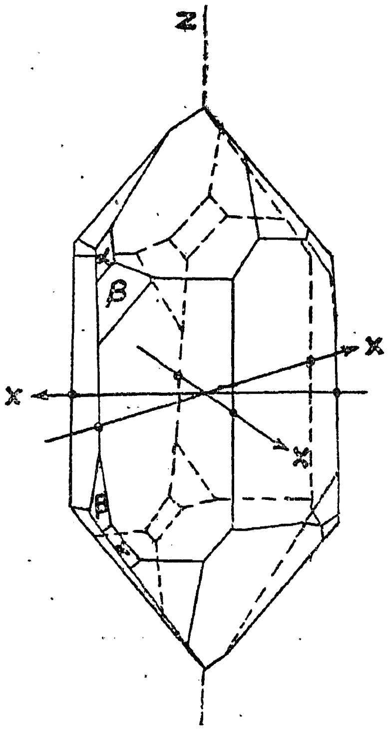

Fig. 1
Left-handed Quartz Crystal

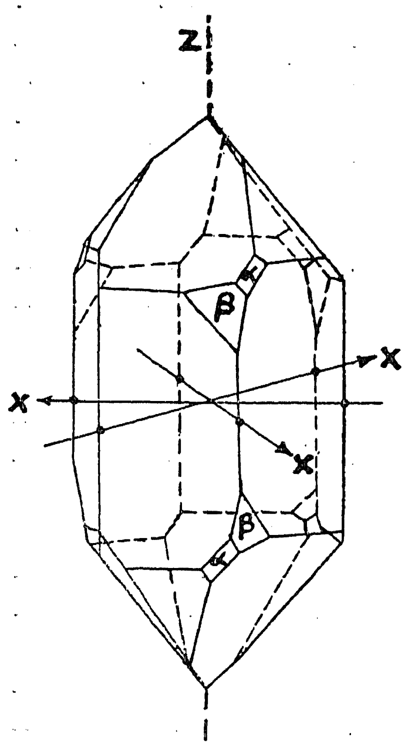

Fig. 2
Right-handed Quartz Crystal

* Natural quartz was very kindly supplied to us by Dr. C. S. Fox, Director of the Geological Survey of India.

nal symmetry about the line joining the vertices of the pyramids at r end, so that the prism and pyramid faces are similar only alternately. line is the optical, trigonal or principal axis and is generally called the is. The crystal further possesses three axes of diagonal symmetry, in a e at right angles to the principal axis. These are known as the electric ie X axes and are perpendicular to the Z-axis and connect in every case opposite edges of the six-sided prism, which, however, are not similar.

For piezo-electric work three more axes, coplanar with and perpendicular ie diagonal axes, have been assumed. These are known as the Y-axes have no crystallographic significance.

Selection

Quartz suitable for piezo-electric work must not have the following cts:

(1) Optical twinning. (2) Electric twinning. (3) Presence of clouds, s, or bubbles and (4) Inclusion of foreign materials.

These defects are detected as follows:

As stated above quartz is of two types—left-handed and right-handed. is due to the atomic structure of the crystal which has got a spiral ngement in the direction of the Z-axis. It is the direction of rotation he spiral which is responsible for the type of the crystal. These types generally be distinguished by looking to the direction of the subsidiary s marked α and β in Figs. 1 and 2 or optically. Sometimes both the s of structures get intermingled in the same specimen. Such a crystal id to be optically twinned. A rough test for the detection of this form vinning is that the horizontal striæ on the prism faces which are parallel ie case of a good specimen become broken by means of irregular growth . The sure and final test, however, is the optical one which consists assing plane polarised convergent monochromatic light through a Z-cut (the cut faces of which have been artificially polished by smearing them nitrobenzene or by fixing glass plates with canada-balsam) along the e axis and examining the rings from the other side by means of an yser. Presence of irregularities in the rings shows that the crystal is cally twinned. A photograph of rings obtained with a good crystal is an in Fig. 3.

Electrical twinning is due to the rotation of the structure through 180° ut the Z-axis in successive layers of the same specimen. This really ns that the crystal has got zones having no obvious crystallographic ntation. This results under stress, in the generation of free electrical charges of opposite signs which neutralize each other wholly or partially and thus reduce the piezo-electric efficiency of the crystal. This is detected by etching with concentrated hydrofluoric acid. Twinned regions are revealed by irregular patches of heavier corrosion and curvilinear triangular pits.

The presence of clouds, cracks, bubbles, etc., is detected visually by placing the crystal in a beaker containing nitrobenzene or a solution of 80 per cent. ethyl cinnamate and 20 per cent. xylol by volume.

Cutting

In the case of a rough specimen, the various axes have to be determined before proceeding with the cutting. There are optical as well as X-ray methods to find these out and need not be described here. We shall only illustrate the method with a more or less well-developed crystal. The crystal is so fixed on the cutting machine that the plane of the cutting disc is perpendicular to the Z-axis and then it is first cut roughly into Z-cut or primary slabs as shown in Fig. 4.

The blanks are now tested for twinning and the perpendicularity of the cut surfaces to the optical axis. The methods for the former have already been described in the previous section while the latter is tested by means of

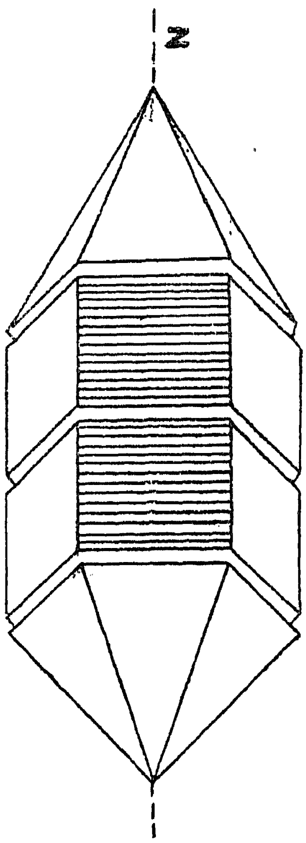

FIG. 4
Ideal crystal showing blanks cutting

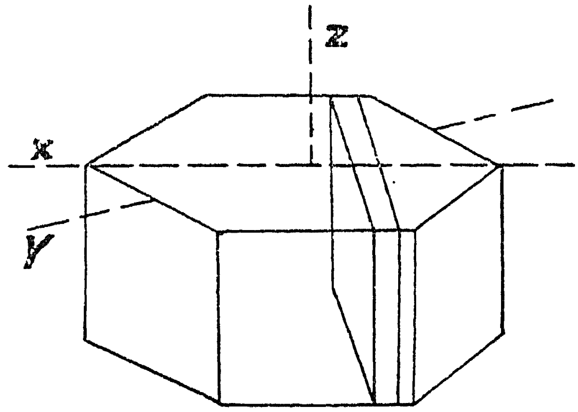

FIG. 5
X-cut Crystal

a polariscope arrangement similar to the one described for optical twinning. Here the rings observed through the analyser will wobble during the rotation of the crystal about a vertical axis if the cut surfaces are not perpendicular to the optic axis. If this happens the axis of rotation is tilted till the wobbling disappears during rotation. The ends are then cut again and the slab re-examined.

Once it has been ascertained that the blank is reasonably free from defects, it is so aligned in the cutting machine that the cutting disc passes in a plane perpendicular to one of the X-axes and thus by successive cuts a suitable X-cut cyrstal, as marked in Fig. 5 is prepared. The cutting machine is described in the following section and is shown in Fig. 6.

The Cutting Machine

It consists of a detachable copper disc (1) Fig. 6 and a wooden pulley (2) mounted on a common axle rotated by another pulley (3) fixed on the rotor shaft of a fractional horse power motor. The motor is fixed to an iron base plate (4) having a slit (5) through which it is further fixed to a wooden base. The slit provides for an easy arrangement of tightening the belt. The motor is slowed down by means of a resistance to give a linear speed of about 150 ft. per second to the edge of the cutting disc (1). This disc rotates in a gaping mouthed mud container. A strip projects from the back portion of the container almost up to the edge of the copper disc to prevent the mud splash raised by the disc, from falling outside the container.

A crystal desired to be cut is fixed between an iron plate (7) having a slit in its middle and a wooden piece (8), the arrangement being tightened by means of two bolts. If due to the shape of the crystal it is not possible to hold it in a proper plane, it is first mounted in plaster of paris and then fixed on the cutting machine. Below the slit in the iron plate (7) is fixed a catch which allows the mud to pass up only along the edge of the disc and not along its sides to guard against uneven cutting. An axle rod (9) is rivetted to the underside of the plate (7) a few inches away from the other end. It is at right angles to the slit and is held by two vertical iron plate pieces (10) fixed on a vertical plank (11) at such a height that the iron plate (7) slopes down upon the cutting disc (1). Care has been taken in mounting the axle holders (10) to keep the plane of the plate (7) at right angles to the surface of the disc (1). A guard is provided in between the cutting disc and the bearings of its axle to prevent the emery mud from falling on the bearings.

As the disc rotates through the mud-emery powder and water, its edge becomes charged with emery particles. These rub against the crystal, which is kept pressed against the cutting edge, and a cut is automatically effected through the crystal. The speed of the cutting disc should be maintained constant to obtain a well-cut surface.

Grinding

After a crystal has been suitably cut, its surfaces have now to be ground. An arrangement, developed in the laboratory to do this work, is described below and is shown in Fig. 7.

The Grinding Machine

It consists of a cast iron disc (1), Fig. 7, mounted on the tapered upper end of an axle (2) rotating in two bearing bushes (3) fixed to the top and bottom planks of the machine. The disc (1) is rotated by means of a pulley arrangement from a fractional H. P. motor. Another pulley system (4), consisting of six pulleys, transmits motion to the crystal holder (5) and keeps it rotating simultaneously with the disc (1), though at a slower speed, to avoid unequal grinding along the radius of the disc due to variation in the linear velocity along this direction. The holder (5) is above the disc (1) and at the lower end of a vertical axle (6) rotating in two bushes (7) fixed to a wooden frame. It is an inverted L-shaped brass block (5), having all of its thickness and flat faces at right angles to each other and the upper face perpendicular to the axle. For keeping the crystal faces in appropriate positions, two guides are put in; one is a brass straight edge fixed to the vertical face of the inverted L-shaped brass block vertically, while the other is a sliding one fixed horizontally to the same block. To fill up the space a wooden cuboid (8) is placed above the crystal. Crystals are fixed between the vertical portion of the brass block and a flat wooden piece (9) by means of two bolts.

A set of four bolts fixed to a frame (10) and touching the upper bush of the crystal holder axle is put in for adjusting the perpendicularity of the axle to the surface of the grinding disc.

A metal collar (11) is fixed along the rim of the disc to keep the emery mud on the surface of the disc; and as the mud collects near the outer rim of the disc on account of the centrifugal force, a metal strip (12) ending in a rubber flap is hung loosely, as shown in the figure, so that the mud strikes against it and is thrown back towards the central region of the disc.

As the crystal holder axle is floating, its own weight keeps the crystal pressed against the surface of the disc which is kept charged with emery mud. A constant rubbing of the crystal against emery particles produces the desired surface.

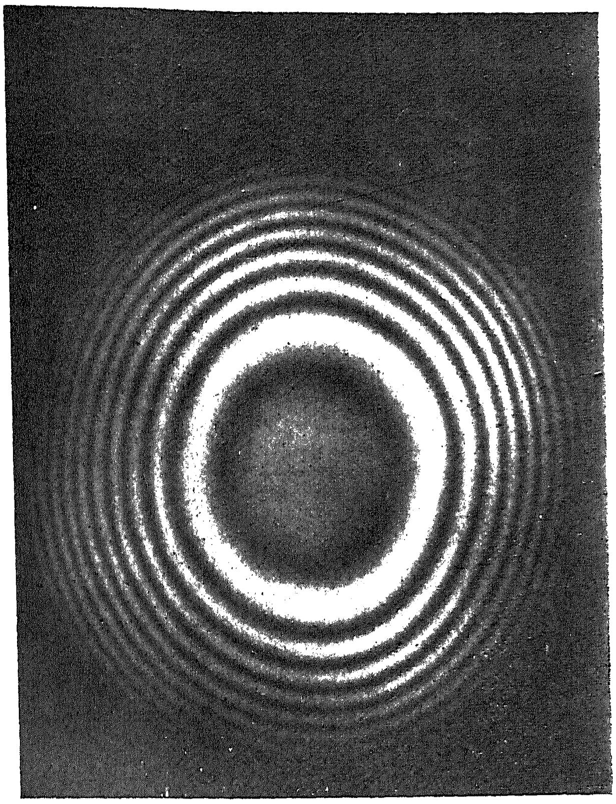

FIG. 3

Regular interference rings showing absence of optical twinning

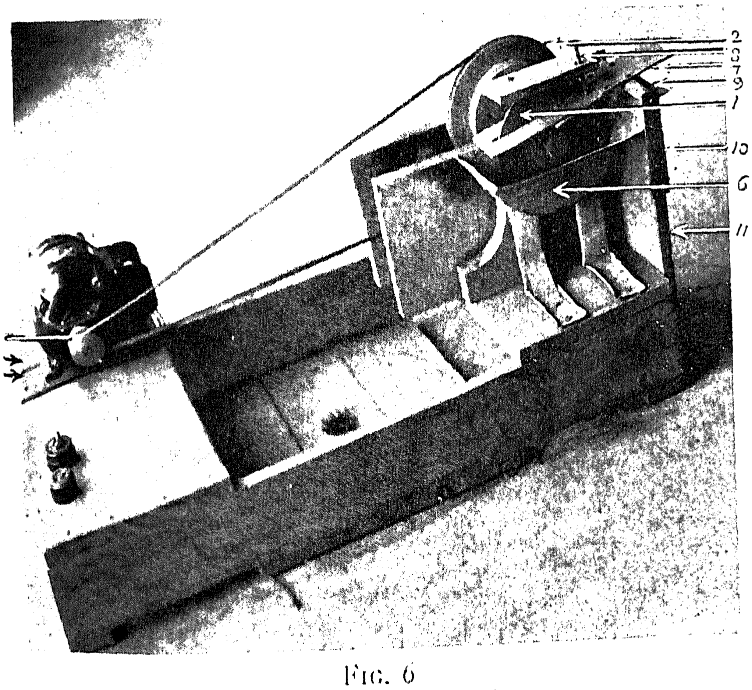

FIG. 6

Crystal cutting machine

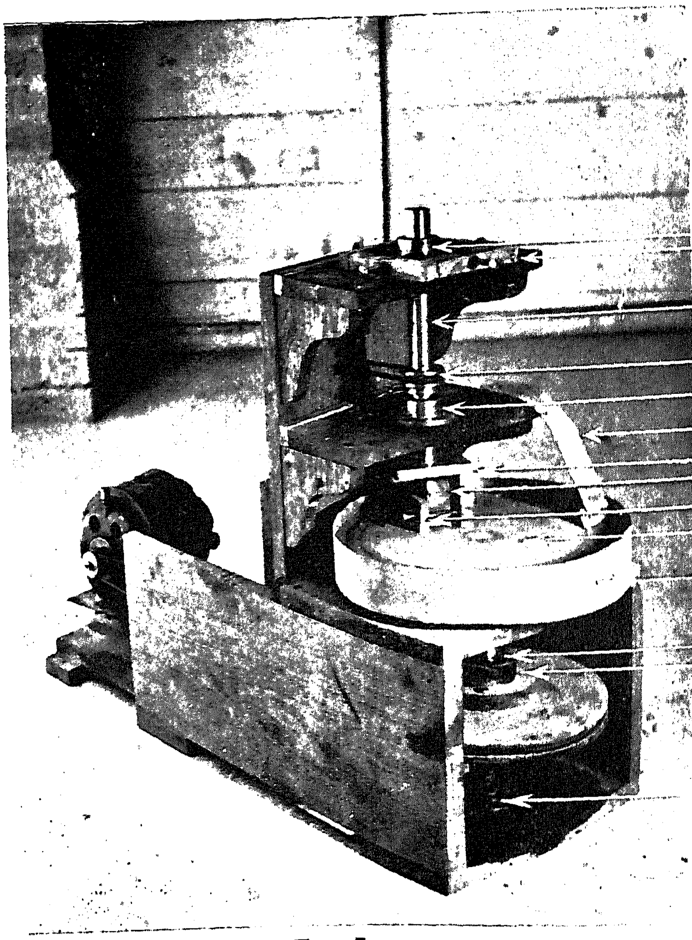

FIG. 7

Crystal grinding machine

The preparation of such cystals is of scientific and technical importance. The method developed and described above works automatically and it was thought that the publication of the technique, though it is only one stage in the solution of our problem, would be of considerable use to workers in the field.

Our thanks are due to Dr. E. McKenzie Taylor for his keen interest in the work.