Title	Thickness measurement by supersonic wave
Sub Title	
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Publisher	慶應義塾大学藤原記念工学部
Publication year	1949
Jtitle	慶應義塾大学藤原記念工学部研究報告 (Proceedings of Faculty of Engineering, Keiogijuku University). Vol.2, No.7 (1949. 12) ,p.115(1)- 120(6)
JaLC DOI	
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Notes	挿図
Genre	Departmental Bulletin Paper
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO50001004-00020007-0001

Thickness Measurement by Supersonic Wave

(Recieved April 26, 1950)

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Abstract

The acoustic interferometer is an instrument for measuring exactly the wave length of sound waves. In recent years several modifications of the instrument have been made for supersonic use and are used to measure the sound velocity in metal plate or the thickness of the plate by means of the relation between wavelength and frequency.

We also found that this equipment is very useful to detect flaws in metal plate.

I. Principle of Measurement

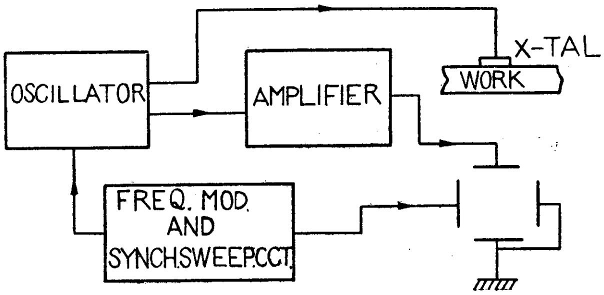

Fig. 1. Block diagram

The block diagram is shown in figure 1. Supersonic waves and their frequencies of which vary automatically within the range of the necessary frequency, and are transmitted from a crystal source into a test piece.

When the thickness of test piece t, sound velocity v and the sender frequency f satisfy the condition

$$t = \frac{n\,v}{2f} \qquad (n = 1, 2, 3 \cdots\cdots) \tag{1}$$

the standing wave will be generated in the test piece. The standing wave reacts against the crystal source and changes the electro-acoustic impedance of it. As a result of the phenomena, anode and grid current of a vacuum tube oscillator which feeds the driving voltage to the piezo crystal plate, are to be changed. If the standing waves are generated to the frequency f_n and f_{n-1}, which are closed to each other, the following condition are to be satisfied instead of equation (1)

$$t = \frac{v}{2(f_n - f_{n-1})} \tag{2}$$

The velocity of sound wave and the thickness of a test piece are to be computed from the equation (1) or (2)

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II. Oscillator

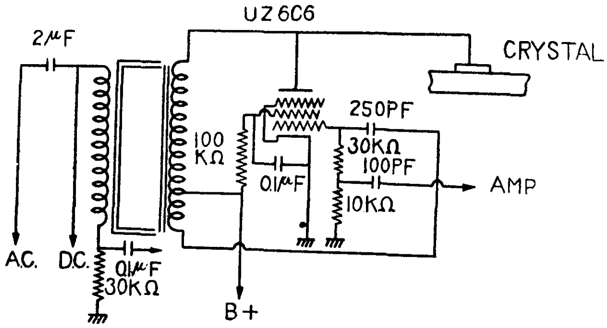

Fig. 2. Oscillator Circuit

Oscillator circuit is shown in figure 2. Hartley circuit is used, but other circuit of ordinary feedback oscillator may be used for this purpose.

To make satisfactory condition for given test piece, the oscillator must be swept within necessary frequency range. For this purpose we wound the oscillating coil around E type dust core and placed it in iron core with exciting coil. When alternating current (50 cycles) which flows through the exciting coil is superposed on direct current, the equivalent inductance of oscillating coil will be changed and oscillator frequency is swept over necessary frequency range.

To obtain linear variation of the oscillator frequency, the value of direct current and the amplitude of alternating current must be carefully selected.

The frequency variation in our experiment is from 2.6 to 4.3 megacycles and the natural frequency of piezo crystal plate (X-cut) is 7 megacycles.

III. Amplifier

Four stage resistance coupled amplifier was used to amplify the pulse voltage due to the abrupt variation of grid current. The maximum voltage amplification factor is 110 decibels, but this high gain is needed only when we want to detect flaws in metal materials. The necessary amplification factor depends decidedly upon the acoustic coupling between crystal source and test piece. We used oil as the medium of acoustic coupling. Water may be used instead of oil.

The time constant of the input coupling circuit of the first stage amplifier must be sufficiently small; otherwise indication will be vague.

More over, great care must be taken to eliminate hum, to diminish noise and to stabilize the amplifier.

IV. Indicator

A cathode ray tube is used for an indicator. The output voltage of the amplifier is impressed upon the vertical axis of the the tube and the sinusoidal voltage which is developed in the resistance by the exciting current is led to the horizontal axis. Then impulse indication which corresponds to the generation of standing waves in a metal plate will be observed on the surface of cathode ray tube, and the orientation of the impulses on the surface will indicate the frequencies that satisfy the relation (1) or (2).

To obtain clear indication should eliminate the figure due to the return half cycle of horizontal sweep voltage. For this purpose negative voltage of rectangular wave form having the adequate phase to the sweep voltage was impressed upon the first grid of a cathode ray tube as shown in figure 3. Superposition of low

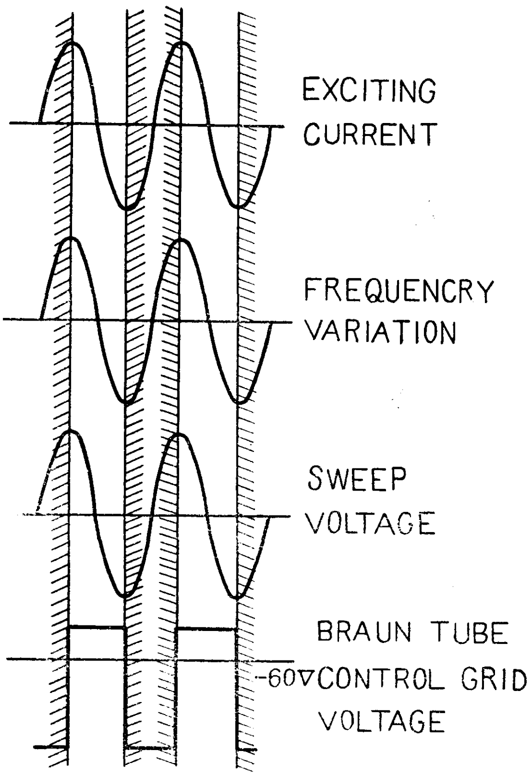

Fig. 3.

frequency oscillating voltage generated by the exciting coil over the sweep voltage makes the image out of focus. This trouble can be prevented by the placing a capacitor between horizontal terminals of the tube and the earth.

Total connection diagram is shown in figure 4.

V. Results

Various impulsive images due to the standing waves are shown in the photographs from figure 5 to 9.

Figure 10 shows a distorted image indicating an artificial flaw made in the same plate of figure 5.

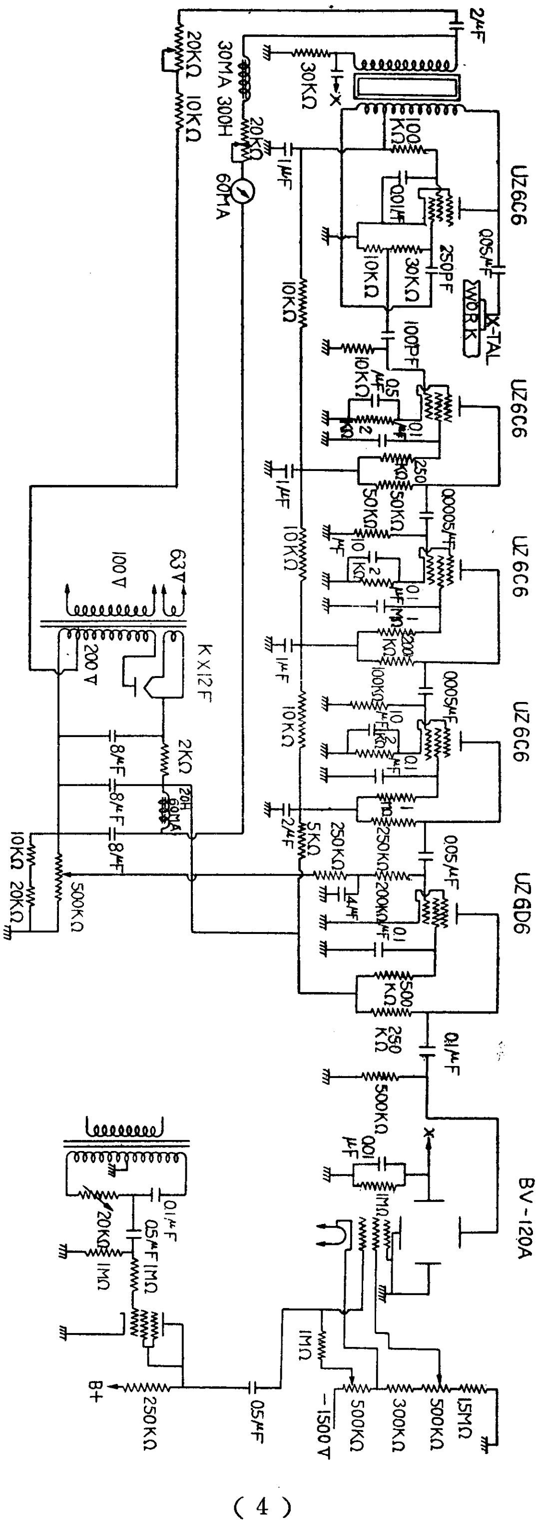
UZ6C6
UZ6C6
UZ6C6
UZ6C6
UZ6D6
BV-120A
X-TAL
WORK
KX12F
6.3V
100V
200V
30MA 300H
60MA
-1500V
B+

Fig. 4.

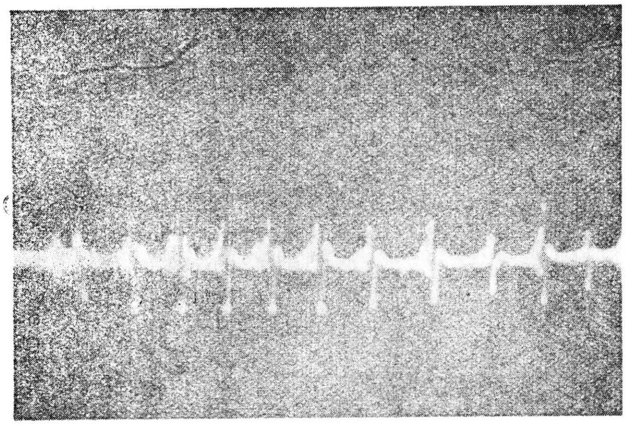

Fig. 5. Aluminum

Thickness 20.27mm × (58 × 300)
Freq. Range.
2.6m.c. – 4.3m.c.
(Right) (Left)

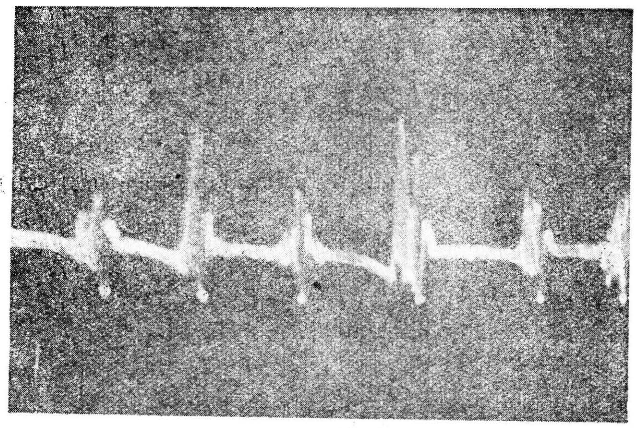

Fig. 6. Iron

Thickness 8.85mm × (49 × 75)
Freq. Range.
2.6m.c. — 4.3m.c.
(Right) (Left)

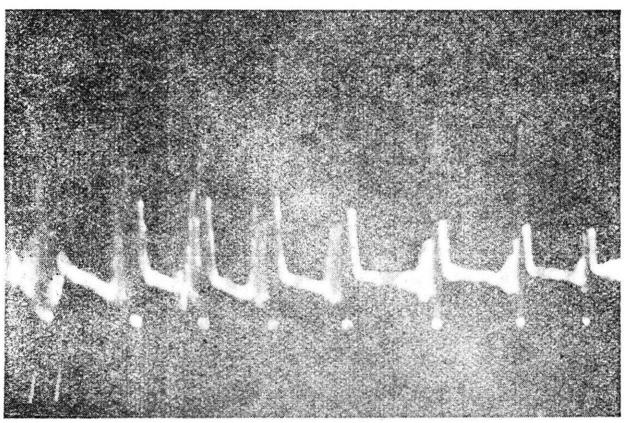

Fig. 7. Brass

Thickness 10mm × (100 × 112)
Freq. Range.
2.6.mc. – 4.3m.c.
(Right) (Left)

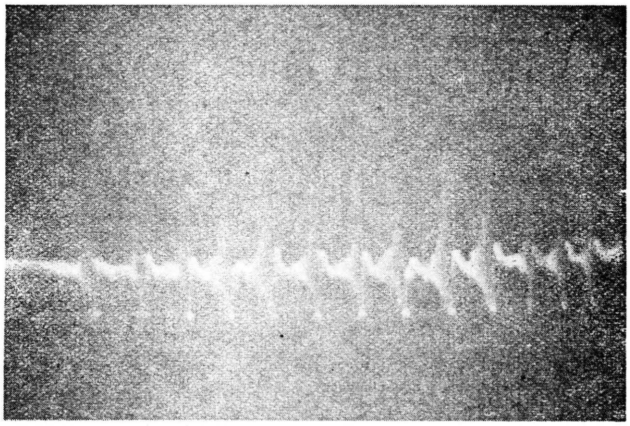

Fig. 8. Glass
Thickness 24mm × (30 × 35)
Freq. Range.
2.6m.c. — 4.3m.c.
(Right) (Lift)

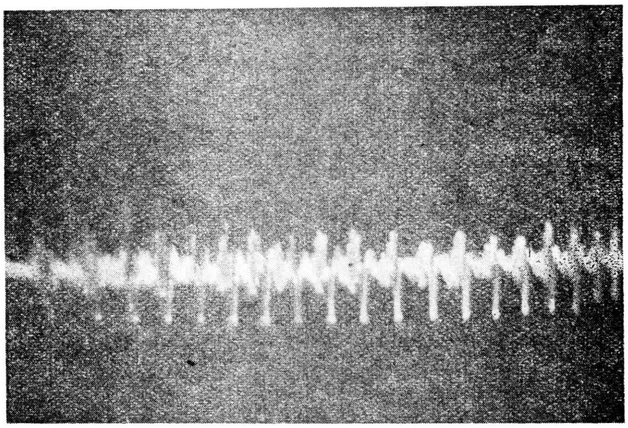

Fig. 9. Glass
Thickness 36mm × (51 × 51)
Freq. Range.
2.6m.c. — 4.3m.c.
(Right) (Lift)

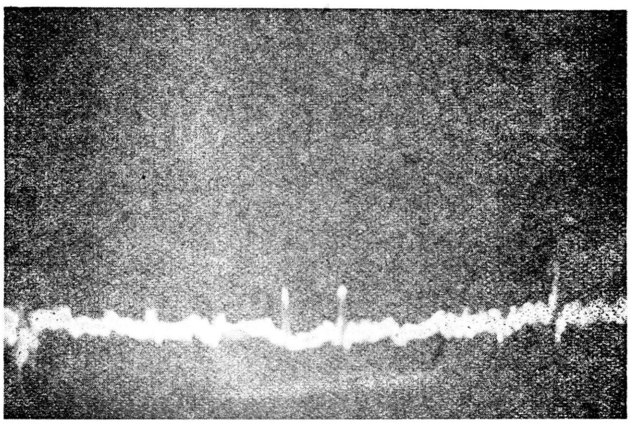

Fig. 10. Aluminum
(Artificical flaw)
Thickness 20.27mm × (58 × 300)
Freq. Range.
2.6m.c. — 4.3m.c.
(Right) (Left)