ACOUSTIC VELOCITY USING THE SCANNING LASER ACOUSTIC MICROSCOPE (SLAM)

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ABSTRACT

A technique has been developed for determining the acoustic velocity in solids using Sonoscan's SLAM which does not require the interferogram image to show continuous interference lines at the reference medium-solid boundary. This has the advantage of eliminating the rather elaborate machining of a "step" into the solid to offset the effects of large differences between the reference (generally a liquid) and solid velocities. The technique has been verified using an independent SLAM technique on aluminum and a commerical thermoplastic.

1. INTRODUCTION

When using the Scanning Laser Acoustic Microscope (Bensenville, IL 60106) to study a solid sample it is often desirable to know the acoustic velocity in the material. Due to the large differences in solid and the liquid (used as an acoustic couple and reference) velocities it was necessary to machine a "step" into the solid to obtain continuous fringe lines in the interferogram image at the solid-liquid boundary. These continuous fringe lines (which represent constant phase fronts) are essential for the previously used method described by Goss and O'Brien [1]. The new method requires only that an accurately machined bevel be cut on one edge of a specimen for a velocity determination to be made.

2. DERIVATION

Consider a sample of thichness T cut to an angle α as shown in Fig. 1. A distance l corresponds to a distance lxk (k a constant magnification factor) in the interferogram image. Also a phase shift by the amount ab in the solid sample will result in a shift of abxk in the interference lines. From figure 2 one has:

$$ab=ac-bc=T\cdot(\cot\theta_0 - \cot\theta_x) \qquad (1)$$

and

$$ab\cdot k = l\cdot k \tan(\beta) \qquad (2)$$

where

$$l = T\cdot\cot(\alpha) \qquad (3)$$

Equating expressions (1) and (2) for ab yields:

$$\theta_x = \cot^{-1}\{\cot\theta_0 - \cot(\alpha)\ \tan(\beta)\} \qquad (4)$$

Applying Snell's Law one obtains the acoustic velocity in the solid:

$$C_x = C_o/\mathrm{Sin}\,(\theta_0)\cdot$$
$$\mathrm{Sin}\,\{\cot^{-1}(\cot\theta_0 - \cot(\alpha)\ \cot(\beta)\} \qquad (5)$$

Thus one may obtain the acoustic velocity in a solid by accurately machining one edge of a sample to the angle α and measuring the resultant angle β from the interferogram image of the incline.

3. EXPERIMENTAL METHOD AND RESULTS

The method was tested on a commerical thermoplastic and aluminum.

Ten samples of the thermoplastic were cut to a variety of angles (α) and computer enhanced interferogram images, as shown in figure 3, were collected [2]. A single sample was also prepared in the earlier "stepped" fashion for comparison. Results from the cut samples varied up to 5% from the 2580 m/s obtained from the stepped sample.

0090-5607/82/0000-0634 $00.75

Samples of aluminum were prepared at angles (α) of five and 20 degrees. To check accuracy in measurement of β, five readings were taken from a single interferogram image of each. The error in hand measurement of β was found to be at least one degree resulting in up to 20% error from the 6200 m/s velocity expected.

4. CONCLUSION

As can be seen in fig. 4a the expression for C_x becomes very sensitive to small variation in β as the differences between the velocity in the reference medium (in this case water 1490 m/s) and in the solid become large. In fig. 4b the error in C_x is shown for a plus one degree error in the measurement of β (again in water). From repeated hand measurement of β in a single image it was determined that this one degree error could be expected. Thus when a material has a much larger velocity than that of the reference medium, the precise measurement of the angle β becomes very critical and the one degree error is not tolerable. A numerical line fit scheme coupled with the computer enhancement would greatly improve the accuracy of this measurement.

ACKNOWLEDGEMENTS

This work was supported by a grant from the National Science Foundation (ENG 76-22450) and the National Institute of General Medical Science (GM 24994).

REFERENCES

[1] Goss, S. A. and O'Brien, W. D., "Direct ultrasonic velocity measurements of mammalian collagen threads". Journal of the Acoustical Society of America, vol. 65, No. 2, pp. 509-510, 1979

[2] Foster, S. G., "An image digitizing system for a scanning laser acoustic microscope", Masters thesis, Department of Electrical Engineering, University of Illinois at Urbana-Champaign, 100 pp. (1981)

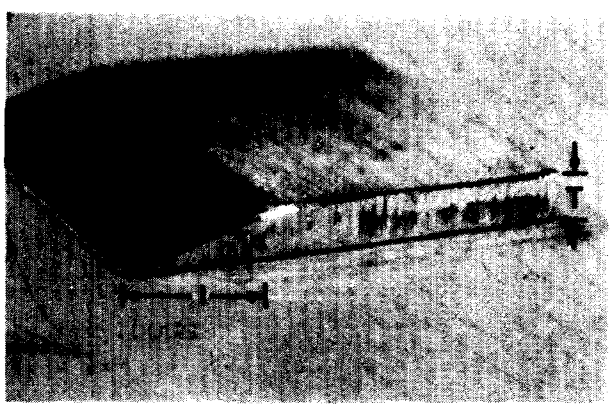

Fig. 1 Sample Design

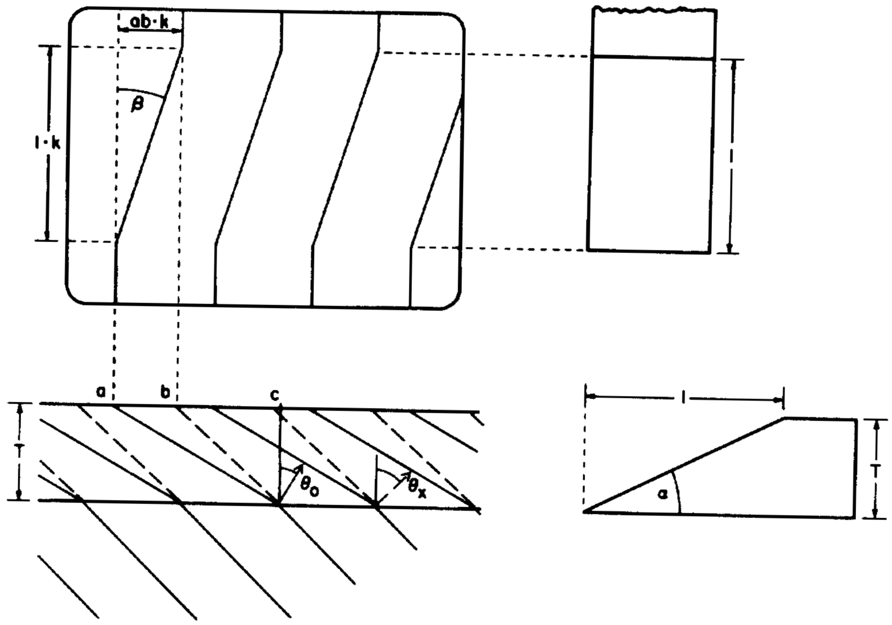

Fig. 2 Clockwise from upper right: Top view of sample; side view of sample; end view of sample showing lines of constant phase in the solid (broken lines) and liquid (continuous lines); corresponding interferogram image.

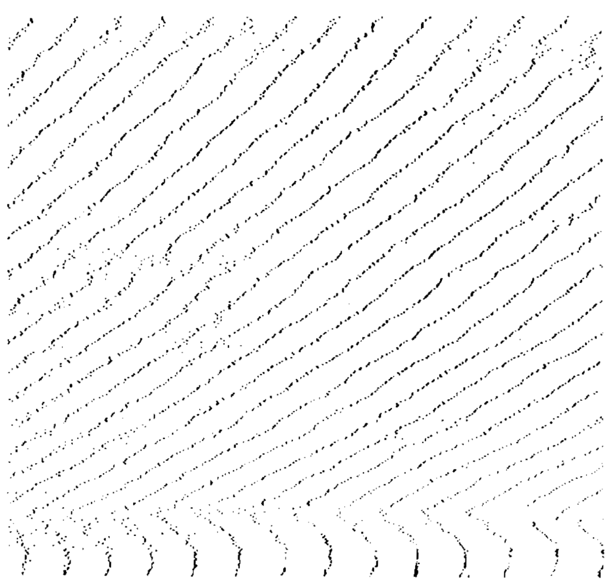

Fig. 3 Computer enhanced interferogram image.

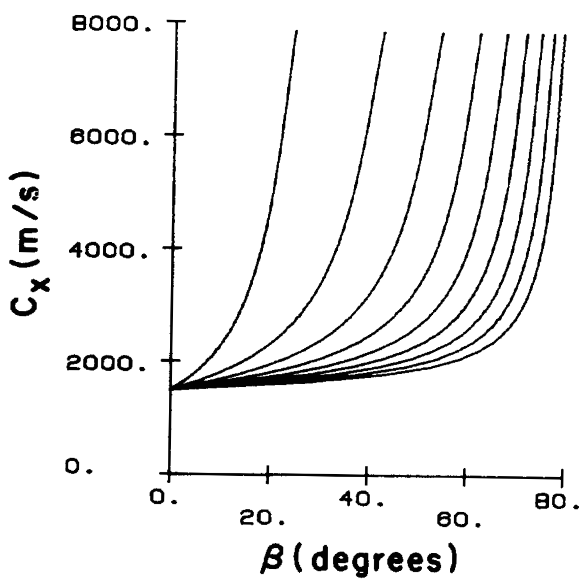

Fig. 4a Sample velocity vs β for lines of constant α (α is five degrees at top left and increases by increments of five to 45 degrees).

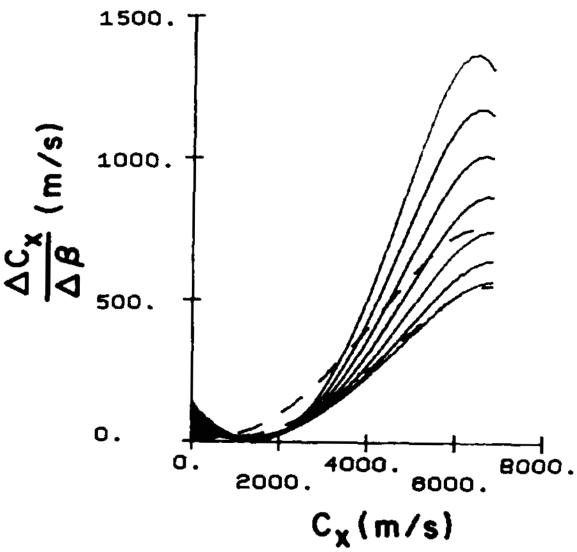

Fig. 4b Error in sample velocity vs sample velocity for lines of constant α (solid lines; α is 15 degrees at bottom right and increases by increments of five to 45 degrees).