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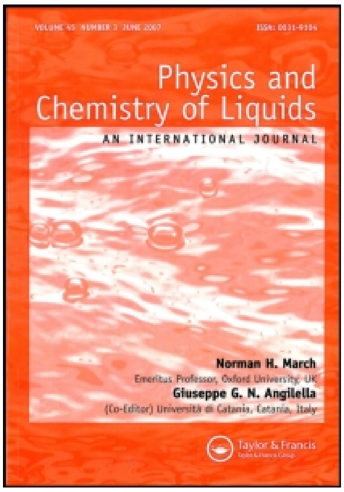

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Sound Velocity in Liquid Titanium, Vanadium and Chromium

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Sound Velocity in Liquid Titanium, Vanadium and Chromium

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A method for measuring the sound velocity in reactive liquid metals of high melting point is described. It uses the configuration of a molten zone. The sound velocity in Ti, V and Cr, has been determined.

1 INTRODUCTION

The sound velocity is related to the compressibility which allows some insight into the atomic structure of the liquid state.[1] The present authors have investigated liquid transition metals of the first series.[2,3] Unfortunately, the reactive metals in the left part of the series cannot be measured with the common experimental methods using sound transmitters made of refractories and other methods must be developed.

In material science, the floating zone technique is a well known method for purifying and drawing crystals and alloys.[4] This paper shows how to use the technique for measuring the sound velocity in the liquid state of high melting point metals.

2 EXPERIMENTAL TECHNIQUE

In the classical methods for acoustic measurements in liquids, the experimental set-up consists of a crucible containing the liquid and one or two buffer rods transmitting the ultrasonic waves to the liquid charge.[4,2] A corresponding configuration of transducers, buffer rods and liquid metal

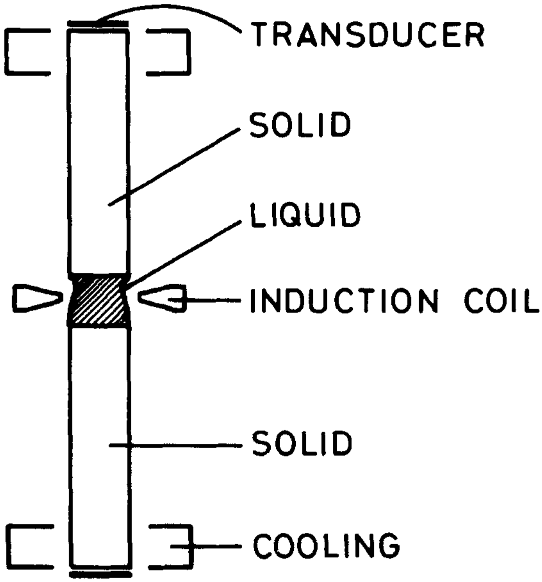

FIGURE 1 Molten zone configuration for sound velocity measurements.

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can be obtained by the use of a molten zone (Fig. 1). The sound conductor is now made of the metal to be measured and the liquid zone is "free" (in vacuum or non reacting gas), thus avoiding any unwanted reaction.

However, this method allows only measurements of the speed of sound at the melting point and the accuracy is limited because the solid–liquid interface may fluctuate. In fact, the pressure of the HF field induces movement and vibration of the molten zone. To reduce such effects and to increase a levitation effect other shapes of the molten zone and HF inductor proved valuable (Figure 2).

A "variable-path" is forced by moving one or the other support over a given distance. Then the sound velocity v is given by

$$v = \delta l/\delta t \tag{1}$$

where δt is the variation of transit time measured when the acoustical path is changed by δl. This movement must be fast so as to leave the molten zone unperturbed. δl is typically 1 mm with an error of measurement of $\pm$ 10 μm. The error in the measurement of the transit time δt was about 20 ns (the equipment otherwise allows to reach 1 ns). This large figure is due to the fluctuations and the difficulty to monitor manually the signal in "real time". Thus the overall estimated error is about 10% or less.

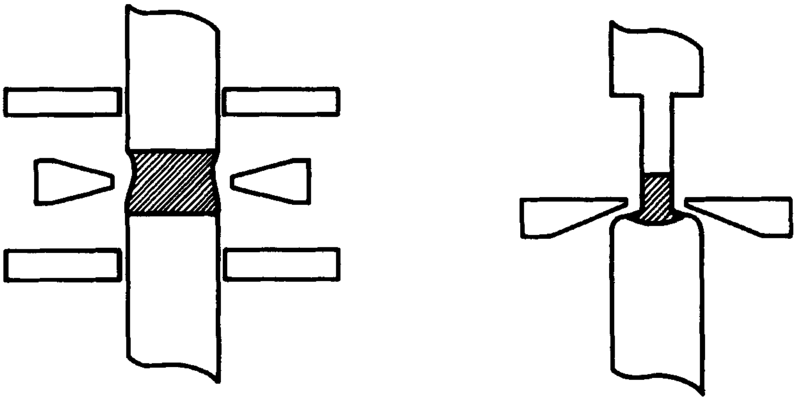

FIGURE 2 Configurations with different stability of the molten zone: (A) With auxiliary cooling plates which compress the molten zone and add a levitation effect, and (B) with a large lower rod supporting the molten zone.

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3 EXPERIMENTS AND RESULTS

Preliminary tests were done with iron which has been studied by different authors.[2,6,7] Optimum experimental conditions were established to obtain a good liquid zone stability, e.g. by using rods of different diameter, where the lower rod is larger than the upper rod, and by changing the configuration of the HF coil so as to enhance levitation forces. The materials studied were Fe(3N), sintered Cr(3N), V(3N) and Ti(2N5) of diameter 15 mm and total length of about 100 mm.

The results of the measurements are given in the table. The value of the sound velocity of iron obtained with the floating zone agrees well with other measurements, considering errors quoted. It is seen that the reproductibility of about 4% is well within the absolute error.

TABLE I
Sound velocities v and rms deviation of v in liquid metals at the melting point T_m

Element	T_m(K)	v(m/s)	r.m.s. deviation (m/s)	Reference
Fe	1808	3917	—	Kats *et al.* (1978)
		3912	—	Kèita *et al.* (1981)
		3984		Tsu *et al.* (1981)
		4052	134	This work
Cr	2130	4298	286	This work
V	2163	4742	84	This work
Ti	1945	4407	108	This work

4 CONCLUSIONS

Measurements of the sound velocity of liquid reactive metals are reported which needed the development of a new method. The precision of this method using a floating zone is limited but could be improved by changing the data acquisition procedure.

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