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A STUDY OF SURFACE TENSION OF TITANIUM ALLOYS USING THE METHOD OF MELTING IN A SUSPENDED STATE

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Foreign Technology Division
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О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

A STUDY OF SURFACE TENSION OF TITANIUM ALLOYS USING THE METHOD OF MELTING IN A SUSPENDED STATE

A. A. Fogel, O. N. Magnitskiy.
M. M. Mezdrogina, and N. I. Bronzova

Surface tension and also wettability under conditions of contact with various refractory materials are among a number of the most important characteristics of casting alloys. These characteristics acquire a special importance when producing thin-walled casts with a thickness of less than 1 mm, when the action of capillary forces is manifested to a considerable degree.

The methods used for ferrous and nonferrous metals are not suitable for studying the surface tension of titanium. For example, the method where surface tension is measured by the maximum pressure of a gas bubble cannot be used due to the interaction between the liquid metal and capillary material.

The stationary drop method which consists of melting a metal on a substrate is also unsuitable, since the insignificant time of their contact changes the contour of the drop completely.

The "falling drop" method can be used to study the surface phenomena of titanium alloys, which consists of the fact that the end of the test specimen which is in the form of a rod placed into a vacuum chamber is melted in an electromagnetic field of the inductor, while the formed drop falls on a substrate made of refractory material.

Strictly speaking the concepts of the boundary angle of wetting and surface tension, determined according to the contour of a drop are inapplicable for titanium, since these concepts presuppose the presence of equilibrium between the liquid drop and substrate. Melted titanium alloys cannot, even for a very brief time, be in an equilibrium state with a refractory material due to an intense interaction. Furthermore, the formation of the contour of a liquid drop after it has fallen cannot occur independently of the surface energy and the interaction forces between the metal and substrate. When filling a foundary mold the liquid metal wets the various refractory materials differently. In this case also there is no state of equilibrium.

Since the method of fusion of the rod's end in the inductor field does not permit the regulation of the degree of overheating and the determination of the metal temperature, and also does not permit a smooth sinking of the drop onto the substrate being studied, in this work we made it a point to study the problem of possible use of a method in which melting is accomplished in a suspended state.

This method of melting metals in a suspended state in an electromagnetic field, developed by the Laboratory of High-frequen[illegible] Electromagnetic of the Physicotechnical Institute im. A. F. Ioffe, AS USSR, is used extensively when studying the properties of refractory and chemically active metals and their alloys.

As compared with other melting methods without the use of a crucible this method has such advantages as the possibility of obtaining a desired temperature, controlled tapping of metal, smooth sinking of the melted metal in an inductor, absence of a contaminating contact with any substance, good mixing of a melt, and a presence of a common liquid pool. These advantages make it possible to use this method for studying surface phenomena of chemically active metals and their alloys.

This method permits a smooth dipping of a melted metal drop heated to a certain temperature onto a refractory substrate inside the inductor.

In a "debiteuse-type" inductor the melted metal can be raised sufficiently high enough so as not to touch the refractory substrate on the bottom of the inductor. In this case, after the given temperature is achieved, the voltage in the inductor gradually drops and the drop sinks slowly onto the refractory substrate. The moment the drop touches the substrate the voltage is completely removed from the inductor and the drop solidifies.

With the given generator frequencies and physical properties of an alloy, in order to obtain the desired temperature, it is necessary to use a certain type of inductors [1]. In certain cases the "debiteuse-type" inductor has to be replaced with inductors having successive or parallel inverse coils. In both last inductors the configuration of the field produces a top-like shape of a drop. The lower portion of the drop enters the lower coil of the inductor. In this case the refractory substrate has to be placed under the inductor. During the tapping of the melted metal, its dropping from a certain height is unavoidable. In this case the shape of the drop on the substrate is determined, in addition to surface phenomena, by the height of its fall. The shorter the distance of its fall, the less change there is in the shape of the drop. In order to diminish the effect of drop's fall the distance between the inductor and substrate was reduced to a minimum.

The analytical expression derived by T. A. Sidorova connects the field parameters and physical properties of the metal with the power transmitted to the metal suspended in the electromagnetic field:

$$F=\frac{1}{2}\sqrt{\frac{\mu_0}{\pi\rho f}}AP,$$

where F - force acting on the part of the electromagnetic field on the metal and which is equal to its weight;

p - power transmitted to the metal;

ρ - specific electrical resistance;

f - frequency of the field;

$\mu_0=4\pi\cdot 10^{-7}$ - magnetic permeability of vacuum;

A - dimensionless coefficient depending on the configuration of the field and metal surface.

This formula is valid in the case where there is surface penetration of the electromagnetic field into the metal.

This formula makes it possible to determine the field parameters which ensure the transmission of power which is equal to the radiation power of the metal at a given temperature for the given types of inductors and the weight of the metal. A detailed description of the method for obtaining the given stabilized temperature and selecting optimum parameters for the melting device are presented in the works of A. A. Fogel, T. A. Sidorova, et al. [1, 2].

A generator with a frequency of 440 kHz was reeded to obtain the stabilized temperature which exceeded the melting temperature by 100°C during the melting of titanium alloys in the amount of 1.5-2 g in helium atmosphere at the pressure of 1 atm. The use of helium atmosphere has eliminated the sputtering of the titanium and enabled us to measure the temperature of the metal using an optical pyrometer through the observation window.

Titanium specimens and its alloys with small additions of Ce and La were melted in the "debiteuse-typy" inductor at the stablized 1800°C. The inductor with an inverse coil has enabled us to obtain a higher temperature which is necessary for melting the titanium alloy specimens containing rhenium and neodium.

Surface tension was calculated according to the contour of a solidified drop, magnified 10 times. The contour of the drop was taken on four cross sections. Surface tension and the angle of wetting were determined for each cross section and then the mean arithmetic value was calculated for the given drop. The drop contour was measured according to the method proposed by V. N. Yeremenko, Yu. N. Ivashchenko, et al. [3], while the surface tension was calculated according to the Bashfort and Adams tables [4].

The scatter of the surface-tension values was within 15%, while that for the wetting angles - within 10%.

Thus, this method can be recommended for studying surface phenomena of highly reactive metals. In this work we studied the effect of certain rare-earth elements and rhenium on the surface tension of titanium and made it a point to determine the possibility of using these elements as inoculents for titanium and its alloys. The surface tension values of Ce, La, Nd, and Re, determined by calculation, are lower than those for titanium.

The table shows the values calculated by the Kunin formula. Consequently, it should have been expected that with the introduction of the given elements into the titanium alloys the surface tension of the latter should decrease.

Table 1

Element	Ti	Zu	Ce	Sc	Re
Surface tension, in dyn/cm	797,1	630	506	496,8	510

Table 2

Alloy composition	Substrate	Weight in g	Atmosphere	Temperature, in °C	Type of inductor	Surface tension	Angle of wetting
BTI	Magnesite	0,6	Helium	1800	Debiteuse	780	79
BTI	Magnesite	0,6	"	1700	"	830	81
BTI	Electrocorundum	1,3	"	1700	"	870	70
BTI	The same	1,3	Vacuum	1720	"	820	86
Ti+5Al	Magnesite	1,3	Helium	1800	"	890	90
Ti+12Al	"	1,3	"	1800	"	1200	105
Ti+0,06Nd	"	1,3	"	1740	Inverse coil	480	75
Ti+0,1Nd	"	1,2	"	1740	The same	410	73
Ti+0,01Ce	"	1,2	"	1720	Inverse coil	700	75
Ti+1Ce	"	1,2	"	1720	The same	400	65
Ti+0,01La	"	1,2	"	1700	Debiteuse	550	80
Ti+0,27La	"	1,2	"	1700	"	470	60
Ti+0,5La	"	1,2	"	1680	"	410	65
Ti+0,01Re	"	1,3	"	1740	Inverse coil	725	69
Ti+1,0Re	"	0,57	"	1740	The same	400	65

This supposition was confirmed by the experiments. Table 2 shows the results of these experiments.

The surface tension values of binary systems, calculated by the A. A. Zhukhovitskiy formula [5], are in satisfactory agreement with the experimental data.

These studies have shown that rare-earth elements can be used as inoculents of class I for titanium alloys. Insidently, the greatest inoculative effect is derived from the additions of La up to 0.5%.

BIBLIOGRAPHY

1. Фогель А.А., Сидорова Т.А., Смирнов В.В., Гуц З.А., Коркин И.В. Выбор оптимальных параметров устройства для плавки металлов во взвешенном в электромагнитном поле состоянии. Известия АН СССР, сер. металлы, № 2, с. 138-146, 1968.
2. Фогель А.А., Сидорова Т.А., Коркин И.В., Моздрогина М.М. Получение заданной установившейся температуры при плавке металла во взвешенном в электромагнитном поле состоянии. Известия АН СССР, сер. металлы, № 1, с. 96-106, 1968.
3. Иващенко Ю.Н., Богатыренко Б.Б., Еременко В.Н. К вопросу о расчете поверхностного натяжения жидкости по размерам лежащей капли. Сб."Поверхностные явления в металлах и сплавах и их роль в процессах порошковой металлургии." АН УССР,1961.
4. Bashfort F., Adams J. C. An attempt to test the theories of capillary action. Cambrige at the University Press, 1883.
5. Жуховицкий А.А. Поверхностное натяжение растворов. Журнал физической химии, 18, 214, 1944.