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Equipment for the treatment of melts via mechanical vibrations

*Gheorghe Huțiu** and *Ion Copaci**

Abstract

The present paper describes the assembly of a vibrating equipment. This system has a single degree of freedom and viscous absorption. The vibrations are generated by an eccentric revolving table. The equipment comprises an a.c. motor (Pn = 2,2 Kw, I= 165 A, n = 17.000 r.p.m.), a mechanical vibrating unit, a VLT 5008 Danfoss frequnecy converter, a Kw 3072 HBM measurement intensifier, an oscilloscope, a B12/1000 HOTTINGER BALOWIN MESS TECHNIK accelerometer, cast iron table, rubber supports. The equipment generates mechanical vibrations which applied to the liquid alloys during solidification alter the solidification conditions and improve the mechanical, tribological, physical and chemical properties of the respective alloys.

---------- *Key words:* vibratory equipment, eccentric table, acceleration, solidification.

Resumen

El presente trabajo describe un equipamiento para producir vibraciones, diseñado y realizado por los autores. Este sistema tiene sólo un grado de libertad y amortización viscosa. Las vibraciones son generadas mediante una mesa excéntrica. El equipamiento comprende: un motor eléctrico de corriente alterna que tiene las siguientes características: P_n = 2,2 kW (potencia nominal), I = 165 A (intensidad de la corriente), n = 17.000 rot/min (velocidad de giro); un mecanismo que produce las vibraciones; un convertidor de frecuencia tipo Danfoss 5008; un osciloscopio; un acelerómetro tipo Hottinger BALO WIN MESS TECHNIK; las mesas de fundición y acero; los soportes de goma; un amplificador de medida tipo KW 3072 HBM.

El equipamiento genera vibraciones que se aplican a aleaciones líquidas durante el proceso de solidificación, con el fin de modificar las condiciones de solidificación mejorando las propiedades mecánicas, tribológicas, físicas y químicas de estas aleaciones.

---------- *Palabras clave:* vibrador, vibración, mesa excéntrica, aceleración, solidificación.

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Introduction

Scientific research has lately demonstrated that the mechanical and tribological properties of metallic materials can be improved not only through alloying or the change of the cooling conditions but also through the application of physical and mechanical treatments during solidification.

The physical and mechanical treatments that have been applied so far are:

- Electromagnetical stirring
- Stirring in gaseous atmosphere
- High energy ultra-sound
- Low frequency mechanical vibrations [2]

These treatments influence the following factors of the liquid alloy:

a. The limiting stratum. Due to the application of treatments, the limiting stratum comes off the mould face and thus determines an intensification of the heat transfer from the alloy and mould. This leads to the increase of the diffusion speed and the decrease of the concentration gradient.

b. The flow of the alloys. By the application of treatments, whirls are produced that destroy the particles existing between the liquid and the solid phases, thus achieving a constant refining of the melt and an increase of the heat transfer between the liquid and the solid phases.

c. Cavitation. The application of treatments brings about the phenomenon of cavitation, i.e. gas bubbles occur that are eliminated through the surface.

d. The surface tension and the moistening angle between the heterogeneous grains and the liquid decrease, a fact which brings about a decrease of the critical phase which in its turn leads to an increase in the number of germination centers.

e. The degree of undercooling decreases and leads to less mechanical work done.

f. The diphase zone decreases and brings about a reduction of the mechanical work of grain formation. At the end of the solidification process, a greater number of grains is obtained, improving thus the mechanical properties of the alloy.

As a conclusion, due to the application of the physical and mechanical treatment, the alloys obtained have finer grains, their chemical composition is homogenous and the amount of gases in the alloys is reduced. All these lead to better mechanical and tribological properties.

The vibration of the liquid alloys during solidification by means of low-frequency vibrations gives good results, mainly in the case of the non-ferrous alloys but also in steels.

Here are some examples obtained in Romania.

Via the vibration applied on aluminum and copper alloys —GAlSi 13 and AlMg 1,5— good results have been obtained [2] as shown in the table 1.

Good results have also been obtained on alloys of Cu Al 10 Fe [2].

Non-ferrous alloys cast in metallic moulds at SC Electroputere Craiova in Romania (an engine producing company) are vibrated [2].

By applying vibrations during the solidification of antifriction alloys for bearings with a base of Sn-Sb-Cu, we have obtained an alloy that contains no Cd or As but whose properties are similar to those of the alloys with Cd and As.

Cd and As are elements used to refine the structure of this type of alloy, thus increasing its mechanical and tribological properties. These substances, however, are considered carcinogen and their use is forbidden in the chemical composition of alloys [5].

Table 2 below shows the chemical composition and mechanical properties of the antifriction alloys vibrated and non-vibrated.

By applying vibrations during the solidification of steels OT 450-1, T15 MoNiCr 18 or T25 NiCr

Table 1 Results obtained via the vibration applied on aluminum and copper alloys GAlSi 13 and AlMg 1,5

GAlSi 13	*Cast non vibrated*	*Cast vibrated*
$R_m N / mm^2$	176	216
$R_{p0,2} N / mm^2$	88	88
A5	5,8	5
AlMg 1,5	-	-
$R_m N / mm^2$	120	136
$R_{p0,2} N / mm^2$	50	81
A5 (%)	15	20

250 it has been shown that the depth of penetration of the shrinking holes has diminished and has led to a decrease in the height of the risers.

Taking into account the results obtained so far worldwide and in Romania, we believe that it is necessary to improve the vibration equipment that uses low- frequency vibrations.

The aim of the present paper is to introduce a mechanical vibratory equipment with unbalanced jarring tables which represents a system with a single degree of freedom and with viscous damping.

Description of the equipment

The equipment comprises:

- Asynchronous a.c. motor (Pn = 2,2 Kw, U= 165 A, N= 17.000 r.p.m.)
- VLT 5008 Danfoss frequency converter
- KW 3072 HBM amplifier
- Oscilloscope
- B12/1000 HOTTINGER BALOWIN MESS TECHNIK accelerometer
- Jarring cast iron table
- Rubber mountings

The electrical motor is rigidly fixed on a steel stand (figure 1, position 2). Stand 2 is mounted in the housing of vibrator 5 via six screws.

The vibrator-motor assembly is mounted on the jarring table by means of four screws. In its turn, the table is fixed on four rubber mountings which act as cushions against the vibrations. The motor conveys the movement to the vibrator by means of shaft 4.

The drive of the asynchronous motor can be achieved with the help of VLT 5008 frequency converter (made in Danmark), having the following characteristics:

- The drive system of the induction motors is achieved via vectors and without sensors, both for the torque and the speed.
- The safety system is entirely digital
- A monitoring and programming interface ensures with the help of a specific Quick menu the simultaneous monitoring of four parameters and the optimum programming of parameters grouped so as to enable an immediate identification of those parameters that are essential for the starting of the motor. In addition, the control panel is detachable, thus allowing for rapid commisioning and trouble shooting operations.

Table 2 Chemical composition and mechanical properties of the antifriction alloys vibrated and non-vibrated

Alloy	*Chemical composition (%)*					*Mechanical properties*			
	Sb	*Cu*	*Cd*	*Ni*	*Pb*	$R_m N / mm_2$	$R_{p0,2} N / mm^2$	*A5 %*	*HB 250/10/60*
HM07 non vibrated	7,6	3,0	1,0	0,2	0,1	90,0	75,0	7,0	26,0
$LgSnR_2$ vibrated on M_1x5500rot. / min	8,9	4,1	-	-	-	88,1	69,0	4,0	25,5

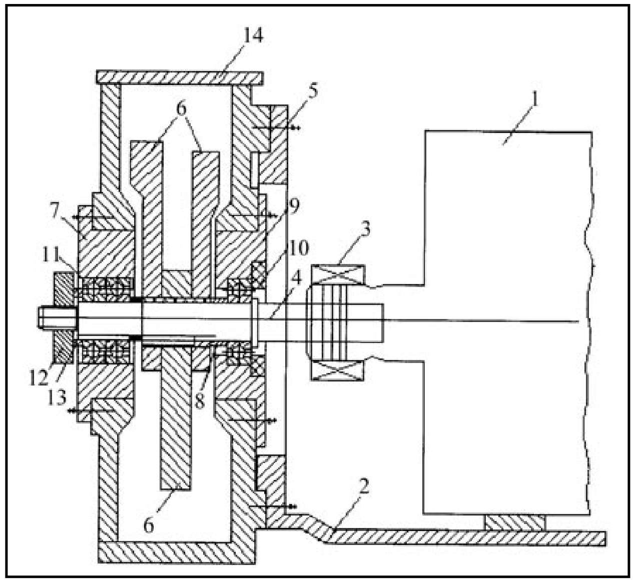

Figure 1 The mechanical vibratory equipment

1. Electrical motor; 2. Electrical motor stand; 3. Bolt nut; 4. Shaft; 5. Housing; 6. Eccentric part; 7. Sleeve for the eccentric part ; 8. Positioning sleeve for the eccentric part; 9-10. Sleeves for the fixing of ball bearings ; 11. Radial ball bearings; 12. Bolt nut; 13. Collar; 14. Lid.

The B12/1000 accelerometer, the oscilloscope and the Kw 3072 HBW amplifier are used to determine the [g] value.

Parameters of the equipment

Two parametrs have been determined on the equipment:

- The speed of the motor dependent on the eccentric part of the vibrator (with the help of the frequency converter) – Table 1
- Acceleration [g] by the help of accelerometer - acc. to figure 2

Maximum motor speed

As far as its structure is concerned, the eccentric part of the vibratory equipment is made out of three parts fixed on a sleeve. The parts located on the exterior part of the sleeve have a fixed position, while the part in the middle (having a weight of 0.504 kg) can revolve on the sleeve.

In the first phase, a static balance of the eccentric part was achieved by rotating the middle part with ≅ 120° against the part facing the motor. At a speed of 8.000 r.p.m. the power of the motor amounted to 2,2 kW, and the frequency converter disconnected the motor.

The middle part was rotated again until the motor reached 2,2 kW, at a speed of 12.000 r.p.m. When the motor reached 2,2 kW, the converter disconnected it (the unbalance angle being of 20°). According to the data in the literature , it follows that good results have been obtained when a frequency of over 180 Hz has been attained. At 12.000 r.p.m. the frequency was of 200 Hz.

By means of this eccentric part the frequency and power of the three jarring tables has been determined (see Table N.°1). The jarring tables have the following weights and dimensions: M1 = 53,94 kg, 500x275x50 [mm] ; M2 = 21,58 kg, and 500x275x20 [mm] ; M3 = 16,19 kg. and 500x275x15 [mm].

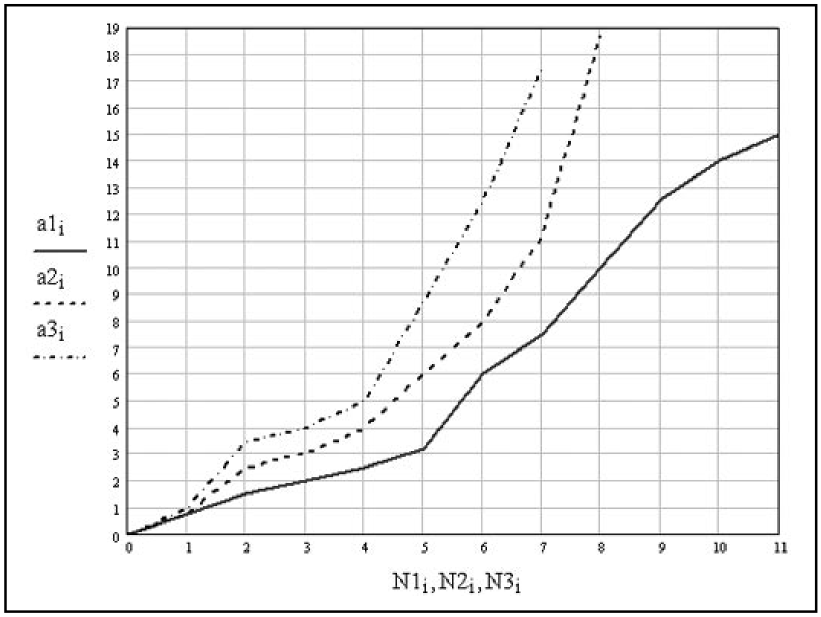

Figure 2 Variation of acceleration [g] dependent on speed (N),on the three tables M1, M2, M3

Jarring table M1 and M2 are made out of Fcx 250, and M3 of OL52.

The following results were obtained:

- For table M1 at a speed of 12000 r.p.m., the power of the motor exceeded the nominal value and the motor was disconnected.
- For table M2 the power of the motor exceeded the nominal value at a speed of 8000 r.p.m. and it was disconnected
- For table M3 the power of the motor exceeded the nominal value of 7800 r.p.m. when it was disconnected.

Acceleration imparted to the vibratory table

The measurement of the acceleration has been performed by means of an accelerometer fixed one ach side of the jarring tables, M1, M2, M3.

Figure 2 shows the variation of the acceleration dependant on the motor speed. It can be noticed that from a speed ranging between 4.000 and 5.000 r.p.m. , the amplitude of the acceleration increases very much, and the resonance phenomenon becomes manifest. Through experiments, it has been noticed that, for a certain eccentric and for a certain table used, the speeds attained may generate vibrations whose frequency is close to the vibrations of the equipment. These vibrations bring about the impairing of the equipment, mainly of the ball bearings.

Figure 2 shows that the acceleration values differ from one table to the other at the same speed.

Experiments have demonstrated that for a certain eccentric at high speeds, moments of high inertia occur in the equipment damaging the ball bearings.

From the graph in figure 2 it follows that high values can be obtained for the acceleration even at lower speeds if jarring tables with a smaller weight are used. Thus, the negative effect of the high inertia moments upon the vibratory equipment is reduced.

Table 3 lists the characteristics of the equipment: P (kW), H(Hz); Speed (r.p.m.) on the three tables for an unbalance angle of 20°.

Conclusions

Following the designing and building of this industrial equipment, vibrations of 200 Hz have been generated with high accelerations and amplitudes. The utilization of this equipment for the vibration of the antifriction alloys with a Sn base during solidification has led to a change in their structure and at the same time to an improvement of the mechanical and tribological properties.

Moreover, the use of a highly performant measurement equipment for the determination of certain parameters enabled us to draw a significant conclusion, namely that high accelerations can be generated at lower speeds if the weight of the jarring table is reduced.

The reduction of the speed brings about an increase in the reliability of the equipment.

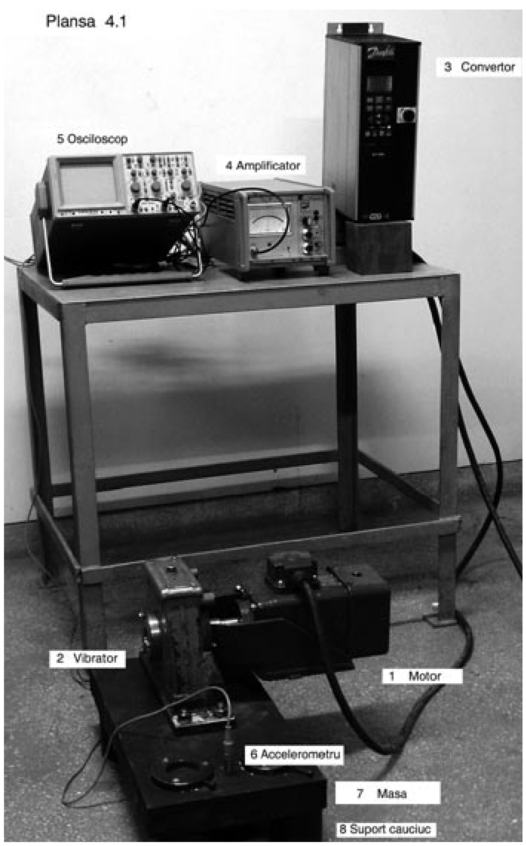

Figure 3 Description of the equipment

Table 3 Characteristics of the equipment

Variation of the motor power and frequency on M1, M2, M3

Speed [N] r.p.m	*f [Hz]*	*P [kW]*		
		M1	*M2*	*M3*
1.000	16,66	0,06	0,05	0,07
2.000	33,33	0,09	0,08	0,09
3.000	50,00	0,12	0,15	0,20
4.000	66,66	0,20	0,21	0,16
5.000	83,33	0,30	0,33	0,36
6.000	100,00	0,45	0,55	0,60
7.000	116,66	0,61	1,30	1,07
8.000	133,33	0,74	2,20	2,20
9.000	150,00	1,19	-	-
10.000	166,66	1,61	-	-
11.000	183,33	2,01	-	-
12.000	200,00	2,20	-	-

Description of the equipment (figure 3)

1. Asynchronous a.c.motor (Pn = 2,2 Kw, I = 165 A, n = 17.000 r.p.m.)

2. The mechanical vibratory equipment

3. VLT 5008 Danfoss frequency converter

4. KW 3072 HBM amplifier

5. Oscilloscope

6. B12/1000 HOTTINGER BALOWIN MESS TECHNIK accelerometer

7. Jarring cast iron table

8. Rubber mountings

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