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Rapid Solidification Processing of Al- 3wt% Mg Alloy

Dr. Talib Khalel Ibrahim* Dr. Ali Sabea Humod

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Abstract:

Metallic ribbons were formed under a chill block melt –spinning process conditions for Al-3 wt% Mg alloy. X-ray diffractometry, optical microscopy, electron microscopy and thermoanalytical data have been used to establish comparison between as–received alloy and ribbons.

Thermogravimetric data showed that the weight gain is lower for the ribbons compared to the as –received alloy.

الخلاصة:

تم تحضير الأشرطة المعدنية تحت ظروف عملية التجمد السريع لسبيكة الألمنيوم المحتوية على ٣% نسبة وزنية من المغنيسيوم. تم استخدام حيود الأشعة السينية, المجهر الضوئي, المجهر الالكتروني, قياسات الصلادة والمعلومات التحليلية الحرارية لإنجاز المقارنة بين السبيكة الأصلية كما هي والسبيكة بهيئة أشرطة بعد إجراء عملية التجميد السريع. بينت التحليلات الحرارية إن الوزن الزائد يكون اقل في حالة الأشرطة بالمقارنة مع السبيكة الأصلية.

Introduction:

Research on engineering materials is an area of national priority today. New materials and methods of production are crucial in the emerging high technology industries for manufacture of products from electronic devices to superconducting, machinery parts and also in more traditional areas, such as the automotive, aerospace and plastic industries [1-6].

Metals and alloys that are rapidly solidified from the molten state are known to exhibit electrical, chemical and mechanical properties quite different from their slowly cooled counterparts [7-10]. Among the methods of production, scientists are focusing on rapid solidification by melt –spinning, a process is first formed and then impinges against a rapidly moving substrate surface which acts both to chill continuously and to transport the material away from the melt impingement area, resulting in the fabrication of a continuous rapidly quenched ribbons or tapes [11-14].

The present work, reportston design of a simple experimental setup of melt-spinning technique and its use for production of rapidly solidified aluminum alloy containing small amounts of magnesium.

Experimental Procedures:

The laboratory experiments initially involved designing an apparatus for producing metallic glasses by melt spinning method, Fig. (1). In this method a rapidly spinning copper is used to conduct the heat a way from the melt rapidly and continuously from the melt.

The experimental apparatus consisted of a ASTM C10100 copper wheel of 7.95 cm diameter and 5.59 cm width fixed to a AISI 304 –stainless steel shaft, a motor which gives 2830 r.p.m used in this possessing and crucible with its holder. All these components were fixed in to a frame of AISI 1045-

* Ministry of Science and Technology / Center of Materials Science
**University of Kufa / College of Engineering

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

carbon steel table in order to avoid vibration during the spinning process.

The material to be melted was crushed to fill the alumina crucible. Different orifice sizes of the crucibles were used. The charged crucible was heated in tubular furnace suspended above the chill surface. Wheel speed of 12 ms^{-1} was employed with varying nozzle to wheel gaps.

The molten material was ejected on the moving chill surface Where different lengths of ribbons were produced.

The alloy used in the present investigation was aluminum alloy rod containing 3 wt% magnesium, the as-received alloy and the ribbons produced were characterized using optical microscopy, electron microscopy, X-ray diffraction, thermal analysis techniques and Vickers hardness measurements. The 5052-Al-Mg alloy rods were sectioned and examined by using optical microscopy (Type Univar) after ground with abrades paper of grades 320, 500 and 1000 µm. Then 10 ml H3PO4 (85%), 80 ml water was used about etching solution in order to obtain the quired detailed information microstructure. Specimens for electron microscopy were prepared and micrographs were taken using JOEL- electron microscope. X-ray analysis was carried out using Cu-Kα radiation with the ribbon mounted on glass slide in a Rigaku X-ray diffractometry. Thermal analysis curves were performed on NETZSCH thermal analysis STA-429. Hardness measurements were made with a standard Vickers tester.

Results and Discussion:

The aluminum–magnesium alloy used in this investigation was a commercial alloy containing 2.85wt% magnesium (A 5252) as detected from the chemical analysis, and was supplied in the form of rods. From the aluminum-magnesium phase diagram (Fig.2) [1], we find the 3% magnesium of alloy 5052 trapped in solid solution in the α (FCC) phase at room temperature.

The Al-Mg alloy has been melt-spun on a copper substrate. The melt spinning conditions have been varied in order to determine the optimum spinning parameters for the apparatus used.

The resulting ribbons have been examined by various techniques, mentioned in the experimental procedure to show the differences in the microstructure. Figure 3a is an optical micrograph showing the microstructure of the as-received Al-Mg alloy. Fig.3b shows the scale of interdendritic phase after rapid solidification processing in the alloy. It is important to remember that, to obtain a metallic glass, crystallization should be prevented. The liquid must be cooled through the freezing range and past the glass transition temperature before a significant number of crystals sould be frome 3. Hardness of the resulting ribbons was 150 HV but the conventional alloy rods had the lowest hardness about 55 HV.

Figure 4a shows typical X-ray profile for as – received Al-Mg alloy. The peaks were corresponding to the pure aluminum except for the differences in the peak height intensitiesson with the ASTM values for pure aluminum metal.

Melt-spinning was carried out using different orifice sizes of the crucibles and different nozzle to wheel gaps. The conditions in which produced the best ribbons were at orifice size 2 mm and nozzle to wheel gap 1 mm.

The ribbons obtained were examined by X- ray diffraction technique (Fig.4b and 4c). All the ribbons which were produced under various conditions of melt- spinning showed presence of a second phase but with varying rates of growth. However, the X-ray patterns revealed that peaks corresponding to the second phase were reached their maximum intensity when the melt-spinning was carried out using nozzle to wheel gap of 1mm. It seems, also that the formation of the second phase created strong texturing effect in the alloy, where a noticeable change was observed in the peak height intensities of the melt- spun ribbons. The formation of this phase was revealed further by electron microscope examination and thermal analysis measurements. The former showed the microstructure to be considerably different as compared to the as received aluminum alloy.

Thermogravimetric data, however indicat that the formation of the second phase improves the oxidation resistance of the produced ribbons, the thermograms show that the weight gain is lower for the ribbons as compared to the as received aluminum alloy (Fig. 5a and 5b).

Consideris when on the above results, the products obtained may be identified to be a mixture of two phases, the face – centered cubic phase and an additional weak phase corresponding to a partially crystalline products as revealed from the electron micrograph and the broad peaks on the X-ray profile.

Conclusions:

1- The substrate surface velocity appears to be an important factor determaion of ribbons thickness only.
2- Hardness of the resulting ribbons was 150 HV but the conventional alloy rods had the lowest hardness.
3- The thermal analysis shows hat the weight gain is lower for the ribbons as compared to the aluminum alloy rods.

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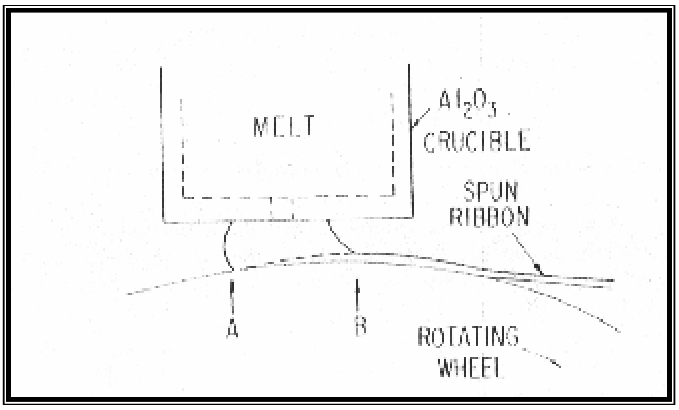


Fig. (1): The schematic of the melt puddle established in the gap between crucible and wheel during the melt spinning.

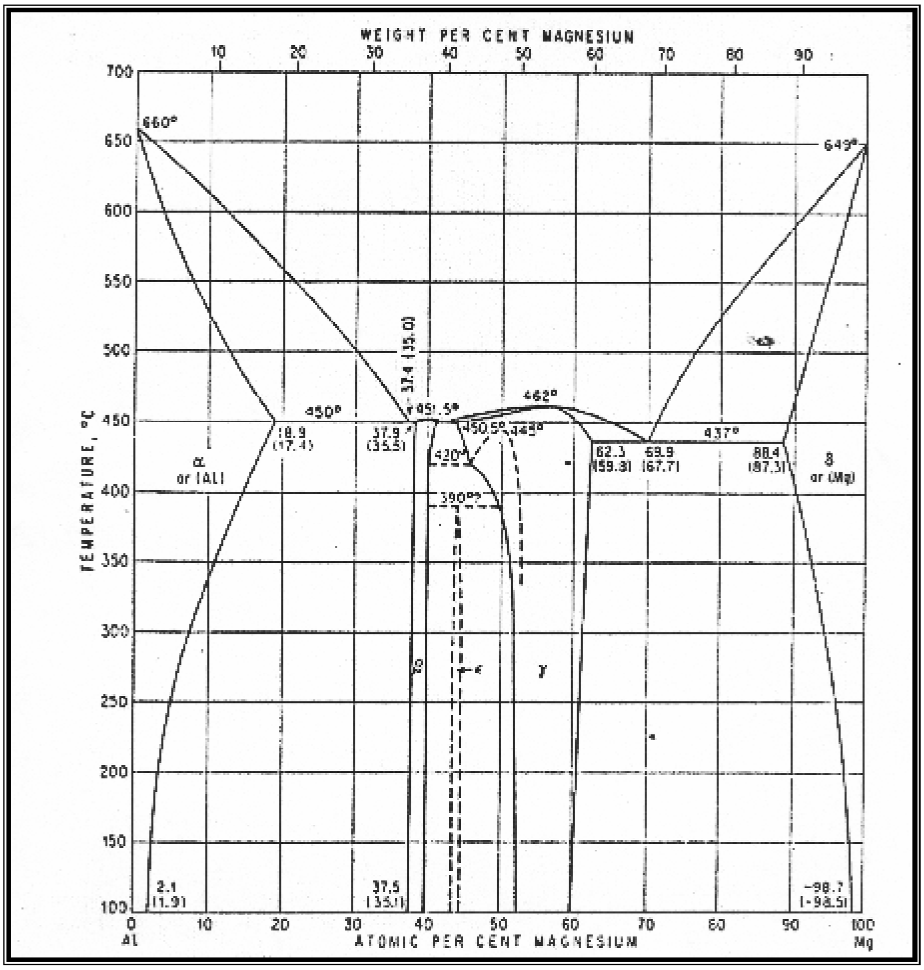
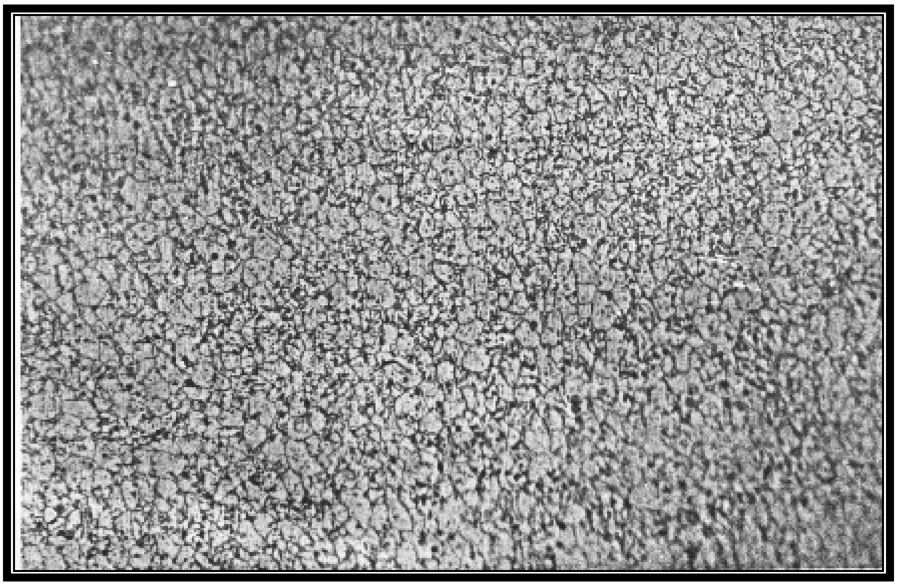
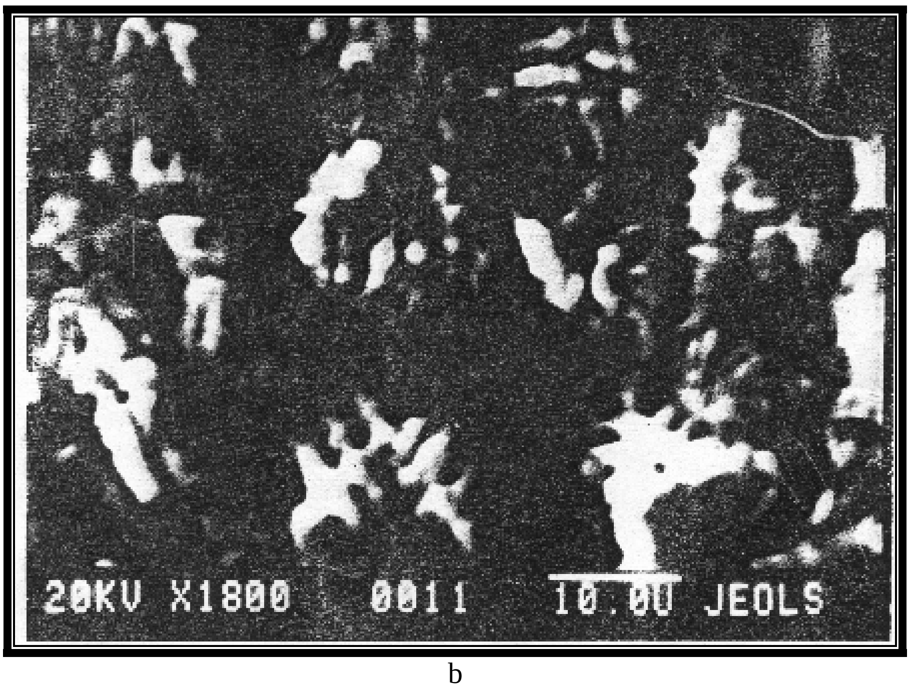


Fig. (2): The aluminum- magnesium phase diagram [1].



a



b

Fig. (3): Micrographs of: a- as-received alloy, b- Melt- spun ribbon.

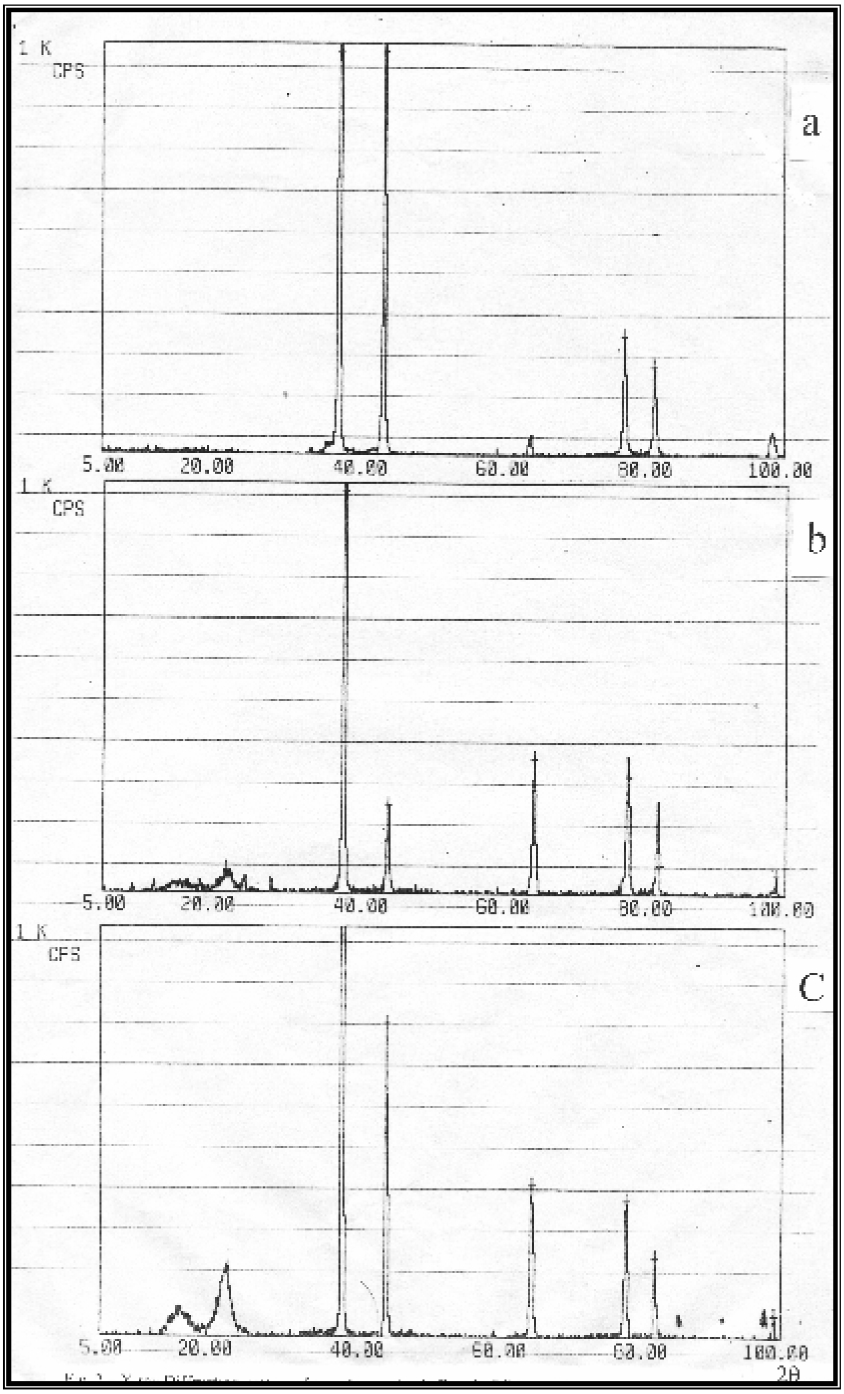


Fig. (4): X-ray diffraction patterns for: a- As- received alloy, b- Ribbon, nozzle to wheel gap 2mm, c- Ribbon, nozzle to wheel gap 1mm.

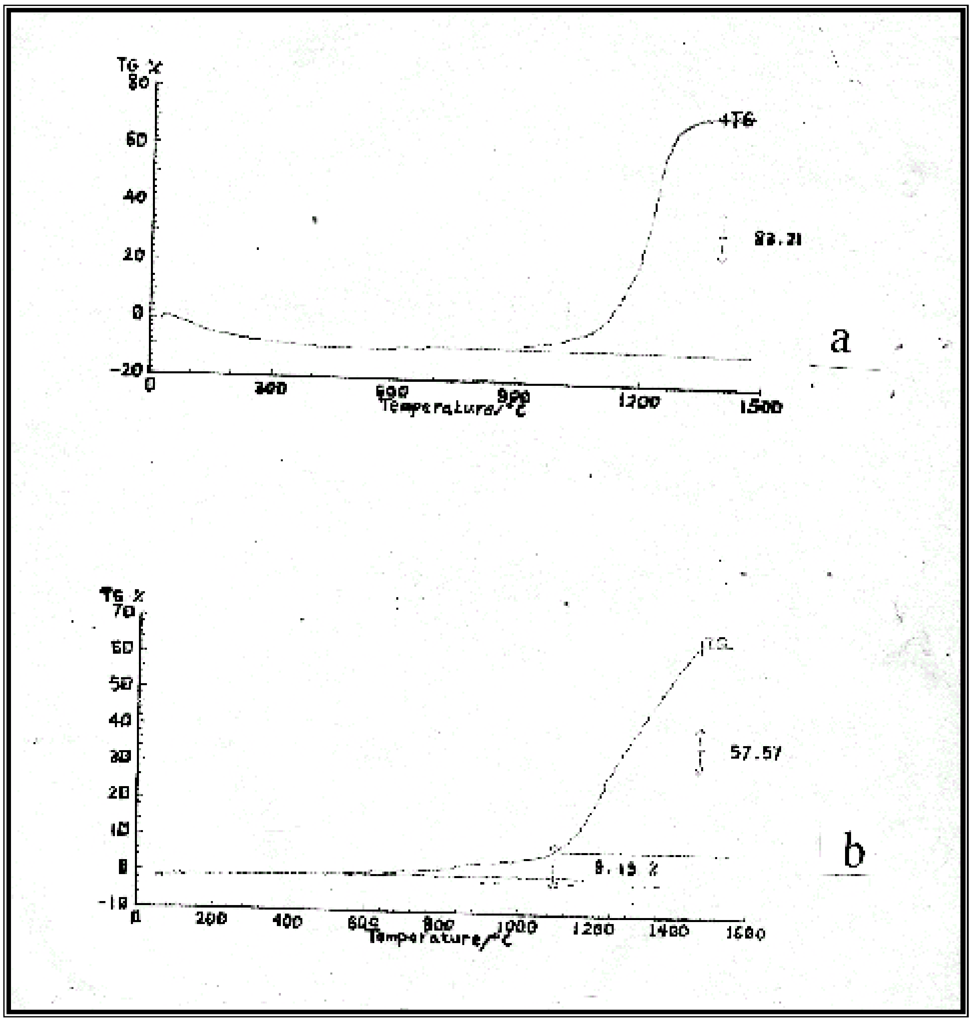


Fig. (5): Thermogravemetric behaviour of:
a- As-received rod,
b- Melt-spun ribbon.