

FUNCTIONAL MODEL AND TECHNIQUE FOR SERIES PARTS MADE FROM LIGHT ALLOYS BY THIXOTROPY

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ABSTRACT: The papers aim is to present the constructive solution of a functional model that makes complex parts by thixotropy process as well as their manufacturing process. Our functional model was used to develop, by pressing when the material reaches a dens plasticization state, in a matrix, light alloys made from Mg-Al obtained from recycling car wheels. The experimental lot characteristics, thus obtained, are detailed in the present paper and highlight a significant growth in performance, compared to previous parts, obtained by classic casting.
The metallographic structure of injected parts is type thixotrop, a lot different from the dendrite structure of cast parts. Resistance to compression-tearing is net superior if compared to cast parts, which facilitates applying the manufacturing process to products that have small geometry.
KEYWORDS: aluminium-magnesium-alloys, thixotrop manufacturing, automotive industry

1. INTRODUCTION

Developing state of the art components, from a technical and economic point of view, imposes using innovative materials and optimized manufacturing technologies; in the present case the materials required are light-weight materials with high resistance and the possibility of recycling. These conditions are excellently met by magnesium alloys. The special proprieties of magnesium and its alloys, a lot superior to that of plastic materials, lead to their usage on a large scale, when manufacturing parts in the electric and telecommunication industries. By optimizing the manufacturing process of complex parts, made from magnesium alloys, thixotrop type [1, 2, 3, 4, 5], developed during research performed on recycled car wheels, namely by melting them to a semi-solid state, through thixotropy and directly injecting them into the mould; open new perspectives on developing complex parts with high mechanical characteristics and high performance [6, 7, 8, 9]; parts for electronic and telecommunication equipment, that require special characteristics and are competitive to similar products developed worldwide, re-launching parts production for phones, cars, and so on.

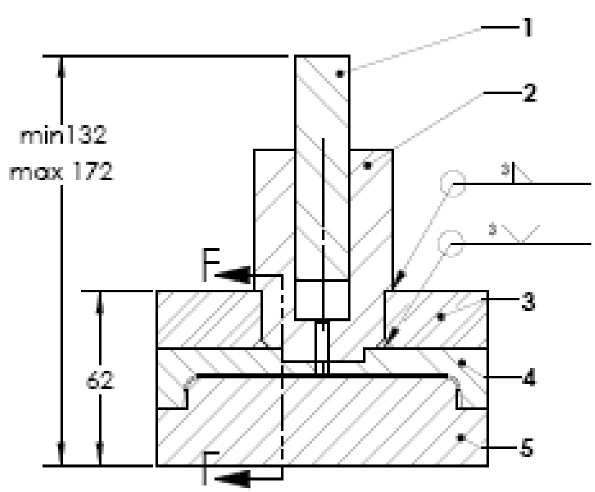


Figure 1. Principle scheme of the matrix
1-Punching force cylinder; 2-CIF force-heating cylinder; 3-Matrix superior body with angular bore for extrusion;4-Intermediar matrix body with semi-model extruded part;5-Inferior matrix body with semi-model extruded part

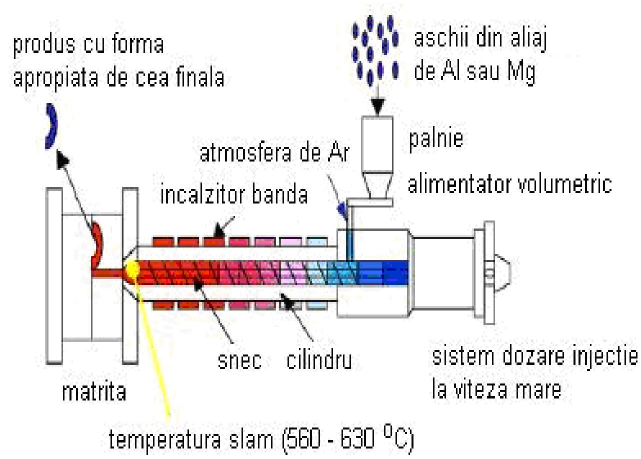


Figure 2. The thixotropy and injection equipment scheme

The new manufacturing technology for complex magnesium parts implies heating in the new research developed equipment of the new thixotrop precursors until it reaches a temperature between the liquid and solid state of the binary alloy, then thoroughly mixing the plasticized alloy and injecting it into the mould. The working principle of the thixotropy matrix and equipment are showed below in figure 1 and 2.

2. EXPERIMENTS

In order to achieve the research objectives scientists developed a functional model in order to obtain thixotrop structure parts; taking into account requirements regarding processing magnesium alloys, work temperature, injection speed and matrix build.

Physical-chemical and technologic characteristics of the materials from constituent elements of the injection and thixotrop matrix are presented in table 1 and 2. The chemical composition was determined by spectral analysis, on the spectrometer SPECTROMAXx, with the help of specialized software for tool steels and is in range of the manufacturer prescriptions.

In order to develop the matrix, we used steels type 45VSiCrW20, in an annealed state. It was processed according to the matrix technical execution documentation, in raw state; the obtained parts were subjected to heat treatments, according to table 2.

The chemical composition determined is according to specifications.

Table 1. Chemical composition

45VSiCrW20	**Chemical elements [% mass]**									
	C	***Si***	***Mn***	***P***	***S***	***Cr***	***Mo***	***Ni***	***V***	***W***
Prescribed	0,4 0,5	0,8 1,1	0,2 0,4	0,03	0,03	0,9 1,2	--	≤0,35	0,15 0,20	1,8 2,1
Determined	0,43	0,98	0,3	0,03	0,03	1,0	--	0,30	0,17	1,9

Table 2. Sclerometer and technological characteristics

Forging temperature [°C]	Annealing temperature, [°C]		Hardening regime			Recurrence temperature, [°C]	Hardness (HRC) for each T_{rev}, [ºC]			
		Hardness HB30	Temp. [°C]	Cooling environment	Hardness, HRC	--------------------------------------				
1050	720	-	890	-	-	180	100	200	300	400
850	750	225	930	Oil	57	300	57	56	54	52
970	730	225	910	Oil	57	235	55	56	53	52

The experimental hardness determined is according to prescriptions. Matrix component parts, figure 3, after hardening, were corrected dimension wise, at the end of the process and mounted in the matrix assembly, which was then tested to see its behaviour during exploitation, figure 4.

The obtained matrix was integrated in the functional model of the equipment that produces thixotrop parts.

Figure 3. Injection heating matrix components

Figure 4. Injection chamber configuration of the experimental product

The equipment is made up, based on the scientific documentation [10, 11, 12, 13, 14], of a CIF heating matrix in which the viscous-plastic state material is injected in; i.e., the material recycled from car wheels is grinded in advance, a hydraulic press of 20Tf, a CIF heating equipment of 20KVA and a temperature measuring equipment, all interconnected between them, figure 5 and 6.

Figure 5. Experimental manufacturing line by thixotropy and injection in matrix

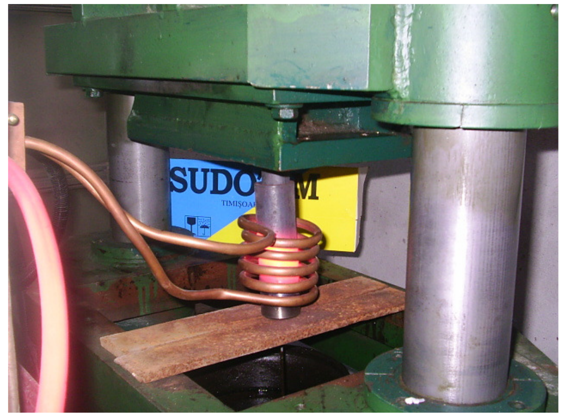


Figure 6. CIF heated injection matrix cylinder

The granulated metallic alloy was heated in the new double effect angled matrix in high frequency currents, to a temperature between the liquid and solid state, semi-solid state, then injected into the matrix cavity. Mechanical sheering of the semi-solid material when cooling generates a thixotrop structure. Material extrusion, when it reached optimal viscosity and is under pressure, is made at high speed into the matrix cavity. Due to high fluidity, the thixotrop structure, the fine grain size and the semi-solid material state, the deformation effort is reduced when the semi-solid material passes through the nozzle and mould into the matrix.

The thixotrop structured part, obtained by injecting magnesium-aluminium alloy or magnesium-aluminium powder in semi-fluid state is presented in figure 7.

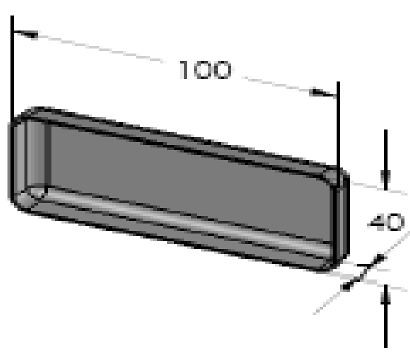


Figure 7. Thixotrop structured part obtained by injection, thickness 0,5mm

3. RESULTS AND COMMENTS

Quality determination on phases, on test specimens taken from the part presented in figure 7, was made by x ray analyse, with a diffract-meter type D8 Advance, Bruker –AXS according to SR EN 13925-1:2003, SR EN 13925-2:2003 and SR EN 13925-3:2005, results are presented in figure 8.

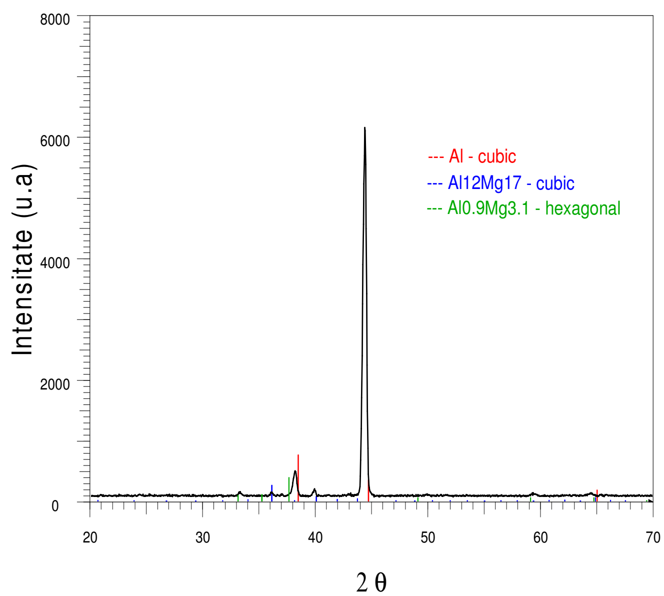
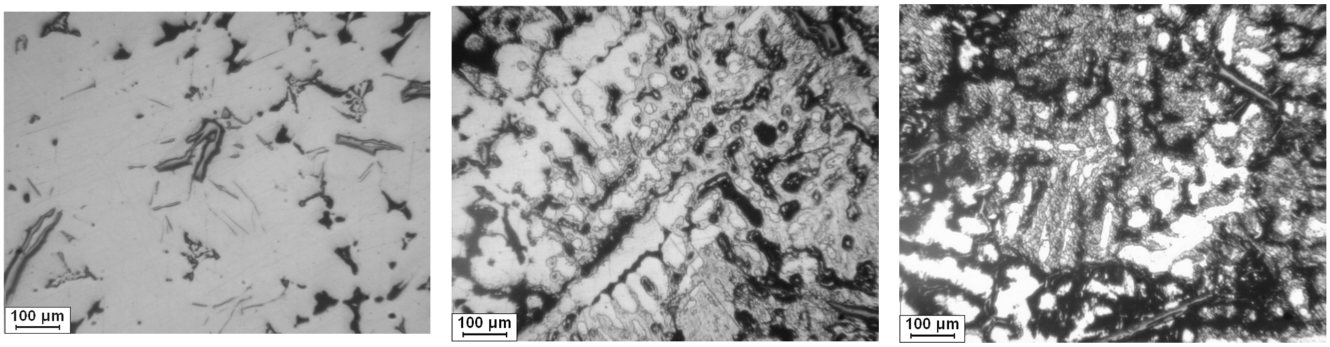


Figure 8. X ray diffraction spectrum

The x ray diffraction spectrum denotes that in the magnesium-aluminium alloy the phase constituents are type α-Al, $Al_{12}Mg_{17}$ and an intermediate phase type $Al_{0,9}Mg_{3,1}$.

Microstructure analysis was performed on an epoxy resin covered test sample at room temperature, polished with diamond paste till it reached mirror polished, with the help of specialized equipment. We proceeded with the chemical attack at temperature of 25 °C, for 10 and 25 seconds, with specific Mg-Al chemical agents. Metallographic analysis was made on an optic microscope type NU2 - VEB Carl Zeiss – Jena, and results are presented below, figure 9.



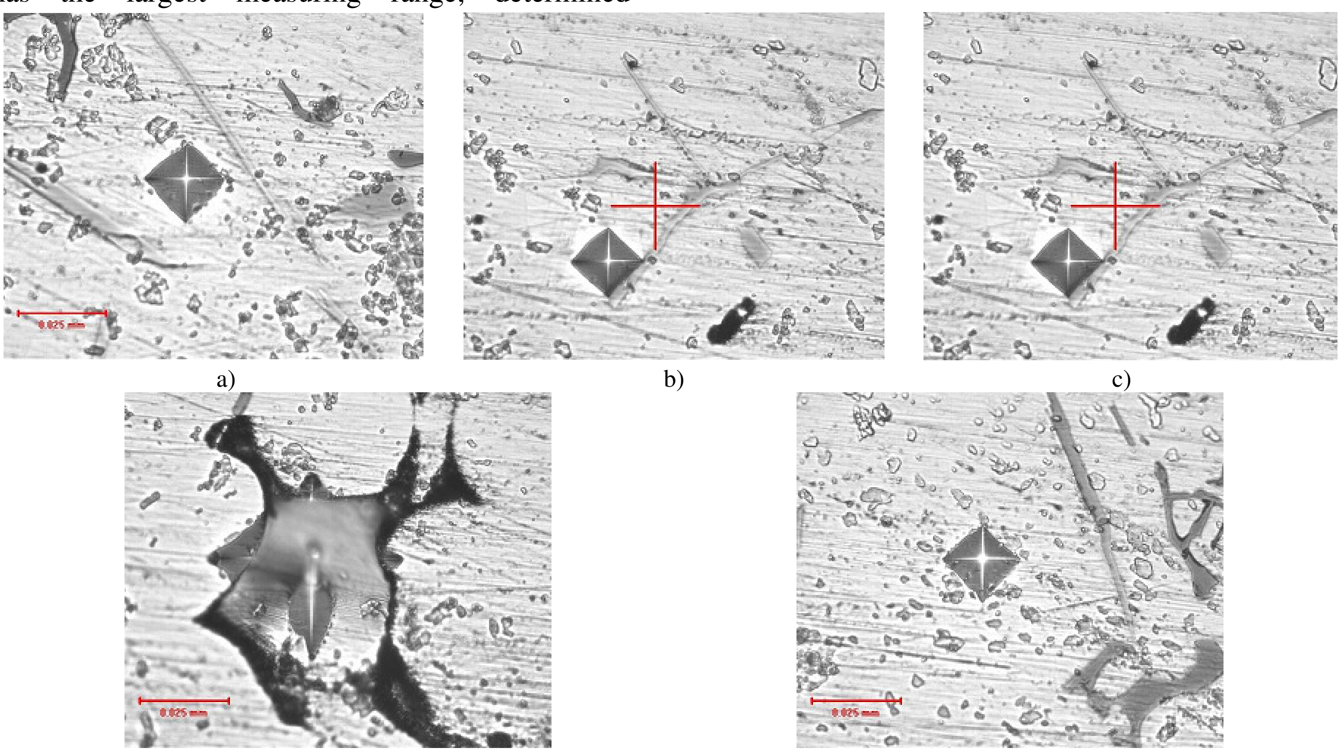
a) b) c)

Figure 9. Microstructure aspect:
a) without chemical attack, b) Chemically attacked 10 s, c) Chemically attacked 25 s (HF, HNO_3, HCl, CH_3OH)

The sample microstructure is presented under the form of a eutectic matrix build from phases (α-Al + $Al_{12}Mg_{17}$) in which there are uniformly dispersed needle like dendrites from α-Al, and low number of particles from phase α-Al, with very different dimensions.

Hardness was determined by Vickers method, which has the largest measuring range, determined according to SR EN ISO 6507-1:2006 and SR EN ISO 6507-4:2006.

Vickers (HV) hardness tests were done on a micro-hardness tester type FM 700 AHOTEC, equipped with digital camera, pressing force 0,245 N, time 10 seconds. Investigated areas and marks from the tip are presented in figure 10.



a) b) c) d) e)

Figure 10. The hardness tester tip marks on various zones of the sample

HV hardness had the following values: 97,5 daN/mm^2, 124 daN/mm^2, 105 daN/mm^2, 85,1 daN/mm^2 and 98,1 daN/mm^2, medium value was 102 daN/mm^2.

The sample is harder in the eutectic matrix (α-Al + $Al_{12}Mg_{17}$) (97,5 daN/mm^2, 124 daN/mm^2, 98,1 daN/mm^2) compared to phase α-Al (105 daN/mm^2 and 85,1 daN/mm^2). We can notice a slight inadvertence due to the materials porosity.

Compression tests were made with a universal static mechanical testing machine, type LFM 30 kN, Walter & Bai AG according to EN 10002-1:2001 and ASTM 1820:2008.

In figure11 we present graphs that represent the variation of resistance at compression, function to the distortion of the compression tests. Compression resistance, determined at ambient temperature is 257,36 MPa.

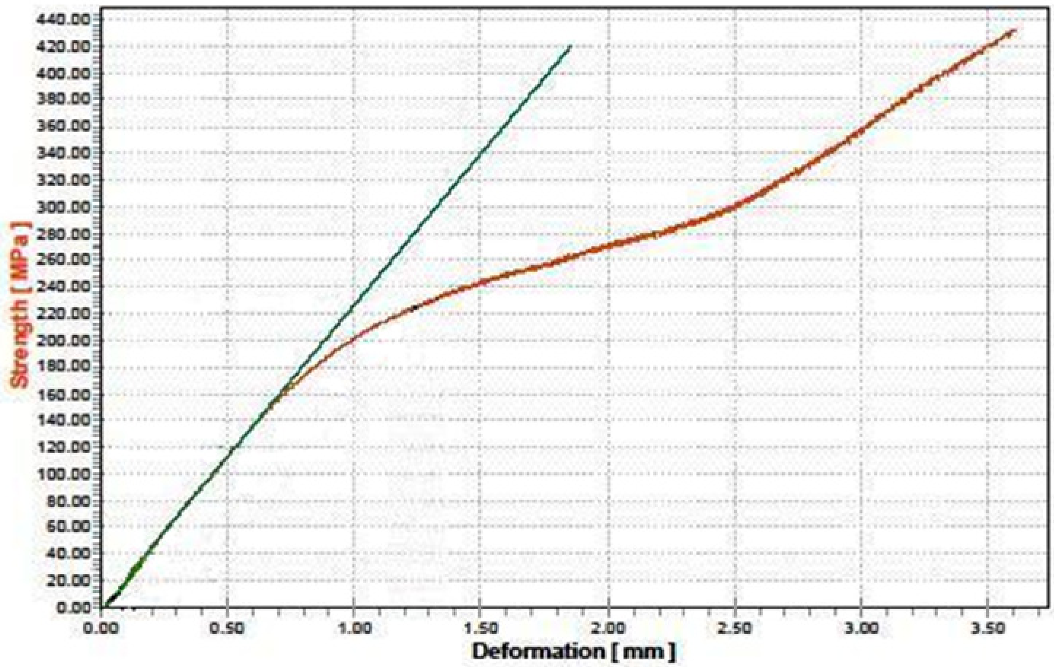


Figure 11. Compression resistance variation

4. EXPERIMENT CONCLUSIONS

1. The method used is preferred when grinding metallic alloys in order to produce fine globular structure, less dendrites. Initial structures can evolve to a thixotrop structure by remoulding until it reached a semi-solid state then applying a deformation force that facilitates grinding;

2. Proper microstructures for semi-solid processing can be developed for different alloys, but the response mechanism varies function to the alloy;

3. It is difficult to explain the importance of the deformation speed effect on magnesium alloy behaviour in semi-solid state. But we can notice a increase in the deformation force values, that occurs with the rise of the deformation speed. This is a classic plasticization behaviour. We can thus affirm that parts that were deformed with a higher deformation speed have finer surfaces; this fact is probably most likely due to thermal effects, not necessarily due to the deformation speed. After injecting the thixotrop magnesium alloy, we observed that at low pressing speeds (2-4 mm/s) and the same heating regime, at a liquid phase quantity of fL=0,33, although the quality of the surface is good, problems appear when we try and remove it from the matrix. We consider that these could have appeared due to a poorly done lubrication of the equipment. At a liquid phase of fL=0,24, the quality of the surface is better and we cannot see any problems when removing parts from the matrix.

4. The above presented data confirms that processing by thixotropy and injection in a matrix, although it is an expensive process, assures developing parts with superior physical-mechanical characteristics to those obtained by other cheaper manufacturing process, fact highlighted by manufacturing, on pilot equipment, of two test lots of thixotrop structure rods.

5. REFERENCES

1. Kopp D., s.a., Different Concepts of Thixoforging and Experiments for Rheological Data, *Journal of Materials Processing Technology*, Volume: 111, Nr. 1-3/2001, pag. 48-52, (2001);
2. Collot Jean, Thixoforming of Magnesium and Aluminium alloys in the semi-solid or semi-liquid state, *Hommes et fonderie*, no.308, nov. (2000);
3. Sahm P.R., Thixocasting: Processing of light metals in the semi-solid state – Potential and applications, *BRAMAT, Brasov*, sept. (2001);
4. Atkinson H.V., Kapranos P., Kirkwood D.H., Alloy development for Thixoforming, Semi-solid processing of alloys and composites, *6th International Conference*, Turin, p.443-450, (2000);
5. Collot J., Thixoforming of Magnesium and Aluminum alloys in semi-solid or semi-lichid, that is the question?, *64th World Foundry Congress*, sept. Paris, (2000);
6. Brown SB, Flemings MC, editors. *In: Proc. 2nd Int. Conf. on Semi-Solid Processing of Alloys and Composites*, Cambridge, MA, USA, June 1992. Warrendale: TMS; (1992);

7. Kiuchi M, editor. In: Proc. *3rd Int. Conf. on Semi-Solid Processing of Alloys and Composites*, Tokyo, Japan, June 1994. Tokyo Institute of Industrial Science, (1994);
8. Tsutsui Y, Kiuchi M, Ichikawa K, editors. *In: Proc. 7th Int. Conf. on Advanced Semi-Solid Processing of Alloys and Composites*, Tsukuba, Japan, Sept 2002. Japan: National Institute of Advanced Industrial Science and Technology and the Japan Society for Technology of Plasticity; (2002);
9. Collot Jean, Les differentes techniques de preparation et de mise en forme à l'état semi-solide des alliages metalliques, *Fonderie-Fondeur d'aujourd'hui*, no.129, (1993);
10. Elthalabawy, W. M. and Khan, T. I. Microstructural development of diffusion brazed austenitic stainless steel to magnesium using nickel interlayer, *Materials Characterization*, 61, 703-712, (2010).
11. Humpston, G. and Jacobson, D. M. Principles of Soldering, ASM International, *Materials Park*, Ohio, (2004).
12. Sun, D. Q., Lang, B., Sun, D. X. and Li, J. B. Microstructure and mechanical properties of resistance spot welded magnesium alloy joints, *Materials Science and Engineering A*, 460, 461, 494-498, (2007);
13. S. Sannes, H. Westengen, in: B.L. Mordike, K.U. Kainer (Eds.), Magnesium alloys and their applications, *Werksto-Informationsgesellschaft mbH*, Frankfurt, Germany, pp. 223±228, (1998);
14. ASM Handbook, Volume 1: Properties and Selection: Irons, *Steels, and High-Performance Alloys*, ISBN: 978-0-87170-377-4, (2010).