Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Squeeze Casting Technology in Production of High-Strength Monolithic Aluminum Alloys and Aluminum Matrix Composites

Piotr Dudek, Jerzy J. Sobczak, Paweł Darłak, Piotr Długosz
Foundry Research Institute, 73 Zakopianska St., Krakow, Poland
piotr.dudek@iod.krakow.pl, jerzy.sobczak@iod.krakow.pl, pawel.darlak@iod.krakow.pl, piotr.dlugosz@iod.krakow.pl

The paper presents the results of investigation of monolithic and composite aluminum-based cast and materials with wrought alloys: AW 2024, AW 6061, AW 7075 in accordance with EN 573-3 and cast alloys AC 42100 according to EN 1706. Castings were produced using VSC 500 stand at a high squeeze pressure of 150 MPa and, for comparison, by gravity casting into permanent mold. Composite castings were performed using both commercially available ceramic preform (based on Al_2O_3 – Saffil® fibers) and preforms produced by Institute of Foundry using high energy ball milling and mechanical alloying of ceramic substrates. The preforms are made from shot Saffil® fibers and colloidal silica (LUDOX®) with fillers increasing porosity. Castings made of aluminum wrought alloy after heat treatment have shown almost double increased mechanical properties. In research characterized the material properties, including the influence on pressure for microstructure, defined physical properties, namely density, electrical conductivity and thermal conductivity, coefficient of thermal expansion, as well as basic mechanical characteristics.

Keywords: *squeeze casting, aluminum alloys, metal matrix composites.*

1. Introduction

Squeeze casting technology allows producing castings with a very accurate representation of their shape and surface. Components made by this method are characterized by a fine microstructure with reduced porosity, which allows applying the heat treatment, welding and resistance welding [1]. It can be thus produce a variety of composites reinforced by ceramic phase, e.g. dispersoids (particules) and/or short fibers or whiskers, long fibers and use porous preforms [2,3]. Low speed of shot plunger and high hydrostatic pressure provide excellent combination of ceramic and metal materials in the uniform homogeneous structure.

Research of squeeze casting and infiltration process has been performed on hydraulic complex VSC 500.

Metal was melted in the resistance furnace with a SiC crucible. The temperature of the die was kept stable by means of two heating/cooling devices and maintained at 200°C. All squeeze castings were solidified under the external pressure of 150 MPa. Moreover, a series of gravity reference castings (solidifying under the atmospheric pressure) were created.

2. Squeeze infiltration of ceramic preforms

In order to fabricate preforms with high open porosity the following methods were applied:
1) introducing different sizes of particles and
2) addition of organic substances.

The highest quality of preforms has been reach using of sawdust as the addition. The result is surprising because during burning sawdust, besides gases, releases pollution which may cause the degradation of the structure of preforms. Ceramic preforms were characteristic of open porosity contribution within measured range from 24 to 75%.

For infiltration preforms were selected with open porosity above 50%. The preheated preforms were infiltrated with 7075 liquid aluminium alloy with the use of the so-called “bottom” infiltration (Fig.1). The external pressure was also posed directly on the liquid metal surface (direct squeeze casting) with the use of a piston. The pressure equaled 150 MPa, and time was 60 seconds.

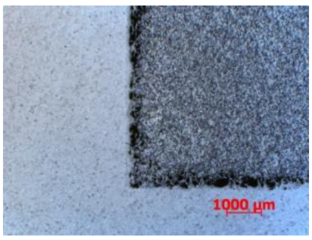
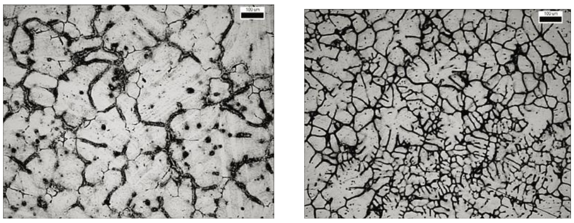


Fig.1 Microstructure of MMC 7075 alloy with Saffil® fibers

3. Squeeze casting

For tested alloys the shot speed was respectively 60, 50, and 40 mm/s, melt temperature: 750, 730, 720 and 690°C, mold temperature: 240, 220, 200°C and a squeeze time 25 sec. The differences of applied parameters are caused by the different alloys technological properties used in attempts.

It was found out those positive changes of microstructure castings solidifying under external pressure caused by the operation of mechanisms that can be divided into mechanical and thermodynamic ones. The first of these cause a significant increase in the rate of cooling of the solidifying metal, by reduction of the gap between the casting and the wall of the mold, thereby increasing the cooling rate of castings. Second increase the rate of nucleation of the solidifying metal by the increase of supercooling (Fig. 2).

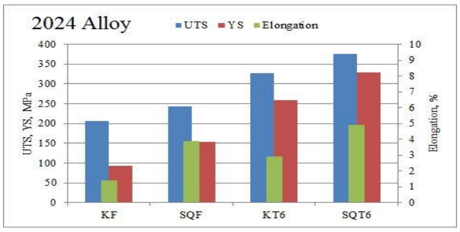


a) b)

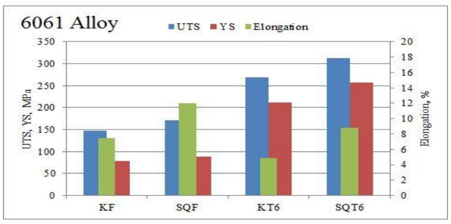
Fig. 2 Microstructures of the 7075 alloy gravity (a) and squeezed cast (b)

The mechanical properties of as-cast samples F, solution T4, the aged artificially T5 and precipitation treatment T6 were performed.

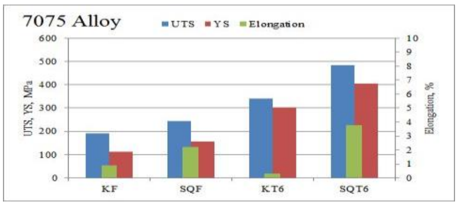
An advantage complex of mechanical properties was obtained regarding to castings made by squeeze casting method compared to standard castings solidified under atmospheric pressure (Fig. 3).



a)



b)



c)

Fig. 3 Mechanical properties of gravity (K) and squeezed cast 150 MPa (SQ) in the as-cast state (F) and after heat treatment to T6 condition: a) 2024, b) 6061, c) 7075 alloys

4. Conclusions

1. The highest porosity and compressive strength were achieved with the application of sawdust as the pore-creating substance, for producing preforms.
2. The wrought alloys can be successfully applied for squeeze casting technology.
3. The increase of exploitation characteristics for investigation materials can be improved by optimizations of squeeze casting parameters and heat treatment conditions.
4. Maximum level of mechanical properties were achieved for squeeze casted 7075 aluminium alloy (UTS = 483 MPa, YS = 405 MPa with elongation of almost 4%).
5. Metal matrix composites obtained by squeeze casting characterized by higher mechanical properties than monolithic alloys. The highest values of mechanical properties obtained for composites made from 7075 alloy fibers Saffil® after heat treatment T6 (UTS = 487 MPa, YS = 385 MPa, elongation – 7%).

Acknowledgements

Studies were performed as part of strategic project No. POIG.01.03.01-00-015/09 entitled “Advanced Materials and Technologies for Their Manufacture”.

References

[1] J. J. Sobczak: Teoretical and practical backgrounds of squeeze casting of non-ferrous metals. Transaction of the Foundry Research Institute, Special Issue 41, Krakow, 1993

[2] R. Ashiri, F. Karimzadeh, B. Niroumand: Materials Science and Technology, 2014, vol. 30, no 10.

[3] T. Reguła, A. Fajkiel, P. Dudek, K. Saja: Transactions of Foundry Research Institute, Volume LIV, Year 2014, Number 4.