

# Aluminium based components with enhanced characteristics through advanced squeeze casting process

M. Rosso, I. Peter, R. Molina, A. Montedoro, G. Tonno, P. Claus

*Components in the field of automotive application produced by a modified squeeze casting process have been considered. This innovative process has been oriented toward the manufacturing of high resistance and high toughness automotive parts using A380 alloys and they have been subjected to T6 heat treatment. Standard samples have been machined directly from real automotive components for tensile properties evaluation and hardness values determination. Superior mechanical characteristics have been obtained thanks to the low porosity content and to the particular microstructure features. Fracture surfaces analysis have been realised on the fractured samples, identifying some minor defects, like the presence of carbon particles (with any dangerous effect on the mechanical performances) and some nano-sized oxide inclusion. Moreover, the same fracture surface analysis highlights the ductile natures of the fracture. On the polished transverse sections of the samples morphological analysis has also been performed.*

*High level of resistance and toughness has been obtained for all considered parts. The achieved results demonstrate the reliability of the modified squeeze casting process for production of automotive components.*

## Keywords:

Aluminium and alloys, automotive, processes, foundry

## INTRODUCTION

The increasing demand for more fuel-efficient vehicles to reduce energy consumption and air pollution is very important for the automotive industry. Some properties of aluminium, such as high strength stiffness to weight ratio, good formability, good corrosion resistance make it the ideal candidate to replace heavier materials (fundamentally steel) in automobile production and to reply to the weight reduction demand within the transport industry.

Forging is an energy demanding process and it has been used to manufacture high performance simple shaped components. High pressure die casting (HPDC) is a popular and cost-effective technique for mass producing Al components and constitutes a suitable option to forging technology. Usually, in those processes, some of intrinsic defects, prevalently gas or shrinkage porosity, are originated reducing the mechanical properties of the alloys [1, 2]. It has been generally accepted that semisolid metal (SSM), techniques including thixo- and rheo methods and employing light alloys show some important benefits compared to the traditional routes [3-7]. SSM techniques are appropriate methods to significantly decrease the presence of the defects in the conventional Al casting or forging process and to obtain in this way good surface quality, high dimensional accuracy, high strength

and ductility, lightweight structural Al components [3-5].

In this context, the advanced squeeze casting (ASC) or the advanced rheocasting techniques [8, 9] can be considered a promising and attractive solution for automotive industry, for safety and high performance components.

Compared to the conventional route, in the ASC process the liquid metal is injected bottom up from the furnace directly into the closed mould, located on the opposite side relative to the nozzle, at very low velocity; once the filling is complete, high pressure is applied on the liquid material on the centre of sprue, thus forging the component. The high pressure is maintained during the whole period of the solidification allowing to obtain a final component with very fine and pore free microstructure. Moreover, this process allows using wrought alloys, usually a high performance alloys that up till now could only be developed by forging. The working cycle is comparable to HPDC process, but all the finishing operations are reduced, thanks to the absence of the risers and scraps from the feeding system. The application of a low pressure to feed the molten metal inside the cavity of a closed die allows reducing the turbulence in the metal flux. Since the turbulence can be associated to the quantity of the gas entrapment within the molten metal it involves the production of a defect free component.

In this paper an investigation on the effect of advanced squeeze casting process parameters on the microstructure and mechanical properties of A380 alloy for the production of automotive components will be considered.

## EXPERIMENTAL

The aluminium alloy, namely the A380 alloy, employed in this paper belongs to the AlSi9Cu3(Fe) system. Its chemical composition is shown in Table 1. A modified squeeze casting process has been used and a series of suspension lever arms have been

M. Rosso, I. Peter

Politecnico di Torino, Department of Applied Science and Technology  
Metallurgy Group; Alessandria Campus; Torino

R. Molina

Teksid Aluminum srl- Carmagnola, Italy

A. Montedoro, G. Tonno

FOMT - Grugliasco - Italy

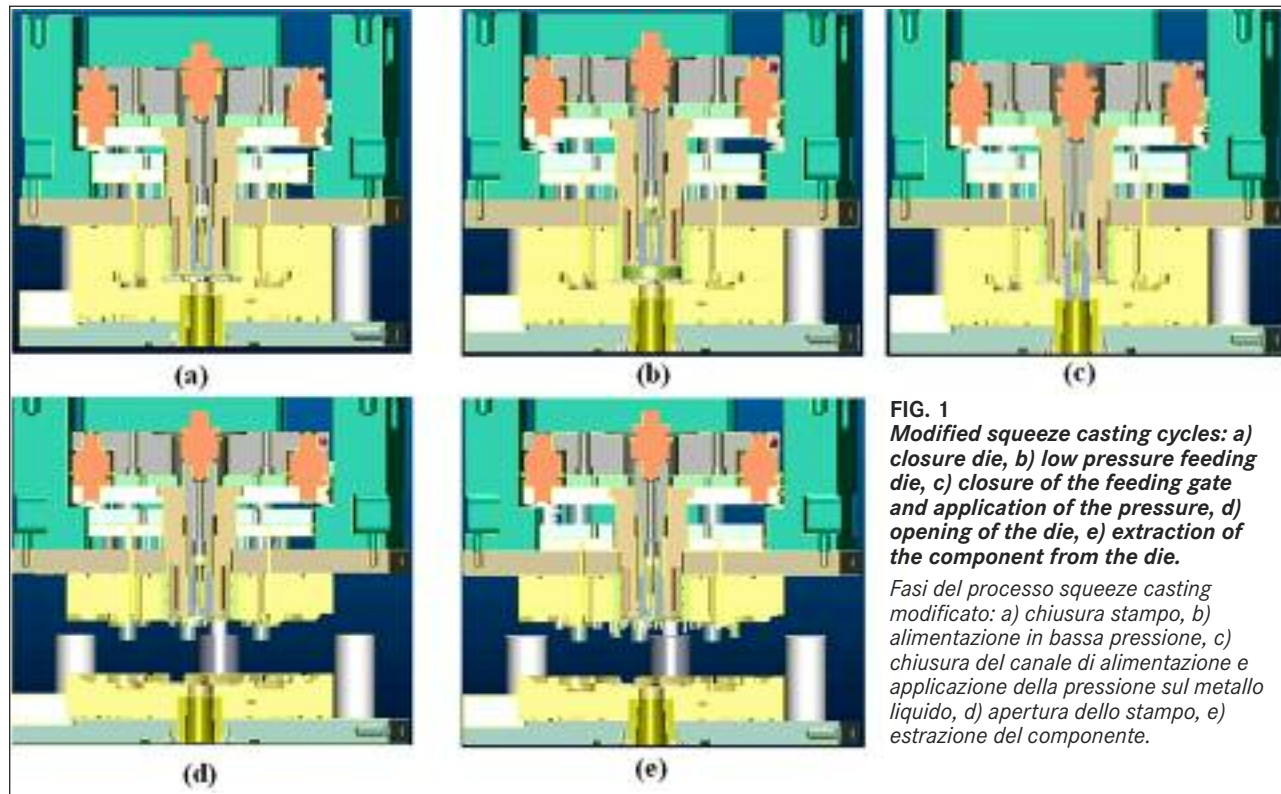
P. Claus

Tecnopres - Chieri - Italy

Elements	Si	Fe	Cu	Mn	Mg	Zn	Others	Al
	8,90	0,85	2,50	0,28	0,28	1,09	< 0.01	balance

**TAB. 1**  
**Chemical composition**  
**(%wt) of the A380 alloy.**

Composizione chimica (%wt) per la lega A380.



**FIG. 1**  
**Modified squeeze casting cycles: a) closure die, b) low pressure feeding die, c) closure of the feeding gate and application of the pressure, d) opening of the die, e) extraction of the component from the die.**

*Fasi del processo squeeze casting modificato: a) chiusura stampo, b) alimentazione in bassa pressione, c) chiusura del canale di alimentazione e applicazione della pressione sul metallo liquido, d) apertura dello stampo, e) estrazione del componente.*

obtained using a dedicated press (Tecnopres KLF 600) at FOMT Spa company. Such technique is a single step process and allows the possibility to use both cast and wrought alloys.

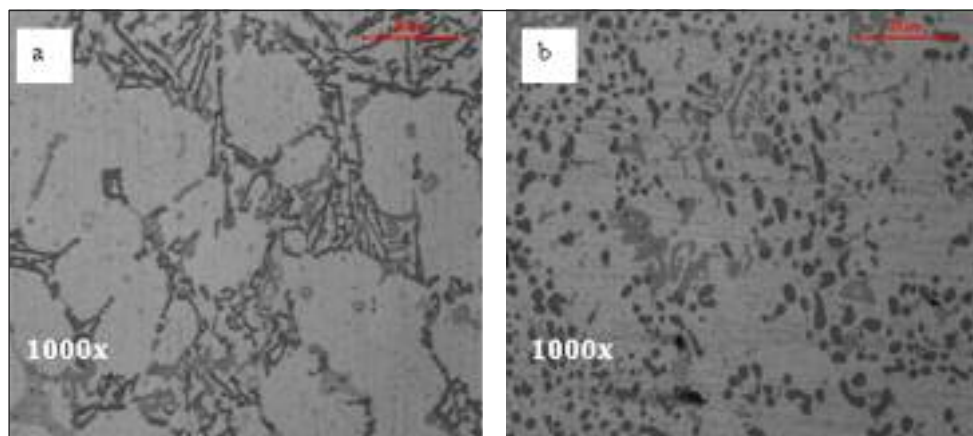
A schematic illustration of the modified squeeze casting process is given in Figure 1. A pre-quantified liquid metal, at 700-730°C is introduced at very low pressure (< 1 MPa) inside the cavity of a pre-heated (about 200°C) die (Figure 1a) followed by the closure of the power system (Figure 1b). Next, a high pressure, about 90 MPa (Figure 1c), is applied on the molten metal and it maintained till the total solidification of the metal. At last, the die is open out (Figure 1d) to allow the extraction of the component (Figure 1e). The continuous application of the pressure during solidification avoids gas entrapment, reducing gas and/or shrinkage porosity development and consequently leads obtaining a dense component.

The effective cycle was varied in 60÷70 s (comparable to high pressure die casting process - HPDC), but all the finishing operations are reduced, due to the lack of the risers and scraps from the feeding system. No contact between the liquid metal and the atmosphere has been occurred: if necessary, it allows the use of protective gas. The inconvenience of the process is associated to the possibility of manufacturing only components with a simple geometry and shape with a high level of regularity. Furthermore, at the actual stage a limited productivity can be realized (the cycle time is slightly higher than 60 s) compared to the HPDC processes (cycle time 30÷60s), but it can be solved efficiently during the continuous evolution of the research and industrially exploitation. The obtained component T6 heat treated, consisting in a solubilisation at 510°C for 3 h and an ageing for 1.5 h at 200°C.

The characterization of the alloys has been realised using traditional methods: the microstructure evolution has been monitored by Optical Microscope (OM, MeF4 Reichart-Jung) and by Scanning Electron Microscopy (SEM, Leo 1450VP). The distributions of the elements were observed by Energy-Dispersive X-ray Spectrometry (EDS, Oxford microprobe). The hardness of all samples was evaluated by a Brinell hardness tester (Volpert DU01 type apparatus) with the load of 50 kgf applied for 15 s. Standard samples has been employed for tensile test and on some un-notched samples has been submitted to impact test, carried out by a Charpy impact pendulum devices at room temperature. On the fractured surfaces SEM analysis has been performed to check the fracture surface development and to identify some reasons of the alloys failure.

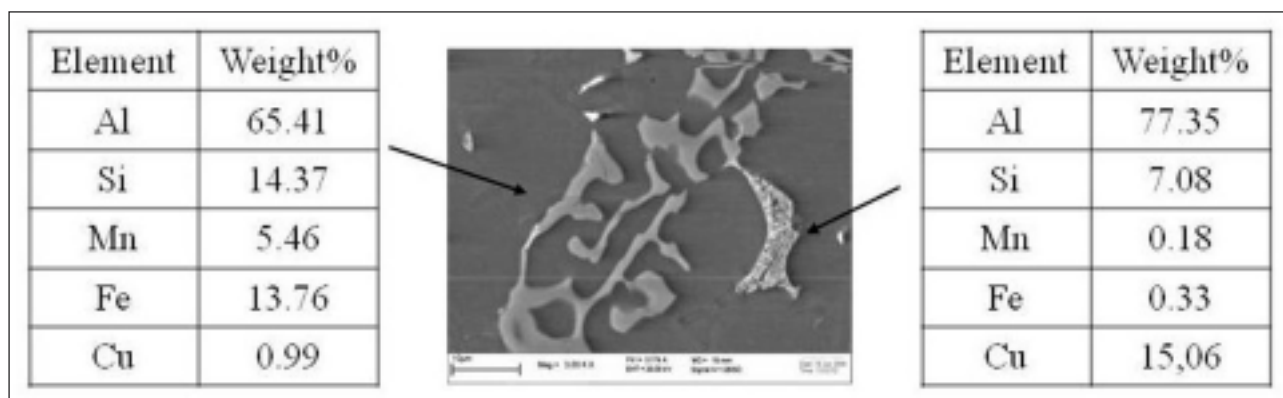
## RESULTS AND DISCUSSION

The visual inspection of the components did not reveal nor large surface nor internal defects, such as porosity or inclusions. The pressure applied during the entire solidification step promotes rapid solidification and a refined microstructure. The microstructure of A380 alloy consists of primary aluminium phase, eutectic silicon and some intermetallic compounds as shown in Figure 2. The morphology of the as-cast (Figure 2a) and T6 treated (Figure 2b) samples are different: following T6 heat treatment the refinement of the structure has been observed. During the heat treatment a morphological transformation of Si particles takes place toward a thermodynamically more stable spherical shape; also the morphology of some intermetallic particles changes, which are chemically constituted by Al, Si, Fe, Mn or appeared in the form of Al<sub>2</sub>Cu (Figure 3). The presence of chinese script inter-



**FIG. 2**  
**OM microstructure of samples in A380 alloy: a) as cast and b) after T6.**

*Microstruttura OM della lega A380: a) stato tal quale b) dopo il trattamento termico T6.*



**FIG. 3** **EDS results on the samples in A380 alloy.**

*Risultati analisi EDS del campione in lega A380.*

metallic compounds plus a block-like  $Al_2Cu$  particles are more accentuated in the case of A380 alloy compared to A356 alloy [8, 9], controlling the matrix stiffness and sometimes having a negative effect on the alloy mechanical properties, especially considering the ductility of the alloy.

The tensile properties of the cast samples have been determined at room temperature, using samples machined from the central part of the components, according to UNI EN 6892-1:2009

As shown in Table 2 the ultimate strength and the yield point of the samples after T6 heat treatment has been increased: the evolution of the dislocations has been avoided following the development of some precipitates, allowing the enhancement of the mechanical properties. The standard deviation of the measurements is quite high: actually, some of the process parameter, i.e. applied pressure and the filling rate, are under optimisation, which are strongly connected to the alloy microstructural quality and to the occasionally presents of internal defects, the most important sources in the case of decreasing of mechanical properties. Impact test has been performed to estimate the alloys impact energy and consequently to evaluate the materials resistance to high velocity impact. The same trend has been observed: the impact energy after T6 treatment increases of about 50% compared to the as-cast state.

As expected from the microstructural observation the enhance of hardness value on T6 samples has been achieved and in this case it appears higher compared to HPDC product ( $BHN = 80 \div 100$ ) [10] suggesting the superiority of the present advanced squeeze casting process.

A380 aluminium alloy has a relatively high Si content which generally decreases the ductility of the alloy at room temperature; however the fracture surface analysis reveals a ductile nature as illustrated in Figure 4a. Such analysis has occasionally eviden-

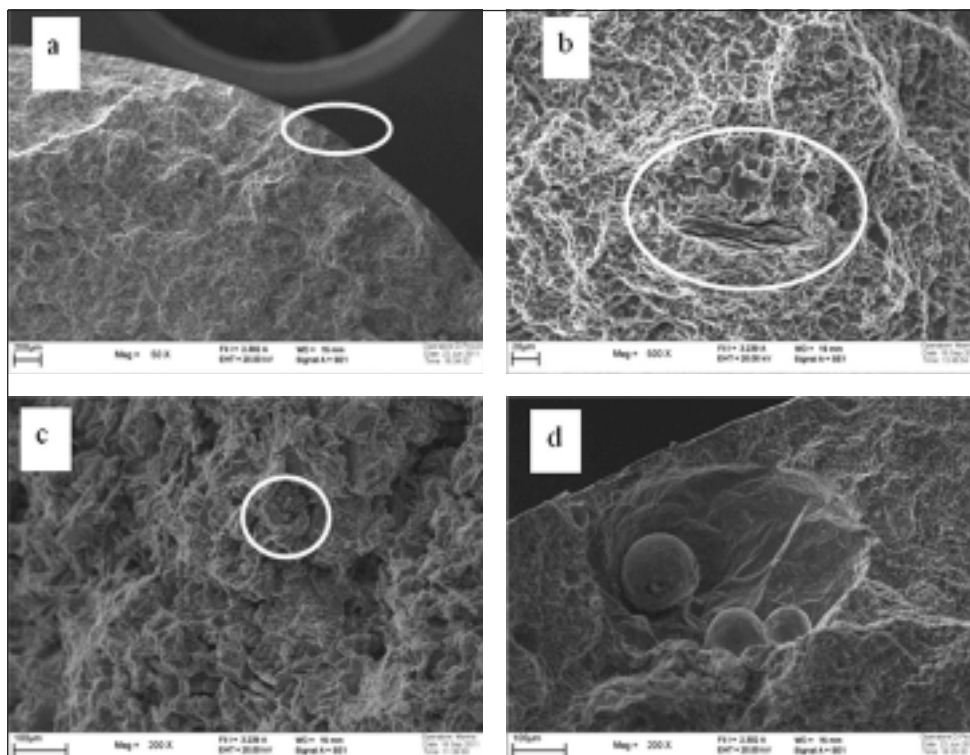
	As cast samples	T6 treated samples
YS [MPa]	257±10	319±10
UTS [MPa]	143±5	256±5
Impact Energy [J]	7,64±1.5	14,87±4.5
BHN	80±5	97±5

**TAB. 2** **Average mechanical properties of the samples in A380 alloy.**

*Media delle proprietà meccaniche dei campioni in lega A380.*

ced the presence of some defects, like external peel (Figure 4a) or graphitic carbon particles (Figure 4b). The presence of these imperfections have no considerable negative influence on the mechanical properties of components produced by the considered semi-solid processes. On the contrary, the presence of defects, i.e. shrinkage (Figure 4c) or the cold drops appearance inside the gas porosity (Figure 4d), revealed after tensile test in some cases harmfully influenced the alloys mechanical properties; they have been identified in samples which have been presented lower tensile values. An internal discontinuity, due to presence of porosity acts as starting point of the crack formation and consequently contributes to the materials failure. On the basis of our precedent experience and using different alloy compositions, A356 alloys ( $AlSi7Mg0.3$ ) seems to be more appropriate, from composition point of view, for the manufacturing of automotive components and in particular for suspension lever arms through modified squeeze casting process. Compared to the A380 condition, in the case of A356 alloy the microstructure appears more globular with





**FIG. 4**  
**SEM micrographs showing the presence of some defects on the fractured samples.**

*Micrografie SEM evidenziando la presenza di alcuni difetti sui campioni fratturati.*

fine particles and leads obtaining higher mechanical properties. Some activities are in progress in order to evaluate the A380 alloy corrosion resistance. The analysis is carrying out in salt spray chambers for 500h and reproduce such environments than the alloy occasionally can encounter during its service. Additionally, the fatigue resistance of the alloy will be monitored at room temperature.

#### CONCLUSIONS

The present study demonstrates that the modified squeeze casting process is suitable for the production of automotive components using A380 aluminium alloy. As expected T6 heat treatment increases the mechanical resistance of the alloy. The positive effect of the applied pressure during solidification has been demonstrated on the microstructure and on the mechanical properties of the modified squeeze casted components.

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### Abstract

#### Componenti in lega di Alluminio con caratteristiche migliorate ottenute mediante tecnica advanced squeeze casting

**Parole chiave:** alluminio e leghe, automotive, processi, fonderia

Nel presente lavoro sono stati considerati componenti utilizzati nell'industria automobilistica prodotti attraverso la tecnica di squeeze casting modificato. Questo processo innovativo è orientato verso la produzione di componenti automobilistici di alta resistenza impiegando la lega A380 soggetta a trattamento termico T6. Sono stati estratti da componenti reali alcuni campioni standard da utilizzare per la valutazione delle proprietà tensili e di durezza. Sono stati ottenuti, grazie alla particolare microstruttura e al basso contenuto di porosità, proprietà meccaniche superiori.

Mediante l'analisi della superficie di frattura sono stati evidenziati alcuni difetti minori, come ad esempio la presenza di particelle di C, con nessuna conseguenza negativa sulle prestazioni meccaniche e la presenza di inclusioni da ossido, con dimensioni dell'ordine del nano. Inoltre, l'analisi delle superficie di frattura ha evidenziato la natura duttile della frattura. E' stata osservata la microstruttura dei campioni opportunamente preparati. Sono stati ottenuti, per ogni parte considerata, alti livelli di resistenza e di durezza. I risultati ottenuti dimostrano l'affidabilità del processo squeeze casting modificato per la produzione dei componenti automobilistici.