The possibilities for reducing reoxidation in gating system

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Abstract

Submitted work deals with the analysis of reoxidation processes for aluminium alloys. Due to the aluminium high affinity to the oxygen, the oxidation and consequently reoxidation will occur. Paper focuses on the gating system design in order to suppress and minimize reoxidation processes. Design of the gating system is considered as one of the most important aspect, which can reduce the presence of reoxidation products - bifilms. The main reason for the reoxidation occurrence is turbulence during filling of the mold. By correctly designing the individual parts of gating system, it is possible to minimize turbulence and to ensure a smooth process of the mold filling. The aim of the work is an innovative approach in the construction of gating system by using unconventional elements, such as a naturally pressurized system or vortex elements. The aim is also to clarify the phenomenon during the gating system filling by visualization with the aid of ProCAST numerical simulation software. ProCAST can calculate different indicators which allow to better quantify the filling pattern.

Key words: Aluminium alloys, reoxidation, gating system, numerical simulation, bifilm

1. INTRODUCTION

The high reactivity of liquid Al with oxygen causes oxidation which result is oxide layer on the surface of liquid metal. Oxide layer essentially protects the melt from external influences, but the problem occurs at the moment when the surface layer is entrained to the internal volume of molten metal. Formation and entrainment of the oxide layer in the casting process are due to the high velocity of the melt, causing turbulence during the mold filling. Reoxidation is the term involving secondary and tercial oxidation of liquid metal during metallurgy operations and the filling process of the gating system. Result of reoxidation processes is so-called bifilms. Prof. Campbell as the first specified this term and he regard, that the formation of many casting defects are associated by bifilms presence. Turbulence of the melt causing folding the surface oxide layer, dry side to dry side, and that create bifilms (Fig.1). [2]

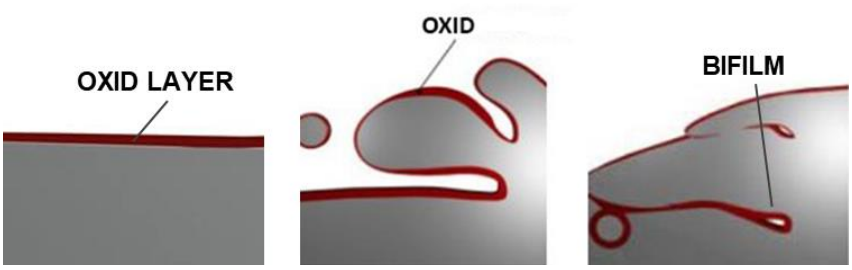

Fig. 1 Process of creation of bifilms

New ("young") formed oxide entrained in this way can be only nanometers thick, the older pieces can be up to micrometers thick, or even thicker of course, so the thickness of bifilms is proportional to this. Bifilms introduced into the melt are crumpled into a small and compact shape, because of turbulence within the melt. In this compact form, they can penetrate through all the filling components (even filter) and ends in the final mold cavity. The volume of air or other gases such as hydrogen is trapped inside the bifilm. In relatively calm environs it will be expanded and forcing the bifilms to become unraveled, and therefore opening and straightening with time. The unfurling of bifilm during solidification can be considered as a nucleation site for various defects. [1,2]

As is mentioned above, the main reason for the presence of reoxidation processes is turbulence of liquid melt, due to mainly by critical velocity (0.5 $m.s^{-1}$) of melt flow. Reducing this high velocity of flow is possible, among other things, by suitable design of the gating system. By correctly designing the individual parts of the gating system, it is possible to minimize the present of turbulence in the system.

2. GATING SYSTEM

Construction of the gating system is commonly divided on pressurized and non-pressurized gating system, based on choke area in system to reduce the velocity of flow. However, in term of reoxidation processes, these systems are deficiently. In 1962 was for the first time mentioned the concept of naturally pressurized gating system by Jeancolas and collective. Nowadays, this specific gating design is subjected to research mainly by prof. Campbell and a group of scientist focusing on reoxidation research.

The naturally pressurized gating system is, in contrast with pressurized and non-pressurized gating system, without choke area. For ideal case, it's constructed by ratio 1:1:1. The whole area of liquid metal is in direct contact with the moldy walls (except for the front area of flow) by natural back pressure in the gating system due to frictional resistance. Oxide layer forming on the front area of flow is pressed on the mold walls (Fig. 2), so the area for another reoxidation is minimizing. Due to the smooth transition without the presence of choke elements is the flow velocity too high and the advantage of a perfectly filled system is lost when the melt passes through the gate to the mold cavity. Due to the smooth transition without the presence of choke elements is the flow velocity too high, so when the melt passing by the gates splashes occurs. Absence of mechanism for reduction of high velocity is often the reason, why this type of system is not used in the casting industry. To reduce the melt velocity was in previous research works used the diffusers, off-set or various extensions of the runner and in recent year is attend to so-called vortex elements. Based on the literary analysis it appears that the satisfactory results can be achieved by ensuring the combination of this element. [3,5]

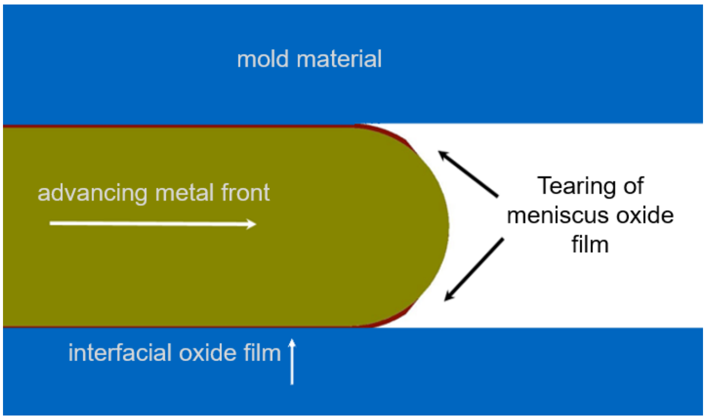

Fig. 2 Advancing metal front in naturally pressurized gating system

3. GATING SYSTEMS ANALYSIS

Study of reoxidation processes was observed of four different types of gating system construction. Two of the design was constructed like non-pressurized gating system and another two like naturally pressurized gating system. For analysis and observation of the melt flow during the filling process was used simulation software ProCAST. The analysis of turbulence and analysis of oxide occurrence was observed there.

3.1 Analysis of turbulence

A) Non-pressurized gating system

The first type is concept of the non-pressurized gating system (Fig. 3a) with ratio 1:4:4, commonly used for aluminum alloys. Analysis of turbulence, witch the tracking indicator has the units [100 cm^2/s^2], shows, that due to the imperfectly filled runner, caused by increased cross-section, there is extensive area for another oxidation, i.e. reoxidation. Turbulences are occurred by corrugating the free surface, and at the end of the runner by the bouncing wave mechanism. The melt is suddenly braked at the end of runner and thus is folded over onto itself (Fig.3b). This makes extensive reoxidation processes.

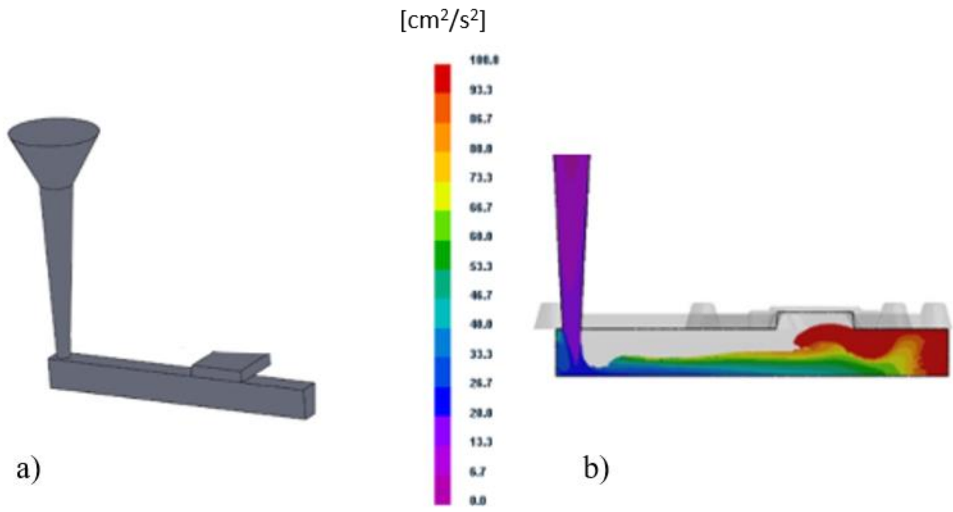

Fig. 3 a) Design of non-pressurized gating system, b) Result of analysis of turbulence (right)

B) Non-pressurized gating system with modification

The second type is also non-pressurized gating system, but with a modification of the end of runner with chamfer (Fig. 4a). The high of the end of the runner is gradually narrow. The modification insured a slight suppression of bouncing wave, but it was still insufficient. There was still extensive turbulence caused by the imperfectly filled runner (Fig.4b).

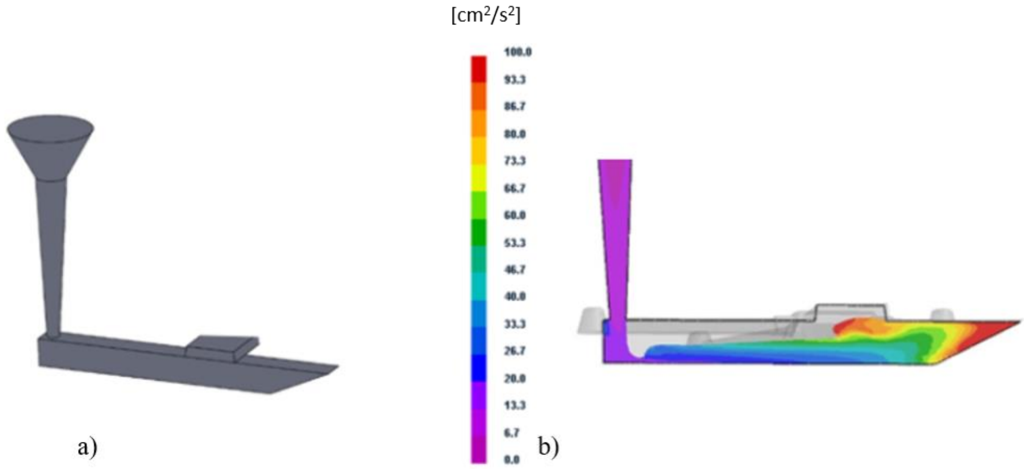

Fig. 4 a) Design of non-press. gat. sys.with modification, b) Result of analysis of turbulence

C) Naturally pressurized gating system

The third type is the concept of naturally pressurized gating system (Fig. 5a) with ratio 1:1,2:1,2. In this case, is the place for turbulence eliminated by the perfectly filled system in every point (Fig. 5b). By literary analysis, we can expect, that the suddenly braked at the end of runner transfer the energy of flow to the area of gates. The extensive turbulence occurs when the melt passes through the gate to the mold cavity and splashes occur. For verification of splashes occur was made analysis of melt flow rate, which confirmed this hypothesis (Fig. 6).

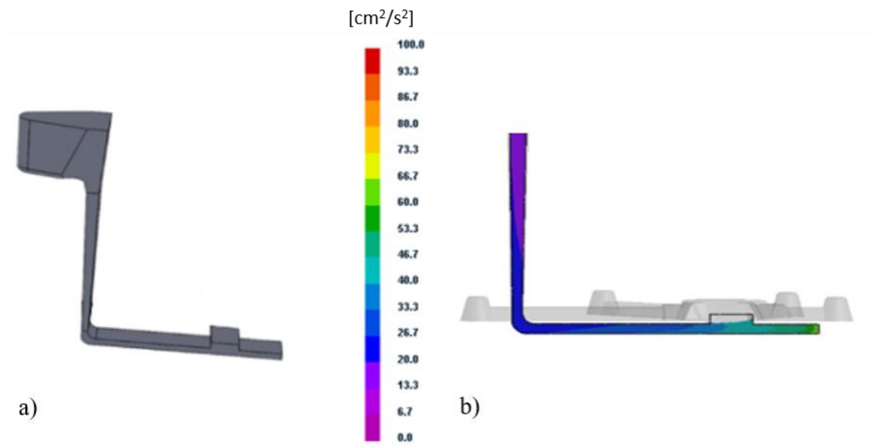

Fig. 5 a) Design of naturally pressurized gating system, b) Result of analysis of turbulence

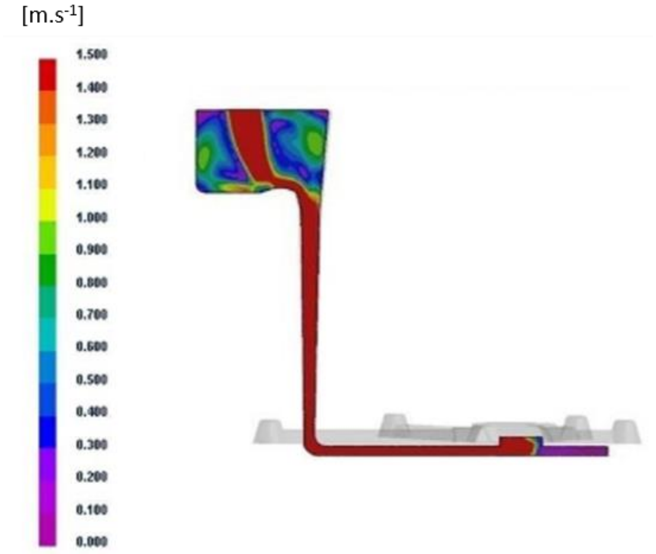

Fig. 6 Analysis of melt flow rate of naturally pressurized gating system

D) Naturally pressurized gating system with modification

The last one of design is the naturally pressurized gating system with vortex extension of the runner (Fig. 7a). The vortex has usually been regarded as a flow feature to be avoided in any case (for a risk of air entering the casting). However, if is the vortex controlled, it can calm down and positively direct the melt flow. Analysis of vortex extensive of runner shows that the turbulence energy was situated to the vortex element, which ensures calm continuity of flow in the runner and other parts of the system are protected from the negative influence of reoxidation (Fig.7b). There was made the analysis of melt flow rate too. Based on obtained result can be stated, that the melt flow was calm down by the application of vortex extension and velocity in gates area is lower compared with the design without modification (Fig. 8). [1]

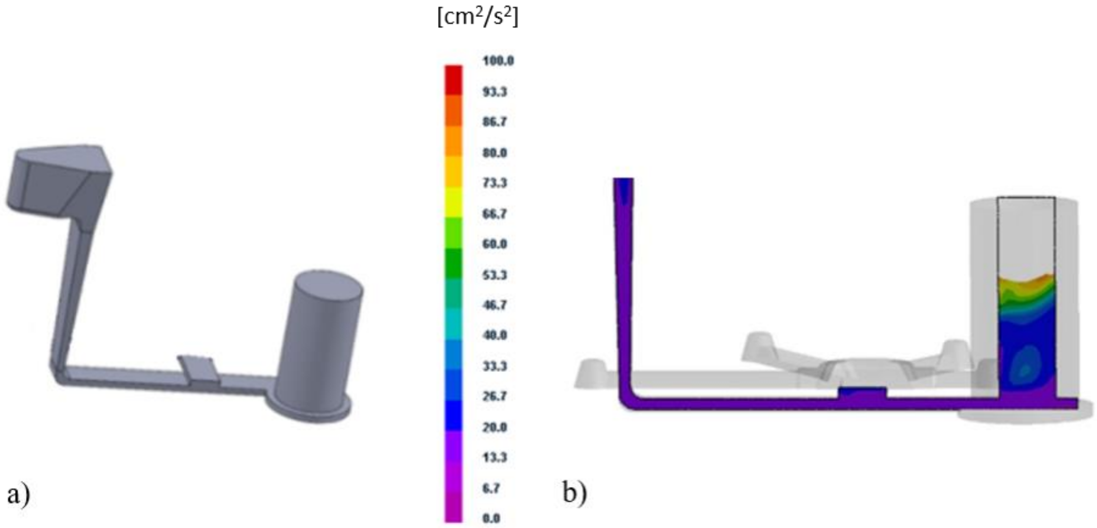

Fig. 7 a) Design of nat. press. gat. sys. with modification, b) Result of analysis of turbulence

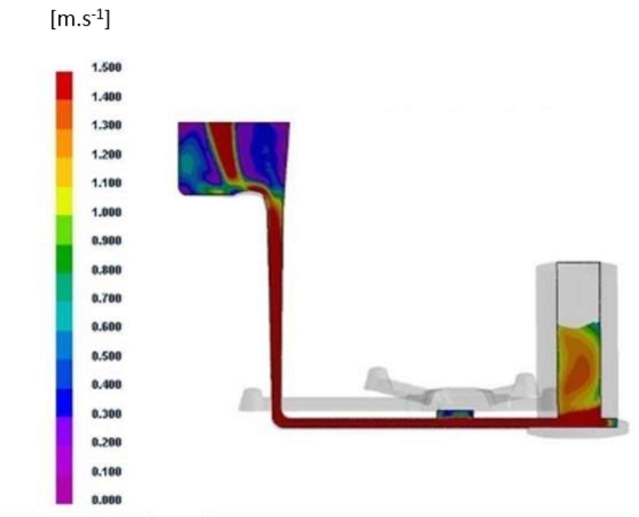

Fig. 8 Analysis of melt flow rate of natural.press. gat. sys. with modification

3.2 Analysis of oxide occurrence

The tracking indicator for oxide occurrence was set to [0.5 cm^2.s]. For the observed oxide occurrence was used casting design for the analysis of the mechanical properties. Based on the obtained results can be stated, that in the area of the biggest turbulence caused by the suddenly braked at the end of runner is oxide occurrence the worst (Fig. 9).

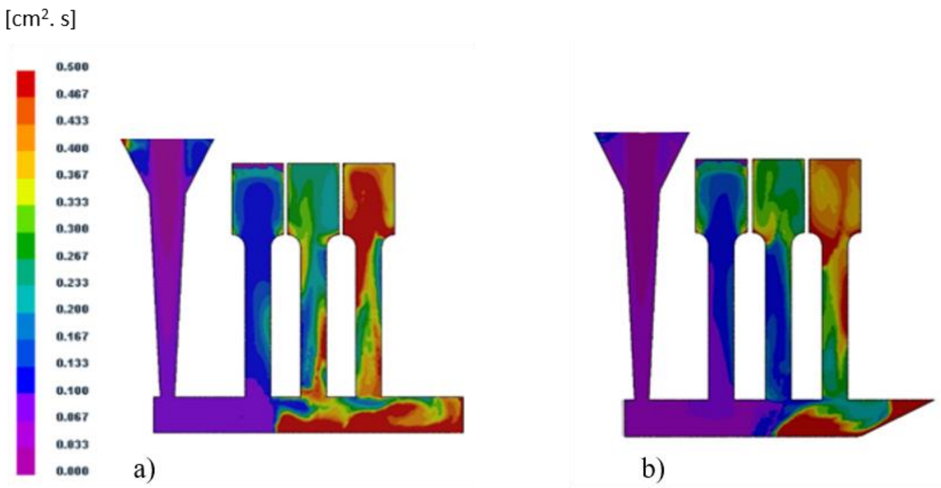

Fig. 9 Analysis of oxide occurrence for non-pressurized gating systems

Concept of naturally pressurized gating system with vortex element at the end of runner shows the best results. The melt is headed to the cylindrical end, where is the flow directed to a tangential gradient eddying motion and most of the oxides is trapped in this area (Fig. 10b). By directing the melt flow into the vortex extension of runner we achieved a significant reduction in the melt velocity, which then enters through the gates at lower speed avoiding spattering as we can see on Figure 11.

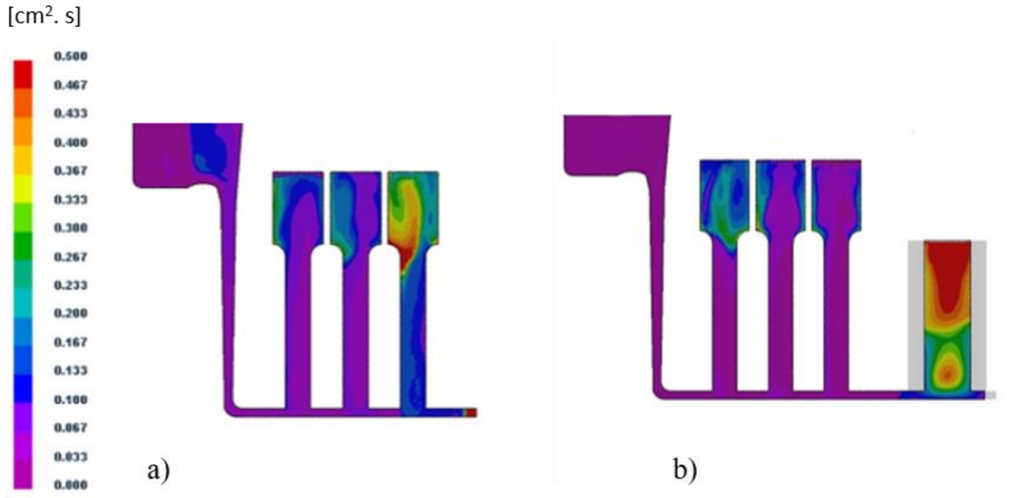

Fig. 10 Analysis of oxide occurrence for naturally pressurized gating systems

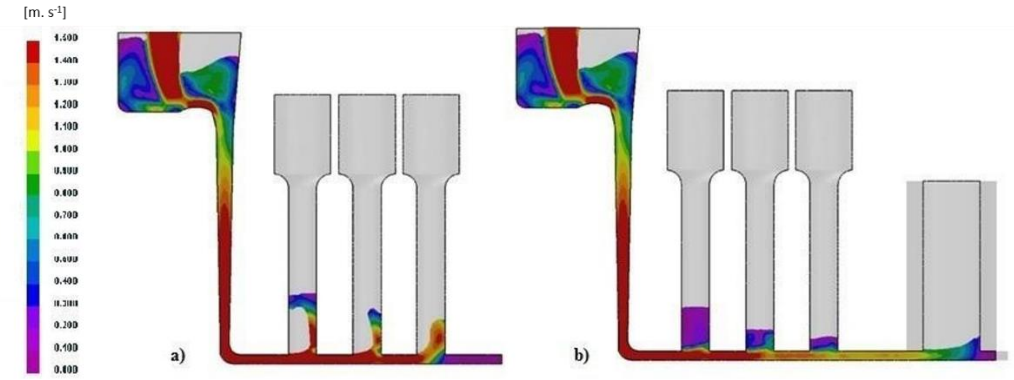

Fig. 11 Analysis of metal spatter

4. CONCLUSION

Aim of the paper was to point out the importance of the gating system. By correct design of the gating system, we can achieve lower speed and calm down the melt flow. The high velocity of melt flow occurs turbulences. By directing the flow can minimize the turbulence occurrence, which has important influence on the presence of reoxidation processes. The result of reoxidation processes are bifilms – 'double oxide layer'. Bifilms have very small and compact shape, so they can penetrate through all the filling components (even filter) an ends in the final mold cavity. When is the mold cavity filled, the turbulent character of flow subsides and the bifilms are in a relatively calm environment. At this point, they begin to acquire their initial shape, i.e. develop into larger dimensions and become a nucleation site for many castings defects. The bifilms presence occurs high variability of mechanical properties and so degradation of the quality of castings and their use in industry.

By simply changing the system design and individual parts of the gating system we can improve mechanical properties and suppress and extensive amount of bifilms introduced to the mold cavity as confirm the results from numerical simulation. The future work will be focused on the processing of real castings and their evaluation of tensile strength, microstructure, X-ray and SEM-EDS analysis to confirm the presented simulation results. Then there will be study of other unconventional elements of the gating system too.

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