An Evaluation for Fundamentals of Die Casting Die Materials Selection and Design

F.K.Arslan*, A.H.Hatman*,S.Ö.Ertürk**, E.Güner***, B.Güner***

*Assab Steel and Heat Treatment Company (Turkish Branch), Dudullu-Istanbul, Turkey

**Akdaş Casting Ind. Trade Company, Ankara, Turkey

***Antrametal Mold and Machine Limited Liability Company, Istanbul, Turkey

Abstract

This study is an evaluation for the basis of pressure die casting methods which are the right mold material selection and mold design. The expectations for the mold material that working under sudden temperature changes and cycling loads, are discussed. Also the applications for mold design principles to achieve in the desired standards product and the melts flow behavior in mold cavity, are studied for a sample work piece solid model with computer aided design and simulation tool. Some phenomenons which gives critical results for pressure die casting process and very difficult or impossible to determine by traditional methods can be calculated by computer simulation easily. The simulation software presents great support to die casting designer with the determination of this phonomenons.

Keywords: Die casting mold, hot work tool steel, molding design, casting simulation

Özet

Bu çalışma basınçlı döküm yönteminin temellerinden; doğru malzeme seçimi ve kalıp tasarımı üzerine bir değerlendirmedir. Tekrarlı yükler ve ani ısıl değişimler altında çalışan kalıp malzemesinden beklenen özellikler üzerinde durulmuştur. Aynı zamanda istenilen standartlarda ürün elde edilebilmesi için kalıp tasarım prensipleri ve sıvı metalin kalıp boşluğundaki akış davranışı, örnek iş parçasının katı modeli üzerinde bilgisayar destekli tasarım ve simülasyon araçlarıyla çalışılmıştır. Basınçlı döküm için kritik sonuçlar veren ve geleneksel yöntemlerle belirlenmesi çok zor veya imkansız olan bazı fenomenler, bilgisayar simülasyonu ile kolaylıkla hesaplanabilmektedir. Simülasyon yazılımı, bu fenomenlerin çözümlenmesi ile basınçlı döküm tasarımcısı için büyük bir destek sunmaktadır.

Anahtar Kelimeler: Basınçlı döküm kalıbı, sıcak iş takım çeliği,kalıp tasarımı, döküm simülasyonu

***Corresponding author:**

ASSAB Steel and Heat Treatment Company (Turkish Branch)

Dudullu OSB 2.Cadde No:26

Tel: +90 216 420 19 26

E-mail: aziz.hatman@assab.com.tr

1. INTRODUCTION

High pressure die casting is an important process in manufacturing of high volume and low cost components for the automotive, house-hold products and electronics. The metal melt (Al, Mg or Zn) is injected into the die at high speed and under high pressure through complex gate and runner systems. Because of the complexity of the dies, three dimensional fluid flows with significant free surface fragmentation and splashing are unavoidable. [1] In mold design positioning the die vents and the filling of die are critical for homogeneous cast components with minimal porosity. This is influenced with the geometry of die and the design of runner system. Also the melt flow behavior in shot sleeve. Several grid r mesh based computer applications used to simulate HPDC process steps. This simulation software's are great for the die designer for avoiding the casting defects due to filling and solidification. But a few of them can simulate the shot sleeve although the melt flow in sleeve affects the melt quality (air entrapments). So firstly to achieve in desired standards product both; high melt quality, right selection of process parameters and the good designed die are needed.

There are many studies about the air entrapment in shot sleeve which decrease the melt quality due to gas and bi-film content in liquid metal.[2,3,4] Air in the shot sleeve can be entrapped during metal pouring and the plunger advancement. A high plunger speed can create surface wave rollover and a low speed can cause reflections. Both of them can cause air entrapment. The Flow3D simulation program can simulate the melts flow behavior in shot sleeve while the plunger movement.

The other issue is the design of runner system and determination of ventilations locations. The casting simulations can also help the designer to fin the right positioning the selection of ingate type and dimensions. Although the simulations are valuable tools for the design engineer, in for competitive manufacturing the designer needs pre-information from experiences about die design. This is important for time and cost saving reasons. In die design firstly the location of ingate is important because of effect on the fill pattern. To find the right ingate position, firstly the designer has to find the thickest section.

The ingate type and position determination has a vital importance for the mold cavity filling. The wrong filling pattern causes damages in die and casting defects. For an ingate, the sectional area and the fill time are critical variables. The ingate area, determines the velocity of the liquid metal. The high speeds of melt can cause erosion of die material. Also the runners which the channels are carrying the liquid metal from shot sleeve to mould cavity has importance. These channels have to carry the liquid metal from the shortest way for avoiding the earl cooling and also the yield improvement of both casting design. [5]And the change in rotation has to be smooth. Because the sharp edges can cause early cooling and the extra turbulence for melt. The cooling of melts in runners is on of the main reason for the solid particle erosion because of the primer Si crystals (For Al-Si alloys). The turbulence runner is an air entrapment mechanism. Another issue for the runner design is the splashing near the ingate. The splashing can occur on surface of cores where near or across the ingate. So to avoid this splashing and let the liquid metal while filling mold cavity, flow as long as possible from ingate, the runner has to be design in right direction.

Usually the die casting mold designers focus on the design and positioning of ventilation channels and overflows. This positioning is strongly depends on runner and ingate design due to the filling pattern of mould cavity. If the cavity has laminar filling pattern while it's counter gravity, the liquid metals sweeps the air in mold with the front surface to the far end of mold cavity. In this type of mold filling the ventilation channels and the overflows has to be located where the liquid metal compresses the air. And for the non laminar filling patterns for mould cavity the ventilations usually positions near by ingates. In traditional methods, the determination of this positioning made by trial and error or by the experience of the mold maker with relatively high costs and time loss. On this step the casting simulations helps the designer to determine the right positions and to get experience by studying on computer with out loose of material and labor costs. Meanwhile the entire structure of ventilation channel and overflows in design lead to misunderstanding for their functions in mold. The overflows main function is to provide melt flow in the thin cavity end and deport the melt which amount of it's entrapped with air. And the ventilations are very thin and complex routed channels where can be located both at the end of overflow and mol cavity.

The steel is suitable in high demand hot work applications like die casting.The most commonly used hot-work tool material is AISI category H13, which presently bests fulfils the demanding properties. Different types of H13 steels, Uddeholm designations DIEVAR®. Their respective chemical composition along with the chemical range for the AISI H13 is listed in Table 1. Uddeholm Dievar® offers the potential for significant improvements in die life, thereby improving the tooling economy.[6]

Table 1. Chemical compositions in wt. %

Steel Grade	C	Mn	Si	Cr	Mo	V
UDDEHOLM DIEVAR ®	0.35	0.50	0.18	5.00	2.30	0.53
AISI H13	0.32-0.4	0.20-0.50	0.80-1.20	4.75-5.50	1.10-1.75	0.80-1.20

Uddeholm Dievar® is a high performance chromium-molybdenum-vanadium alloyed hot work tool steel which offers a very good resistance to heat checking, gross cracking, hot wear and plastic deformation. Heat checking is one of the most common failure mechanism e.g. in die casting. Uddeholm Dievar's superior ductility yields the highest possible level of heat checking resistance. With Uddeholm Dievar's outstanding toughness and hardenability the resistance to heat checking can further be improved. Uddeholm Dievar is the material of choice for the high demand die casting industries.

2. EXPERIMENTAL DETAILS

LPG tanks of vehicles to be used in high-pressure valve upper covers was designed for production how A380 Al alloy was high pressure die casting by method on the part solid model images were shown in Figure 1.

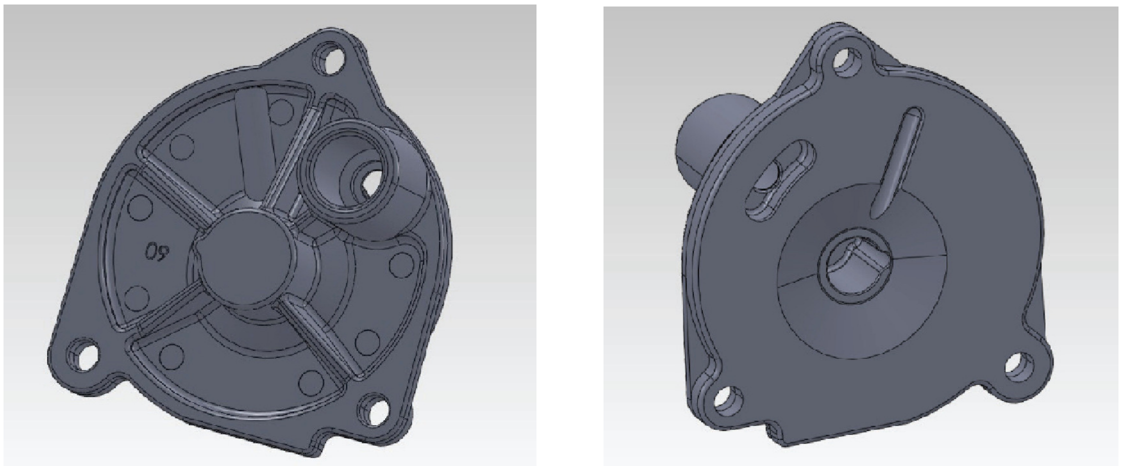


Fig.1.Solid models of part

After the design was solid models of part, the first die design was founded. Shown in Figure 2

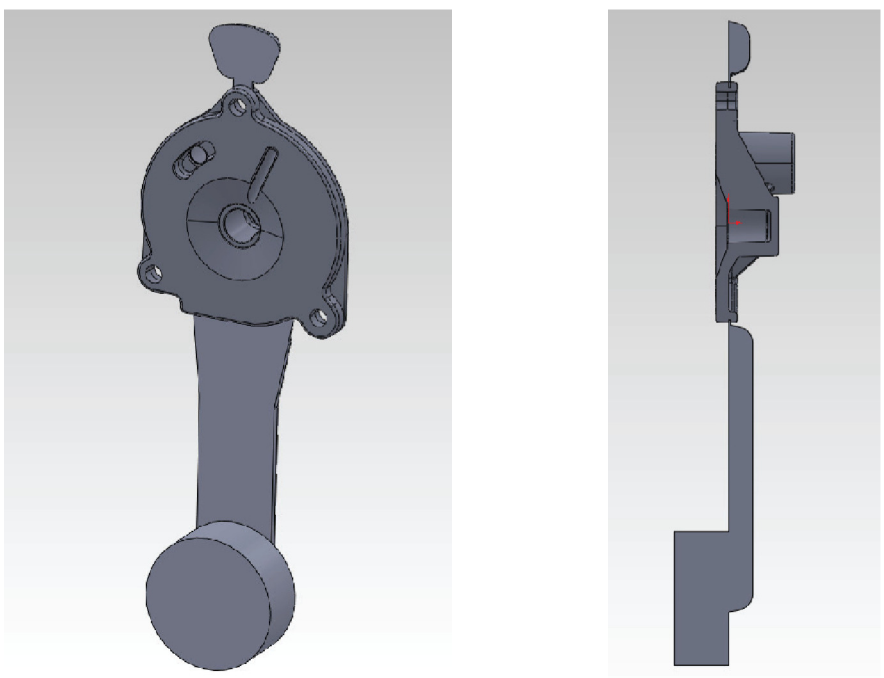
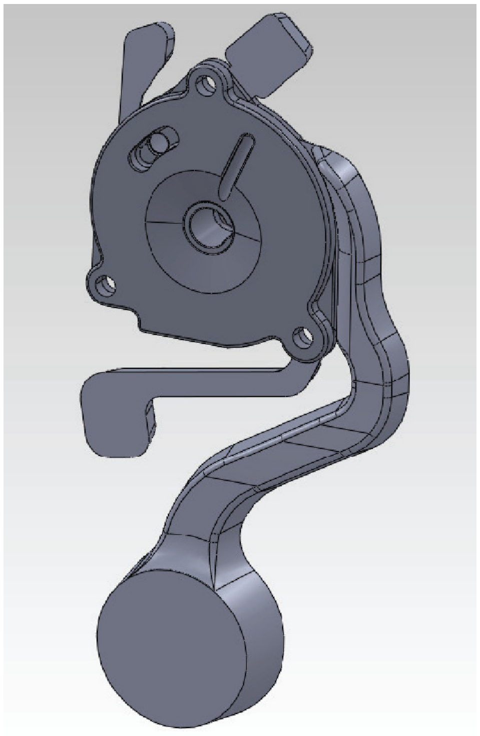


Fig. 2. The first die design

However, real parts could not get approval after the casting. Because leakage test as well as other tests were not appropriate. Therefore, design of die is made of different. The second die design images are given in Figure 3.



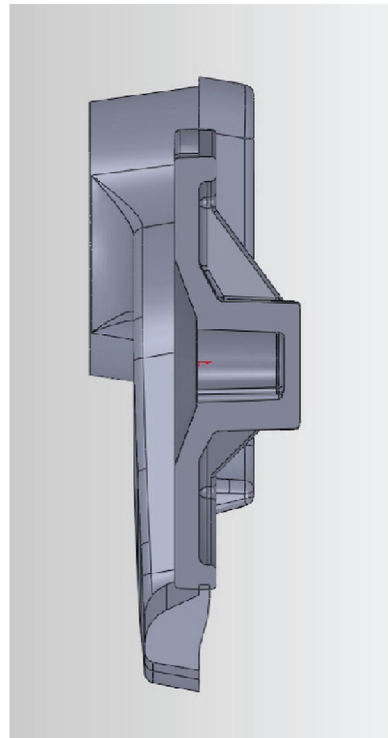


Fig.3. The second die design

Both of these die design were made simulations by used Flow-3D ® software.Thus ,according to the first die design can not get the approval of a valid after the casting. The second die design can receive the check may have been detected before leakage test.

Weights of gating and air packet is given Table 2 within either die design. Because of part working conditions, gating and air packet of weight ratios have been set at naught.

Table 2. Weights of gating, air packet and part for one cavity die

Die Components	First Die Design	Second Die Design
Part weight(g)	294 g	294 g
Gating weight(g)	155 g	119 g
Air Packet total weight(g)	40 g	105 g
Total weight(g)	489 g	518 g

Calculated as casting parameters for one cavity die entered in the simulation program and tool steel physical properties,shown Table 3.

Table 3. Calculated as casting parameters and tool steel physical properties

Casting Parameters	First Die Design	Second Die Design
Al alloy	A380	A380
Casting Temperature(°C)	680°C	680°C
HPDC machine 1st phase velocity(m/sn)	0.25 m/sn	0.25 m/sn
HPDC machine 2nd phase velocity(m/sn)	2.5 m/sn	2.5 m/sn
HPDC machine 3rd phase pressure(bar)	762 bar	762 bar
Die Locking Force(t)	378 t	378 t
HPDC Cold Chamber Machine Force(t)	450 t	450 t
Core Tool Steel Grade	Uddeholm Dievar®	Uddeholm Dievar®
After heattreatmeant of tool steel hardness	47-49 HRc	47-49 HRc
Thermal conductivity of tool steel to 400 °C	31 W/m °C	31 W/m °C
Modulus of tool steel elasticity	210000 MPa(20°C) 180000 MPa(400°C)	210000 MPa(20°C) 180000 MPa(400°C)

High mesh size was used in order to investigation more accurate simulation results. Flow-3D mesh used in the the number of total and active, shown Table 4.

Table 4. The number of of total and active mesh

Number of mesh	First Die Design	Second Die Design
Active mesh	956.783	1.234.675
Total mesh	3.898.314	4.256.123

According to the results given by the simulation program;

Ingate velocities are given Figure 4. Based on this, 2nd phase initiation times are shown.

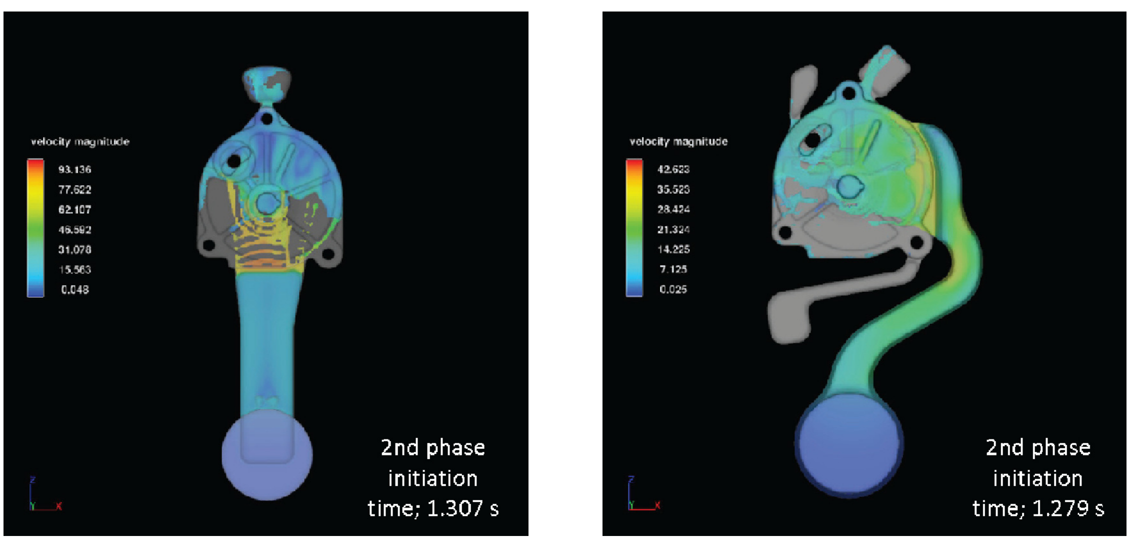


Fig.4. Ingate velocities of die design

During casting depending on design was established areas where high turbulence energy, shown Figure 5. Turbulent flow prevented in part of second die design. So that the part were minimize in the air entrapment with the prevention of the turbulent flow. Air entrapment volume fraction is given Figure 6.

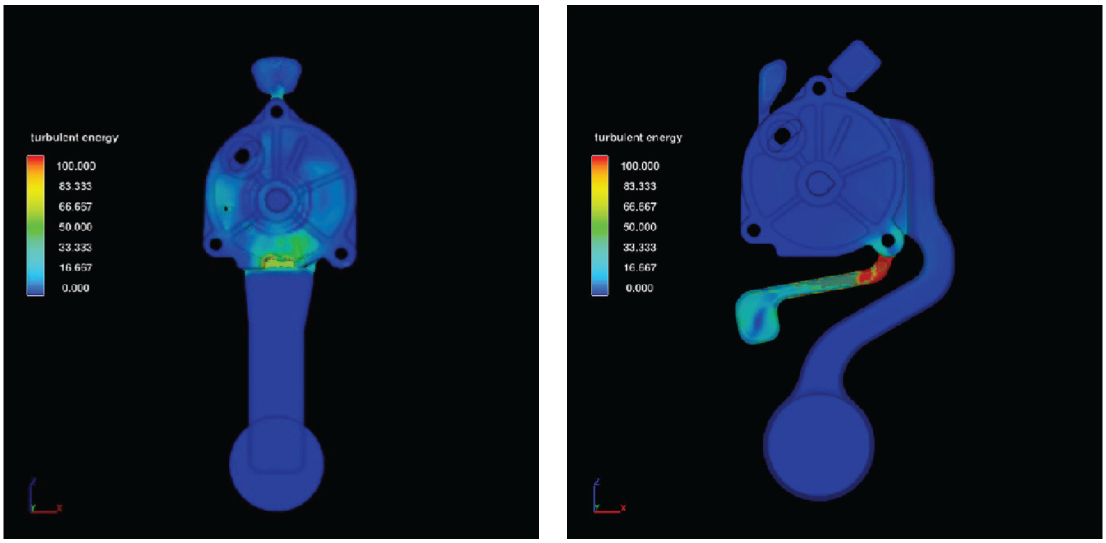


Fig.5. Turbulence energys of die design

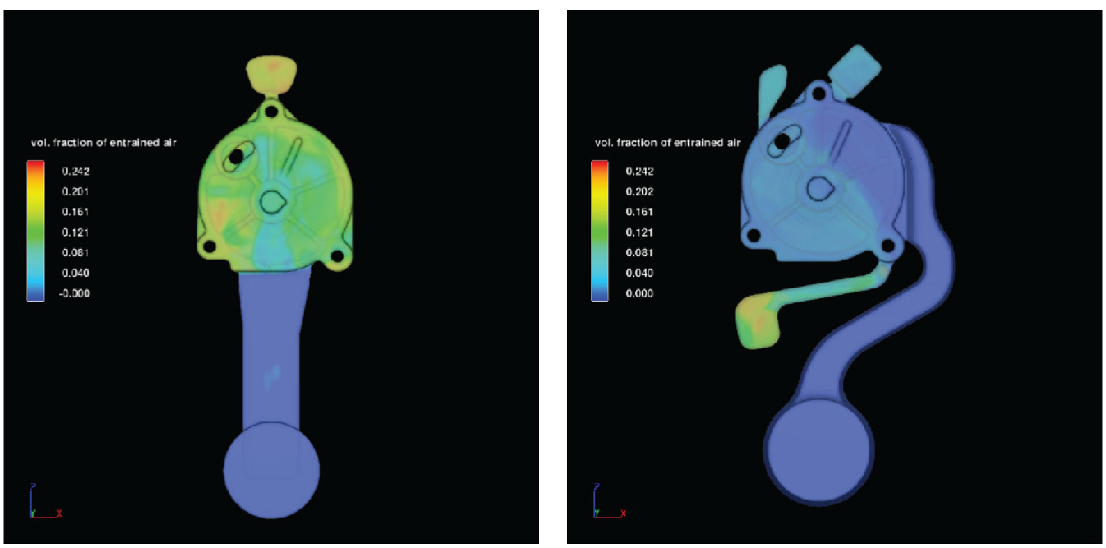


Fig.6. Air entrapments of die design

Part of the remaining average air volume fraction and oxide ratios may ocur, shown Table 5.

Table 5. Oxide of formation in part for die design

Vol. Fraction , %	First Die Design	Second Die Design
Air entrapment avg.(vol.fraction, %)	0.24	0.04
Oxide of formation(vol.fraction, %)	34	7

Fluid residence time values were examined and compared the efficiency of part, shown Fig. 7. Thus, the fluid was measured per unit of time significant points.

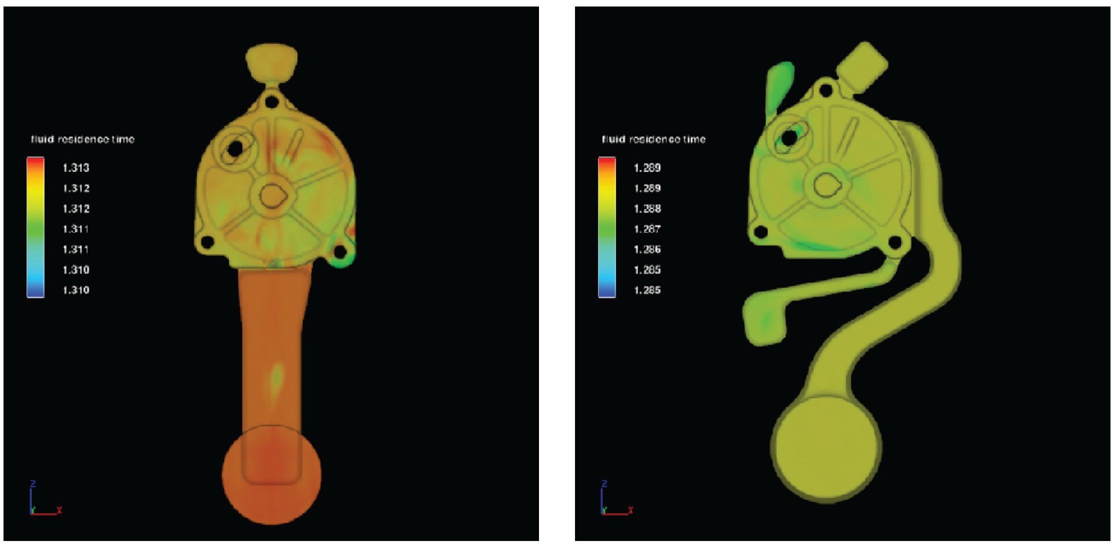


Fig.7. Fluid residence times of die design

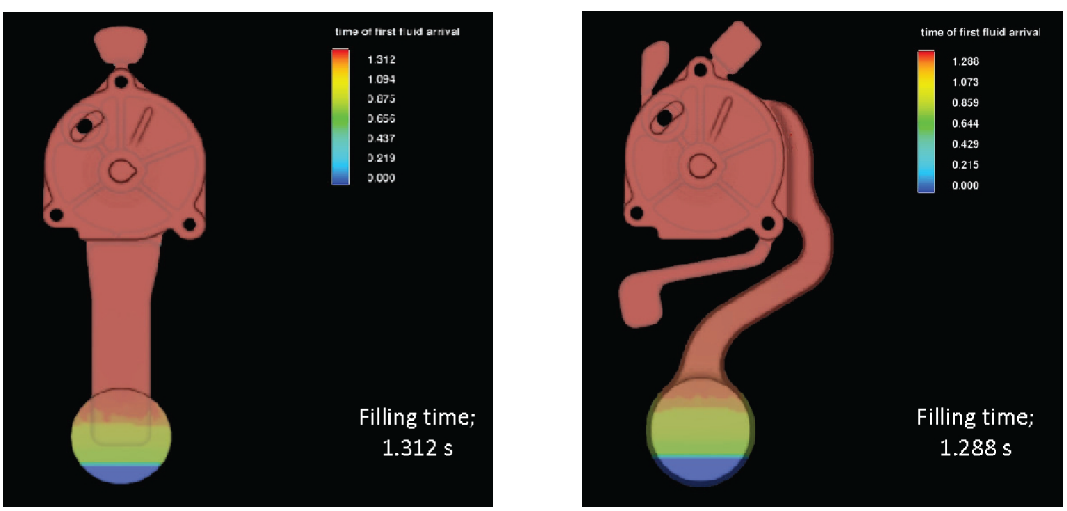


Fig.8. Part filling times of die design

3.RESULTS AN DISCUSSION

The performed Flow-3D ® simulations for two different type of die design shows clear and comparable results for designers. Firstly, the ingate velocity, why it is critical for a die casting part discussed before, varies the due to ingate area because the same shot parameters applied for both two designs. For the revised (second) design the ingate velocity is reduced into acceptable range.(Fig.4) Also the volume fraction of entrained air results are important for this part related to its impermeability on service life. Similar to ingate velocity, the the entrained air as factor reduced in the revised design.(Fig.6) This factor is related to amount of oxide particles in part and this amount is inverse to impermeability.

In general the aim is focused on the avoiding turbulences in design of die casting part. The simulation study of this part presented an exciting results for the turbulent energies for these two designs. Although in the first design a lower turbulent energy occured, more risky because of the location where it's in front side of ingate region. And the second design a higher turbulent energy but it's not risky due to it's outside position from part.(Fig.5)

Finally, when examining the Flow-3D ® results for the sample die casting part and the literature, we can see that there many phonomenons which are very difficult and impossible to determine by traditional methods. This simulation software has a great support to die casting designer with the determination of this phonomenons. Except the simulation is a general guide for designer, the Flow-3D® has unique results, because the Flow-3D ® is in general based on fluid mechanics and also the die filling strongly depends on it.

ACKNOWLEDGEMENTS

The authors thank to ASSAB Company and Antrametal Mold and Machine Limited Liability for their valuable supports.

REFERENCES

[1]PAUL W. CLEARY, JOEPH HA, MAHESH PRAKASH, THANG NGUYEN "SHORT SHOTS AND INDUSTRIAL CASE STUDIES: UNDERSTANDING FLUID FLOW AND SOLIDIFICATION IN HIGH PRESSURE DIE CASTING" APPLIED MATHEMATICAL MODELLING.

[2] L.WANG, T.NGUEN, M.MURRAY, "SIMULATION OF FLOW PATTERN AND TEMPERATURE PROFILE IN SHOT SLEEVE OF A HIGH PRESSURE DIE CASTING PROCESS"

[3] M.R.BARKHUDAROV "MINIMIZING AIR ENTRAINMENT IN A SHOT SLEEVE DURING SLOW-SHOT STAGE", DIE CASTIN ENGINEER MAY2009, 34-37

[4]M.SIVIÖ, S.VAPALAHTI, J.VAINÖLA "COMPLETE SIMULATION OF HIGH PRESSURE DIE CASTING PROCESS"

[5] STREET A. "THE DIECASTING BOOK",PORTCULLIS PRESS LTD. ENGLAND (1984)

[6] UDDEHOLM HOT WORK TOOL STEEL BOOK,SWEDEN(2003)