Enhancement and Analysis of Pressure Die Casting Method with Aluminum Alloy to Increase its Material Machinability and Workability by using Finite Volume Method

Vaibhav Swami [1], Prachi Jain [2]

M. Tech Scholar[1], Asst. Professor [2]
Department of Mechanical Engineering[1,2]
Sagar Institute of Research & Technology Excellence,Bhopal, India

Abstract

Present analysis is on fluent 15.0. It was carried out on considering A356 (molten aluminium) material with steel die. The study was conducted by using the Finite volume method. Reynolds stresses and wall shear stresses, has been analyzed by ANSYS 15.0. A simplified and idealized finite volume model by using symmetry assumption and a non-simplified finite volume model of process have been used in the analyses. The major study was done on pressure die casting by using different fillet radius and chamfer angle.

In our analysis, ANSYS is used and the model is developed on UNIGRAPHICS 8.0 and also analysed for FLUENT 15.0. The analysis results show that 30 degree of chamfer angle and 6mm of fillet radius gives absolute convergence on pressure and temperature, Validation and optimization is done to determine the effect of pressure die casting process during working condition. The Reynolds stresses is analysed in pressure die casting for enhancement of machinability to reduce internal stresses generated due to imbalance of temperature and pressure.

Wall shear stresses were also analysed at the die and molten metal interface zone for enhancement of workability for product and to reduce surface defects on manufactured product.

Hence chamfer angle of 30 degree on die and fillet radius of 6mm shows minimum Reynolds stresses and wall shear stress with high temperature and pressure distribution on squeeze die casting process..

Keywords— *Pressure, Temperature, wall shear stresses, Reynolds stresses, fillet radius, chamfer angle, squeeze die casting process.*

I INTRODUCTION

Squeeze Casting combines the processes and advantages of Gravity Casting and Forging. Squeeze Casting makes use of metal permanent molds and it has a cloth tank. The pouring method uses a cylinder at the lowest of the fabric tank to push the material into molds. This pouring system is similar as Gravity Casting, but Gravity Casting makes use of gravity rather than a cylinder to load the mildew. After fabric goes into the mould, the cylinder of the cloth tank continues loading strain, about 300 lots, till the quit of the casting cycle. When the material in the mould begins to cool down, it's going to begin to cut back. The cylinder will preserve the loading strain to push extra steel into the mildew, making the casting greater strong and with more element. This makes the technique just like Forging. The casting excellent of Squeeze Casting is near Forging. Squeeze casting is a combination of casting and forging system. The technique can bring about the highest mechanical homes viable in a forged product. The improvement of squeeze casting process, can bring in outstanding possibility for manufacturing of additives of aluminium alloys, which aren't well commercialized as yet. It also can be effective in for import substitution of important additives.

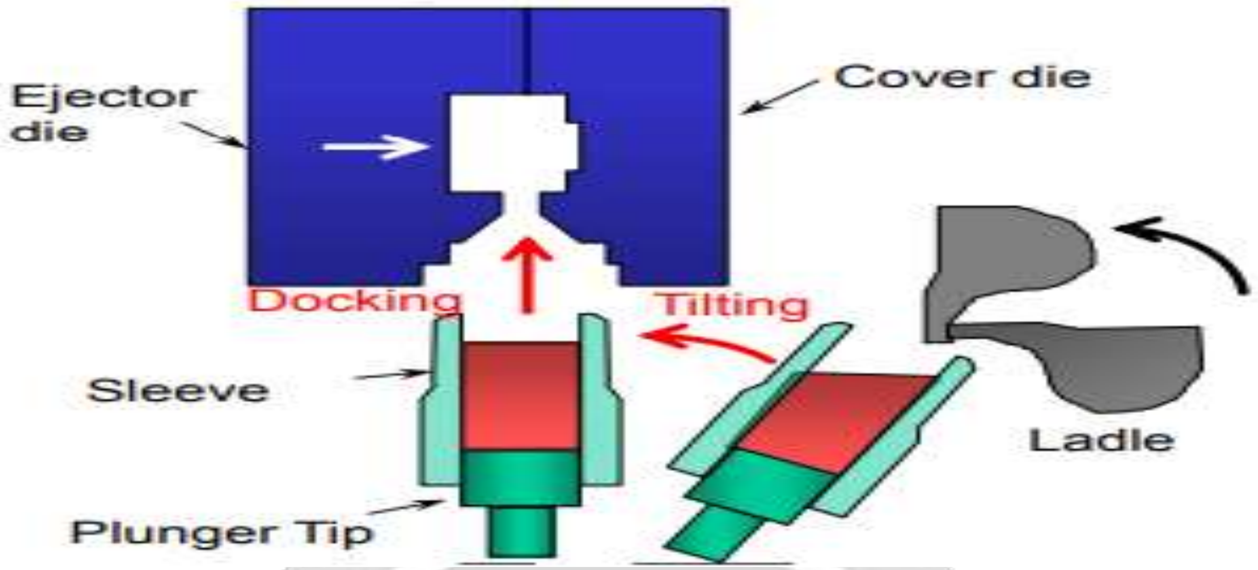

Figure 1-1 Squeeze casting machine

The process starts offevolved whilst the molten metallic is poured into the lowest half of a pre-heated die. As quickly because the metal begins solidifying, the top 1/2 of the die closes and begins applying pressure during the solidification process. The extent of strain applied is substantially less than that in forging. Parts of notable element can be produced. Coring may be utilized in tandem with the manner to form holes and recesses. The excessive strain and the close touch of molten alloy with the steel die surface outcomes in minimum porosity and improvised mechanical homes. This process can be used for each ferrous and non-ferrous metals. This approach could be very lots applicable for making fiber-bolstered castings from fiber cake preform

II DIE CASTING

A – Die casting is a manufacturing system for producing as it should be dimensioned, sharply described, clean or textured-surface metallic elements. It is completed via forcing molten steel under high strain into reusable metal dies. The process is frequently defined because the shortest distance between raw cloth and completed product. The term "die casting" is likewise used to explain the finished component. The term "gravity die casting" refers to castings made in steel molds beneath a gravity head. It is called everlasting mould casting inside the U.S.A. And Canada. What we call "die casting" right here is called "stress die casting".

Die casting is a manufacturing procedure that could produce geometrically complex steel components through using reusable molds, referred to as dies. The die casting procedure involves the use of a furnace, steel, die casting system, and die. The metal, typically a non-ferrous alloy together with aluminum or zinc, is melted inside the furnace and then injected into the dies within the die casting machine. There are main forms of die casting machines - warm chamber machines (used for alloys with low melting temperatures, together with zinc) and cold chamber machines (used for alloys with high melting temperatures, such as aluminum). The variations between these machines could be special inside the sections on device and tooling. However, in each machines, after the molten metallic is injected into the dies, it rapidly cools and solidifies into the very last part, referred to as the casting. The steps in this system are defined in extra element within the next segment.

III PROCESS CYCLE OF DIE CASTING

Clamping - The first step is the instruction and clamping of the two halves of the die. Each die half of is first wiped clean from the previous injection after which lubricated to facilitate the ejection of the subsequent element. The lubrication time increases with component length, in addition to the variety of cavities and facet-cores. Also, lubrication won't be required after every cycle, but after 2 or 3 cycles, depending upon the cloth. After lubrication, the 2 die halves, that are connected within the die casting device, are closed and securely clamped together. Sufficient pressure should be applied to the die to hold it securely closed while the metallic is injected. The time required to shut and clamp the die depends upon the machine - larger machines (people with more clamping forces) would require greater time. This time may be estimated from the dry cycle time of the machine.

Injection - The molten metal that is maintained at a hard and fast temperature inside the furnace, is next transferred into a chamber in which it can be injected into the die. The approach of shifting the molten steel is dependent upon the type of die casting system, whether a warm chamber or cold chamber device is being used. The difference on this system could be specific inside the next phase. Once transferred, the molten metallic is injected at excessive pressures into the die. Typical injection strain tiers from 1,000 to twenty,000 psi. This strain holds the molten metallic inside the dies at some point of solidification. The quantity of metallic this is injected into the die is known as the shot. The injection time is the time required for the molten steel to fill all of the channels and cavities in the die. This time is very short, generally much less than zero.1 seconds, with the intention to save you early solidification of anyone a part of the metallic. The right injection time may be determined by way of the thermodynamic homes of the cloth, in addition to the wall thickness of the casting. A extra wall thickness will require an extended injection time. In the case wherein a chilly chamber die casting gadget is being used, the injection time ought to also consist of the time to manually ladle the molten metallic into the shot chamber.

Cooling - The molten metallic that is injected into the die will start to cool and solidify once it enters the die cavity. When the entire hollow space is filled and the molten metal solidifies, the very last shape of the casting is formed. The die can't be opened until the cooling time has elapsed and the casting is solidified. The cooling time may be expected from several thermodynamic residences of the metal, the maximum wall thickness of the casting, and the complexity of the die. A extra wall thickness will require an extended cooling time. The geometric complexity of the die also calls for a longer cooling time due to the fact the extra resistance to the float of warmth.

Ejection - After the predetermined cooling time has surpassed, the die halves may be opened and an ejection mechanism can push the casting out of the die hollow space. The time to open the die may be expected from the dry cycle time of the device and the ejection time is decided via the size of the casting's envelope and have to consist of time for the casting to fall freed from the die. The ejection mechanism have to follow some pressure to eject the part due to the fact in the course of cooling the component shrinks and adheres to the die. Once the casting is ejected, the die may be clamped shut for the subsequent injection.

Trimming - During cooling, the fabric inside the channels of the die will solidify connected to the casting. This excess cloth, alongside any flash that has took place, die casting method.

Objective of the Work

The main objective of the current work is

- The main objective of our proposed work is validation of the pressure die casting models by comparing the experimental outcome.
- To predict temperature and pressure for different die chamfer angle and fillet radius.
- To simulate for analyzing Reynolds stresses and wall shear stresses at constant pressure of 70 MPa.
- To define temperature and pressure distribution, Reynolds stresses, wall shear stresses for the different chamfer angle and fillet radius at constant pressure input.
- Predict temperature distribution along the pressure die casting process..

Problem Formulation

The survey of different previous works we predict the pressure and temperature is higher as compared to present study is shown in our base paper. The purposes of this study reduce the temperature and increase the workability and machinability at various chamfer angle and fillet radius in pressure die casting..

VI MODELING AND ANALYSIS

4.1 Design procedure of Pressure die casting

The procedure for solving the problem is

- Modeling of the geometry.
- Meshing of the domain.
- Defining the input parameters.

- Simulation of domain.

Finite volume analysis of pressure die casting.

Analysis Type- CFD, FLUENT.

A. 4.2 Preprocessing

Preprocessing include CAD model, meshing and defining boundary conditions.

4.2.1 CAD Model

Table 4. 1 Dimension of Pressure die casting

Diameter of product	15 mm, 12mm
Casting area block	140x90x30 mm
Length of product	62 mm

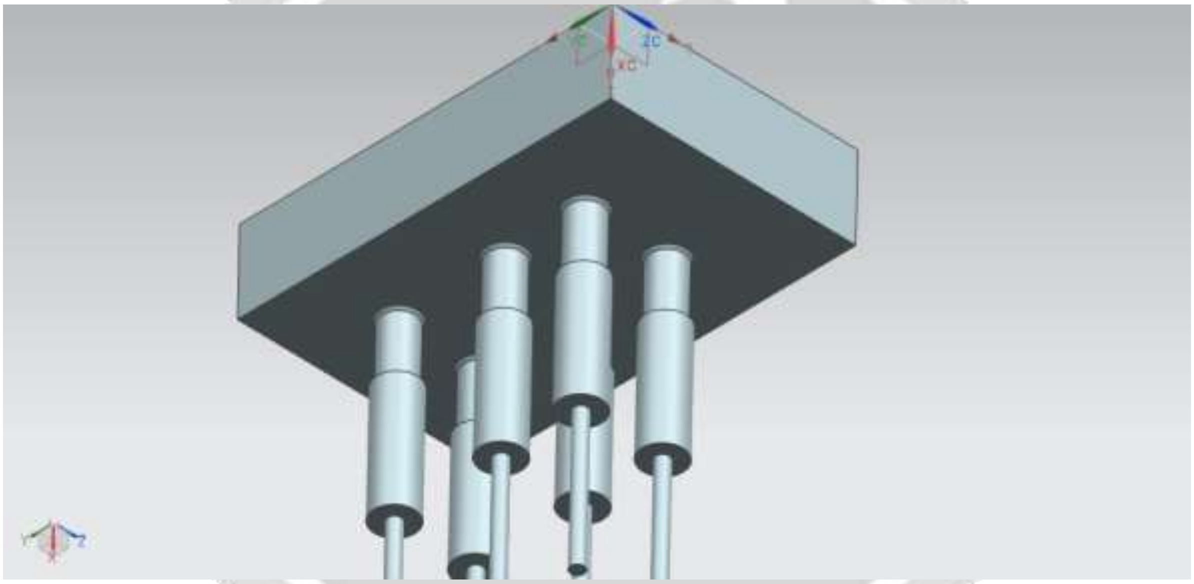

Figure 4.1 *CAD Model of pressure die casting*

B. 4.3 Meshing data for pressure die casting

NODES	291154
ELEMENTS	190369

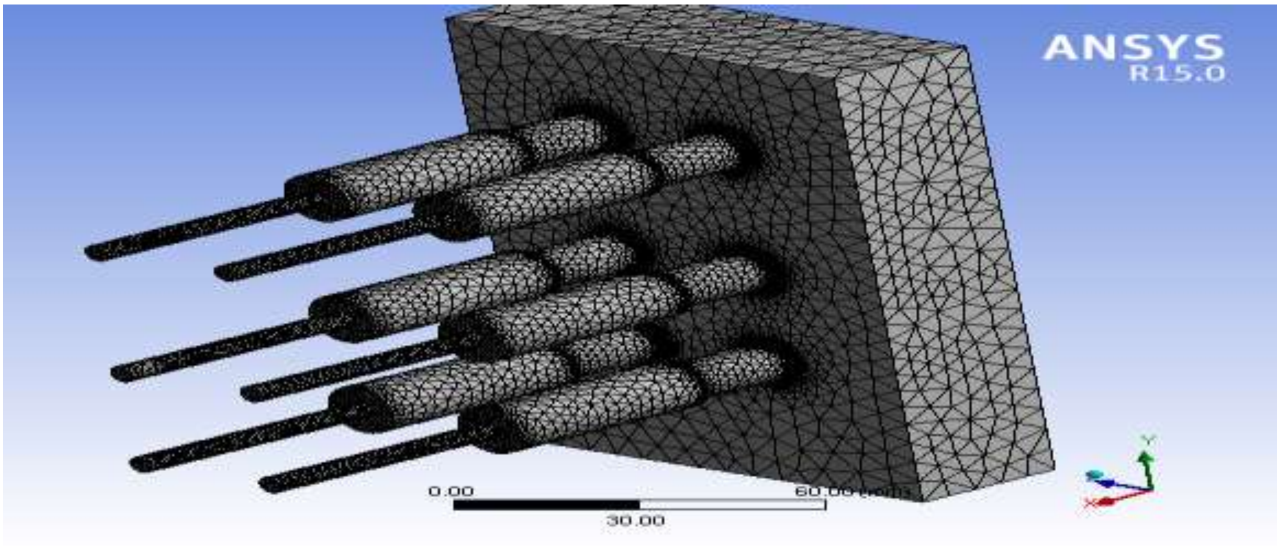

Figure 4. 2 ***Mesh domain of pressure die casting***

Table 4. 1 Properties of different material

Material Properties	A356	H13
Thermal Conductivity	159	31.2
Specific heat	1154	478

VII RESULT AND DISCUSSION

The effects of pressure and temperature on squeeze casting process is proceeded for present analysis the Reynolds stresses and wall fluxes were also determined for enhancement of workability and machinability of a product produced by pressure die casting process. The results have been compared with experimental value of same parameter and also compare with present base paper model with different chamfer angle and fillet radius of die for operating under similar operating conditions to discuss the enhancement in heat transfer and pressure as well as wall fluxes and Reynolds stresses on account of pressure die casting

Table 5.1 Validation results of pressure determine with numerical simulation

Validation			
70 MPa	46MPa	23MPa	Time
27.6	13.8	1.6	0
29.3	15.9	3.8	5
32.5	18.2	6.1	10
35.2	21.4	8.2	15
37.4	24.7	10.5	20
41.3	26.9	12.8	25

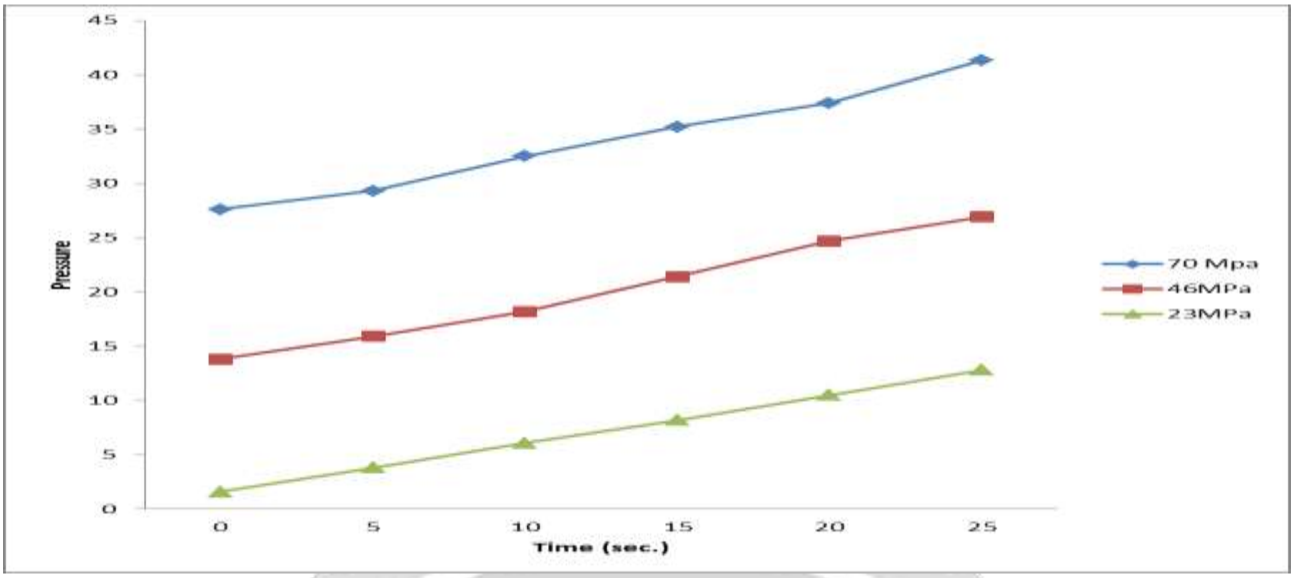

Figure 5.1 Comparison of pressure with different values of plunger pressure w.r.t. time

The values of pressure with different plunger pressure signifies, the convergence of present analysis with base paper values, thus experimental data with different conditions seems to be approximately average with present numerical simulation., 70 MPa and 46 MPa exhibits higher pressure during die casting process as shown above in the graphical representation, these values are w.r.t. time

Table 5.2 Comparison of temperature distribution on squeeze die casting process on different plunger pressure

	Validation		
Time (Sec.)	70 MPa	46 Mpa	23 Mpa
0	280	250	225
5	385	325	260
10	425	370	300
15	445	390	325
20	455	400	340
25	500	430	370
30	525	450	385
35	530	475	400

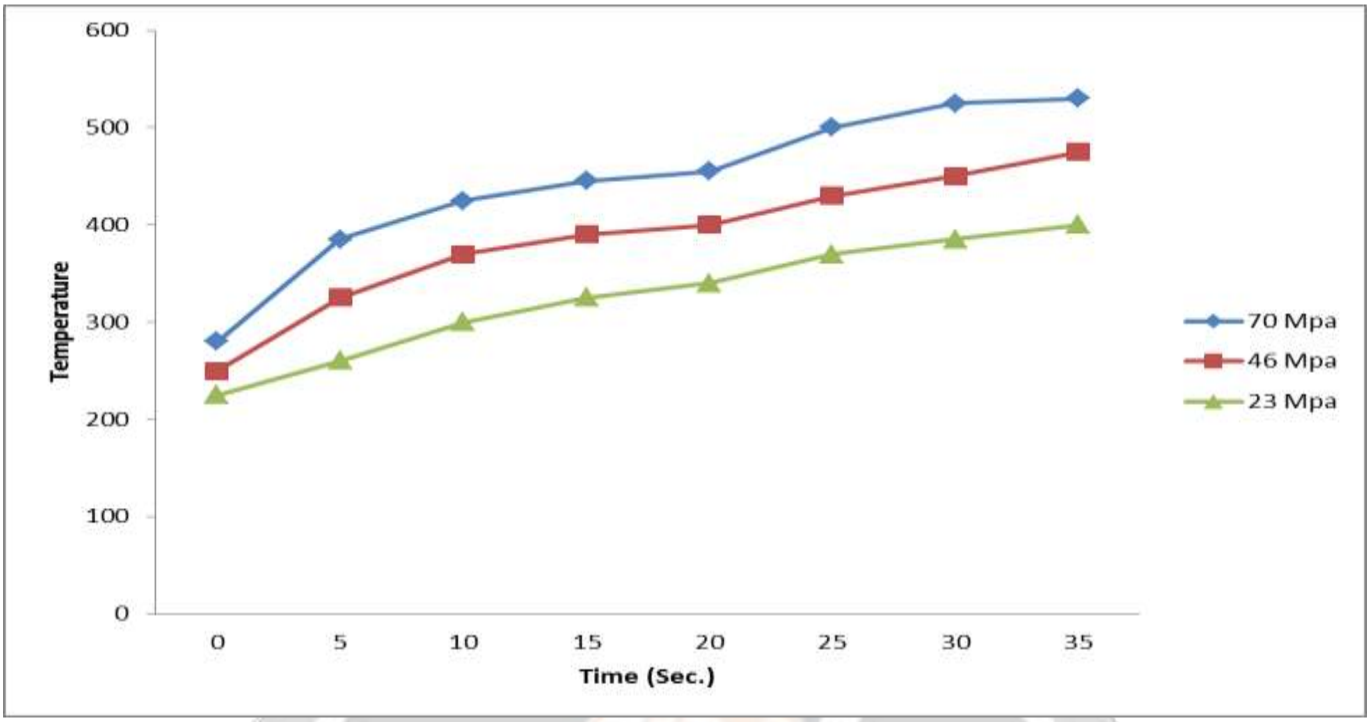

Figure 5.2 Comparison of temperature with different values of plunger pressure w.r.t. time

5.2 Contour plots of pressure die casting with different plunger pressure

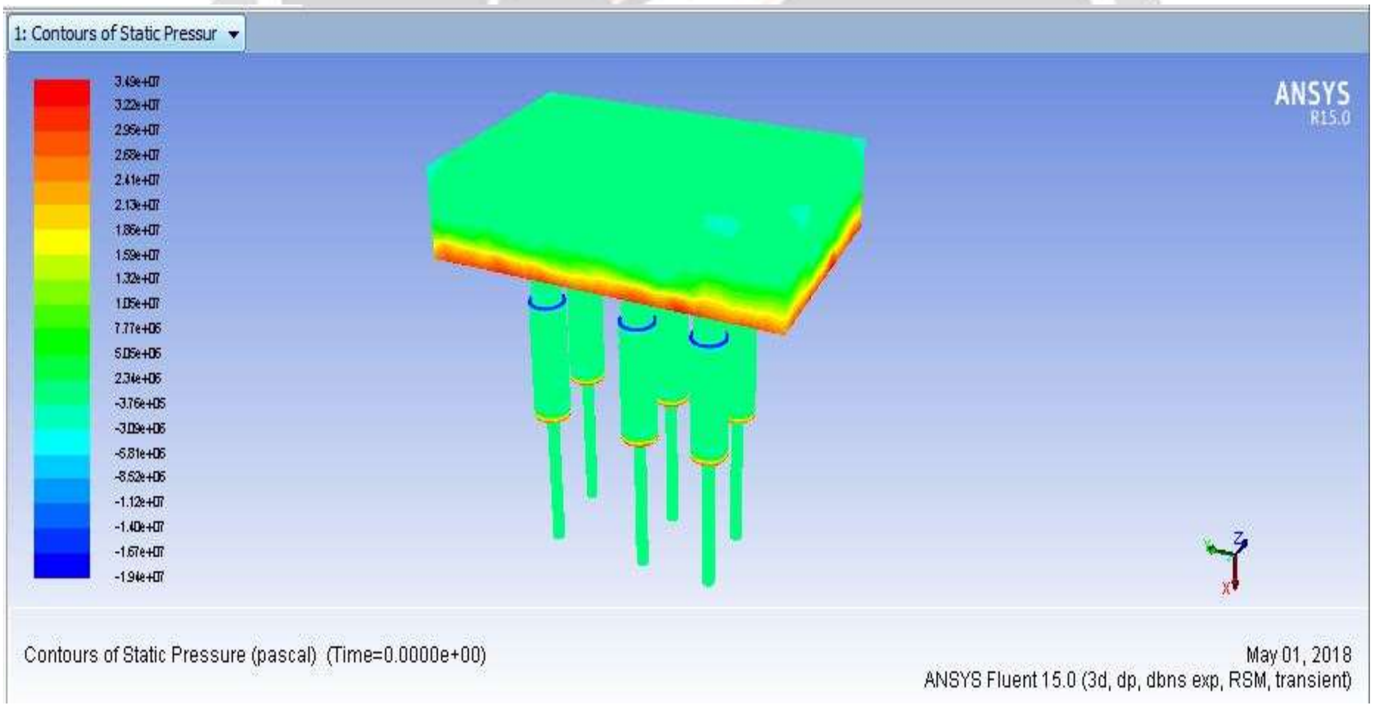

Figure 5.3(A) pressure distribution of squeeze die casting process with material A356

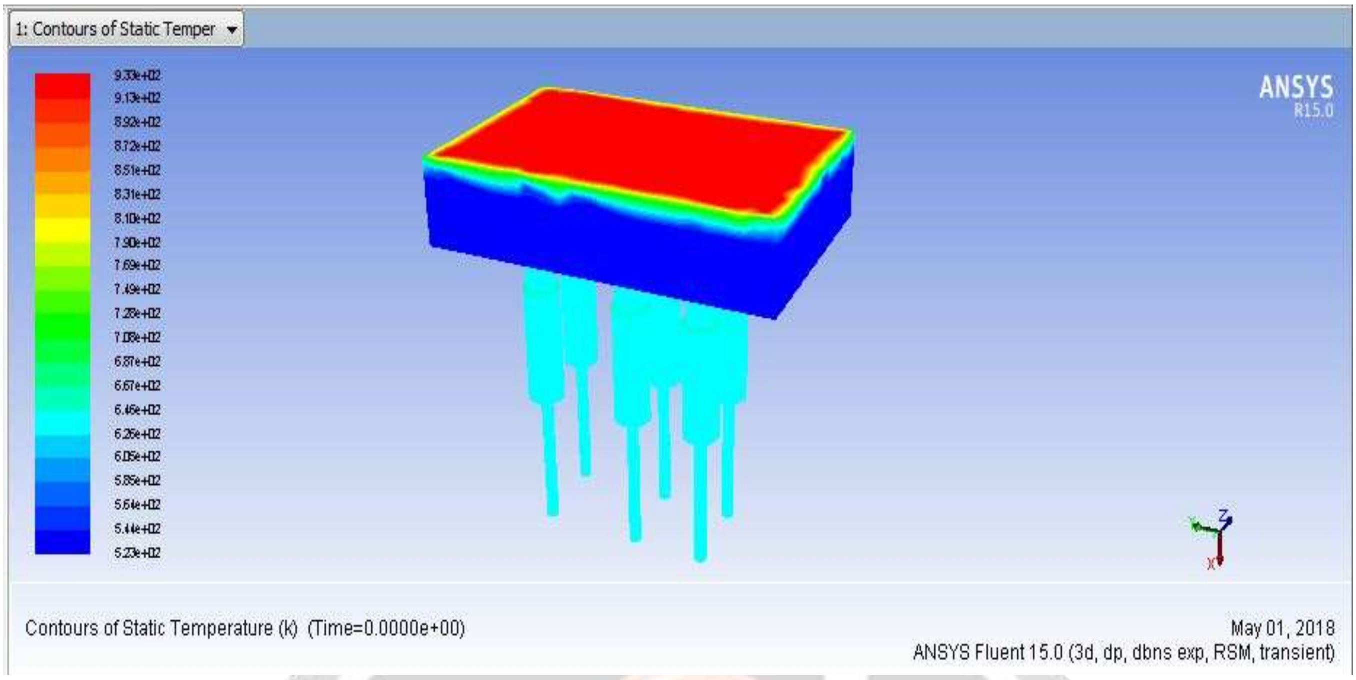

Figure 5.3(B) Temperature distribution of squeeze die casting process with material A356

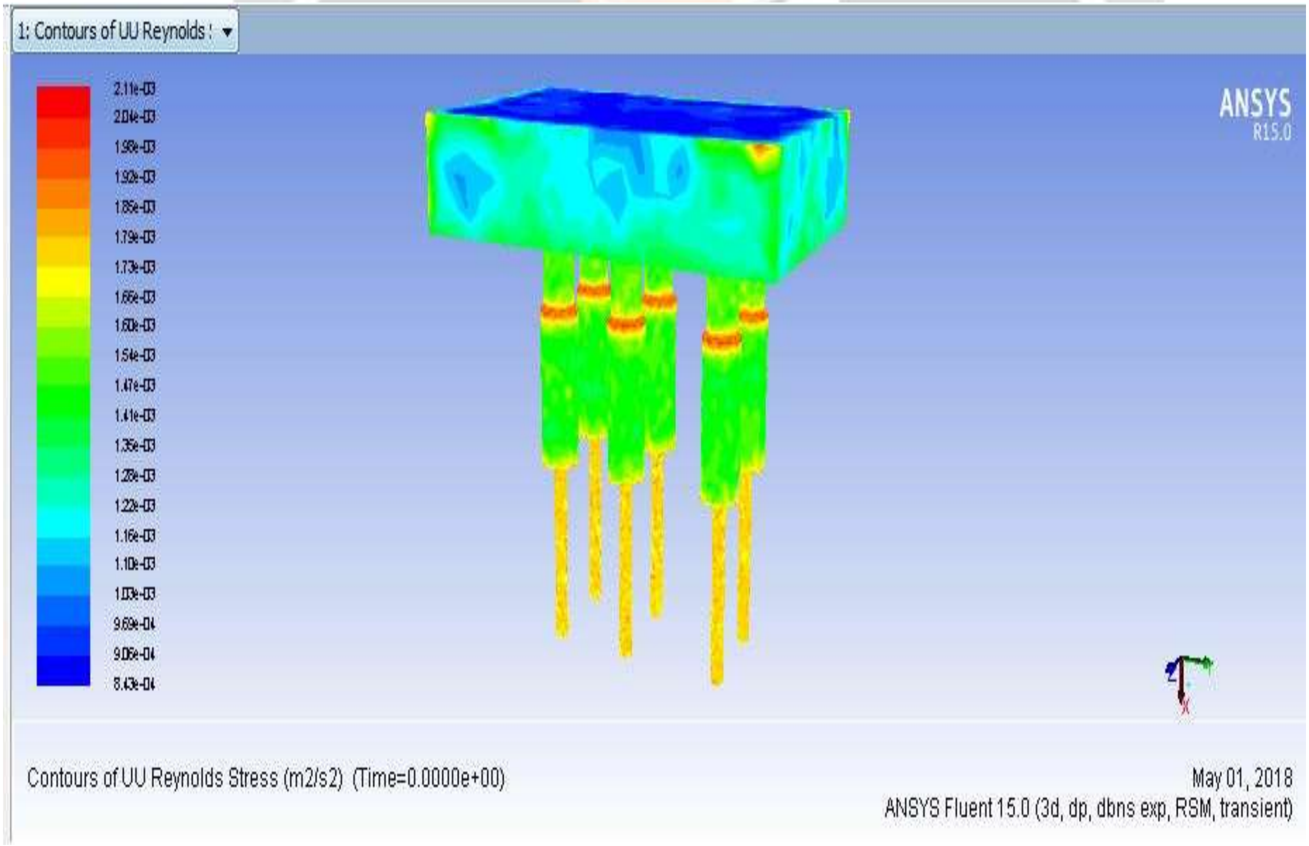

Figure 5.3(C) Reynolds stresses effect on squeeze die casting process with material A356

5.3 Optimization on squeeze die casting model with different chamfer angle

Table 5.3 shows the values of pressure with different chamfer angle

Pressure (70MPa)		
30 °	**45 °**	**60 °**
26.3	28.1	30.2
28.2	30.3	32.9
31.1	33.6	35.8
33.9	36.8	39.1
35.7	39.4	41.7
39.1	40.7	43.6

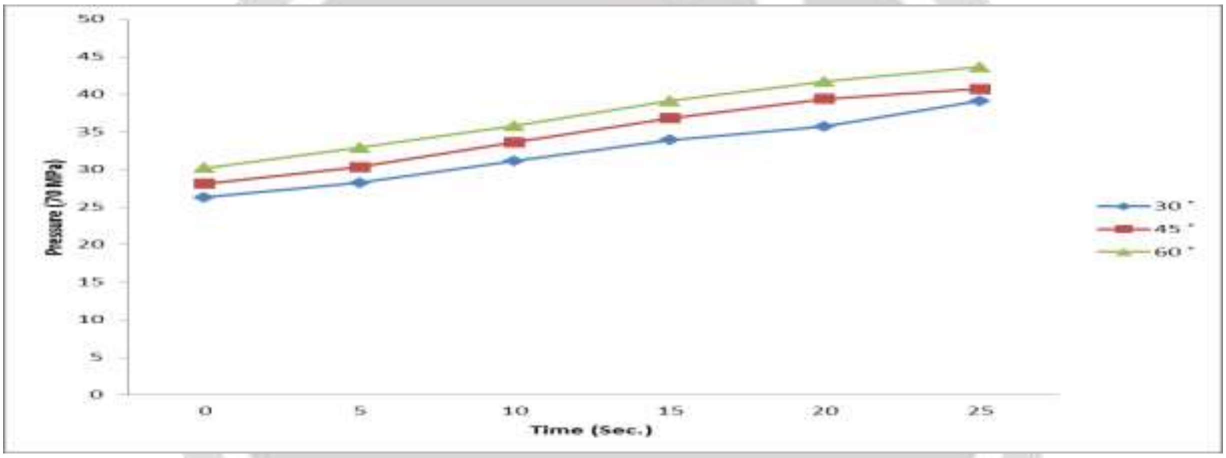

Figure 5.4 Comparison of different pressure values w.r.t. time and chamfer angle

Table 5.4 shows the values of temperature with different chamfer angle

Temperature (70 Mpa)		
30 °	**45 °**	**60 °**
270	285	298
365	390	405
412	430	445
437	450	475
450	465	485
485	510	530
500	535	550
515	550	575

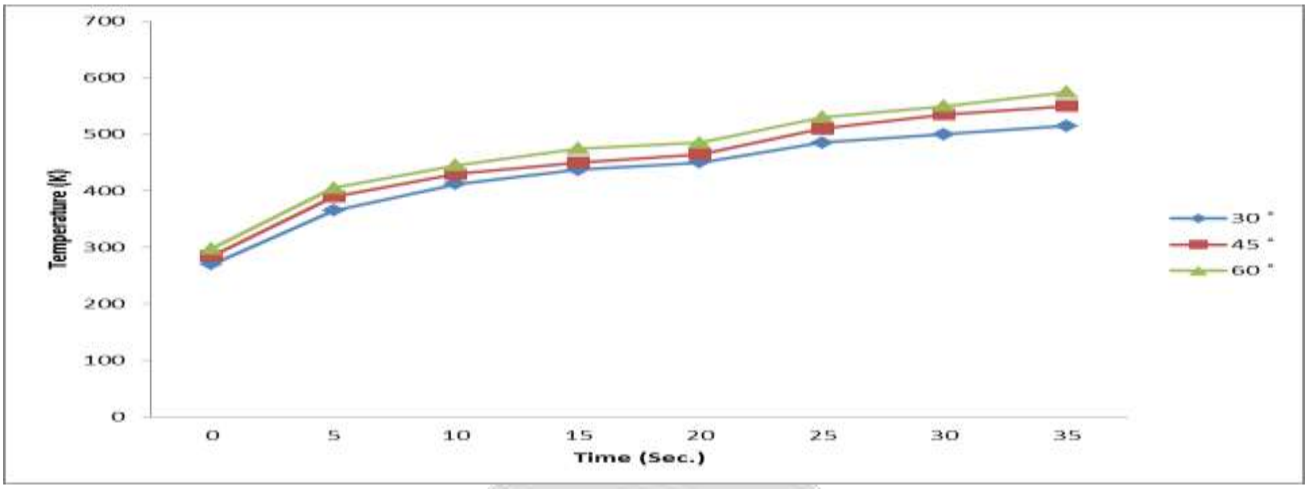

Figure 5.5 Comparison of different temperature values w.r.t. time and chamfer angle

Table 5.5 shows the values of Reynolds stresses effect with different chamfer angle

Reynolds stress (70 MPa)		
30 °	**45 °**	**60 °**
0.00209	0.00213	0.00216
0.00215	0.00219	0.00223
0.00221	0.00225	0.00229
0.00229	0.00234	0.00236
0.00234	0.00241	0.00245
0.00239	0.00249	0.00256

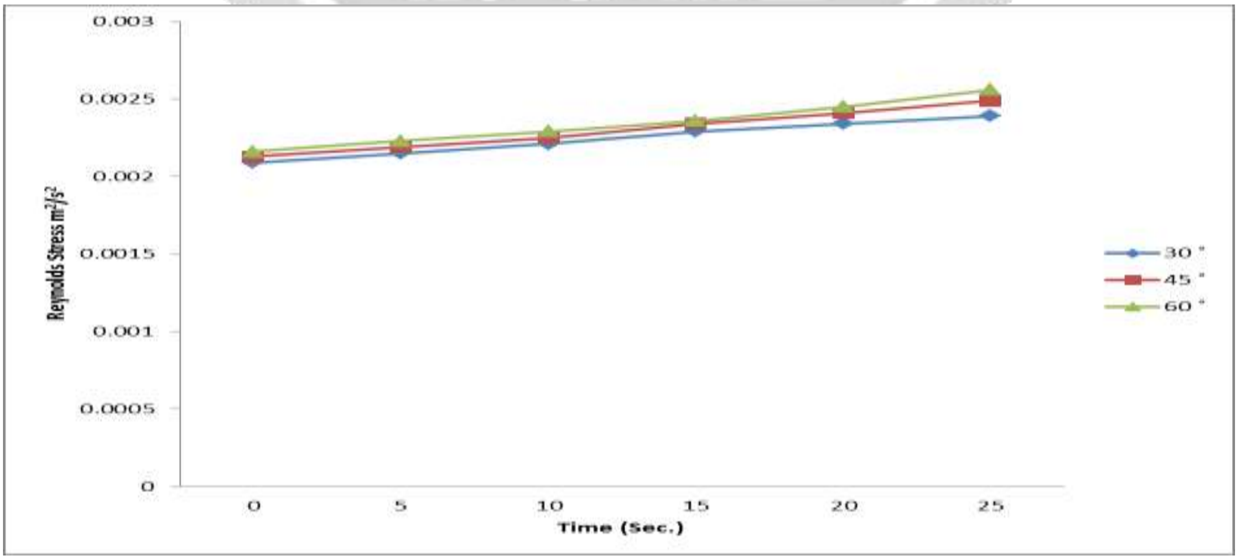

Figure 5.6 Comparison of different Reynolds stresses effect values w.r.t. time and chamfer angle

Table 5.6 shows the values of Wall Shear stresses effect with different chamfer angle

Wall Shear stress (Pa) 70MPa		
30 °	**45 °**	**60 °**
20.1	20.6	21.2
20.9	21.4	21.8
21.3	21.9	22.3
21.8	22.3	22.9
22.6	23.1	23.8
23.2	23.9	24.6

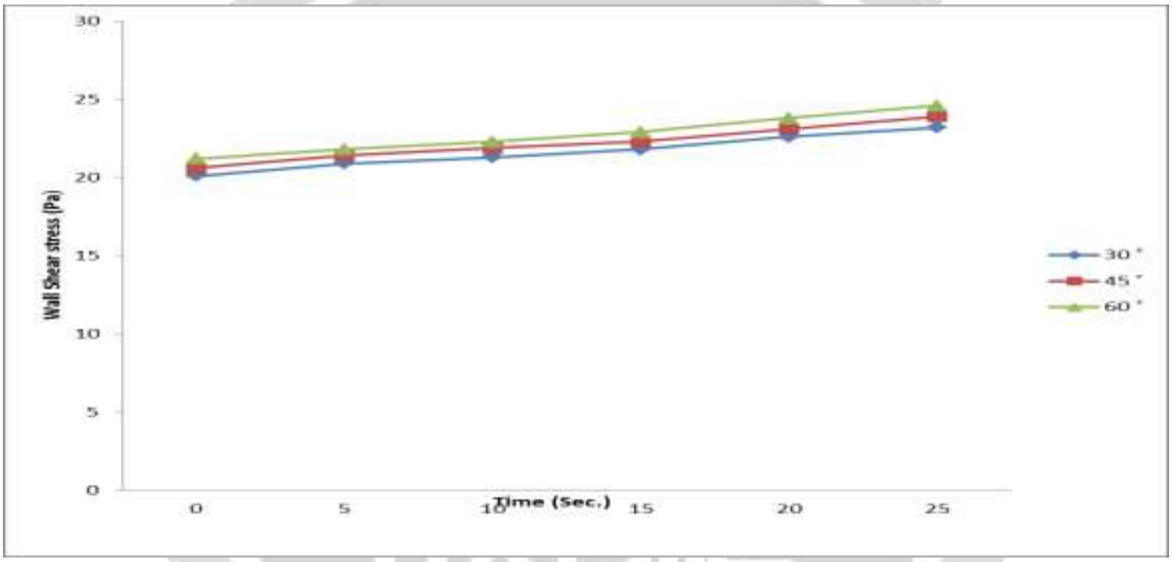

Figure 5.7 Comparison of different wall shear stresses effect values w.r.t. time and chamfer angle

5.5 Optimization on squeeze die casting model with different fillet radius

Table 5.7 shows the values of pressure with different fillet radius.

Pressure (70MPa)			
Time (Sec)	**2 mm**	**6mm**	**8mm**
0	27.9	26.1	29.3
5	29.5	27.9	32.8
10	32.7	29.8	34.6
15	34.9	31.5	38.2
20	37.8	33.8	39.9
25	39.6	36.9	42.1

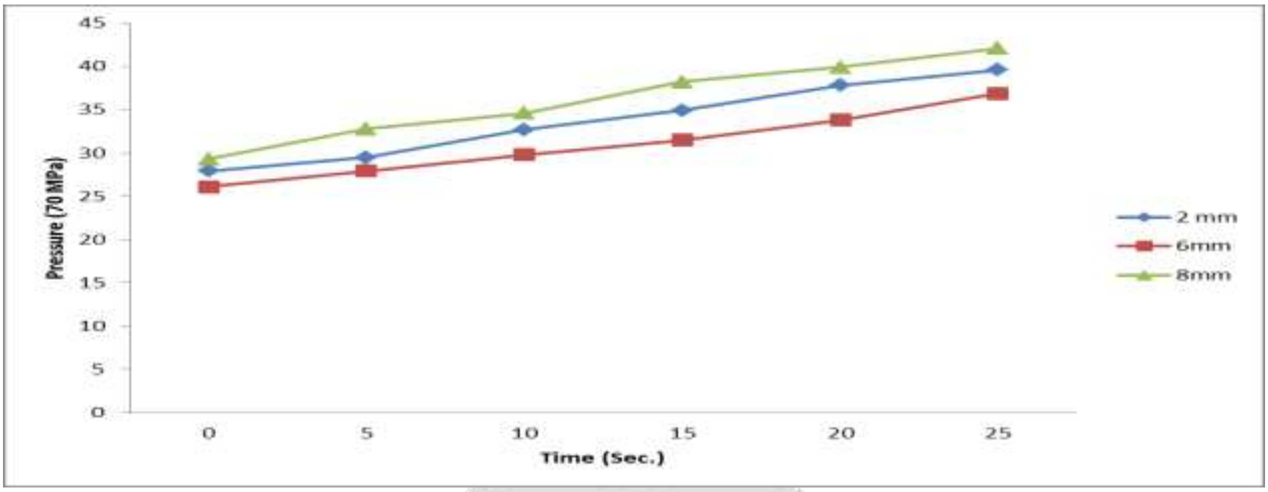

Figure 5.11 Comparison of different pressure values w.r.t. time and fillet radius

Table 5.8 shows the values of temperature with different fillet radius

Temperature K (70Mpa)			
Time (Sec)	**2 mm**	**6mm**	**8mm**
0	287	272	297
5	389	364	410
10	435	415	450
15	460	440	485
20	472	455	497
25	515	480	535
30	545	498	560
35	556	510	582

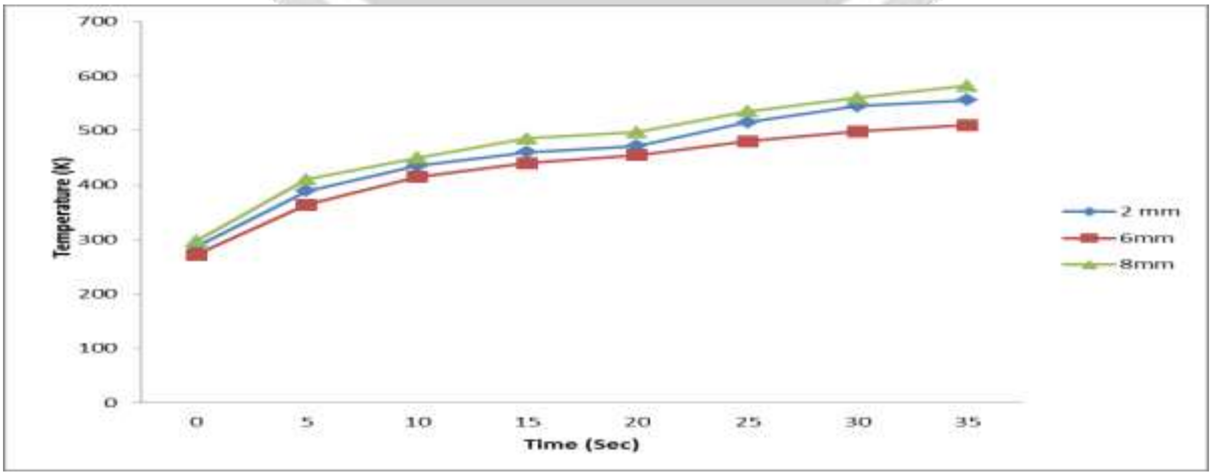

Figure 5.12 Comparison of different temperature values w.r.t. time and fillet radius

Table 5.9 shows the values of Reynolds stresses effect with different chamfer angle

Reynolds Stress m^2/s^2 (70MPa)			
Time	**2 mm**	**6mm**	**8mm**
0	0.00215	0.00211	0.00218
5	0.00221	0.00218	0.00225
10	0.00227	0.00224	0.00233
15	0.00236	0.0023	0.00238
20	0.00243	0.00236	0.00248
25	0.00254	0.00241	0.00259

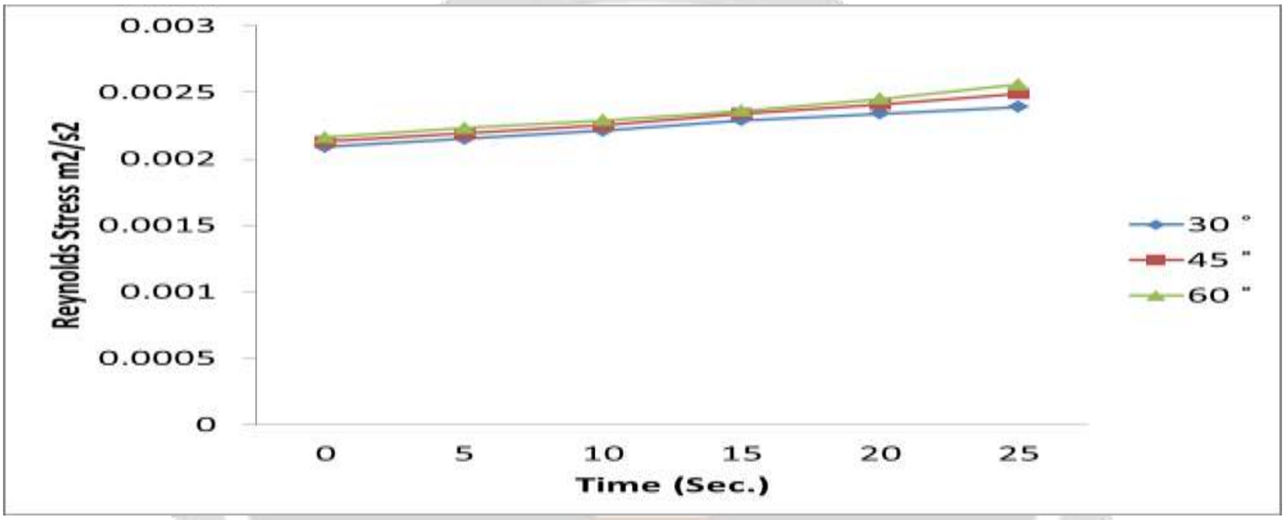

Figure 5.13 Comparison of different Reynolds stresses effect values w.r.t. time and fillet radius

Figure 5.13 Comparison of different Reynolds stresses effect values w.r.t. time and fillet radius

Wall Shear stress (Pa) 70MPa			
Time (Sec)	2 mm	6mm	8mm
0	20.8	20.4	21.4
5	21.6	21.1	21.9
10	22.3	21.5	22.5
15	22.8	22.1	23.1
20	23.7	22.8	24.2
25	24.3	23.4	24.8

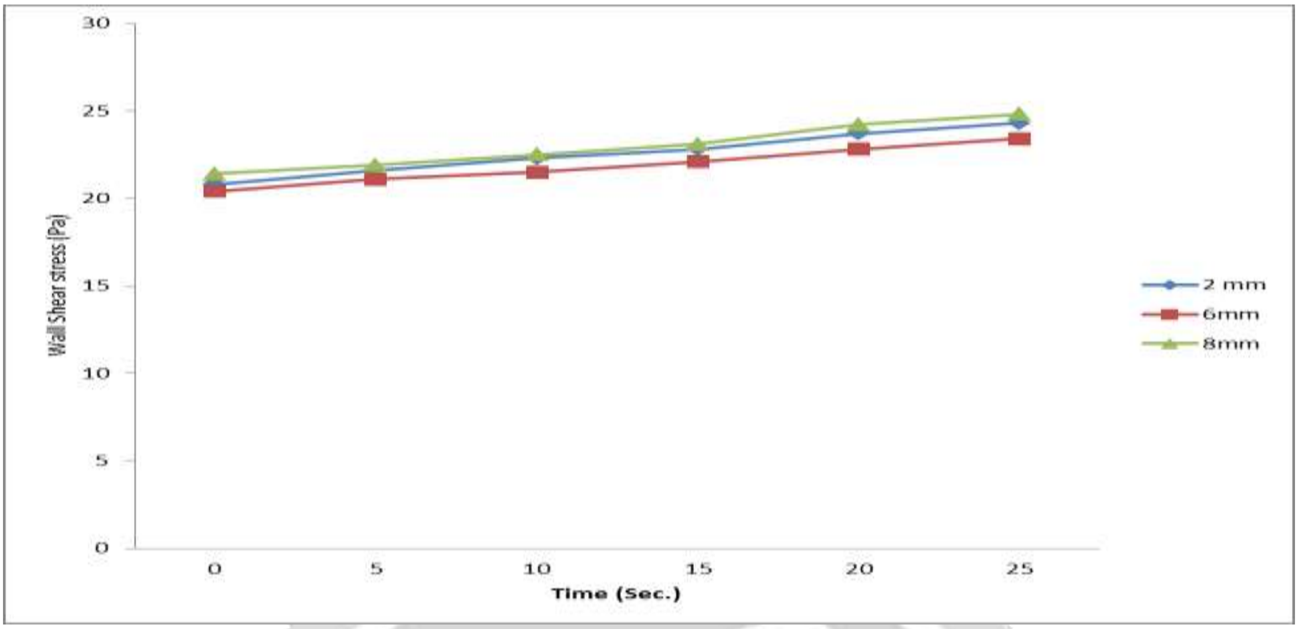

Figure 5.14 Comparison of different wall shear stresses effect values w.r.t. time and fillet radius

VIII CONCLUSION

6.1 CONCLUSION

- Average deviation of result obtained from CFD in pressure die casting process, for base model the pressure and temperature distribution lies within the range, pressure is deviate 3.76% for simulation model and temperature distribution is deviate 3.91% as compared to experimental work of the Author.
- Average deviation of results obtained for different chamfer angle from CFD in temperature is deviated by 17.01 % i.e., temperature decreases for 300 chamfer angle geometry at a pressure of 70MPa for analysis.
- Average deviation of result obtained for different fillet radiusof squeeze die casting process from CFD in pressure is deviated by 20.15% i.e., pressure decreases for 6mm fillet radius geometry w.r.t. time at each time steps for analysis.
- Reynolds stresses decreases for 30 degree chamfer angle and fillet radius 6mm for different time steps on squeeze die casting process, the average variation is analyze by 6.7% and for wall shear stresses w.r.t. it is decreased by 18.63%, 24.12%, and 19.35%, 16. 97% respectively.
- This CFD analysis clearly indicates that 6mm of filet radius and 30 degree of chamfer angle on plunger pressure of 70MPa decreases the Reynolds stresses and wall shear stresses due to this effect workability and machinability of a manufactured product increases, hence it also signifies the actual convergence of pressure and temperature management provides actual time of pressure die casting to produce a product with less manufacturing defect, Thus 30 degree of chamfer angle and 6mm of fillet radius would be used for dies design in squeeze die casting process.

6.2 SCOPE FOR FUTURE WORK

- For the future works in this area the following outlines are -
- Simulation could be done for the die casting in different angles as well as with different pressure.
- Simulation could be done for the different molten material also including die material for pressure die casting process.
- Simulation could be done for the different die temperature.
- Simulation could also be done by varying different fillet radius.

References

[1] Feifan Wang, Qingxian Ma, Wen Meng, Zhiqiang Han, Experimental study on the heat transfer behavior and contact pressure at the casting-mold interface in squeeze casting of aluminum alloy, International Journal of Heat and Mass Transfer 112 (2017) 1032–1043.

[2] M. Baghi, B. Niroumand, R. Emadi, Fabrication and characterization of squeeze cast A413-CSF composites, Journal of Alloys and Compounds 710 (2017) 29-36.

[3] R.Soundararajan, A.Ramesh, S. Sivasankaran, M.Vignesh, Modeling and Analysis of Mechanical Properties of Aluminium Alloy (A413) Reinforced with Boron Carbide B4C) Processed Through Squeeze Casting Process Using Artificial Neural Network Model and Statistical Technique Proceedings 4 (2017) 2008–2030.

[4] Dongdong You, Xiang Wang, Xueyu Cheng, Xiaomo Jiang, Friction modeling and analysis of injection process in squeeze casting, http://dx.doi.org/doi:10.1016/j.jmatprotec.2016.08.011.

[5] Wen-bo YU, Zi-hao YUAN, Zhi-peng GUO, Shou-mei XIONG, Characterization of A390 aluminum alloy produced at different slow shot speeds using vacuum assisted high pressure die casting, Trans. Nonferrous Met. Soc. China 27(2017) 2529−2538.

[6] Xuezhi Zhang, Li Fanga, Henry Hu, Xueyuan Nie and Jimi Tjong, Interfacial heat transfer of squeeze casting of wrought aluminum alloy 5083 with variation in wall thicknesses, Advances in Materials and Processing Technologies, 2017 https://doi.org/10.1080/2374068X.2017.1336352.

[7] P. Sharifi, J. Jamali, K. Sadayappan, J.T. Wood, Grain Size Distribution and Interfacial Heat Transfer Coefficient during Solidification of Magnesium Alloys Using High Pressure Die Casting Process, http://dx.doi.org/doi: 10.1016/j.jmst.2016.09.004.

[8] Teng Liu, QudongWang, Yudong Sui, Qigui Wang, Wenjiang Ding, An investigation into interface formation and mechanical properties of aluminum–copper bimetal by squeeze casting, Materials and Design 89 (2016) 1137–1146.

[9] M. Dhanashekar, V. S. Senthil Kumar, Squeeze Casting of Aluminium Metal Matrix Composites- An Overview, Procedia Engineering 97 (2014) 412 – 420.

[10] Manjunath Patel G C, Robins Mathew, Prasad Krishna, Mahesh B. Parappagoudar, Investigation of squeeze cast process parameters effects on secondary dendrite arm spacing using statistical regression and artificial neural network models, Procedia Technology 14 (2014) 149 – 156.

[11] Pu-yun DONG, Hai-dong ZHAO, Fei-fan CHEN, Jun-wen LI, Microstructures and properties of A356−10%SiC particle composite castings at different solidification pressures, Trans. Nonferrous Met. Soc. China 23(2013) 2222−2228.

[12] R. Ahmad, D.T. Gethin, R.W. Lewis, Design Element Concept of squeeze casting process, Applied Mathematical Modelling 36 (2012) 4760–4788.

[13] Zhizhong Suna, Henry Hu, Xiaoping Niu, Determination of heat transfer coefficients by extrapolation and numerical inverse methods in squeeze casting of magnesium alloy AM60, Journal of Materials Processing Technology 211 (2011) 1432–1440.

[14] M.T. Abou El-khair, A. Lotfy, A. Daoud, A.M. El-Sheikh, Microstructure, thermal behavior and mechanical properties of squeeze cast SiC, ZrO2 or C reinforced ZA27 composites, Materials Science and Engineering A 528 (2011) 2353–2362.

[15] J.O. Aweda, M.B. Adeyemi, Experimental determination of heat transfer coefficients during squeeze casting of aluminium, journal of materials processing technology 209 (2009) 1477–1483.

[16] G.R. Li, Y.T. Zhao∗, H.M.Wang, G. Chen, Q.X. Dai, X.N. Cheng, Fabrication and properties of in situ (Al3Zr+Al2O3)p/A356 composites cast by permanent mould and squeeze casting, Journal of Alloys and Compounds 471 (2009) 530–535.

[17] Roland W. Lewis, Z.Q. Han, David T. Gethin, Three-dimensional finite element model for metal displacement and heat transfer in squeeze casting processes, C. R. Mecanique 335 (2007) 287–294.

[18] K.J. Laws, B. Gun, M. Ferry, Effect of die-casting parameters on the production of high quality bulk metallic glass samples, Materials Science and Engineering A 425 (2006) 114–120.

[19] Z.W. Chen, Skin solidification during high pressure die casting of Al-11Si-2Cu-1Fe alloy, Materials Science and Engineering A348 (2003) 145/153.

[20] J.H. Lee, H.S. Kim, C.W. Won, B. CantorEffect of the gap distance on the cooling behavior and the microstructure of indirect squeeze cast and gravity die cast 5083 wrought Al alloy, Materials Science and Engineering A338 (2002) 182-190.

[21] C.A. Santos, J.M.V. Quaresma, A. Garcia, Determination of transient interfacial heat transfer coefficients in chill mold castings, Journal of Alloys and Compounds 319 (2001) 174–186.

[22] M.T. Abou El-khair, Microstructure characterization and tensile properties of squeeze-cast AlSiMg alloys, Mater. Lett. 59 (2005) 894–900.

[23] Z.P. Guo, S.M. Xiong, B.C. Liu, M. Li, Determination of the heat transfer coefficient at metal–die interface of high pressure die casting process of AM50 alloy, Int. J. Heat Mass Transf. 51 (2008) 6032–6038.

[24] H. Hu, A. Yu, Numerical simulation of squeeze cast magnesium alloy AZ91D, Modell. Simul. Mater. Sci. Eng. 10 (2002) 1–11.

[25] X.P. Niu, B.H. Hu, I. Pinwill, Vacuum assisted high pressure die casting of aluminum alloys, J. Mater. Process. Technol. 105 (1–2) (2000) 119.