ijecs open access
www.ijecs.in
International Journal of Engineering and Computer Science
Volume12 Issue 04, April 2023, PageNo.25700-25705
ISSN:2319-7242DOI: 10.18535/ijecs/v12i02.4671

Reduction Of Blow Hole Formation In Die Casting And Enhancement Of Strength Of Casting

Vinod Kumar Verrma[1], Sandeep Phogat [2], Sanjeev Sharma[3],
Amity University, Gurgaon, Haryana, India.
Email-ID:vinod2005verma@gmail.com, sandeepphogat1@gmail.com, ssharma26@ ggn.amity.com.

ABSTRACT:

In Automotive And Other Manufacturing Industries Making Light Weight Part With Corrosion Resistance Was The Challenges. Looking At These Challenges, Casting Part Is The Best Replacement Which Can Fulfil Both The Requirements Corrosion Resistance And Light Weight. Minimizing The Operational Cost Is The Today's Requirement .High Pressure Die Casting Process Is The Best Solution, Multicavity Die Can Be Used To Produce The Components With In Few Seconds. In HDPC There Is Inherent Characteristics Of Porosity Or Voids Or Shrinkage Porosity These Casting Defects Can Be Managed And Controlled But It Cannot Be Eliminated Permanently. Looking At This Phenomenon, In This Research Work Process Parameters Optimization Have Been Taken To Reduce Porosity /Shrinkage Porosity Those Parameters Are Holding Furnace Temperature ,Die Temperature , First Phase Plunger Speed, Second Phase Plunger Speed And Third Phase Intensification Pressure Or Accumulated Pressure Best Result Achieved On Following Parameters. Holding Furnace Temperature 700 ˚C, Die Temperature 195 ˚ ˚C First Phase Speed 0.23 M/S, Second Phase Speed 2.5 M/S, Intensification Pressure 285 Bar. Taguchi Methodology Have Been Used For Optimization Of Process Parameters. UTM Has Been Used For Testing Strength, Radiography Machine Used For Porosity Level Assessment And Spectro Machine Have Been Used For Chemical Composition.

Key Words : High Pressure Die Casting Porosity & Shrinkage Break Load &Radiography

1-INTRODUCTION

High-pressure die casting is a process in which molten metal is imposed under pressure into a safe locked metal mould cavity, where it is held by a powerful hydraulic press until the molten metal gets solidify. After solidification of the metal, the mould is unlocked, opened, and the casting comes out. Very high hydraulic pressure is applied to lock the mould till the solidification of the castings. Single, double and multicavities mould are being developed based on the requirement of the castings and compatibility in pricing. By using high pressure mould casting critical, intricate profile and accurate components are made. The working principle of pressure mould casting are made in three phases in first speed molten metal reached to the gate of mould ,in second speed mould cavity gets filled and in final third phase that is called accumulated pressure which is applied to locked the mould till the solidification of castingsDie casting process is divided into two types of casting processes, first low pressure die casting process and second is high pressure die casting process. Low pressure die casting and high pressure die casting parts are used for making light weight parts which are corrosion resistance as well. Basic five steps are used to produce pressure die casting parts i.e. clamping, injection, cooling, ejection and trimming. The first step in die casting is clamping. The dies are cleaned and lubricated to aid in step two, injection. Once the dies have been properly cleaned and lubricated, the die halves are closed and clamped together with high pressure. Molten metal taken from furnace and placing into die cavity is called injection. After injection of molten metal into die cavity it is kept in cavities till solidification this process is called cooling just after solicitation casting is ejected and to remove extra flashes called trimming process.

In pressure die casting processes several castings defects are appears therefore process parameters are required to be enhancement so that best use can be done ,defects are shrinkage, gas porosity, voids, cold shut, hot tear flow marks, dirty metal, RATS test is used to check the gas entrapment in holding furnace .

[1] V.D. Tsoukalas (2008) has studied on the

Elements	Si	Cu	Mn	Mg	Fe	Zn	Ni	Al
Wt%	8 to 11	2 to 3.5	0.5max.	0.1 to 0.5	1.2 Max.	1.0	0.3	Rest
Wt%	**9.68**	**2.45**	**0.186**	**0.204**	**0.82**	**0.69**	**0.073**	Rest

Table-1.0 AlSi9Cu3 Alloy. Specification and observations.

porosity formation used multivariable variable leaner regression software after process parameter optimization 0.73% to 0.25% porosity reduced. [2]N.Rathinam et al. (2020): they have done experimentation in high pressure die casting and optimized porosity formation, ADC12 material has been used for blow holes / porosity formation. Limit swaitchposition,1st stage velocity ,2nd stage velocity ,third stage high pressure ANOVA tool has been applied. [13] Nagasankar.P et al. (2018): have reduced blow holes after optimization of process parameters and improving gate design 20% to 8.9% blow holes reduced. These authors have done almost Similar work.

Die Material

H13 die steel has been used to make casting tool as per AISI ,this material has very good toughness resistance to abrasive. Tool life is good of this tool material.

Fig.1.0 DIE fixed and movable half & Die Casting M/C (Reference.VC Tier-1SRS)

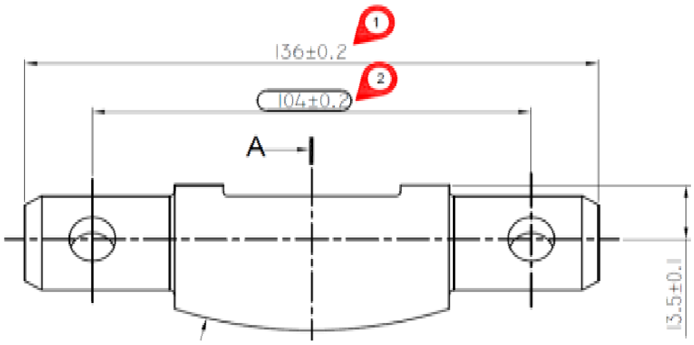
1.30 Part Geometry:

Part size length, width and thickness are 138mm,54mm and 24.1mm respectively ,this part has been selected for porosity /shrinkage porosity

Raw Material

Material AlSi9Cu3 Aluminium alloy has been used ,detail mentioned in the Table-1.

optimization and improvement in the casting part strength. This is the thicket part is considered for po-



rosity formation optimization. Density of the part is 2.75gm/cm3.Ref.Fig 2.0.

Fig. 2.0 Moulded and Child part (Reference VC).

1.40 Application

Part has been made for engine mounting for automotive OEM ,this part is corrosion resistance having ability to absorve the vibration of the engine .engine mount is made through rubber injection moulding process before injection moulding surface treatment process is done which gives strong bonding between casting part and rubber/outer part.Casting parts now a days are being used as light weight part in electrical industries, electronics industries, aerospace ,automotive industries and house hold appliance. In all the industries porosity are changings which reduces the strength and problem in machine.

Experimental Procedure

Flow Chart

Total 9 steps are followed in HPDC process ,In this experimentation ram material AlSi9Cu3aluminium alloy has been used .Alloy is taken in form of ingot which then melted in melting furnace after melting molten metal is placed in holding furnace under controlled temperature Ref.Table 2.Next step is HPDC process basic principle of high pressure die casting is completed in three stages in first stage molten metal reaches to the gate of die in second stage cavities get filled and in last stage that is called high pressure or accumulation pressure ,it is applied till the solidification of the castings. after solidification of casting trimming and felting operations are done once these operation is done porosity is testing by X-ray machine Ref.Fig.4.0. after testing of porosity strength of casting is tested by UTM machine final and last step is to compare the result as per standard and expectation.

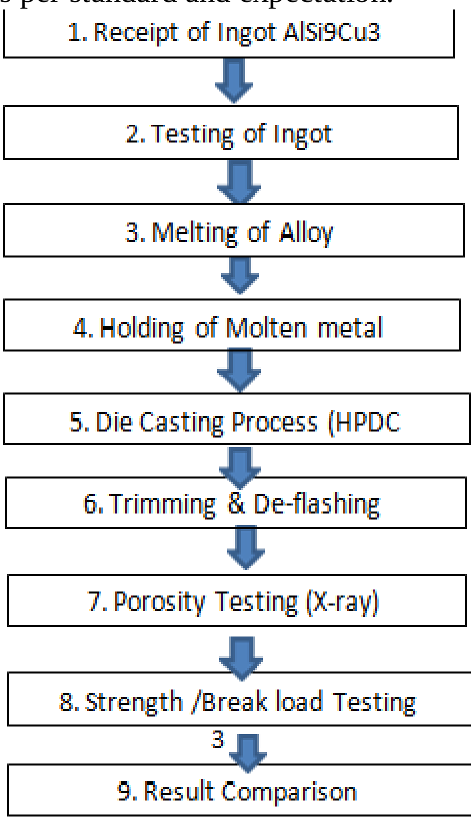


Fig 3 Process Flow Diagram of High Pressure Die Casting Process

Set up for Die casting and Testing.

X-Ray (Radiography machine) for porosity testing,Spectro machine for raw material testing and 500 Tom die casting machine available at SRS die casting. UTM machine available at Vibracoustic.

Fig.4.0 UTM M/C at VC with set up of break load & Radiography Equipment (Reference

Universal Testing Machine (UTM) | X-ray (Radiography) | X-ray (Radiography)

Taguchi design:

Minimization of porosity formation in HPDC process is very challenging because there are several variables are involved in this process each and every parameter is having their own significance towards porosity formation. Some of the key causes listed in cause and effect diagram which are shown in Fig.4.out of these causes we have selected five key and significant causes for porosity formation reduction and improving the break load of casting.

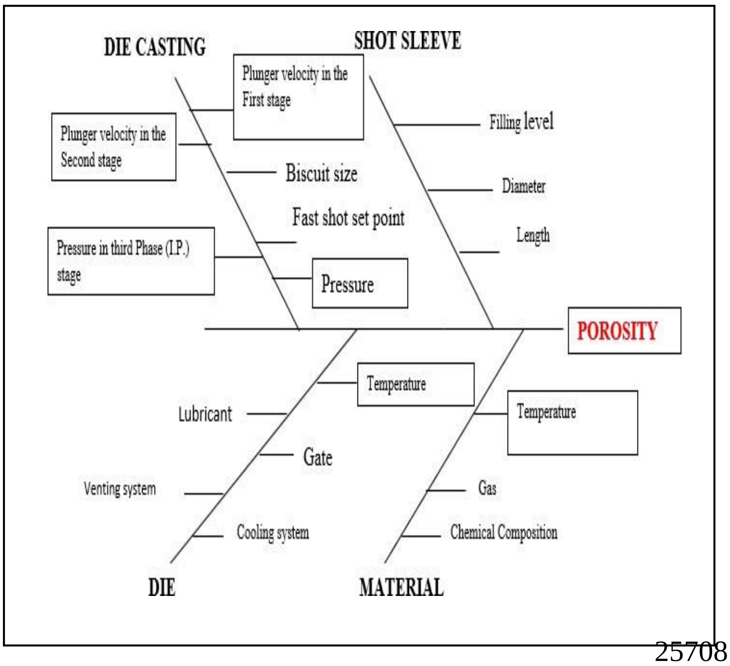


Fig. 5.0 Cause and effect diagram for die casting porosity.

Plunger velocity first stage , Plunger velocity second stage ,Accumulation high pressure, holding furnace temperature and die temperature rages selected respectively

0.3~0.43m/s,2.5~3.1m/s,185~285Bar,655~700 ˚C and 195~245 ˚C for reduction of porosity formation. Their detail has been given in Table-2.0.Taguch methodology has been selected for this experimentationbecause this one of the best ,efficient cost effective time saving and simple tool. It is based on matrix called orthogonal array.

2.3 Process parameters listed in the table with data ranges & three levels.

Category	PP	UOM	PR	Level-1	Level-2	Level-3
A	Holding furnace temperature	˚C	655-700	655	678	700
B	Die temperature	˚C	195-245	195	220	245
C	Plunger velocity 1st stage	m/s	0.03-0.43	0.03	0.23	0.43
D	Plunger velocity 2nd stage	m/s	2.5-3.1	2.5	2.8	3.0
E	Multiplied pressure 3rd Stage	Bar	185-285	185	245	285

Table 2.0 process parameters with range and their value

The minimum number of trials in the array is given by: N min = (Ln-1)Pn+1 (Ref.V.D.Sokalas 2008) In which ,Pn is the number of parameters,Nmin is no of trials ,Ln is trial level,in this experimentation ln is 3,Pn is 5 hence i N min comes 11.and there fore as per Taguchi quality design concept ,L27 orthogonal array has been selected .The experimental layout plan using L27 orthogonal has been shown in Table 4.2 Each combination of experiments shall be repeated three times to achieve accurate result in this process.The Taguchi optimization procedure starts with the selection of the orthogonal array having distinct number of levels (In) defined for each of the parameter selected. The minimum number of trials in the array has been shown by :

Trails	HFT ˚C	DT ˚C	PVS-1 m/s	PVS-2 m/s	MP-3 Bar
1	1	1	1	1	1
2	1	1	2	2	2
3	1	1	3	3	3
4	1	2	1	2	2
5	1	2	2	3	3
6	1	2	3	1	1
7	1	3	1	3	3
8	1	3	2	1	1
9	1	3	3	2	2
10	2	1	1	2	3
11	2	1	2	3	1
12	2	1	3	1	2

13	2	2	1	3	1
14	2	2	2	1	2
15	2	2	3	2	3
16	2	3	1	1	2
17	2	3	2	2	3
18	2	3	3	3	1
19	3	1	1	3	2
20	3	1	2	1	3
21	3	1	3	2	1
22	3	2	1	1	3
23	3	2	2	2	1
24	3	2	3	3	2
25	3	3	1	2	1
26	3	3	2	3	2
27	3	3	3	1	3

Table 3.0 L27Orthogonal array.

Process Parameters Optimization

Three levels of trials have been considered in this experimentation and their result have been verified byindustrial x-ray (radiography equipment) which is shown in Table 2.0

Trial	HFT ˚C	DT ˚C	PVS-1 m/s	PVS-2 m/s	MP-3 Bar	# of shots taken	Porosity Status compared with ASTM E 505(LEVEL)
1	655	195	0.03	2.5	185	8	Level 02
2	655	195	0.23	2.8	245	8	Level 02
3	655	195	0.43	3	285	8	Level 02
4	655	220	0.03	2.8	245	8	Level 02
5	655	220	0.23	3	285	8	Level 02
6	655	220	0.43	2.5	185	8	Level 03
7	655	245	0.03	3	285	8	Level 02
8	655	245	0.23	2.5	185	8	Level03
9	655	245	0.43	2.8	245	8	Level 02
10	678	195	0.03	2.8	285	8	Level 01
11	678	195	0.23	3	185	8	Level 04
12	678	195	0.43	2.5	245	8	Level 01
13	678	220	0.03	3	185	8	Level 02
14	678	220	0.23	2.5	245	8	Level 01
15	678	220	0.43	2.8	285	8	Level 01
16	678	245	0.03	2.5	245	8	Level 01
17	678	245	0.23	2.8	285	8	Level 01
18	678	245	0.43	3	185	8	Level 03
19	700	195	0.03	3	245	8	Level 01
20	**700**	**195**	**0.23**	**2.5**	**285**	**8**	**Level 01**
21	700	195	0.43	2.8	185	8	Level 04
22	700	220	0.03	2.5	285	8	Level 02

23	700	220	0.23	2.8	185	8	Level 04
24	700	220	0.43	3	245	8	Level 03
25	700	245	0.03	2.8	185	8	Level 04
26	700	245	0.23	3	245	8	Level 02
27	700	245	0.43	2.5	285	8	Level 03

Table 4.0 Process Parameters Optimization Experimentation.

Process parameter pre and post optimization

Pre and Post optimization of process parameters and their porosity formation result has been shown in Table 5.0.Before optimization holding furnace temperature was 640 ˚C, Die temperature 185 ˚C, Speed first stage 0.12m/s, second stage speed 0.32 m/s and third stage multiplied pressure was 130Bar.After optimization of porosity formation fixed parameters are holding furnace temperature was 700 ˚C, Die temperature 195 ˚C, Speed first stage 0.23m/s, second stage speed 2,5 m/s and third stage multiplied pressure was 285Bar.

Category	PP	UOM	Pre Optimization Porosity L3/ L4 BL-12,7.9,10.70&10.90 kN	Post Optimization Porosity L1,BL-21.22,28.00,22.23&24.79kN
A	Holding furnace temperature	˚C	640	700
B	Die temperature	˚C	185	195
C	Plunger velocity 1st stage	m/s	0.12	0.23
D	Plunger velocity 2nd stage	m/s	0.32	2.5
E	Multiplied pressure 3rd Stage Bar	Bar	130	285

Table 5.0.Process Parameter Pre and Post Optimization.

We have checked 4 parts in which porosity level observed Level3 and level4 their breal load tested 12,7.9,10.70&10.90 kN respectively same has been shown in Fig.6

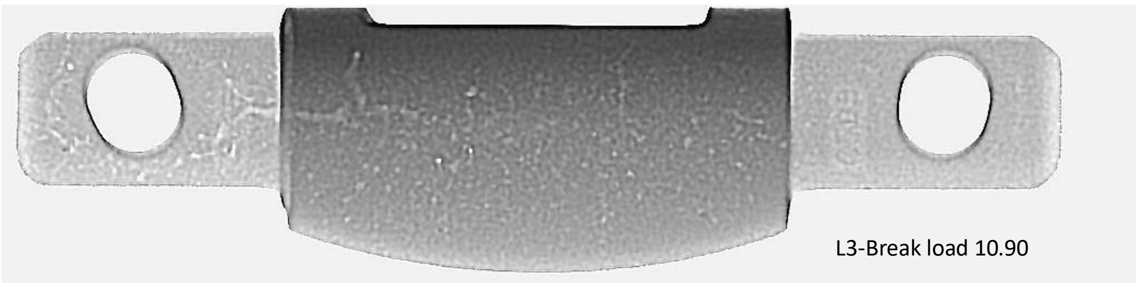


Fig. 6.0 Porosity Level 3 Break load 10.90 kN.

Below shown part is having level 4 porosity as well shrinkage porosity after testing break load reported 7.9kN which is lowest these kind of parts have very serious concern in application

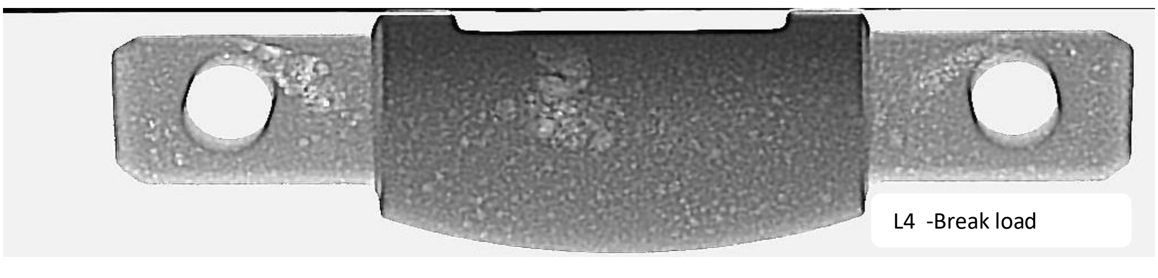


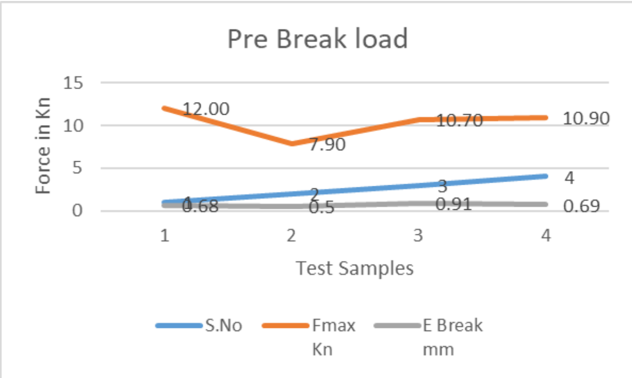
fig 7.0.

Fig. 7.0 Break load observed 7.90kN at Porosity more than Level 4.

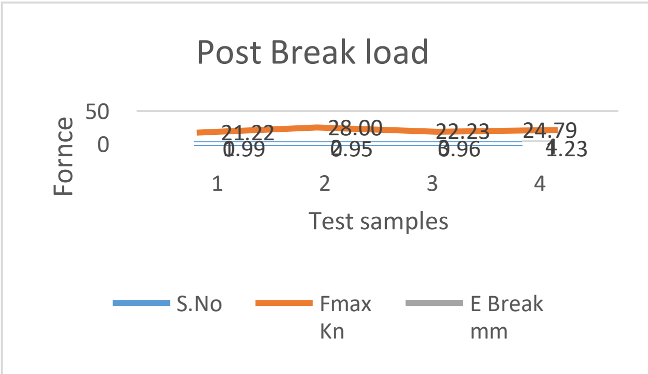
Break load test results

Break load test result have been mentioned in Fig.10.0 after improvement of porosity formation break load observed as mentioned hereunder break load test values are 21.22,28.00,22.23 & 26.0 kN as shown in the graph Fig.10.0 and table 9.0 and 10.0.

In the graph on Y Axis ,controlled force is applied and subsequently strain is observed on X-Axis there are four parts have been checked and subsequent nominal strain has been shown in fig.8.0 & Fig9.0



Pre Optimization- Break load (X-ray) Fig.



Post Optimization- Break load (X-ray) Fig.9.0

Comparison of break load

Process parameter pre optimization, porosity level & subsequent break loadHolding furnace temperature 640˚C ,Die temperature 185˚C, Plunger velocity 1st stage 0.12m/s, Plunger velocity 2nd stage 0.32 m/s, Multiplied pressure 3rd Stage 130 Bar and its break load observed 12.0kN,7.9 kN,10.70kN and 10.90 kN and porosity level observed L3/L4 shown in Table6.0

Post process optimization porosity level-1 and break load 28.0kN achived on Holding furnace temperature 700˚C ,Die temperature 195˚C, Plunger velocity 1st stage 0.23m/s, Plunger velocity 2nd stage 2.5 m/s, Multiplied pressure 3rd Stage 285 Bar shown in Table 7.0

X-Ray report Leve4-1Fig.11

X-Ray report Le

Results		
S.No	Fmax Kn	E Break mm
1	12.00	0.68
2	7.90	0.5
3	10.70	0.91
4	10.90	0.69

Table 6.0 Pre Optimization- Break load

Results		
S.No	Fmax Kn	E Break mm
1	21.22	0.99
2	28.00	0.95
3	22.23	0.96
4	24.79	1.23

Table 7.0 Post Optimization- Break load

1- RESULTS AND CONCLUSION

3.1 Result and Conclusion

After optimization of process parameters i.e. first stage plunger speed, second stage plunger speed and intensification pressure (multiplied pressure) porosity level-1 achieved, Casting strength tested break load for four parts and break load observed 21.22, 22.23 26.0 & 28.00, kN. Best result achieved at holding furnace temperature Best result achieved at holding furnace temperature 700 ˚C, Die temperate 195˚C ,First stage plunger speed 0.23 m/s, Second stage plunger speed 2.5m/s, third stage multiplied
pressure 285 Bar by using these process parameters porosity achieved level 01 and break
load achieved maximum 28.00 kN.
Total 16kN break load increased after experimentation.

NOMENCLATUR

HDPC	High Pressure Die Casting
PP	Process Parameter
PDC	Pressure Die Casting
DC	Die casting
LPDC	Low Pressure Die Casting
ANOVA	Analysis of Variation
MVLR	Multi variable linear regression
TD	Tensile ductility
VC	Vibracoustic
SRS	SRS Die casting
UOM	Unit of measurement
PR	Parameter Range
HFT	Holding Furnace Temperature
DT	Die Temperature
PVS-1	Plunger Velocity Stage-1
PVS-2	Plunger Velocity Stage-2
MP-3	Multiplied Pressure Third Stage
BL	Break Load

REFERENCES

[1] V.D. Tsoukalas (2008) Optimization of porosity formation in AlSi9Cu3 pressure die casting using genetic algorithm analysis. Department of marine engineering, Athens Merchant Marine Academy, Paralia Aspropyrgou 19300,aspropyrgos,Athens,Greece.

[2]N.Rathinam et al. (2020): Optimizing process parameters to reduce blowholes in high pressure die casting using Taguchi methodology. Department of Mechanical Engineering, Pondicherry Engineering College, Pillaichavady, Puducherry, 605014, India.

[3]N. Nagabhooshanam at el (2020) : Optimization of shrinkage porosity in AlSi5Cu1Mg alloy using response surface methodology. Department of Mechanical Engineering, St. Peter's College of Engineering and Technology, Avadi, Chennai 54, India.

[4] Paul W. Cleary at el (2009): has studied on casting short filling their reason and affecting process parameters.They have also given the conclusion that material quantity filling and dei temperature plays significant role in short filling. They belong to claton south Australia.

[5] R. Chandrasekaran et al (2019): Reduction of scrap percentage of cast parts by optimizing the process parameters.

ISEP-School of Engineering, Rua Dr. António Bernardino de Almeida 431, 4200-072 Porto, Portugal.

[6] R.Venkata Rao et al (2014) : Parameters optimization of selected casting processes using teaching– learning-based optimization algorithm. Department of Mechanical Engineering, S.V. National Institute of Technology, Surat, Gujarat 395007, India.

[7] Djordje Cica et al. (2018) :Intelligent process modelling and optimization of porosity formation in highpressure die

casting. Faculty of mechanical engineering, university of banja ,bulevar vojvode stepe stepanovica71,78000banja luka bosnia and Herzegovina.

[8] R. Venkata Rao et al. (2017):Optimization of Selected Casting Processes Using Jaya algorithm. Sardar Vallabhbhai National Institute of Technology, Surat 395007, India.

[9] Arun Kumar Gupta at et al. (2020):Optimization of Process Parameters during Pressure Die Casting of A380: a Silicon-Based Aluminium Alloy Using GA & Fuzzy Methodology.Pratheesh G Panicker et al. (2020) : Parameter

[10] Optimisation of Squeeze Casting Process using LM 20 Alloy:

Numeral Analysis by Neural Network and Modified

[11] Bjørn Håkon Frodal et al.(2019) : On the effect of plastic anisotropy, strength and work hardening on the tensile ductility of aluminium alloys . Structural Impact Laboratory (SIMLab), Department of Structural Engineering, Norwegian University of Science and Technology (NTNU), NO-7491, Trondheim, Norway.

Coefficient-based Deer Hunting Optimization. Research Scholar, Department of Mechanical Engineering, Mahatma Gandhi University, Kottayam, Kerala, India; bHOD in Department of Mechanical Engineering, Mar Athanasius College of Engineering, Kothamangalam, Kerela, India.

[12] Quang-Cherng Hsu et al.(2013):Minimum Porosity Formation in Pressure Die Casting by Taguchi Method. Department of Mechanical Engineering, National Kaohsiung University of Applied Sciences, 415 Chien-Kung Road, 80778 Kaohsiung City, Taiwan.

[13] Nagasankar.P et al. (2018): Reduction of Blow holes in Aluminium High Pressure Die Casting Machine Department of Mechanical Engineering, Vel Tech High Tech Dr.Rangarajan Dr.Sakunthala Engineering College, Chennai - 600062, India . Department of Mechanical Engineering, Jaya Engineering

College, Chennai - 602024, India.

[14] Mi Guofa et al. (2009) :Numerical simulation of low pressure die-casting aluminum wheel (Department of Mechanical Engineering, Chengde Petroleum College, Chengde 067800, P. R. China)

[15] Amitkumar Advekar1 et al. (2015): Simulation of High Pressure Die Casting Process for Identifying and Minimising Defects Dr. M S Srinath3 Associate Prof., Dept. of Mechanical Mechanical Engineering Malnad College of Engineering Hassan-573201(Karnataka), India

[16] Suraj Marathe et al. (2015):Thermal Factor of Aluminium High pressure Die Casting Container (Mould) to achieve Six Sigma Quality of Castings Research Scholar, Mechanical Engineering Department, Assam Don Bosco University, Guwahati, India

[17] Y. Abdulfatah et al. (2016):Abdu Design and Analysis of Pressure Die Casting Die for Automobile Component Global Journal of Researches in Engineering: A Mechanical and Mechanics Engineering.

[18] Yulong Zhu et al. (2004):Evaluation of soldering, washout and thermal fatigue resistance of advanced metal materials for aluminum die-casting dies Department of Materials Science and Engineering, Case Western Reserve University, White Building Room 112, 10900 Euclid Avenue, Cleveland, OH 44106, USA.

[19] Q. HAN et al. (2004):Analysis of the Mechanism of Die Soldering in Aluminum Die Casting. IPC Communication Services Attn: Sheryl Dickenson 501 Colonial Drive St. Joseph, MI 49085.

[20] Ming-Wang. Fu et al. (2020) :Die Casting for Fabrication of Metallic Components and Structures in Reference Module in Materials Science and Materials Engineering, 2020.

[21] E. Anglada et al. (2015) :Adjustment of a high pressure die casting simulation model against experimental data TECNALIA Industry and Transport Division, Mikeletegi Pasealekua.

[22] Devaraj S Patilat et al. : Review on State of Art and Techniques in High Pressure Die-Casting (HPDC) .

[23] E. Anglada et al.2015 :Simplified models for high pressure die casting simulation. TECNALIA Industry and Transport Division, Mikeletegi Pasealekua.

[24] Mohammad Sadeghi et al..(2012): Experimental and Theoretical Studies on the Effect of Die Temperature on the Quality of the Products in High-Pressure Die-CastingProcess. HST Department, MAlardalen University, P.O. Box 883, 721 23, Vasteras, Sweden.

[25] Quang-Cherng Hsu et al. (2013): Minimum Porosity Formation in Pressure Die Casting by Taguchi Method. Department of Mechanical Engineering, National Kaohsiung University of Applied Sciences, 415 Chien-Kung Road, 80778 Kaohsiung City, Taiwan.

[26]Vinod V Rampur et al..(2016): PROCESS OPTIMIZATION OF PRESSURE DIE CASTING TO ELIMINATE DEFECT USING CAE SOFTWARE. Assistant professor, Department of mechanical engineering, PESITM Shimoga, Karnataka, India.

[27]Kun Doun et al. (2021): A Novel Approach to Optimize Mechanical Properties for Aluminium Alloy inHigh Pressure Die Casting (HPDC) Process Combining Experiment and Modelling. Journal of Materials Processing Technology · April 2021.

[28] Laihua Wang et al. (2011) : Gas content in high pressure die casting Cast cooperative Research Centre,CSIRO Process Science and Engineering ,Gate 5,Normanby Road Clayton,VIC 3168,Australia.

[29] Sanjeev Sharma et al. “Annealing Re-

sponse of Aluminum Alloy AA6014 Processed by Severe Plastic Deformation" Institution of Engineering and Technology" (Web of Science & Scopus Listed Journal).

[30] Sanjeev Sharma et al. "Bonding Characteristics of Al and Al-Alloy Strips: Processed by Severe Plastic Deformation" International Journal of Engineering and Technology (Scopus Listed Journal).

[31] Sanjeev Sharma et al. (2016)" Accumulative roll bonding of Mg-Al Alloy" International Journal of innovation in Engineering and Technology vol. 6 issues 3 Feb. 2016 (Thomson Reuters listed Journal).