INVESTIGATION TO OPTIMIZE PROCESS PARAMETERS ON MECHANICAL PROPERTIES OF ALUMINIUM ALLOY IN DIE CASTING USING TAGUCHI METHOD

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Abstract: *Aluminium alloy (7178) of die casting involves process parameters like weight percentage of Zn, Mg, Cu, Cr Si. Fe, Mn and Ti etc. with this Zn, Mg, Cu and Cr are selected as process parameters and other parameters are kept constant. Experiments were conducted Taguchi's L-9 orthogonal array. Castings were made under the various parameter at three different level. In this investigation, the effect of process parameters on mechanicalproperties of castings of aluminium alloy (7178) is studied. Taguchi method design of experiments employed to optimize the parameters of process that leads maximum mechanical properties. The investigation has indicated that influence of parameters like Zinc (Zn), copper (Cu) magnesium(Mg) and chromium (Cr) on properties of mechanical like Tensile strength, Hardness and microstructure analysis. Results were analysed by ANOVA Technique. Microstructures were studied under optical microscope.The optimal parameters of process for castings of aluminium alloy for better mechanical properties have been determined.*

Keywords: *Aluminium Alloy 7178, Die Casting Method, Taguchi Method, Anova.*

1.INTRODUCTION

Aluminium alloy 7178 is a high strength alloy with Zinc, magnesium and chromium as major alloying elements. It is heat treatable and improve mechanical properties with adding alloy elements AA 7178 is sensitive to high temperature range between 200^{0}C to 250^{0}C. IT has strong corrosion resistance and high electrical conductivity. commonly used in the manufacture of aircraft and other structures. It contains Si 0.4 wt.%, Fe 0.5 wt.%, Cu 1.75 wt.%, Mn 0.3 wt.%, Mg 2.5 wt.%, Cr 0.2 wt.%, Zn 6wt%. Physical properties of AA 7178 have Density 2.82g/cm^2 and melting point 482^{0}C.

In manufacturing process there are various parameters like weight percentage of Zn, Cu, Mg and Cr with three different levels, which may influence the final characteristics of the product to optimise a manufacturing process, Taguchi method is used to identify the best parameters to manufacture a quality product. These experimental methods are employed to solve problem and understand the influence of varies parameters on the final product. (Ref 3.4,5).

However, the problem associated with the die casting process. The quality of cylindrical parts obtained during die casting process is influenced by various process parameter like weight percentage of ZN, Cu, Mg and Cr (Ref 7).

The present investigation is focused on the optimization of process parameters during die casting process of AA 7178 by Tuguchi method using analysis of Anova which is statistical tool applied to result. Taguchi approach is a systematic approach of analysis and design of experiments for the improving the quality characteristics. ANOVA was used for analysing the results of designed experiments. (Ref 8,9).

2.OBJECTIVE AND METHODOLOGY

(a) The object of present study most influencing process parameters of aluminium alloy 7178 in die casting process and optimise them to improve mechanical properties like Tensile strength, hardness and microstructure. Taguchi method of experiments are analyzed to achieve the following objectives

Preparation of Aluminium alloy 7178 specimens in die casting process with various compositions

Establish the best or the optimum condition for a product

Estimate the contribution of individual parameters and interaction

3. TAGUCHI METHOD & EXPERIMENTATION

(a) Taguchi method

The method of Taguchi for four process parameters as three levels were used for the experiments. The orthogonal array L-9 selected is shown

Table 1: Level of Process Parameters

Process Parameters	Level 1	Level 2	Level 3
Weight % of Zn (A)	6.3	6.8	7.3
Weight % of Mg (B)	2.4	2.75	3.1
Weight % of Cu (C)	1.6	2	2.4
Weight % of Cr (D)	0.18	0.23	0.28

Table 2: L-9 (3^4) Standard Orthogonal Array

Expt No	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

table-3 has 9 rows corresponding to the number of tests with the required columns. The selection of a particular orthogonal array is based on the number of level process parameter

Degree of freedom

DOF=P(L-1)

Where P- Number of process parameters

L= Number of level

DOF=4(3-1)=8

Thus L-9 orthogonal array was selected.

(b) Experimentation

3.1 Material selection

In the present investigation AA 7178 aluminium has been to taken to makecastings.

3.2 Die Casting Process

Die is prepared with cast iron metal for a cylindrical shape castings. AA718 is melted in furnace to $700c^o$ to 750^0 and poured in to die, molten metal enter into die by the gravity force and casting is taken out after solidification.

Fig 1. Metal Furnace

Table 3

Metal	Zn	Mg	Cu	Cr	Si	Fe	Mn	Ti	Al
Wt %	6.3-7.3	2.4-3.1	1.6-2.4	0.18-0.29	0.4	0.5	0.3	0.2	Balance

Fig 2. Molten Metalpouring into Die

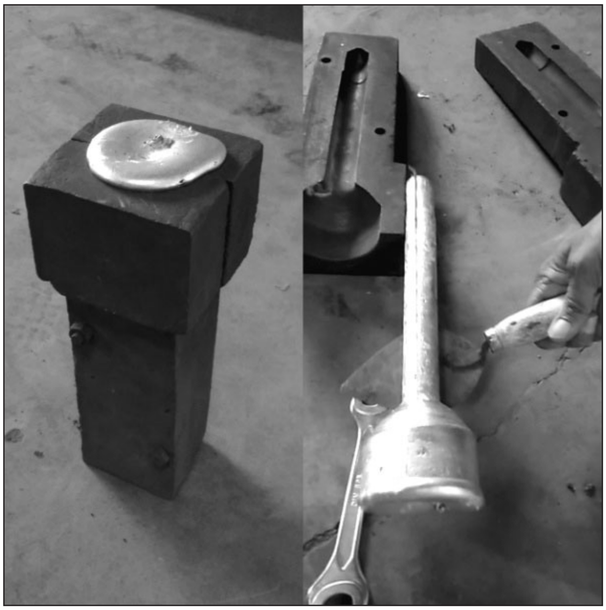


Fig 3. Solidified Castings

Fig 4. Castings of Different Compositions

3.3 Machining

After the casting, machined according to ASTM (American Section of the International Association for Testing Materials) standards on highly sophisticated lathe.

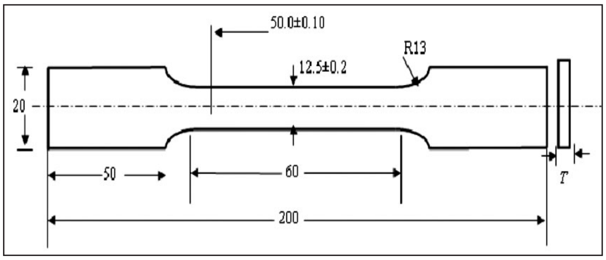


Fig 5. Dimensions of Tensile Test Specimen

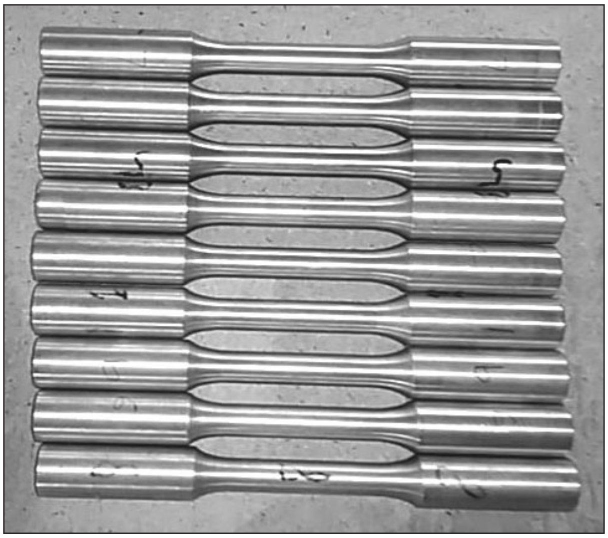


Fig 6. After Machining Specimens

4. TESTING

Following tests are carried out in this process

1. Tensile test
2. Hardness test

a) Tensile Test

This test was conductedin DMRL (Defence Metallurgical Research Laboratory), Hyderabad, Telangana, India. And was performed in WALTER+BAI.AG Universal testing machine (UTM) as shown in fig 11. The maximum load of this machine is 200kN. In this test Yield strength, Ultimate tensile strength and ductility were evaluated.

First holding the work piece by using bottom

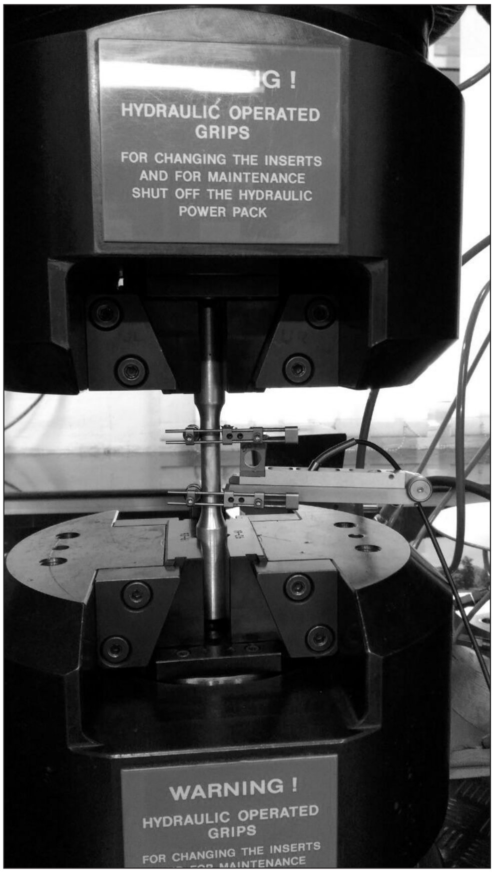


Fig 7. Attaching the Sensor to the Specimen

Table: 4 Tensile Test

S. No	Sample Designation	UTS (MPa)	Max Load (KN)	% of Elangation
1	Al-Alloy-1	115	14.14	0.8
2	Al-Alloy-2	148	18.02	0.1
3	Al-Alloy-3	127	15.59	OGL
4	Al-Alloy-4	102	12.52	0.8
5	Al-Alloy-5	87	10.73	0.1
6	Al-Alloy-6	117	14.37	0.7
7	Al-Alloy-7	83	10.15	0.1
8	Al-Alloy-8	71	8.7	0.5
9	Al-Alloy-9	98	11.98	0.3

hydraulic gripper (BHG) and upper hydraulic gripper (UHG). In this upper hydraulic gripper is movable and bottom hydraulic gripper is constant. Adjust the settings in the DION PRO software as per requirement. Attach the sensor clip to the

Fig 8. Fractured Specimen

Fig 9. All Specimens After Fracture

specimen is shown in figure7.

After this, the machine is started and the upper gripper is moved vertically upwards with ‘1mm/ min’. By moving upper gripper the specimen is elongated and there will be a breaking point after some time. This speed is used for first two specimens and other two specimens are conducted with speed of 0.5mm/min. And the maximum load is applied in this tests is 100kN.

Table 5: S/N Ratio for Tensile Strength

Exp No	A	B	C	D	S/N Ratio
1	1	1	1	1	41.213
2	1	2	2	2	43.405
3	1	3	3	3	42.076
4	2	1	2	3	40.172
5	2	2	3	1	38.79
6	2	3	1	2	41.363
7	3	1	3	2	38.381
8	3	2	1	3	37.025
9	3	3	2	1	39.825

Table 6: Anova for Tensile Test

Sum of Level	A	B	C	D
1	42.231	39.922	39.867	39.942
2	40.108	39.74	41.134	41.049
3	38.41	41.088	39.749	39.757
Max-Min	3.821	1.348	1.385	1.292
Rank	1	3	2	4
Optimum level	A_1	B_3	C_2	D_2

Response Curve

Figure-1 Shows the variation of Tensile strength with changes of process parameters from levels. The response curves indicate that the S/N ratio is maximum at process parameters of weight percentage of Zn (A). Mg (B). Cu (C) and Cr (D) of Al alloy 7178 castings in die casting process. It is evident from the above graphs that optimal parameters for casting of AA 7178 for better Tensile strength corresponds to a weight % of Zn 6.3, weight % of Mg 3.1, weight % of Cu 2 weight % of, Cr 0.23 When the die casting was done at the specified optimal process parameters of level combination, the Tensile strength of the samples have higher.

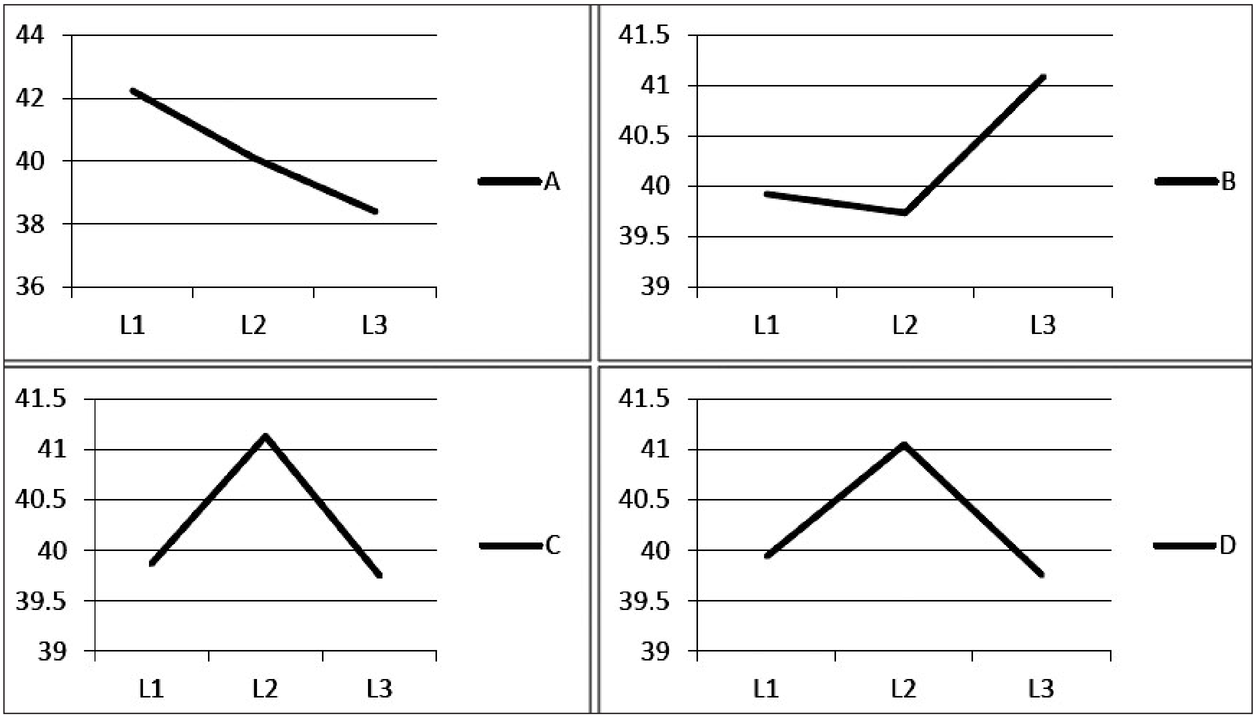
Confirmation Test

Confirmation Test for Tensile strength is conducted on the optimised condition of process parameters like weight percentage of Zn 6.3, Mg 3.1, Cu 2 and Cr 0.23. The confirmation result for Tensile strength is found is 150Mpa

b) Hardness Test

First the specimen is placed in the base of the machine and adjusts the settings of the machine as per requirement. start the machine, the tool is moves vertically down wards to the specimen with the maximum time of 10 seconds and the maximum load applied in this machine

Reference curves for Tensile Test



is 5Kg, by this load the maximum depth is occurred in the specimen with 1x as shown in fig 23. This depth is known as indentation and this is calculated in hardness Vickers (HV).

- The software is used to calculate this result is TAURUS 3000 and the testing machine is shown figure10

Fig 10. Hardness Testing Machine

Fig 11. Hardness Specimens

Type of Hardness: Brinnel Hardness Tester

Indentation : 5mm

Load applied : 250 Kgs

Table: 7 Hardness Test

S.No	Sample identification	Location	Impression 1	Impression 2	Impression 3	Average
1	Al-Alloy-1	On surface	90.7	91.7	90.7	91.03
2	Al-Alloy-2	On surface	114	112	114	113.33
3	Al-Alloy-3	On surface	115	115	117	115.67
4	Al-Alloy-4	On surface	117	117	118	117.33
5	Al-Alloy-5	On surface	120	120	118	119.33
6	Al-Alloy-6	On surface	123	123	124	123.33
7	Al-Alloy-7	On surface	114	114	112	113.33
8	Al-Alloy-8	On surface	121	121	120	120.67
9	Al-Alloy-9	On surface	121	121	123	121.67

Table: 8S/N Ratio for Hardness

Exp No	A	B	C	D	S/N Ratio
1	1	1	1	1	39.164
2	1	2	2	2	41.086
3	1	3	3	3	41.213
4	2	1	2	3	41.38
5	2	2	3	1	41.533
6	2	3	1	2	41.821
7	3	1	3	2	41.086
8	3	2	1	3	41.632
9	3	3	2	1	41.703

Table: 9 Anova for Hardness

Sum of Level	A	B	C	D
1	40.487	40.543	40.872	40.958
2	41.578	41.417	41.389	41.331
3	41.473	41.579	41.277	41.408
Max-Min	0.105	0.162	0.517	0.45
Rank	4	3	1	2
Optimum level	A_2	B_3	C_2	D_3

Reference curves for Hardness

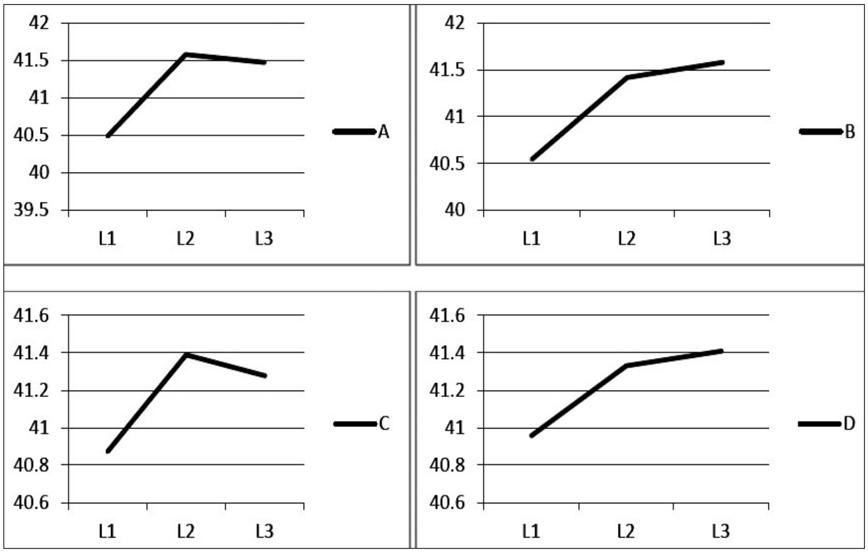


Figure shows variation of hardness with change in the level of process parameters of weight percentage of Zn, Mg, Cu and Cr respectively. From this graph, observed that hardness of specimens changes significantly with the various in the level of the respective process parameters. Castings of Al alloy 7178 for better hardness corresponds to a weight % of Zn 6.8,weight % of Mg 3.1, weight % of Cu 2 weight % of, Cr 0.28. When the die casting was done at the specified optimal process parameters of level combination.

Confirmation Test

Confirmation Test for Taguchi method at the optimised parameters levels was done and the hardness is found by the die casting specimens of Aa7178 was found is 125.45 BHN

4.1 Discussions

From graphs, it observed that weight % of Zn, Mg, Cu and Cr in the aluminium alloy effecting on Tensile strength and hardness. As the increase Zn leads to decrease Tensile strength and increase hardness. Similarly Mg, Cu and Cr are increased there is increased Tensile strength and hardness.

5. MICROSTRUCTURE ANAYSIS

Microstructure shows fine dendriaticstructure with precipitation of Zn rich phase with in the dendriatic region and some intermetallic compounds that contains AlCu, AlCuMg, MgCu in the matrix of Al solid solution.

Etchant used: Kellars Reagent

Figure A: Microstructure shows dendriatic structure with precipitation of Zn rich phase with in the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

Figure B: Microstructure shows slightly coarsestructure dendriatic structure with precipitation of Zn rich phase within the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

Figure C: Microstructure shows very finedendriatic structure with precipitation of Zn rich phase with in the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

Figure D: Microstructure shows some more prominent dendriatic fine structure with precipitation of Zn rich phase within the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

Figure E: Microstructure shows finedendriatic structure with precipitation of Zn rich phase with in the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

Figure F: Microstructure shows coarse dendriatic structure with precipitation of Zn rich phase with in the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

Maginification used : 100x

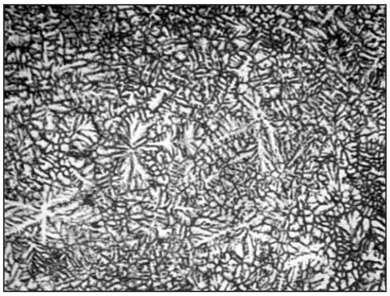


Figure A

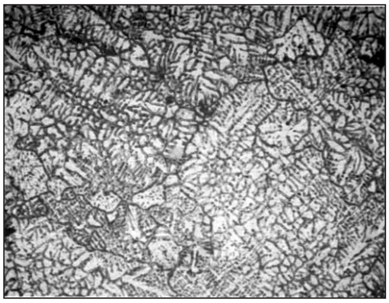


Figure B

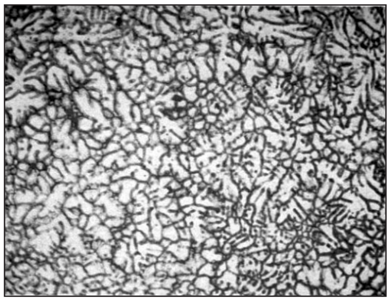


Figure C

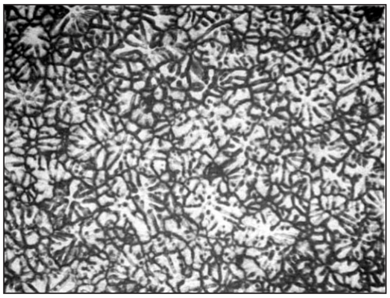


Figure D

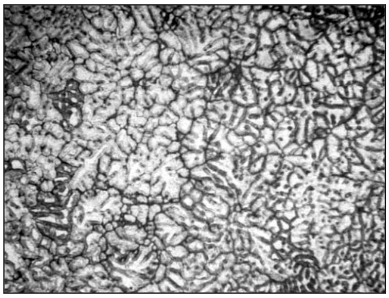


Figure E

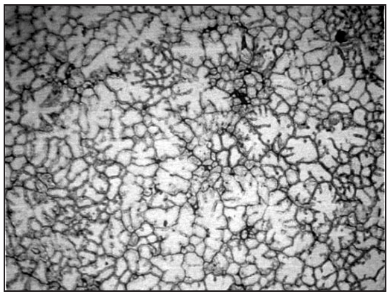


Figure F

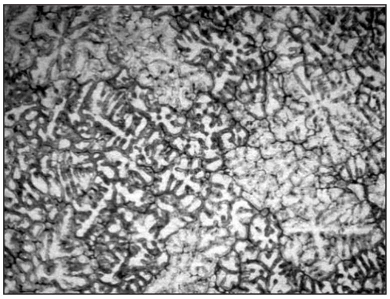


Figure G

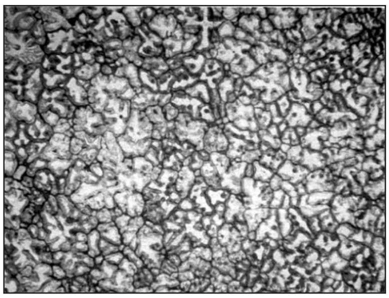


Figure H

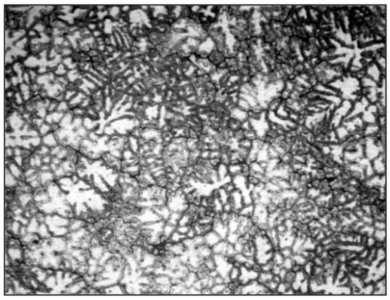


Figure I

Figure G: Microstructure shows fine dendriatic structure with precipitation of Zn rich phase with in the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

Figure H; Microstructure shows fine dendriatic structure with precipitation of Zn rich phase with in the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

Figure I: Microstructure show coarse dendriatic structure with precipitation of Zn rich phase with in the dendriaticregion and some intermetallic compounds that contains AlCu, AlCuMg. MgCu in the matrix of Al solid solution.

5 CONCLUSIONS

The experiments have shown that process parameters have selected that influence on mechanical properties of Al alloy 7178.

1. Prepared Al 7178 castings with varying compositions.
2. Identified the process parameters at optimum level.
3. Conduction of L-9 trails using Taguchi method.
4. Decrease in weight % of Zn level increase Tensile strength.
5. Increase in weight % of Mg, CU, and Cr their by increase Tensile strength.
6. Increase in weight & of Zn, Mg, Cu and Cr leads to increased hardness.

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