Study on influence of process parameters in hot rolling of al 7178 metal matrix materials

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ABSTRACT

KEYWORDS

Al 7178 alloy,
Silicon Carbide (SiC),
Aluminium Oxide (Al_2O_3),
Taguchi Method.

Aluminium and its alloys are in demand for the manufacturing of components due to their high strength to weight ratio. As the technology is advanced the demand for high strength to weight ratio is increased exponentially. Many researchers are explore alternatives to pure aluminium by way of adding silicon and metal matrix of Mg, SiC and Al_2O_3.

The present work aims at preparation of optimized Al7178 by stir casting process and extruding to preparation of aluminium matrix materials consisting silicon carbide and aluminium oxide (Al_2O_3*) powder of 40µm particle size at 6% weight percentage with a objective of investing the influence of process parameters of hot rolling process.*

Investigation is undertaken in order to minimize the rolling force of Al7178 aluminium metal matrix in hot rolling forming process where in the process parameters inlet thickness, rolling speed, percentage reduction of thickness, rolling temperature are considered as input parameters. Experimentation on hot rolling process concludes that 6% weight percentage of SiC and Al_20_3 *needs minimum rolling force 2.6 and 1.3 kN corresponding to 9mm inlet thickness, 15rpm rolling speed, 10% of thickness reduction at rolling temperature of 600°C.*

1. Introduction

The present work focus on selection of Al 7178 alloy and optimizing the composition for better yielding (High tensile strength). Taguchi orthogonal array is considered for conducting of experiments for specimen preparation by stir casting process. Further the specimen are subjected to metal forming through Hot rolling process. The investigation is extended considering metal matrix materials (Al 7178-SiC and Al 7178-Al_2O_3).

2. Literature Review

Mathai et al. (2015) investigated that AlSi alloys are in demand for some devices due to their high strength-to-weight ratio. Alloys with different Si contents, ie 4, 6, 8, 10, 14, and 16%, are produced by die casting. The tensile strength and hardness observed here increased with increasing silicon content, and the heat treatment produced microstructures and improved mechanical properties. Al-Si is mainly used in the automotive engineering of piston alloys.

Zhang et al. (2010) studied 10% SiCp/Al-Mg composites by semi-rigid mechanical stiring technology. The distribution of SiCp reinforcements in the matrix improves with increasing Mg content due to the excellent weld ability between the reinforcements and the matrix. The composite showed superior tensile strength compared to the Al-Mg alloy. In addition, the mechanical properties of the composite were improved by the addition of Mg content.

Saroya et al. (2013) studied that metals are cast by stir casting with 5%, 10%, 0.15%, and 20% silicon carbide particles and various weight percent of aluminum 7178. It is observed that the tensile strength of the composite increases with an increase in the weight percent of SiC and a uniform dispersion of SiC particles in the Al matrix.

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Ezatpour et al. (2014) studied that Al 7075 is used as a matrix metal, Al_2O_3 is 20wt% and Si3N4 is 0.25% & 0.75%. This is because the reinforced composite is manufactured by the stirring casting process. Increases the hardness of the component and decreases the tensile strength. The microstructure shows that grain boundaries, a dendritic network of Al_2O_3 and Si3N4, are distributed in the matrix metal.

Bharath et al. (2014) studied the Al 6061 is reinforced with aluminium by using the stir casting method. The matrix materials were prepared with wt % of aluminium as 3%, 6%, 9%, 12%, and 18%. The stirring operation was performed at speed of 300rpm for 10min to improve the distribution of the aluminium particle in molten AA 6061. It was noted that clearly have superior properties to base Al alloy and improved Tensile strength and hardness up to 9% behind that reduces.

Rebba et al. (2014) studied the growth of science and technology, which is a requirement for advanced engineering materials that make up metal matrices for high-performance applications such as aerospace, automotive, military, and ocean. Metal Matrix Composites are a combination of Al7178 Metal Matrix and Al_2O_3 Reinforcement for altering mechanical properties.

Fukuda et al. (2017) studied the effects of rolling conditions and thickness reduction on the mechanical properties and microstructure of rolled Mg8Al1Zn1Ca alloy sheets at rolling temperatures of 80°C and sample temperatures of 430°C. As a result, it was found that the mechanical properties of tensile strength and ductility were improved, and a fine-grained structure was obtained with a thickness reduction rate of 42%.

Vijay Kumar et al. (2017). investigated Al5% Cu fortified with chromium powder produced by the stirring casting process. The prepared sample is rolled in the hot rolling process in the vertical and horizontal directions to achieve various thickness reductions. It can be seen that the hardness in the homogenized state is high. In the rolling process, the horizontal hardness is stronger than the vertical hardness.

Azpen et al. (2018) reviewed the aluminium alloy 7075 reinforced with SiC and Al_2O_3 to produced metal matrix materials, the range of deformation temperature 300^o-500^oC, parameters like temperature and strain rate have been analyzed by hot workability of Al 7075-SiC. In addition, the flow stress is inversely proportional to temperature and directly proportional to the strain rate, and ductility is proportional to the temperature and inversely to strain rate.

Ezatpour et al. (2014) investigated that Al 7075 is used as matrix metal and wt % Al_2O_3 is 20% and Si_3N_4 is 0.25% & 0.75% as reinforcement composites are produced by stir casting method, here found that percentage of SiN_4 is increased hardness of components is increased and Tensile strength is decreased. The microstructure is shown that grain boundaries, inter dendritic network of Al_2O_3 and Si_3N_4 is distributed in matrix metal.

Puneeth et al. (2015) investigated that A356.1 aluminium was reinforced with silicon carbide with different wt % of SiC (0,5,10,15) of the sample. The hardness of the metal matrix material increased with the addition of SiC and maximum hardness was achieved at wt of 15%. SEM micrographs indicate that SiC particles dispersed throughout the matrix.

Rayjadhav and Naik (2016) studied that hardness increases with an increase in reinforcement particle of silicon carbide power 5wt% of silicon carbide give hardness 65 BHN and maximum hardness 102BHN is obtained at 10wt% of silicon carbide as reinforcement in aluminium metal matrix. Developed metal matrix composites show improvement of mechanical and physical properties.

Raghavendra et al. (2017) Investigated that aluminium 7075 metal matrix with reinforcement silicon carbide were fabricated through stir casting method for 1%, 2%, 3%, and 4% of reinforcement. The hardness of composites was increased by increasing the weight percentage of silicon carbide particles. It was observed that yield and ultimate Tensile strength Increases by increasing the weight percentage of silicon carbide particles.

Sharma et al. (2015) investigated that AA 5083 metal matrix was reinforced with nano SiC by stir casting process using Design of experiments, Al 5083 alloy was reinforced with silicon carbide by different wt % of SiC 0%, 5% 10%, and 15%. The hardness of the MMC increased with the addition of SiC and maximum hardness achieved at wt of 15%, The optimized value of the parameter is obtained at the optimum value of hardness components.

Dhaneswara et al. (2017) studied that aluminium A356 is reinforced with different volume fraction SiC, fabrication of metal matrix in stir casting technique. It was observed that the effect of addition nano SiC improves mechanical properties of A356 composites such as tensile strength, hardness, and slight wear resistance reduces. The grain size of α-Al was measured that the addition of nano SiC reduces the grain size of α-Al.

Rana et al. (2017) studied that AA 5083 is reinforced with nano SiC composites were fabricated by the stir casting method. Design of experiments was conducted to influence process parameters like casting temperature, stirring speed, and weight percentage of reinforcement on the hardness of composites. It was noticed that optimized process parameters to obtain optimum hardness. As per ANOVA analysis, the F value is greater than the standard F-value, hence the model is validated with a 99% significant level. Micrograph of Al 5083-2wt% SiC shows uniform distribution of nano particle and some places inter metallic compounds are visible.

Veeresh Kumar et al. (2010) investigated the preparation of Al 6061-SiC and Al7075-Al_2O_3 composites using the stir casting method. The micro-structural studies revealed that uniform distribution of the particles in the metal matrix. Micro-hardness of the composites was found to increase with increasing the filler content and the increased hardness of Al 6061-SiC & Al7075- Al_2O_3 composites. The tensile strength of the composites is found higher than that of base matrix and Al 6061-SiC composites superior tensile strength than that of Al 7075 Al_2O_3 composites (Azpen et al., 2018).

Mazahery and Shabani (2011) influence on mechanical properties of composite like matrix alloy, aging condition, weight fraction, and grain size of reinforcement and reinforced with B_4C and Al_2O_3 particle leads to increase the strength of the composite. Hot-working of Al 7075-SiC composites are heated to temperature ranges 300°C to 500°C. It is revealed that the flow stress of the aluminum metal matrix is proportional to the weight fraction of reinforcement and the strain rate is inversely proportional to the temperature of the composite. Moreover, ductility is proportional to temperature and inversely proportional to strain rate.

Nagaral et al. (2013) studied that aluminium 6061 alloy is reinforced with pre-heated Al_2O_3 particle from 0-9% processed by liquid metallurgy. The metal matrix composites of tensile strength and hardness were examined. It found that tensile strength and hardness are increased with increases of Al_2O_3 particles in the aluminium 6061 alloy. Microstructure analysis of composites shown that Al_2O_3 particles are uniformly distributed in the matrix and XRD analysis revealed that the presence Al_2O_3 phase.

Muniamuthu et al. (2016) Studies on mechanical properties of Al 7073 is a matrix metal and Al_2O_3 is reinforced with various weight fraction are 2%, 4%, 6%, and 8% by using stir casting technique for fabricating metal matrix composites. It is observed that increase Al_2O_3 with increasing Tensile strength and hardness of metal matrix.

Yerrenagoudar et al. (2016) studied that the behavior of Al 6061 alloy was reinforced with a different weight percentage of Al_2O_3 and mica particulate with the stir casting process. It is nano Al_2O_3 confirmed that in the base alloy hardness increases with increasing the reinforcement and SEM revealed that Al_2O_3 particulate is fairly distributed in the aluminum alloy matrix.

Singh (2016) investigated that aluminium alloy of 6063 with the addition of a varying percentage of Al_2O_3 and graphite made by the stir casting technique. It was observed that Tensile strength and hardness increased with increasing the weight percentage of reinforcement and also revealed that micrographs of Al-Graphite-Aluminium matrix composite which are examined under SEM show that the distribution of reinforcement in the matrix are fairly uniform.

Kandpal et al. (2017) studied the production and testing of AA 6061 reinforced with Al_2O_3 by stir casting method. It was found that Tensile strength and hardness were improved as the percentage of reinforced increased from 5% to 20%.

Mondal et al. (2011) studied that the microstructure of aluminium 7178 alloy can be modified and refined through calcium addition. The addition of calcium suppresses eutectic reaction and different types of inter metallic precipitates are formed in the microstructures. Fibrous type Al_4Ca precipitates were present along the grain boundary while submicron precipitates are formed within the dendrites arms and increase in elastic limit stress and flow stress of AA 7178 due to the addition of calcium.

Changqing et al. (2011) studied that the mathematical model of the rolling force equation is established to calculate the rolling force. The mathematical model is a very precise rolling force. The formula for calculating rolling force P can be written as $P = FP_mBlc$ where lc = R` F = projection of contact area, Pm = average unit pressure. B is the average width of the laminated part, the radius R` of the roll and Δh is the reduction of the pass.

Mao et al. (2012) investigated the effect on properties of AZ31B magnesium alloy strips were rolled with a horizontal twin-roll casting machine through compound energy field cast-rolling. The sample strip was heated on the resistance furnace for 1hour for different temperatures 250°C, 300°C, and 400°C from initial thickness 4.8mm to 3mm at speed 4.0m/mm. It is revealed that recrystallized temperature of compound energy-field cast-rolling magnesium was lower than those of the general cast-rolling magnesium strip. The microstructures have been observed for different passes in general casting strips have coarse grains in the first pass and fibrous structure becomes finer in the third pass.

Hallberg (2013) investigated the influence of process parameters like rolling friction, thickness reduction, and rolling asymmetry on grain refinement in AA 1050 aluminum during cold rolling. Plastic deformation of sheet effect with rolling friction coefficient is 0.15, 0.2 & 0.25 for reduction of sheet 20%, 50% & 60% per pass. The grain refinement becomes for more thickness of reduction and higher value of friction coefficient are considered due to high rolling force.

Lei et al. (2013) studied the hot behavior of Cu-6Ni-1.05Si-0.5Al-0.5Mg-0 Cr alloy by hot compressed experiments. The stress and strain curves of copper alloy hot deformed temperature with different strain rates. Initially, flow stress is increased rapidly due to strain hardening further deformation decreased due to recovery. Flow stresses decreased with the increase of deformation temperature under the same strain rate. The microstructure of the sample after hot deformed at 750°C. when deformation temperature is increased to 850°C completely recrystallization occurred and fine uniform grains.

Pandey et al. (2013) investigated the deformation mechanism in AA 5754 using the uniaxial tensile test. The material showed that negative strain rate sensitivity at room temperature and a positive strain rate sensitivity at more than 150°C. The yield and flow stress for ND compression specimens followed a trend similar to plane DD compression specimens at all to dynamic recovery. Texture with changes in strain rates and temperature during the uniaxial test and shear deformation. The temperature sensitivity of the material increased with strain rate and changes to dynamic recovery.

Rajabi et al. (2013) studied the effect of rolling parameters on the mechanical behavior of Al 6061 alloy during rolling at a temperature range of 250°C-450°C. It was observed that during rolling, the dynamic recovery and dynamic recrystallization occurred at 150°C-250°C. The tensile results were shown that the room temperature strength and ductility increasing with increasing rolling temperature and yield strength decreases with increasing strain rate.

Zhang et al. (2014) investigated the effect of rolling parameters, such as flow rate, stress, and deformation of the coil hot rolled, on the strain distribution of 7075 aluminum alloy. In serpentine laminate, the flow rate of the lower layer is much higher than that of the upper layer due to the higher flow rate of the lower layer. Due to the high speed of the lower layer, the equivalent stress and strain of the lower layer is higher than the equivalent stress and strain of the lower layer.

Vijay Kumar et al. (2017) investigated that Al-5% Cu is reinforced with chromium powder which is manufactured by stir casting process. The prepared samples are rolled for different thickness reduction by Hot rolling process with longitudinal and transverse directions. It is revealed that hardness is high at the homogenized condition. In the rolling process hardness is more in the transverse direction compared with the longitudinal direction.

Fukuda et al. (2017) investigated that the effect of the rolling conditions and thickness reduction on mechanical properties and microstructure of Mg-8Al-1Zn-1Ca alloy rolled sheet at rolling temperature 80°C and sample temperature 430°C. The results have shown that mechanical properties of tensile strength and ductility were increased and fine grains structure was obtained at 42% of thickness reduction ratio.

Shafiei and Dehghani (2018) The influence of deformation on rolling force during variable gauge rolling. The sudden change in the abrupt force when up and down. The rolling force depends on the absolute thickness reduction, roll diameter and friction coefficient. The results show that the rolling force increases as the absolute thickness reduction increases.

Table 1
Optimum composition of Al 7178 alloy.

Elements	Zn	Mg	Cu	Cr	Si	Fe	Mn	Ti	Al
Wt %	6.3	2.75	2	0.23	0.4	0.5	0.3	0.2	98.32

Azpen et al. (2018) reviewed that aluminium alloy 7075 reinforced with SiC and Al_2O_3 to produced metal matrix materials, the range of deformation temperature 300°-500°C, parameters like temperature and strain rate have been analyzed by hot workability of Al 7075-SiC. In addition, the flow stress is inversely proportional to temperature and directly proportional to the strain rate, and ductility is proportional to the temperature and inversely to strain rate.

Gupta et al. (2019) Through the hot isothermal compression test in the temperature range of 623°C-723°C, aluminum alloys 7010 and 7075 were studied. It is observed that flow stress varies with temperature at different strains. The flow stress increases with increasing strain rate and decrease with increasing temperature for both alloys due to the combined effect of strain hardening and strain to soften. Hot deformation samples were observed with optical microscopy. It is noted that at high temperature and strain rate deformation result in adiabatic at temperature 698°C and fine grains are obtained.

3. Objectives and Methodology of Experimental Work

In the current paper the objectives of work are identified and respective methodology is elaborated.

3.1. Objectives of work

- To prepare metal matrix material Al 7178-SiC and Al 7178-Al_2O_3 with the optimum elemental composition during the casting process with stirring.
- To characterize mechanical properties such as Tensile strength, Brinell hardness and Microstructure studies..
- To optimize rolling force of Al 7178-SiC and Al 7178-Al_2O_3 alloys for hot rolling process.

3.2. Methodology of work

The objective function is roll separation force as smaller for better performance. The effect of process parameters and more significant factors are determined by using the Taguchi method. Optimized Al 7178 metal matrix is reinforced with a weight percentage 6% of silicon carbide and aluminium oxide to produce metal matrix material. These alloys are processed by hot rolling method to determine optimum conditions of forming parameters and response. Brinell hardness tests and micro structural analysis are conducted for the rolled specimens and compare the Al 7178 and its matrix material.

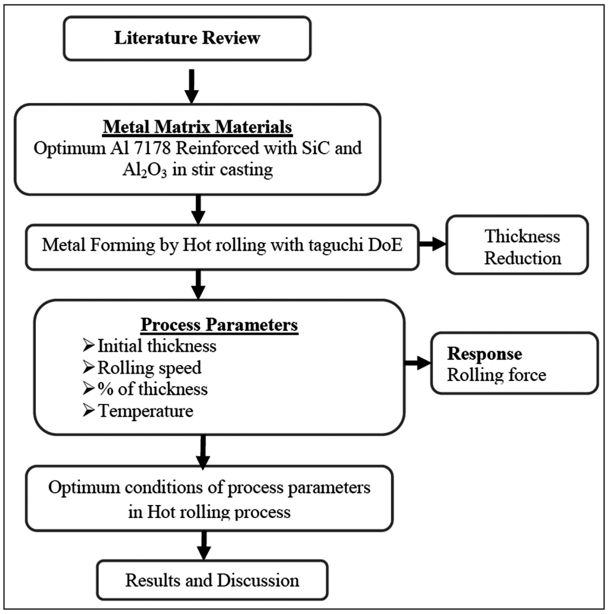


Fig. 1. Flow chart of experimental work.

4. Experimentation

The experimentation consists of two sections

- Preparation of Al metal matrix by stir casting
- Hot forming on rolling machine

In this current work optimum composition of Al 7178 alloy as shown in Table 1.

4.1. Preparation of metal martix samples for hot rolling

The optimum composition of Al 7178 alloy is reinforced with Silicon Carbide and Aluminium oxide materials at weight percentage of 6% of samples. Stir casting is utilized to manufacture of

Table 2
Rolling force of Al 7178 - 6% wt of SiC and 6% Al_2O_3.

Expt. No.	Inlet thickness (mm) h_1	Rolling speed (rpm) S	% of thickness reduction Δh	Rolling temperature (°C) T	Rolling force F (kN)	
					SiC	Al_2O_3
1	5	10	10	400	7.5	9.9
2	5	15	15	500	7.3	7.3
3	5	20	20	600	5.3	6.8
4	7	10	15	600	4	4.3
5	7	15	20	400	32.4	17.2
6	7	20	10	500	3.9	2.8
7	9	10	20	500	19.1	18.2
8	9	15	10	600	2.6	1.3
9	9	20	15	400	39.5	7.8

Table 3
Optimum process parameter for rolling force of matrix materials.

S. No.	Process Parameters	Optimum Value for Al 7178-6% SiC	Optimum Value for Al 7178-6% Al_2O_3
1	Inlet thickness (mm)	9	9
2	Rolling speed (rpm)	15	15
3	% of thickness reduction	10	10
4	Roll Temperature °C	600	600

metal matrix materials and stir casting process is shown in Figures 2 and 3.

Fig. 2. Stir casting technique.

Fig. 3. Al 7178-SiC slurry is poured into mold.

The Al 7178 alloy is reinforced separately 6% by weight of SiC and Al_2O_3 metal matrix samples are manufactured by stir casting process. The prepared samples are shown in Figures 4 and 5.

Stir cast 7178-SiC matrix material is machined by CNC machining process with dimensions of 150mm in length, 50mm in width, and different thickness are 5mm, 7mm and 9mm. The samples are shown in Figures 6 and 7.

Hot Rolling on hot rolling machine

The hot rolling is carried by varying the process parameters of inlet thickness w_1, rolling speed (S), percentage reduction in thickness (Δh) and rolling temperature at three levels by L9 taguchi design of experiments. The rolling force is taken as response and same is tabulated in case 2.

For Brinell hardness and microstructure studies, the Al 7178-SiC laminated samples are prepared for test samples. The prepared samples are shown in Figure 10 and 11.

5. Results and Discussion

Minimum of rolling force is considered as optimum level. The optimum process parameters are shown in Table 3.

Fig. 4. Al 7178 - 6% SiC casting.

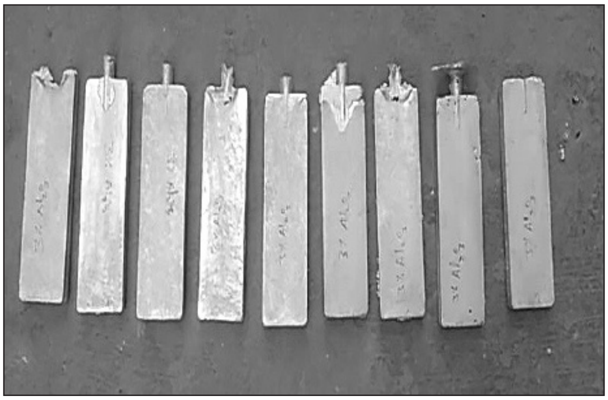


Fig. 5. Al 7178 - 3% Al_2O_3 castings.

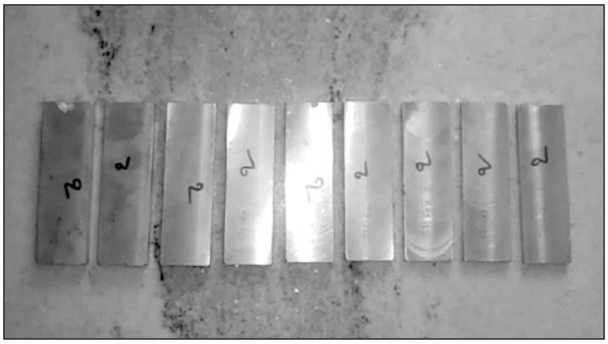


Fig. 6. Al 7178 - 6% SiC specimens.

Fig. 7. Al 7178 - 6% Al_2O_3 samples.

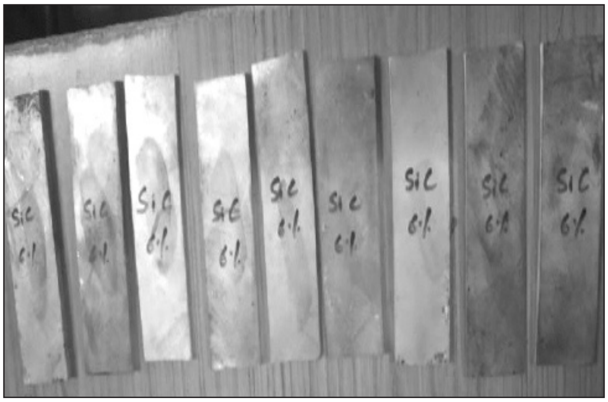


Fig. 8. Al 7178 - 6% SiC rolled samples.

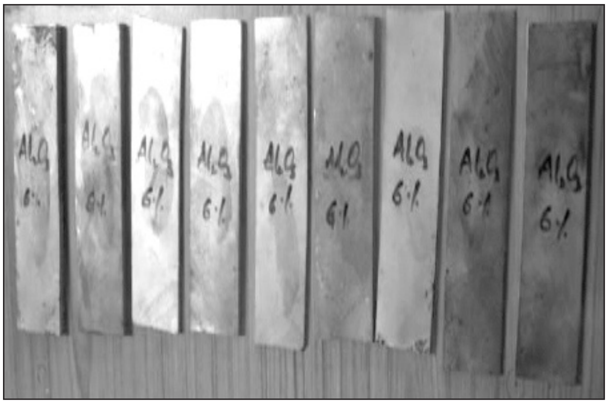


Fig. 9. Al 7178 -6% Al_2O_3 rolled samples.

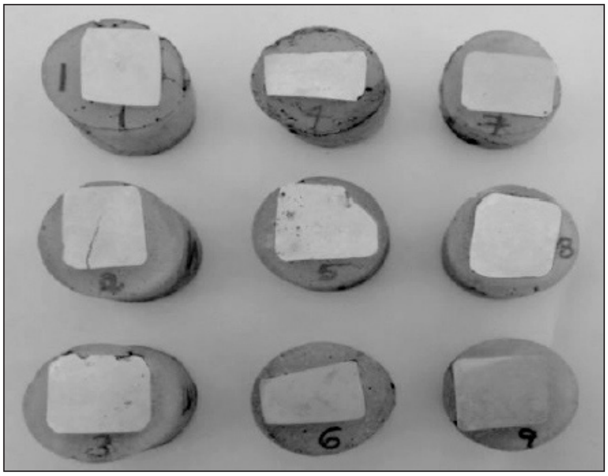


Fig. 10. Prepared Al 7178 - wt of 3% SiC.

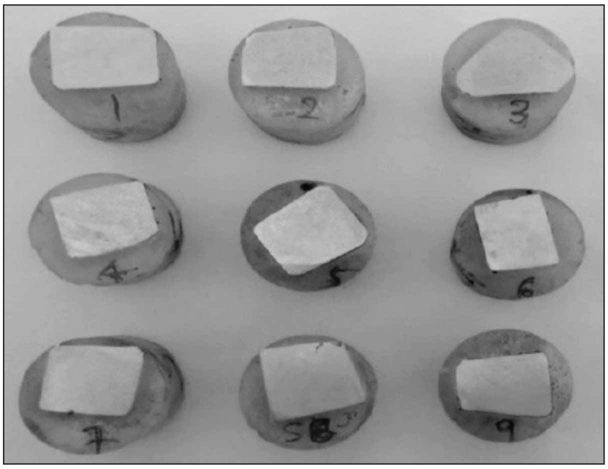
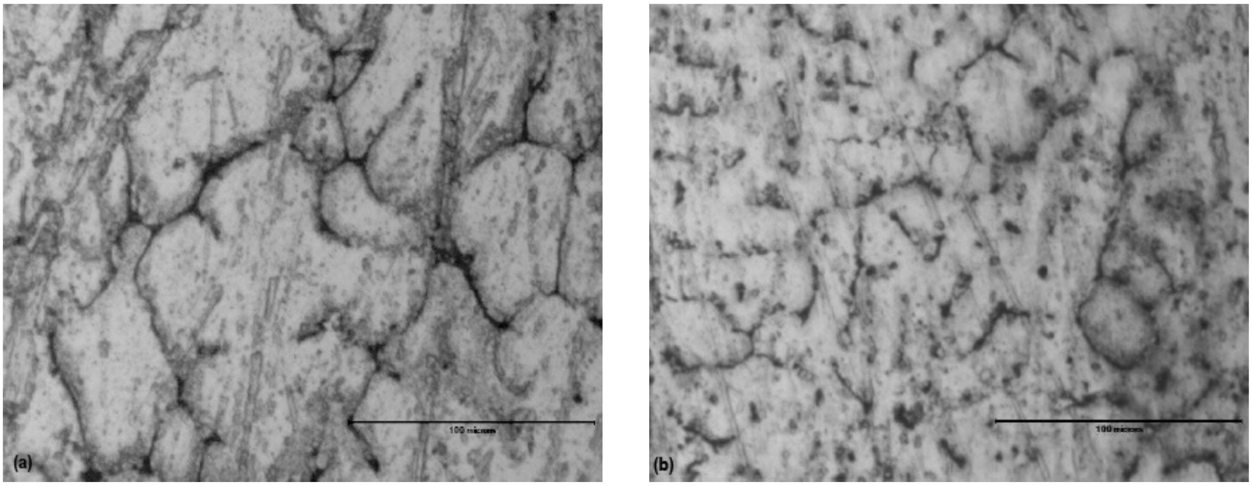
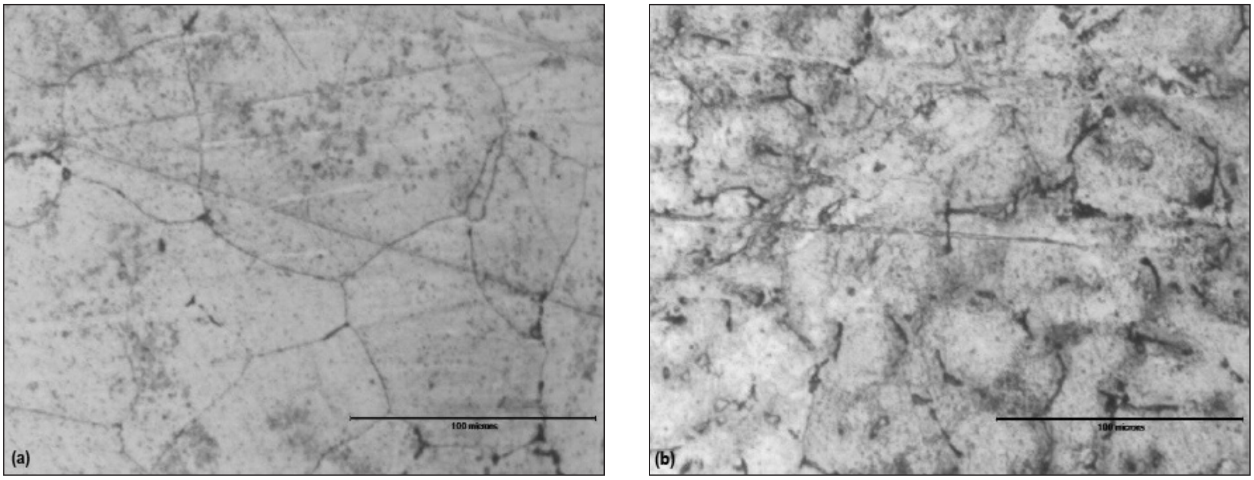


Fig. 11. Prepared Al 7178 - wt of 6% SiC.



(a) Minimum rolling force 500x (b) Maximum rolling force rolling 500x

Fig. 12. Comparison microstructures of Al 7178- 6% SiC at minimum rolling force.



(a) Minimum rolling force 500x (b) Maximum rolling force rolling 500x

Fig. 13. Comparison microstructures of Al 7178- 6% Al_2O_3 at minimum rolling force.

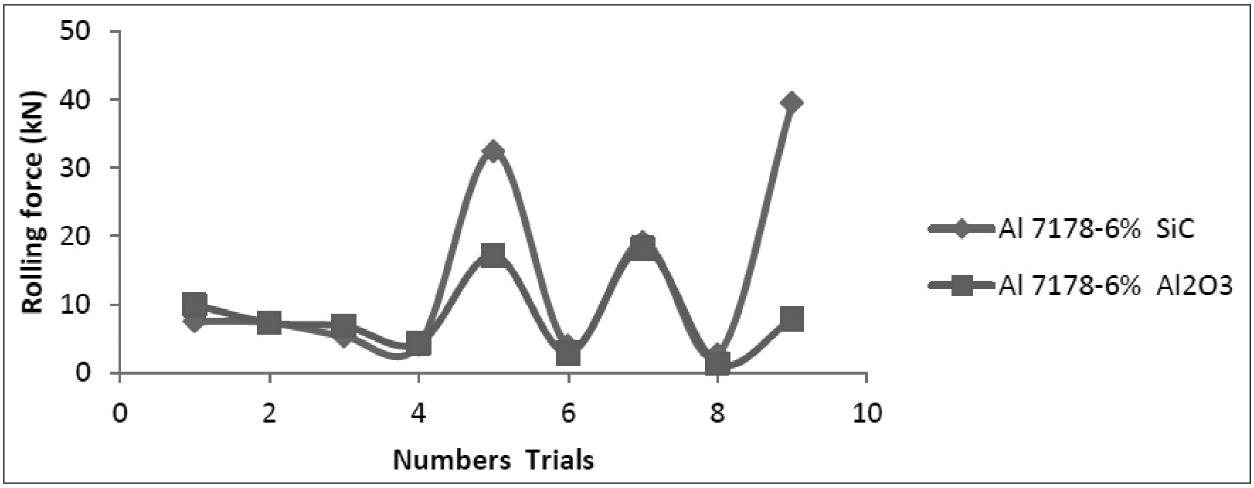


Fig. 14

Table 4
Brinell hardness test result of Al 7178-6% wt of SiC and Al 7178-6% wt of Al_2O_3.

S. No.	Observed value BHN	
	Al 7178-6% wt of SiC	Al 7178-6% wt of Al_2O_3
1	90.62	86.3
2	142.67	137.5
3	129	132
4	121.67	86.33
5	96.23	83.66
6	128.67	143.8
7	138.67	87.66
8	136	90.33
9	108.33	94.3

5.1. Brinell hardness test

After hot rolling using taguchi program at various process parameter levels, Brinell hardness tests were conducted for samples of Al 7178 with 6% by weight SiC and Al_2O_3. The hardness of the sample is measured by a Brinell hardness tester, the observation results are shown in Tables 4.

5.2. Microstructure analysis

The microstructure analysis was carried out for the rolled Al 7178 – wt 6% of SiC specimens using optical microscope. Grain refinement is obtained by the deformation of hot rolling process. The Etchant is utilized KELLARS REAGENT. The microstructure are shown in the following Figure 12.

Figure 12(a) shows microstructure of a fine dendritic structure with uniform distribution SiC particles in the aluminum matrix and it is homogeneous. 12(b) microstructure of the rolled sample shows that the grains are refined and uniform, and the SiC particles are precipitated and distributed in the Al metal matrix produced by roll deformation at higher temperature and cause to strength decreases and hardness increased to 136 BHN.

Figure 13(a) shows microstructure of a fine dendritic design with uniform appropriation Al_2O_3 molecule in the aluminum framework. The figure 13(b) microstructure of the rolled sample shows that fine dendritic structure with Al_2O_3 particles are precipitated and uniformly distributed in the Al metal matrix produced by roll deformation at higher temperature grains size number increased by 7.6, cause to strength increases and hardness decreased to 90.33 BHN.

5.3. Comparison of rolling force

The rolling force is determined by experiments using the Taguchi method in the hot rolling process of aluminium metal matrix alloys. Comparison of Rolling forces are tabulated in figure 14.

Figure 1 shows comparison of rolling force of metal materials. The Al 7178 - 6% weight of Al_2O_3 has lowest rolling force is 1.3kN, adding Al_2O_3 causes hardness reduction. The Al 7178 - 6% weight of SiC has highest Rolling force is 39.5kN, adding SiC to the Al 7178 alloy and cause to hardness increases.

6. Conclusions

The matrix alloy is reinforced with the SiC and Al_2O_3 which were considered as weight percentage. All the materials are investigated for hot rolling process. The following are the conclusions derived from the work.

- Minimum rolling force was observed when Al 7178 is reinforced with 6% of SiC and Al_2O_3 but SiC required more force compared to Al_2O_3 for same process parameters.
- The Brinell hardness of Al 7178 alloy was enhanced with addition of reinforcement particle with weight percentage of 6% SiC and Al_2O_3. When maximum hardness was obtained, Al 7178 alloy is reinforced with 6% weight of SiC.
- Microstructure analysis of rolled samples shows the grains are refined and uniform, and the reinforcement particles are precipitated and distributed in the Al metal matrix. Which is attributed to higher hardness of SiC matrix compared to Al_2O_3 and also formation of fine dentric structure as revealed by microstructural studies.

The future scope of the work is

- Major alloying elements in Al 7178 are Zn (6.3 –7.3%), Mg(2.4 – 3.1%). The compounds of Zn, like ZnO and Mg as MgO can be used as metal matrix materials and investigation can be carried out.

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References

Azpen, Q. M., Baharudin, B. T. H. T., Shamsuddin, S., & Mustapha, F. (2018). Reinforcement and hot workability of aluminium alloy 7075 particulate composites: A review. *Journal of Engineering Science and Technology, 13*(4), 1034 – 1057.

Bagheripoor, M., & Bisadi, H. (2014). An investigation on the roll force and torque fluctuations during hot strip rolling process. *Production and Manufacturing Research, 2*(1). https://doi.org/10.1080/21693277.2014.895916

Bharath, V., Nagaral, Madev., Auradi, V., & Koric, S. A. (2014). Preparation of 6061Al-Al$_2$O$_3$ MMC by stir casting and evaluation of mechanical and wear properties. *Procedia Materials Science, 6*, 1658 – 1667.

Changqing, H., Hua, D, Jie, C, Xinghua, H. U., & Shuangcheng, Y. (2011). Research on rolling force model in hot-rolling process of aluminum alloys. *Procedia Engineering, 16*, 745 – 754.

Dhaneswara, D., Syahrial, A. Z., & Ayman, M. T. (2017). Mechanical properties of nano SiC-reinforced aluminum A356 with Sr modifier fabricated by stir casting method. *Procedia Engineering, 216*, 43-50. https://doi.org/10.1016/j.proeng.2018.02.087

Ezatpour, H. R., Sajjadi, S. A., Sabzevar, M. H., & Huang, Y. (2014). Investigation of microstructure and mechanical properties of Al6061-nanocomposite fabricated by stir casting. *Materials and Design, 55,* 921-928. https://doi.org/10.1016/j.matdes.2013.10.060

Fukuda, Y., Noda, M., Ito, T., Suzuki, K., Saito, N & Chino, Y. (2017). Effect of Reduction in Thickness and Rolling Conditions on Mechanical Properties and Microstructure of Rolled Mg-8Al-1Zn-1Ca Alloy. *Advances in Materials Science and Engineering*, 1-9.

Gupta, R. K., Anil Kumar, V., Sarath Krishnan, A., & Niteshraj, J. (2019). Hot deformation behavior of aluminum alloys AA7010 and AA7075. *Journal of Materials Engineering and Performance, 28*(8). https://doi.org/10.1007/s11665-019-04231-8

Hallberg, H. (2013). Influence of process parameters on grain refinement in AA1050 aluminum during cold rolling. *International Journal of Mechanical Sciences, 66,* 260-272. https://doi.org/10.1016/j.ijmecsci.2012.11.016

Kandpal, B. C., Kumar, J., & Singh, H. (2017). Fabrication and characterisation of Al2O3/aluminium alloy 6061 composites fabricated by stir casting. *Materials Today: Proceedings*, *4*(2), 2783–2792. https://doi.org/10.1016/j.matpr.2017.02.157

Kumar, T. V., Jayashankar, G., Srinivas, B., Jithendra, J., & Sumedh, M. (2017). Effect of rolling on hardness of aluminium metal matrix composites-an experimental study. *International Journal of Mechanical Engineering and Technology, 8*(5), 525-530.

Lei, Q., Li, Z., Wang, J., Xie, J. M., Chen, X., Li, S., Gao, Y., & Li, L. (2013). Hot working behavior of a super high strength Cu-Ni-Si alloy. *Materials and Design, 51,* 1104-1109. https://doi.org/10.1016/j.matdes.2013.05.001

Mao, D., Zhang, B., Li, J., Li, Z., & Shi, C. (2012). Effect of hot-rolling and warm-rolling process on properties of cast-rolling AZ31B magnesium alloy strip. *Procedia Engineering, 27,* 887-894. https://doi.org/10.1016/j.proeng.2011.12.535

Mathai, B., Mathew, C., Pratheesh, K., & Varghese, C. K. (2015). Effect of silicon on microstructure and mechanical properties of Al-Si piston alloys. *International Journal of Engineering Trends and Technology, 29*(6), 299-303.

Mazahery, A & Shabani, M. O. (2011). Investigation on mechanical properties of nano-Al2O3-reinforced aluminum matrix composites. *Journal of Composite Materials, 45*(24), 2579–2586.

Mondal, D. P., Jha, N., Badkul, A., Das, S., Yadav, M. S., & Jain, P. (2011). Effect of calcium addition on the microstructure and compressive deformation behaviour of 7178 aluminium alloy. *Materials and Design, 32*(5), 2803–2812. https://doi.org/10.1016/j.matdes.2010.12.056

Muniamuthu, S., Raju, N. L., Sathishkumar, S., & Kumar, K. S. (2016). Investigation on mechanical properties of Al 7075-Al2O3 metal matrix composite. *International Journal of Mechanical Engineering and Technology, 7*(6).

Nagaral, M. (2013). Effect of Al2O3 particles on mechanical and wear properties of 6061al alloy metal matrix composites. *Journal of Material Science & Engineering, 2*(1).

Nayan, N., Gurao, N. P., Narayana Murty, S. V. S., Jha, A. K., Pant, B., Sharma, S. C., & George, K. M. (2015). Microstructure and micro-texture evolution during large strain deformation of an aluminium-copper-lithium alloy AA 2195. *Materials and Design, 65,* 662-668.

Pandey, A., Khan, A. S., Kim, E. Y., Choi, S. H., & Gnäupel-Herold, T. (2013). Experimental and numerical investigations of yield surface, texture, and deformation mechanisms in AA5754 over low to high temperatures and strain rates. *International Journal of Plasticity, 41,* 165-188.

Puneeth, H. M., Girish, K. B., & Vasudevamurthy, B. H. (2015). Experimental Investigation and Mechanical Behavior of A356.1 Aluminium Alloy Matrix Composite Reinforced With Silicon Carbide. *International Research Journal of Engineering and Technology (IRJET), 2*(3), 774–778.

Raghavendra, M. J., Praveen Kumar, K., Arun, R., & Arjun, S. (2017). A study on microstructure and characterization of aluminum 7075 metal matrix reinforced with silicon carbide particles using stir casting method. *International Journal of Research in Engineering and Technology, 6*(12). https://doi.org/10.15623/ijret.2017.0612015

Rajabi, F., Zarei-Hanzaki, A., Eskandari, M., & Khoddam, S. (2013). The effect of rolling parameters on the mechanical bevavior of 6061 aluminium alloy. *Material Science & Engineering: A, 578*, 90-95.

Rana, R. S., Purohit, Rajesh., Mishra, P. M., Sahu, Pramod & Dwivedi, Shailendra. (2017). Optimization of mechanical properties of AA 5083 Nano SiC composites using design of experiment technique. *Materials Today: Proceedings, 4*(2), 3882–3890.

Rayjadhav, S. B., & Naik, V. R. (2016). Characterization of developed Al 6061-SiC metal matrix composites produced by the stir casting method. *International Journal of Innovative Research in Science and Engineering, 2*(3), 92-103.

Rebba, B., & Ramanaiah, N. (2014). Evaluation of Mechanical Properties of Aluminium Alloy (Al-2024) Reinforced with Molybdenum Disulphide (MOS_2) Metal Matrix Composies. *Procedia Materials Science, 6*(1), 1161–1169.

Saroya, B., Singh, D., Jaswanti, & Meena, K. L. (2013). Experimental investigation to analysis of mechanical properties of the developed Al/SiC-MMC's. *International Journal of Advanced Trends in Computer Science and Engineering, 2*(1), 130-134.

Shafiei, E., & Dehghani, K. (2018). Effects of deformation conditions on the rolling force during variable gauge rolling. *Journal of Manufacturing and Materials Processing, 2*(3). https://doi.org/10.3390/jmmp2030048

Sharma. S., & Rana R. S. (2015). Optimization of mechanical behaviour of AA 5083 nano sic composites using design of experiment. *Journal of Material Science & Engineering, 4*(4).

Singh, M. (2016). Studying the mechanical properties of aluminum alloy reinforced with graphite and Al2O3 by stir casting process. National Journal of Advanced Research, 2(3), 04-09.

Veeresh Kumar, G. B., Rao, C. S. P., Selvaraj, N., & Bhagyashekar, M. S. (2010). Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites. *Journal of Minerals & Materials Characterization & Engineering, 9*(1), 43-55.

Vijay Kumar, T., Jayashankar, G., Srinivas, B., Jithendra, J., & Sumedh, M. (2017). Effect of rolling on hardness of aluminium metal matrix composites-an experimental study. *International Journal of Mechanical Engineering and Technology, 8*(5), 525-530.

Yerrennagoudar, H., Goudar, D. M., Balaji, M., & Ravikumar, D. (2016). Studies on wear behaviour of aluminium 6061alloy reinforced with Al_2O_3 & MICA particulates hybrid metal matrix composite, *International Journal of Innovative Research in Science, Engineering and Technology, 5*(6).

Zhang, H., Geng, L., Guan, L., & Huang, L. (2010). Effects of SiC particle pretreatment and stirring parameters on the microstructure and mechanical properties of SiCp/Al-6.8Mg composites fabricated by semi-solid stirring technique. *Materials Science and Engineering A, 528*(1), 513-518. https://doi.org/10.1016/j.msea.2010.09.046

Zhang, T., Wu, Y. X., Gong, H., Zheng, X. Z., & Jiang, S. S. (2014). Effects of rolling parameters of snake hot rolling on strain distribution of aluminum alloy 7075. *Transactions of Nonferrous Metals Society of China (English Edition), 24*(7), 2150-2156. https://doi.org/10.1016/S1003-6326(14)63326-4

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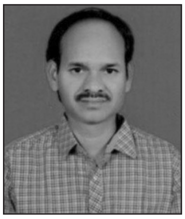

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