A Review on Role of Aluminum Matrix Materials, Failure Causes and Optimization Techniques

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ABSTRACT

Aluminum is a metal matrix material which is widely used in different industrial as well as engineering applications.it has a great advantage due to its remarkable properties like less density, formability, and light in weight, recyclability and other properties. but, failure of aluminum matrix materials are the main problems in aluminum industries now a days.in this review role of aluminum and its alloys as matrix materials, their failure modes, causes of failure and optimization techniques to minimize this failure modes and causes of failure are discussed. Sources are reviewed which are from 2005 to recent one. Consequently, most modes of failure, causes of failure and most optimization techniques of aluminum and its alloy matrix materials are found. most modes of failure are mechanical related like fatigue failure, surface cracking, ductile failure, porosity formation, and stress related like stress corrosion cracking, surface weakness due to repeated stresses and other factors are summarized.in causes of failure mostly like corrosion formation, wear formation and poor mechanical properties are discussed.

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1. INTRODUCTION

Aluminum is the most broadly utilized metal on the planet today after iron. aluminum based matrix materials which are pure aluminum and its alloys have great role in aluminum industries, aerospace, defense, automotive and general engineering applications due to the aluminum and its alloy better properties like, excellent malleability, low density, great thermal conductivity, low electrical resistivity, great formability ,easy workability, high electrical/heat conductivity, good reflectivity, recyclability and other properties. Aluminum and its alloys are extensively used in aircraft structures due to their high strength-to-weight ratio, excellent formability and good machinability. Although aluminum and its alloys possess good resistance to general corrosion due to the rapidly formed Al2O3 film, they are prone to pitting corrosion in aggressive environments[1].today aluminum and its alloys are used greatly in aerospace industry due to it's light weight application [2].

Aluminum matrix materials are easily workable and can be sheared, forged, rolled, slit and shaped by extrusion through dies into many better shapes or can be casted into many shaped products. Aluminum also has many attributes such as low density, high thermal and electrical conductivity, light and heat reflectivity, non-ferromagnetic property and nontoxic qualities for food related or contact applications[3]. As an engineering materials aluminum material ranks next to iron and steel, its production is increased year to year[4].now a days many industries used aluminum and its alloys as a matrix materials due to its remarkable properties. But the duration of application of aluminum and its alloy is not much enough and the failure of aluminum and its alloys is one of the main problems in aluminum industry. Aluminum and its alloy requires further optimization techniques which can minimize edits failure as much as possible. Therefore, determining the improvement techniques in perspective of failure causes and modes, and finally bringing overall enhancement is a homework for engineers.

Therefore, in this review paper three things should be addressed and conclusion would be made based on the result of these investigation area issues. These are:

1. Failure modes of aluminum and its alloy matrix materials to know its properties.
2. Causes of these failure modes to clarify the way to reach the solutions and
3. Optimization techniques to address the problems and proposed solutions.

Baik, Choi [5] reported that stress corrosion cracking in 7039 Al-alloy was initiated by the dissolution of the grain boundary precipitates and propagated by mechanical processes such as creep. **Kannan and Raja [6]** explained that the coarse or large size intermetallic particles can serve as potential sites for the initiation of stress cracking. They have revealed that the passive film breakdown in the region of copper rich intermetallic caused the crack

Initiation in the aluminum alloy. The fracture surface analysis revealed that the continuous nature of grain boundary precipitates caused easy dissolution and crack propagation system.

Boileau and Allison [7] revealed that porosity has a great influence on fatigue strength of Al-Si casting alloys where it acts as a site best site for fatigue-crack initiation. porosity decrease the time to crack initiation by creating high stress concentration region give to this microstructural defect and is mainly responsible for decreasing the fatigue life of these alloys. **Li,Shen [8]** showed that aluminum based aircraft structural components are always faced to many inspections to guarantee their life and for early recognition of inevitable damage by variable and dynamic stresses, especially the ultimate failure by fatigue fracture.

Wan, Si [9] investigated the morphology variation, composition alteration and microstructural changes in 1060 aluminum. The results show that the forming of surface damages was related with preferentially sputtering of Al component.

After all the above stated researcher works on stated failure causes of aluminum and its alloys matrix materials, the failure modes are mechanical, thermal related and the optimization techniques could be categorized under:

- ✓ Mechanical related optimization techniques
- ✓ Composition related optimization techniques
- ✓ Other related optimization techniques

2. METHODS

The methods of this review paper are flow chart that used to finish the review from sources of review to general conclusion of the review. Researches reviewed, factors of failure of aluminum and its alloys matrix materials, causes of failure and optimization techniques would be identified. Flow of reviewing is in bellow chart.

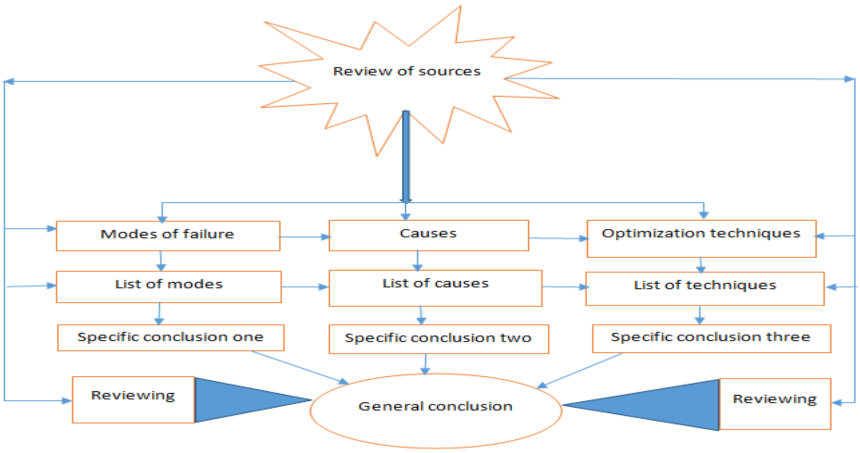

Figure 1. Outline of Flow Method Chart

3. LITERATURE REVIEW

3.1. Preliminary review

Ou,Yang [10] claimed that through step-homogenization and step-quenching and aging heat treatment, both optimum strength and Stress corrosion resistance can be achieved for 7050 aluminum alloy. The result show that that high stress corrosion resistances resistance can be achieved without loss of strength through a novel heat treatment known as retrogression and re-aging (RRA) heated at elevated temperature. However, the disadvantage of such a treatment is its short retrogression time, which limits its application to only thin sheets. **Obi [11]** investigated the corrosion behavior of cast Al-Mg alloy composites containing fly ash reinforcement using weight-loss and electrochemical corrosion tests in NaCl solution at room temperature. The findings showed that the corrosion rate of the composites increased with decreasing fly ash content. **Aballe, Bethencourt [12]** explained the effect of intermetallic on corrosion behavior of AA050 and AA5083 in NaCl solution. The higher eroding resistance of AA1050 was attributed to less cathodic intermetallic phases in the aluminum alloy.

Akbari, Mirzaee [13] studied the mechanical properties of A356 aluminum alloy reinforced with Nano Al2O3 produced using stir casting process. The authors found that addition of Nano particles greatly improved the mechanical properties of composites compared to aluminum alone.

The authors looked that porosity of this resulted composite increased with increasing stirring time and reduced the mechanical properties. The fracture surface of composite revealed that failure of matrix while investigated the broken tensile specimens under scanning electron microscope. But the authors did not reveal the optimization of parameters like time, volume content of reinforcement.

Mazahery and Shabani [14] studied the effect of boron carbide (B4C) particles reinforcement in A356 aluminum alloy produced by squeeze casting process. Reinforcement of boron carbide particles improved the hardness, ultimate tensile strength, elastic constant and strain hardening as compared to matrix. But less optimization and effect of time did not considered in this study. **Selvam, Smart [15]** explained the influence of fly ash wt. % reinforcement in AA6061 aluminum alloy produced by compo casting process.

The author's' result revealed that fly ash was uniformly dispersed in the aluminum matrix and the process performed at low temperature eliminated the interfacial reaction between fly ash and aluminum. The mechanical properties like micro hardness and tensile strength increased with wt.% increasing of reinforcement. The gab of this finding is effect of pressure did not consider pressure effect and less parameter optimization.

Sharma, Paliwal [16] investigated the wear behavior of Al6061 reinforced with graphite particles produced by liquid casting process. Particle size of 26-30µm was used and weight fraction of reinforcement from 0-16%.the authors found that the addition of reinforcement of graphite particles greatly increased the mechanical and wear properties of composites compared to aluminum alloy matrix alone. Also the researchers result show that wear rate of composite reduced with increasing wt.% of graphite particles reinforcement. But the authors didn't focus on optimization of weight% of reinforcement.

Rajan, Ramabalan [17] investigated the effect of titanium dibromide (TiB2) reinforcement in AA7075 aluminum alloy produced using in-situ process. Reinforcement of TiB2 particles in aluminum matrix highly increased the mechanical properties of castings. The authors found that hardness and tensile strength of composite increased with wt.% of reinforcement particles. The limitation is that the authors did not show effect of temperature during the addition process is not discussed and also optimization not mentioned.

Lu, Chen [18] studied effect of metallic powder of zirconium and iron (Zr and Fe) and Sic particles on Al7075 aluminum alloy. The result of researchers shows that the mechanical properties of silicone carbide and Al 7075 aluminum alloy composite improved greatly with the addition of zirconium particles. However, the addition of Fe particles have an opposite influence on the mechanical properties of the composites. **The authors** use digital micro hardness Nano indenter, tensile testing machine, and transmission electron microscope (TEM) to test mechanical properties. but the authors did not noticed that the negative impact behind Fe particle on hybrid composite and the mechanical tests were at constant strain and room temperature, so temperature effect didn't considered. Another gabs of the authors is that optimization of parameters are not considered.

Kok [19] investigated the influence of particle size and weight fraction of Al2O3 reinforced Al2024 aluminum alloy produced by stir casting and squeeze casting process. The author results showed that reinforcement of Al2O3 particles increased the hardness and tensile strength of composites as compared to matrix alone.

The author uses Brinell hardness testing machine for measuring hardness value of the resulted composite. But the author did not consider the optimization of temperature effect (up to what extent positive result is revealed) and the effect of stirring or mixing speed during fabrication process. And another limitation of the author's investigation is that experimental density measurement is based on Archimedean principle by cutting small pieces of cylindrical composite and trial methods which results less accuracy and wrong conclusion.

Alaneme, Bodunrin [20] studied the effect of bamboo leaf ash (BLA) on fracture toughness in the Al/Sic/BLA composite. The authors result show that the fracture toughness of the composite is increased as compared to Al matrix alone due to the chemical composition of bamboo leaf ash(BLA) that contains refractory oxides such as, aluminum oxide, iron oxides, and silicon oxides that are better and attractive reinforcements for fracture toughness.

But the authors did not reveal how the bamboo leaf ash prepared specifically for this matrix materials and how much amount of ash is added to the Al matrix to enhance fracture toughness. And an other limitation of the authors is that they did not consider temperature effect at each stage of composite fabrication such as pouring stage. And the authors also did not show the effect of each component of ash composition (oxides).This limitations are leads to wrong conclusion of the result. **Ravesh and Garg [21]** explained that fracture toughness of Al/Sic/fly ash hybrid composite was improved with increasing weight % of reinforcements. The authors looked that maximum fracture toughness was obtained for composite that contain 10 weight percent of silicone carbide and 5 wt.% of fly ash. The authors result show that fly ash contains SiO2, Al2O3, FeO3, and CaO as its composition. The authors found that the fracture toughness of Al/Sic/fly ash composite were improved.

But the authors did not consider optimization of weight % of the ash reinforcement (up to what amount the fracture toughness is increased) and they did not reveal the effect of each component of the composition of the fly ash. And other limitations of the authors were they did not analysis the effect of change of speed of stirring.

Zhang, Chen [22] investigated the effect of aluminum nitride (AlN) as reinforcement in aluminum produced by squeeze casting technique.in this process addition of AlN as reinforcement particles increased the ultimate tensile strength and yield strength of the aluminum matrix.

The authors use 3 point bending test using ISTRON5569 universal test machine and tensile tests on DSS-10T-S electron tension testing system to analyze tensile strength. But the authors performed the bending and tensile test on room temperature which can be hidden the effect of the temperature. and also the authors take several theoretical model, predictions which leads to less accuracy result. **Ahmadi, Siadati [23]** studied wear behavior of addition of TiO2 and CuO as reinforcements by powder metallurgy techniques.TiO2 and CuO particles additions provided better wear resistance than that of pure Al.

The authors used to Vickers micro hardness tester to determine the hardness of composite that is measure of wear resistance according to ASTM standard **[24]**. The authors result show that micro hardness and wear resistance of the Al/TiO2+CuO composite were improved. But this study only focused on

Investigating the effect of Nanoparticles on wear mechanism, while maintaining other Factors constant. And other limitations of the authors is that the small number of indentation trial were taken which could not leads to precise and accurate result. The effect of change in sliding velocity during wear test is not considered. **Iacob, Ghica [25]** investigated the wear behavior and micro hardness of aluminum alloy that was Reinforced with Al2O3 and graphite (Gr) particles.

As investigated by different researchers in the above the aluminum and its alloy matrix materials failure modes are the following:

- ✓ Stress surface cracking [5,6,8,10,11]
- ✓ Excess porosity formation [7,13,22]
- ✓ Surface morphology variation[9]
- ✓ Fatigue stresses failure [7,8]
- ✓ Surface weakness due to repeated stresses [8,9]
- ✓ Gradual degradation of its surface[5,10,12,16,23,25]
- ✓ Ductile fracture[15,17,18,20,21]
- ✓ Strain hardening and grain boundary distortion [14]
- ✓ Microstructural failure[17,25]

The above failure modes of aluminum and its alloy metal matrix material mainly caused by:

- ✓ Poor mechanical properties [13,14,15,17,19]
- ✓ Corrosion formation[5,10,11,12]
- ✓ Wear formation [16,25]
- ✓ Interfacial reaction [15]
- ✓ Creep formation [5]
- ✓ Composition alteration [9]

As different researchers investigated in the above preliminary review the pure aluminum and its alloy matrix materials properties like mechanical properties, corrosion resistance

And wear resistance behaviors are not much enough and it requires optimization enhancement.in this review most of researchers were used reinforcement addition optimization techniques and some are heat treatment to enhance the better properties of aluminum and its alloy matrix martials.

To optimize performance and life service of aluminum matrix perspective of the above factors and causes of failure we can use the following optimization techniques.

1. Improved mechanical properties by reinforcement addition optimization [13,15,17,18,19]
2. Increasing wear resistance behavior of aluminum matrix martials with reinforcement addition optimization [16,23,25]
3. Increasing corrosion resistance behavior of aluminum matrix materials by reinforcement addition optimization [5,10,11,12,]
4. Heat treatment [9,10,14]
5. Improving microstructural and aging behavior of aluminum matrix [7,9].

3.2. Summary of survey review

Table 1. Summary of Findings

Authors name	Ref.no./ year	Al matrix	Considered Parameters	Failure modes	causes	Optimization techniques	Findings Or results	Remark/ limitations
Ou et al.	10/2007	7050 aluminum alloy	Temperature, Weight %,time	Stress corrosion cracking	Corrosion, Poor mechanical properties	Heat treatment	Strength of alloy and its stress corrosion cracking resistance were enhanced.	Short retrogression (heating at elevated temperature) time, less temperature optimization.
Emenike	11/2008	Al-Mg A535 alloy	Weight % of content, PH value, time	Corrosion stress cracking	Corrosion, poor mechanical properties	Enhance mechanical properties Corrosion resistance by Reinforcement addition optimization	Corrosion resistance is increased within optimum reinforcement	Corrosion test is at room temperature which did not mention effect of temperature.
Aballe et al.	12/2005	AA5083, AA1050	Time, weight %,surface area	Pitting or erosion cracking	Corrosion, poor mechanical properties	Enhance mechanical properties and Corrosion resistance by reinforcement addition	Corrosion resistance is modified	Characterization measurement is taken at small area of surface, lack of homogeneity in surface distribution.
M.Karbalaei et al.	13/2013	A356 aluminum	Volume (%), speed of stirring, temperature, time of duration size of reinforcement	Porosity, fracture	Poor mechanical properties	Improved mechanical properties by reinforcement addition	Strength of aluminum matrix was improved and increased	Authors Did not reveal up to what time of duration, volume, size of reinforcement that strength was improved i.e. optimization is not considered.

A.Mazahery et al.	14/2012	A356 aluminum	Size, volume % of reinforcement, speed ,squeeze pressure, weight %	Porosity, elastic failure	Poor mechanical properties	Improved mechanical properties by reinforcement addition optimization	Hardness, tensile strength, elastic behavior , strain hardening of Al matrix were improved and increased.	Temperature effect is not considered, optimization of parameters (up to what extent is positive result is revealed) is not considered.
David et al.	15/2013	AA6061 aluminum	Size, shape of reinforcement, weight % of reinforcement, temperature.	Surface weakness	Interfacial reaction, poor mechanical properties	Improved mechanical properties by reinforcement addition optimization	Interfacial reaction, hardness, tensile strength, Interfacial bonding were improved.	Amount of temperature, pressure effect is not considered, optimization of parameters is not considered.
P.Sharma et al.	16/2017	Al6061	Size, weight % fraction of reinforcement, speed, time of duration, sliding velocity, load, sliding distance	Gradual degradation, material loss, flexural failure	Wear, poor mechanical properties	Enhance wear resistance and improved mechanical properties through reinforcement addition	Wear resistance, hardness, tensile strength, ductility, flexural strength were improved.	Optimization (up to what wt.% is result is positive) is not considered.
H.B.Michael et al.	17/2013	AA7075 aluminum alloy	Weight % of reinforcement, time	Microstructural failure	Poor mechanical properties	Improved mechanical properties by reinforcement	Micro hardness, tensile strength were improved.	Effect of temperature, pressure were not considered, optimization were not mentioned
T.lu et al.	18/2019	7075Al hybrid	Squeeze pressure, percentage content of reinforcement	Fracture, surface cracking	Poor mechanical properties	Improved mechanical properties by Reinforcement addition optimization	Ultimate tensile strength, fracture resistance, Young's modulus were improved.	Other parameters like temperature, size of reinforcement, effect were not analyzed, negative impact behind Fe is not looked, mechanical test were performed at constant strain and room temperature(effect of temperature did not considered)

M.Kok	19/2005	Al2024	Weight %,size of reinforcement, pressure	Surface weakness	Poor mechanical properties	Enhance mechanical properties by reinforcement addition optimization	Hardness, tensile strength, Wettability force between aluminum and Al2O3 were enhanced.	Duration of time of stirring, speed, , temperature effect not considered, no optimization of parameters (up to what value size, wt.% the result is positive),experimental density is based on try and error of Archimedean rule.
Alaneme et al.	20/2018	Al	wt.%,size of reinforcement, temperature, speed RPM, time duration of stirring	fracture	Composition alteration, poor mechanical properties	Reinforcement addition optimization	Fracture toughness of composite is increased as compared to Al matrix	Effect of temperature did not revealed, effect of ash compositions (Al2O3, FeO3 and SiO2) are not analyzed.
Ravesh and garg	21/2005	Al	Speed RPM,temperature,wt.%,size, time duration of stirring	fracture	Poor mechanical properties	Reinforcement addition optimization	Fracture toughness of Al/SiC-fly ash composite is enhanced.	No optimization of wt%,effect of compositions(SiO2,Al2O3,FeO3 and CaO) of fly ash did not considered, effect of change of speed during stirring is not noticed.
Q.Zhang et al.	22/2006	Al	Size of reinforcement, volume % of reinforcement, squeeze pressure, tiring temperature	Porosity, shrinkage	Poor mechanical properties	Improved mechanical properties by reinforcement	Ultimate tensile strength, yield strength, coefficient of thermal expansion of matrix were improved	Effect of optimization(up to what extent positive result is revealed) not considered, tensile test is performed on room temperature, more prediction and theoretical model are there.
M.Ahmadi M.H.Siadati	23/2018	Pure Al	-	Microstructural failure, gradual degradation	Wear, poor mechanical properties	Increase wear resistance and improve mechanical properties by reinforcement	Yield strength, hardness, wear resistance were improved.	Parameters (temperature, time, wt. %, volume%,) not mentioned.

G.laco et al.	25/2015	Aluminum hybrid	Weight % of reinforcement, milling time, content of reinforcement	Microstructural failure, surface weakness	Wear, poor mechanical properties	Increase wear resistance and improve mechanical properties by reinforcement	Wear resistance, micro hardness, hardness were improved.	Pressure , size of reinforcement effect were not considered, optimization is not considered.

This table shows the modes of failure and causes and their corresponding optimization techniques.

4. RESULT AND DISCUSSION (Findings of Researchers)

Many researchers tried to find the failure modes, causes of failure of aluminum and its alloys metal matrix materials at the same time they tried to find the optimization techniques based on reinforcement addition optimization, heat treatment and other techniques. Based on these techniques researchers tried to find enhancement of mechanical properties, wear resistance and corrosion resistance behaviors. The result of investigations on mechanical properties enhancement, wear reduction enhancement and stress corrosion cracking minimization were tabulated in table and made in bar charts and line charts bellow.

Table 2. Mechanical properties of aluminum and its alloys matrix materials.

Alloy of aluminum as matrix	Reinforcement particles	Reinforcement wt.% or vol.%	Mechanical properties		References
			Hardness in BHN or VHN	Ultimate Tensile Strength (MPa)	
A356 alloy	Al2O3	1.5 vol.%	120–135 in BHN	65	[13]
Al2020 alloy	Al2O3	30 wt.%	120–140 in in BHN	100–120	[19]
Al	AlN	50% vol.%	120-130 in BHN	154	[22]
A356 alloy	SiC	0.5, 2.5, and 4.5 wt.%	60–80 in BHN	200–300	[14]
AA6061 alloy	Fly ash	8 and 12 wt.%	100–120 in VHN	210–250	[15]
A356 alloy	MgO	2.5 and 5 vol.%	65–75 in BHN	850–1000	[14]

AA7075 alloy	TiB2	6 and 9 wt.%	120–130 in VHN	275–300	[17]
Al6101 alloy	Gr	8, 12 and 16 wt.%	44–48 in VHN	145–160	[16]

From table 2. mechanical properties of different aluminum and its alloy as matrix materials were improved and increased by addition of reinforcement optimization technique by different researchers.

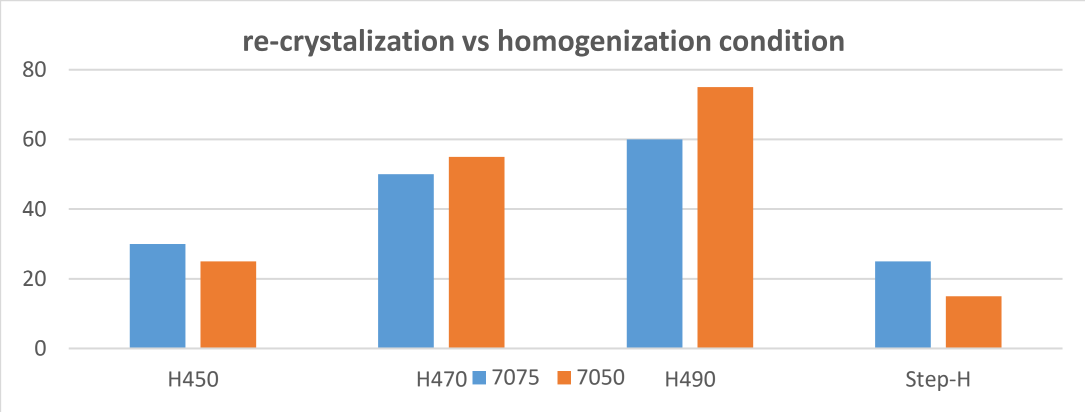

Figure 2. Homogenization Conditions of Heat Treatment on 7075 Aluminum and 7050 Aluminum Alloys

Fig 2. is the result of heat treatment (re-crystallization) vs optimization techniques (homogenization heat treatment). In the y-axis recrystallization fraction % and in the x-axis homogenization(H) conditions in °C .from this figure the result of optimization techniques on aluminum 7075 and 7050 were identified. Recrystallization (return back the deformed grain to original and make it strengthened) fraction of alloys as a function of homogenization conditions show Step-H alloy contains low fraction of recrystallized grains. Step-homogenization and step-quenching provided not only an optimum strength in 7050 alloy but also a favorable morphology of grain boundary precipitates for high Stress corrosion resistance. The researchers also found that such a treatment was not applicable for 7075 alloy because of its inherent high quench sensitivity.as we look in this review chart the strength and stress corrosion cracking (one of failure mode) resistance were enhanced up to optimum condition.

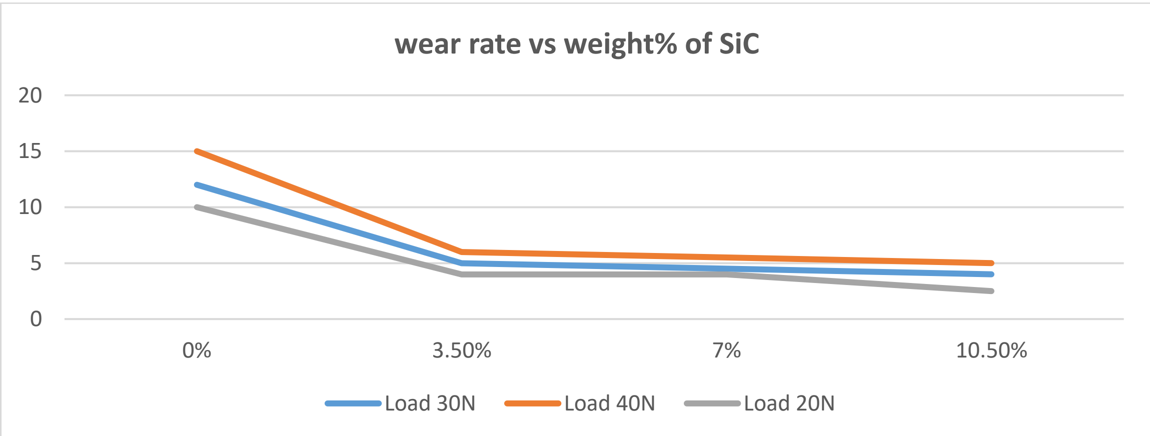

Figure 3. Wear Rate for AA6063/SiC Composite for Different Applied Loads

From fig 3. Result of addition of reinforcement (SiC) optimization technique to enhance wear resistance behavior of aluminum alloy (AA6063) is identified.in the y-axis wear rate ($x10^{-3}mm^3/m$) and in the x-axis wt.% of SiC particles are used. the wear rate is in material loss in volume per wear distance or sliding distance during wear test. The result show that the wear rate of aluminum matrix is decreased as wt.% of SiC addition increased up to the optimum condition.

5. CONCLUSION

In this review, the investigation of different researchers works on role of aluminum matrix materials with their modes of failure , causes of failure and their optimization techniques to enhance better mechanical properties, wear resistance and corrosion resistance behavior of aluminum and its alloy matrix materials have been summarized. Sources of this review (research journals, articles) reviewed in this work are published from 2005 to recent. Tables, bar chart and line charts are drawn from Microsoft word 2013.After all the following conclusion are made:

- ✓ most of researchers are used reinforcement optimization techniques to enhance the mechanical, wear resistance and corrosion resistance of aluminum matrix materials.to add the reinforcements to matrix casting processes are used and also researchers considered parameters like temperature, time, weight percent and volume percent content, pressure during addition of reinforcements to matrix.
- ✓ Heat treatment also are used to optimize properties of matrix as stated in fig 2.
- ✓ Wear resistance can be increased by reinforcement additions at stated in chart of fig 3.
- ✓ Generally, from table 1 it can be concluded that failure modes, causes of failures are minimized by heat treatment, increasing microstructure properties, increasing wear and corrosion resistance behavior with reinforcement.

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REFERENCES

[1] Speidel, M.O.J.M.T.A., *Stress corrosion cracking of aluminum alloys.* 2007. **6**(4): p. 631.
[2] Polmear, I.J.L.A., third ed., Edward Arnold, London, *Metallurgy of the light metals.* 2005.
[3] Katsas, S., et al., *Corrosion resistance of repair welded naval aluminium alloys.* 2007. **28**(3): p. 831-836.
[4] McMillan, C.A., G.A.J.E.s. Keoleian, and technology, *Not all primary aluminum is created equal: life cycle greenhouse gas emissions from 1990 to 2005.* 2009. **43**(5): p. 1571-1577.
[5] Baik, Y., Y.J.T.P.o.M. Choi, and Metallography, *The effects of crystallographic texture and hydrogen on sulfide stress corrosion cracking behavior of a steel using slow strain rate test method.* 2014. **115**(13): p. 1318-1325.
[6] Kannan, M.B. and V.J.J.o.M.S. Raja, *Role of coarse intermetallic particles on the environmentally assisted cracking behavior of peak aged and over aged Al–Zn–Mg–Cu–Zr alloy during slow strain rate testing.* 2007. **42**(14): p. 5458-5464.
[7] Boileau, J.M. and J.E.J.S.t. Allison, *The effect of porosity size on the fatigue properties in a cast 319 aluminum alloy.* 2006: p. 648-659.
[8] Li, B., et al., *Casting defects induced fatigue damage in aircraft frames of ZL205A aluminum alloy–A failure analysis.* 2011. **32**(5): p. 2570-2582.
[9] Wan, H., et al., *Morphology variation, composition alteration and microstructure changes in ion-irradiated 1060 aluminum alloy.* 2018. **5**(2): p. 026501.
[10] Ou, B.-L., et al., *Effect of homogenization and aging treatment on mechanical properties and stress-corrosion cracking of 7050 alloys.* 2007. **38**(8): p. 1760-1773.
[11] Obi, E.R., *Corrosion behaviour of fly ash-reinforced aluminum-magnesium alloy A535 composites*. 2008, Citeseer.
[12] Aballe, A., et al., *Influence of the cathodic intermetallics distribution on the reproducibility of the electrochemical measurements on AA5083 alloy in NaCl solutions.* 2005. **45**(1): p. 161-180.
[13] Akbari, M.K., et al., *Fabrication and study on mechanical properties and fracture behavior of nanometric Al2O3 particle-reinforced A356 composites focusing on the parameters of vortex method.* 2013. **46**: p. 199-205.
[14] Mazahery, A. and M.O.J.T.o.N.M.S.o.C. Shabani, *Characterization of cast A356 alloy reinforced with nano SiC composites.* 2012. **22**(2): p. 275-280.
[15] Selvam, J.D.R., et al., *Microstructure and some mechanical properties of fly ash particulate reinforced AA6061 aluminum alloy composites prepared by compocasting.* 2013. **49**: p. 28-34.
[16] Sharma, P., et al., *A study on wear behaviour of Al/6101/graphite composites.* 2017. **5**(1): p. 42-48.

[17] Rajan, H.M., et al., *Synthesis and characterization of in situ formed titanium diboride particulate reinforced AA7075 aluminum alloy cast composites.* 2013. **44**: p. 438-445.

[18] Lu, T., et al., *Influence mechanisms of Zr and Fe particle additions on the microstructure and mechanical behavior of squeeze-cast 7075Al hybrid composites.* 2019. **798**: p. 587-596.

[19] Kok, M.J.J.o.m.p.t., *Production and mechanical properties of Al2O3 particle-reinforced 2024 aluminium alloy composites.* 2005. **161**(3): p. 381-387.

[20] Alaneme, K.K., M.O. Bodunrin, and A.A.J.J.o.K.S.U.-E.S. Awe, *Microstructure, mechanical and fracture properties of groundnut shell ash and silicon carbide dispersion strengthened aluminium matrix composites.* 2018. **30**(1): p. 96-103.

[21] Ravesh, S.K. and T. Garg, *Preparation & analysis for some mechanical property of aluminium based metal matrix composite reinforced with SiC & fly ash.*

[22] Zhang, Q., et al., *Property characteristics of a AlNp/Al composite fabricated by squeeze casting technology.* 2006. **57**(8): p. 1453-1458.

[23] Ahmadi, M., M.J.J.o.A. Siadati, and Compounds, *Synthesis, mechanical properties and wear behavior of hybrid Al/(TiO2+ CuO) nanocomposites.* 2018. **769**: p. 713-724.

[24] Standard, A.J.W.C., PA: ASTM International, *E384, Standard test method for microindentation hardness of materials.* 2010.

[25] Iacob, G., et al., *Studies on wear rate and micro-hardness of the Al/Al2O3/Gr hybrid composites produced via powder metallurgy.* 2015. **69**: p. 603-611.