Khalid Almadhoniet al. Int. Journal of Engineering Research and Applications www.ijera.com
ISSN: 2248-9622, Vol. 5, Issue 10, (Part - 2) October 2015, pp.17-27

RESEARCH ARTICLE OPEN ACCESS

ThermophysicalProperties of Cellular Aluminium andCeramic Particulate / Aluminium Composites

Khalid Almadhoni*, Sabah Khan**
*Ph. D. Student, Department of Mechanical Engineering, Faculty of Engineering and Technology, JMI, Jamia Nagar, New Delhi-110025 (India).
**Dr. Assistant Prof., Department of Mechanical Engineering, Faculty of Engineering and Technology, JMI, Jamia Nagar, New Delhi-110025 (India)

ABSTRACT

In this paper, the thermophysical properties of cellular Al and Ceramic Particulate / Al Composites were explored. Thermophysical properties are defined as material properties that vary with temperature without altering the material's chemical identity including thermal conductivity (TC), coefficient of thermal expansion (CTE), energy absorption, porosity and relative density. The significance of cellular Al and AMMCs reinforced by ceramic particles lies in their propertieswhich are difficult to be available combined in other engineering materials. New cellular AMMCs that meet the needs of the required engineering applications could be synthesized by selection an appropriate reinforcements. Different kinds of ceramic particles such as oxides, carbides, nitrides, as well as carbon nanotubes can be utilized as reinforcements for manufacturing of cellular AMMCs. Thermophysicalproperties of cellular AMMCs consisting of Al as continuous matrix phase and ceramic particles as reinforcements are directly influenced by type, size, and geometry of dispersions, also the RVR. In addition, the constituents of ceramic particulate / aluminium composites characterized by different heat transfer mechanisms, wherethe TC mechanism in metals is attributed to free electrons, while phonons are primarily responsible for TC in nonmetallic materials, as well as an interfacial thermal barrier resistance influence effectively on heat transfer inside the composite and thus the thermophysical properties. In this paper, based on the literature review, thermophysical properties of cellular Al and AMMCs reinforced by ceramic particles were discussed.

***Keywords* -** Al foams, Cellular AMMCs, Ceramic particles, Thermal properties, physical properties.

I. INTRODUCTION

Cellular metals and metal composites are relatively new materials offer opportunities in a wide range of an engineering applications. They have been have been under increasing development and commercial utilization in different sectors of the economy such as building and architecture, mechanical, chemical industries. This type of materials can be used, for example, to fabricate light-weight structures, filters, heat exchanger, biomedical implants, sound absorbers, sensors, catalyst substrates and mechanical damping devices [1].Cellular materials are highly porous, with relative density lower than 0.3, and present an interesting combination of physical, thermal and mechanical properties, as low weight, high impact absorption, damping properties, sound and thermal insulation, etc. [2-3].Because of consisting different physical, thermal and mechanical properties cellular metals and metal composites are become more popular and new applications o these materials are brought out each passing day. There are many different composite materials can be produced by different methods. Metal Matrix Composites (MMCs) is one of these materials. Cellular MMCs keeping a combination of many advantageous properties of metal matrix composites with low relative density, present an interesting combination of properties, as low weight, high energy absorption, etc. Various kinds of ceramic materials, e.g. SiC, SiO_2, Al_2O_3, MgO, ZnO, BeO, MnO_2, TiO_2, TiC, etc. are generally used as reinforcement elements. Superior properties of these materials such as refractoriness, high compressive strength and hardness, excellent wear resistance, etc. make them appropriate for use as reinforcement in MMCs [4-5-6].Metal foams are characterized by high performance applications as multifunctional materials in electronic, mechanical, civil, chemical and biochemical engineering. These materials are anticipated to find many more applications. The foams make high efficiency heat exchanger (i.e. for stirling engines, latent heat cooling systems and regenerators in solar power plants) and industrial filters. Furthermore, metal foams are used as electrode materials for fuel cells and rechargeable batteries because they have very high specific surface areas, characteristics required for flow-through applications or when surface exchange are involved. Hybrid foams (composites consisting to two foamed constituents), in addition to combining metal foams with ceramic and polymer materials are expected to see more exposure [7].Metal foams keeping a combination of numerous advantageous properties of metals with low relative density, are cellular materials containing pores filled with gas. There are two types of metal foams: closed- and open cell metal foams. If pores insulated by metal walls from each other, then this is named as closed cell metal foam, if pores interconnected with each other is referred to as open cell metal foam or metal sponge.

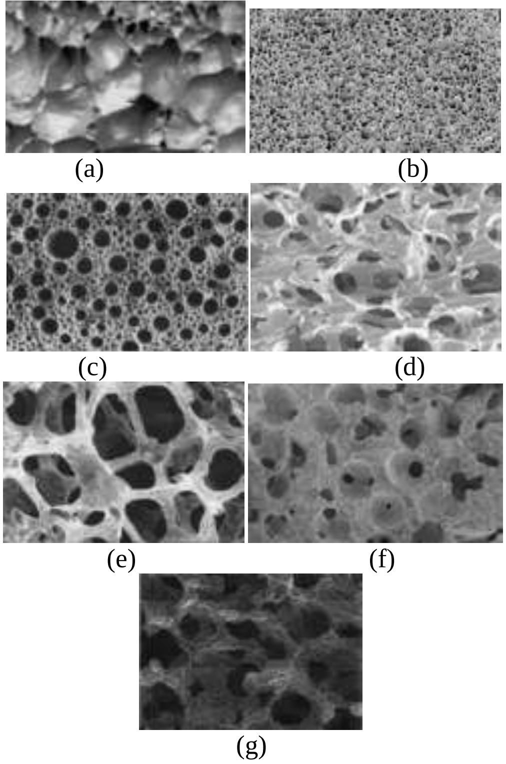


Fig. 1.1 (a): Al foam produced by a continuous process of gas injection to a viscous melt (Banhart, 2001), (b): Pore structure of aluminum foamed by gas releasing agent (TiH2) (Duarte and Banhart, 2000), (c): Pore structure of aluminum foamed by solid–gas eutectic solidification (Banhart, 2001), (d): SEM micrograph of pure aluminum foam produced by replication (Marchi& Mortensen, 2001), (e): SEM image of Al foam parts made by investment casting (Banhart, 2001), (f): Cellular aluminum material made by using space-holding fillers.Density1.1g/cm and (g): SEM micrographof a typical Al foam manufactured by SDP (Zhaoand Sun, 2001).

The relative densities ranging from 50 to 98% can be achieved. Open-celled aluminum foams can be produced via varied methods. Investment casting, pre-form infiltration and SDP are the most widely used techniques. For production of closed-celled aluminum foams, Alcan, Alporas and gasar are the most widely routes, (figures 1.1-a, -b, -c, -d, -e, -f and –g) show various structures of Al foams produced by different techniques. Due to rapidly increasing demand for higher quality Al foams, there has been a growing requirement for developing other cost effective manufacture technologies. [8].

Thermal properties of cellular metal matrix composites reinforced by ceramic particles are affected bytype, shape, distribution and the size of particles, as well as the reinforcement volume ratio (RVR) and cell size. AL alloy AA2011 was infiltrated in the semisolid state into preforms of sintered NaCl particles. Results showed thatthe feasibility of the application of semisolid technology to fabricatean open cell and closed cell syntactic foams, as well as low density metal matrix composites viathixoinfiltration of the alloy into removable preforms of NaCl particles or non-removable preforms of hollow glass microspheres and ceramic porous particulates. Concerning the materials produced, results showedcomposites containing porous reinforcements can present some mechanical characteristics of the conventional cellular metals,figure 1.2.

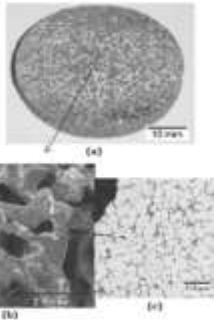


Fig. 1.2: Typical sample produced by thixoinfiltration of AA2011alloy into a preform of removable NaCl particles; (a) generalaspect; (b) general aspect of the architecture; (c) microstructure ofcell walls.

Due to this behavior associated to the low density and other specific properties inherent to metal matrix composites, more attention should be paid to this kind of material, [9].

A closed cell AlMg4.5Mn0.7 / SiCp composite foam was fabricated by direct foaming at semi-solid temperature, and the effects of reinforcement size and fraction on energy absorption were investigated, results show that energy absorption capability increase with increasing reinforcement ratio and decreasing reinforcement size, (figures 1.3-a, -b, -c and –d).

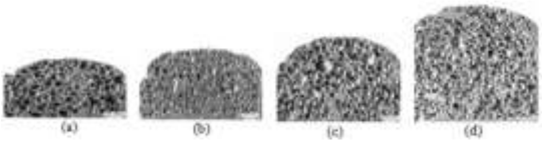


Fig. 1.3: Product of foam with different fraction of SiCp (12μm), a) %5, b) %10, c) %15, d) %20.

It was realized that composite foam with produced by smaller size of reinforcement is more capable to absorption of energy [10].

An Open-cell Al alloy (AC3A) composite foams with 1-5% SiC particles have been successfully manufactured via pressure infiltration casting route with polyurethane preform. An addition of higher ceramic particle led to higher volume fraction of the particles both in the matrix and on the strut surface, as a result, improved the compressive strength, energy absorption and microhardness of the foams, as illustrated in figure 1.4 [11].

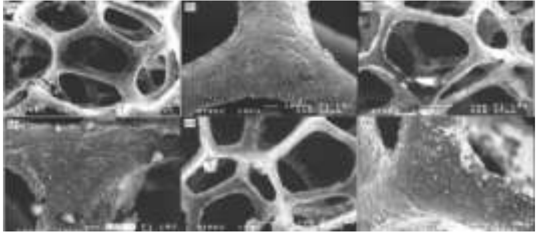


Fig. 1.4: SEM micrographs showing structures of pure AC3A and composite foams containing 1% and 5% SiC particles: (a), (b) Pure AC3A; (c), (d) AC3A+1%SiC; (e), (f) AC3A+5%SiC.

Thermal property of a material is its physical property related to application of heat energy and explain its response. As a solid body absorbs energy in the form of heat, its temperature increases and its dimensions increase. Heat capacity, thermal expansion, and thermal conductivity are properties that are often critical in the practical utilization of solids. Heat is transferred at a higher rate across materials of high thermal conductivity than across materials of low thermal conductivity. The reciprocal of thermal conductivity is called thermal resistivity [12].

Different kinds of engineering materials (metals, ceramics, polymers and composites), so the thermal conductivity mechanism depends on kind of material. TC mechanism in materials is attributed to electrons and phonons. Due to a large numbers of free electrons with high free mean paths and velocities in high pure metals, the electron mechanism of heat transfer is much more efficient than the phonon contribution. The TC in pure metals remains approximately constant with rising temperature. Metals with crystal structure type of FCC are characterized by the highest TC. Metals have crystal structure of BCC exhibit an order of magnitude lower TC. Alloying metals with impurities result in a reducing in the TC. Atoms of different metals have different sizes, act with impurities as scattering centers and lead to lowering the efficiency of electron motion.Nonmetals, such as glass, ceramics and polymers, are thermal isolating materials as much as they lack numbers of free electrons. Phonons are primarily responsible for TC in nonmetallic materials and they are scattered much more than electrons by lattice imperfections, so they are not as effective as free electrons in the transport of heat energy.Crystalline ceramics are characterized by higher thermal conductivities thananother amorphous ceramics, since the phonon scattering is much less than effective when the atomic structure is little disordered and irregular. With rising temperature, increases the scattering of lattice vibrations. As a result, the TC of most ceramic materials normally diminishes with increasing temperature, especially at relatively low temperatures (Figure 1.5).

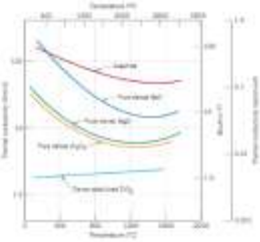


Fig. 1.5: Dependence of thermal conductivity on temperature for several ceramic materials

Porosity may have a considerable effect on TC of ceramics. Increasing the pore volume will lead to a decreasing of the TC [13-14-15] .

Thermal boundary resistance “Interfacial thermal resistance” is defined as a measure of an interface's resistance to thermal flow. The heat energy carrier (phonon or electron, depending on the type of material) will scatter at the interface when it attempts to travel through the interface. The probability of transmission after scattering will depend on the available energy states on both the sides of interface. Two primary models are utilized to understand the thermal resistance of interfaces: the acoustic mismatch and diffuse mismatch models. Both are based only on phonon transport, with ignoring of the electrical contributions. Therefore, they should be used for interfaces where at least one of the materials is electrically insulating. That means the thermal resistance will result from the transfer of phonons across the interface. Heat energy is transferred when higher energy phonons exist in higher density in the hotter material propagate to the cooler materials, which in turn transmits lower energy phonons, resulting a net energy flux. The decisive factor in determining the thermal resistance at an interface is the overlap of phonon states., as shown in figures 1.6-a and –b [16].

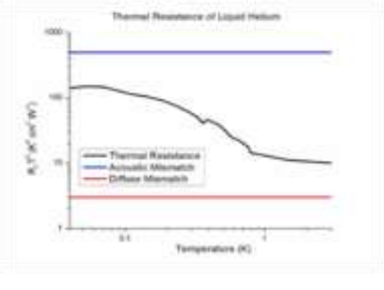


Fig. 1.6-a: Typical Interfacial Resistance of liquidHelium With metals. Resistance has beenmultiplied by T3 to remove the expected T-3 dependence.

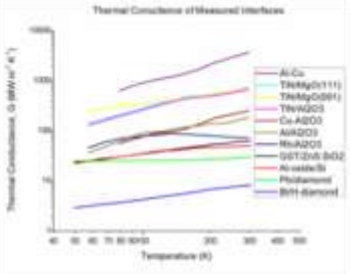


Fig. 1.6-b: Thermal conductance of measured interfaceof some Composites (Composites and alloys).

An expressions for the effective TC of composite materials consisting of a continuous matrix phase with dilute concentrations of dispersions with spherical, cylindrical and flat plate geometry with a thermal barrier resistance at the interface between the constituents were derived by a modification of the original theories of Rayleigh and Maxwell. Due to the existence of an interfacial thermal barrier resistance in composites, it was found that the effective TC not only depends on the volume fraction of the dispersed constituent but also on the dispersion size. However, interfacial thermal barriers are expected to be effective only if they are non-parallel to the direction of heat flow. This suggests that for non-spherical dispersions with preferred orientation, the existence of a thermal barrier resistance can serve as an additional mechanism for introducing anisotropy in TC even when K_d (dispersion TC) = K_m (matrix TC) [17].

The thermal resistance can be caused by different types of phonon scattering processes such as phonon-phonon scattering, boundary scattering, scattering from static point imperfections, dislocations of atoms, stacking faults and grain boundaries. In some cases was found that phonon-boundary scattering effects dominate the thermal conduction processes and decreasing TC. Due to the large band gap between the valence and conduction bands, most ionically and covalently bonded materials show very low TC, but covalently bonded solids tend to have higher TCs than thus of ionically bonded solids. The distance between phonon scattering centers represents the relevant mean free path. Collisions between phonons are not relevant because they do not change the net momentum of the phonons involved in transport whereas so-called umklapp processes, in which two phonons interact with the lattice to yield a third scattered phonon. Phonons travel at the speed of sound and for maximizing the TC, these phonon scattering processes must be minimized. In composites, the scattering of phonons is mainly because of the interfacial thermal barriers, resulting from acoustic mismatch and flaws associated with the filler-matrix interface. There are four criteria must be met in the solid nonmetallic material in order to be high TC: low atomic mass, chemical bonding, simple crystal structure and low anharmonicity in the molecular vibrations [18-19].

II. THERMOPHYSICAL PROPERTIES OF AL/CERAMIC COMPOSITES

MMCs are fabricated and developed for an optimization of thermal and physical properties in an engineering applications. For these applications, the thermal expansion can be controlled with a negligible penalty in TC. TECdecreases with increasing volume fraction of silicon carbide in a 2080/SiCp composite. Because of the TC of SiC which is similar to those of Al, AMMC reinforced with SiC will not lose much in the way of TC. In particular, a bimodal distribution of the particles was used, due to a small reinforcement particles fit in the space between large particles. Enhanced TC and lightweight in a CTE – matched material are the features being exploited in using Al/SiC and Al/C MMCs in electronic industrials., Continuous boron fiber-reinforced aluminum composites made by diffusion bonding were also used as heat sinks in chip carrier multilayer boards. Al/carbon fiber composites are characterized by high TC along the fiber direction, the conductivity transverse to the fibers is two-third those of aluminum. C/Al composites are useful in heat transfer applications where lightweight is required. These composites are also useful to utilize in high speed airplanes for dissipation of heat from the leading edges of wings. Also, the importance of MMCs lies in its utilize for covers of inertial guidance system for a missile system [20].

The TCs and TECs of semiconductors, ceramics and thermal materials used in microelectronic, optoelectronic, and MEMS packaging are illustrated in figure 2.1, [21].

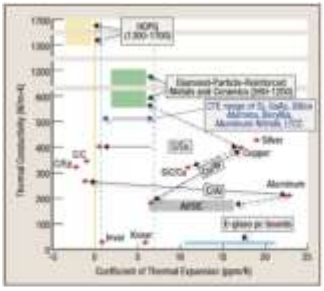
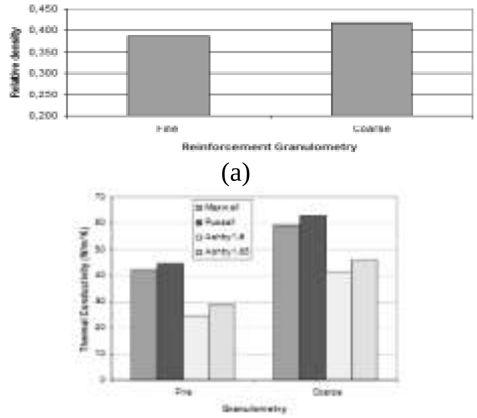


Fig. 2.1: Thermal conductivities and coefficients of thermal expansion of semiconductors, ceramics and thermal materials used in microelectronic, optoelectronic and MEMS packaging.

2.1. Investigative review on thermal properties of cellular Al and Al/ceramics composites

M. Robert and A. Jorge used AA7075 alloy as matrix and porous, lightweight and low cost SiO_2/MgO/Al_2O_3 ceramic particles as reinforcements to produce a cellular AMMC viathixoinfiltration technique.



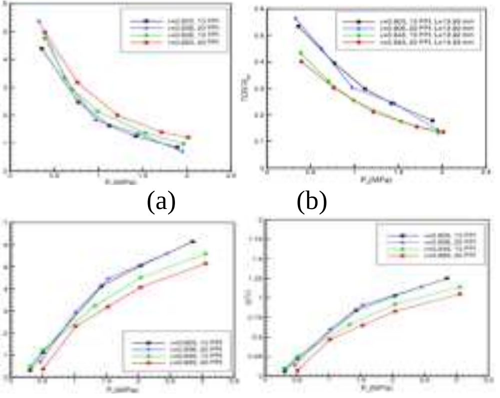
(a)

(b)

Fig. 2.2(a): Relative density of the AA7075/SiO_2-MgO-Al_2O_3 composite produced and (b): Thermal conductivity of AA7075/SiO_2-MgO-Al_2composites, estimated by different theoretical models.

Results showed that the new cellular composite material can present low thermal conductivity, in the order of 30% of the conductivity of the alloy without reinforcement (depending on RVR of reinforcement), the relative density (figure 2.2-a) and the thermal conductivity of the cellular composite increased with increasing the particles size, as shown in figure 2.2-b. [22].

The effective thermal conductivity and thermal contact resistance (TCR) of ERG Doucel aluminum foam samples with different porosities and pore densities in a vacuum under varying compressive loads are measured., Results showed that the effective TC increases with increasing the foam density It is relatively insensitive to compressive load up to 2MPa. It is found that the TCR contributes more than 50% of the total thermal resistance, for relatively low compressive loads.



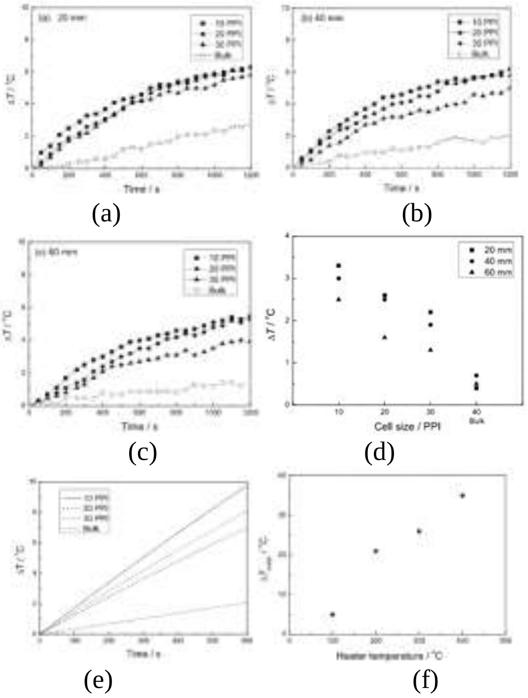
(a) (b)

(C) (d)

Fig. 2.3 (a): TCR of different Al foam samples over a range of compression, (b): TCR to total thermal resistance ratio fordifferent Al foam samples under compression, (c): Real contact areato cross-sectional area for various Al foam samples under compression and(d): ratio of total contact area to cross-sectional areafor various Al foam samples under compression.

As illustrated in figures 2.3-a, -b,-c and –d, Also, TCR increases with reducing the ratio of contact area to the cross-sectional area and it is more sensitive to the compressive load rather than porosity and pore density. It decreases with increasing the foam density [23].

The6063 aluminum open cell foams have been produced via conventional precision casting route to investigatethe thermal, A water heating system was organized for measuring of heat transfer. Measurement of heat transfer showed that the temperature between the top and bottom of the foam increased and became larger with increasing the cell size, figures 2.4-a, -b, -c, -d, -e and -f.



(a) (b)

(c) (d)

(e) (f)

Fig. 2.4 (a, b and c): Temperature increase of the 20, 40 and 60 mm thick foams, respectively, with time, (d): Temperature increase of the 20, 40 against cell size after 300 s, (e): Simulated temperature increase of temperature increase of water plotted and (f): The 60 mm thick foams with time against the setting temperature of heater.

This means that temperature rise effect is greater for larger cell size foam, even with the same amount of heat due to low density of the foam [24].

Coefficient of thermal expansion (CTE) values of the aluminum alloy A356 matrix syntactic foams filled with SiC hollow particles (SiC_{HP}) was investigated. As illustrated in figure 2.5, it was found that syntactic foams had lower CTE compared to the matrix alloy. The syntactic foam demonstrated a higher CTE values at higher temperature [25].

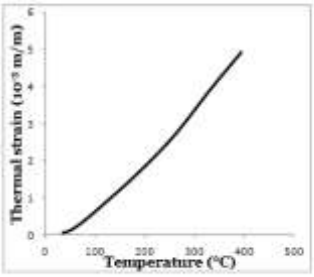


Fig. 2.5: Coefficient of thermal expansion values of the A356/SiCHP syntactic foams

Thermal properties of different density Alporas aluminum foam wasinvestigated via X-ray tomography andcomparative method in the function of the temperature at 30, 100, 200, 300, 400 and 500 °C,respectively.

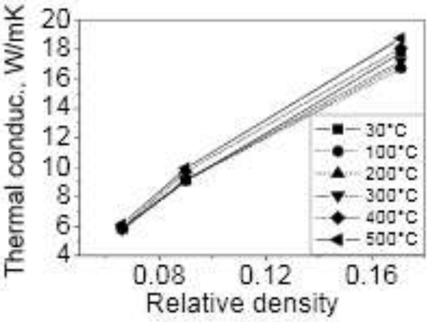
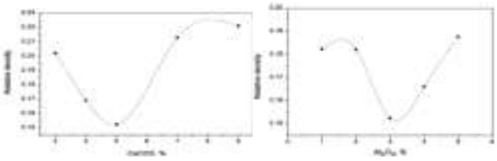


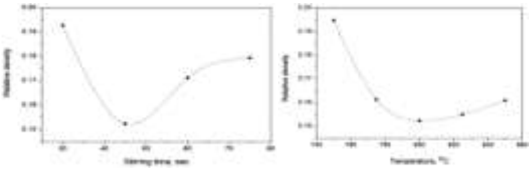
Fig. 2.6: Thermal conductivity of foams atdifferent temperatures

As illustrated in figure 2.6, the results highlighted that the thermal conductivity and its ratio increases in the function of relative density [26].

H. Osman, A. Omran and others studied the optimum parameters affecting the preparation of aluminum foam from recycled aluminum. The parameters are: temperature, $CaCO_3$ to aluminum scrap wt.% as foaming agent, Al_2O_3 to aluminum scrap wt.% as thickening agent, and stirring time. The results indicated that the optimum parameters are ranging from 800 to 850 ^{o}C, $CaCO_3$ to aluminum scrap was 5%, Al_2O_3 to aluminum scrap was 3% and stirring time was 45 second with stirring speed 1200 rpm. The produced foam apparent densities ranged from 0.40-0.60 g/cm^3, as shown in figures 2.7-a, -b, -c and –d, [27].



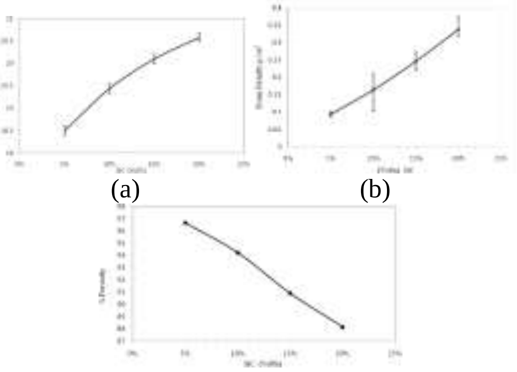
(a) (b)



(c) (d)

Fig. 2.7 (a): Effect of CaCO3 on aluminum foam density, (b): Effect of alumina on relative density, (c): Effect of stirring time on relative density and (d): Effect of temperature on relative density.

Commercial A356 cast aluminum alloy as matrix and SiC particles with purity of 98.0 wt.% and mean particle size of 10 μmas reinforcement were used for fabrication aluminum foams via melt gas injection process. Results showed that the cell size of the sample foamed increases with increasing SiC particle concentration at constant foaming temperature and the cell wall thickness increases with increasing SiC particle concentration at constant foamingtemperature, figures 2.8-a, -b and –c, [28] .

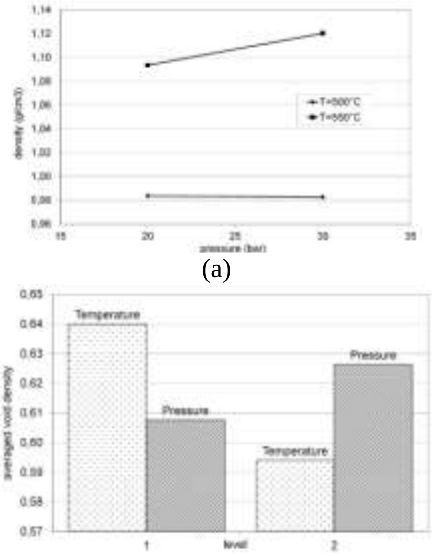


(a) (b)

(c)

Fig. 2.8(a): Effect of volume fraction SiC particle o n the cell size of the aluminum foam, (b): Effect of volume fraction SiC particle on the foam density of the aluminum foam and (c): Effect of volume fraction SiC particle on the porosity of the aluminum foam.

Replicated AlSi7Mg0.3 alloy foams were manufactured by infiltrating preforms of NaCl particles, varying themetal infiltration pressure and the mould temperature. The results showed that when the mould is preheatedat 500 °C there is an excessive chill and the liquid metal does not develop a smooth skin through intimate contact withthe mould surface. When the mould is preheated at 550 °C the void density decreases by increasing the applied pressure. Increasing the infiltration leads to an enhancement the metal infiltration through the salt pattern., so thevoid density distribution is more regular and there is a more effective replication of salt particles with a consequent reduced void circularity, figures 2.9-a and –b, [29].



(a)

(b)

Fig. 2.9 (a): Foam density according to temperature and pressure variations on two levels, and (b): Main effects of temperature and pressure on the averaged void density.

B. Kumar, C. Kumar and V. Reddy produced a low cost aluminium foams with better quality using $CaCO_3$as foaming agent in the closed cell aluminum foam and polystyrene granules as space holders in open cell aluminium foam. As illustrated in figures 2.10-a, -b and –c, experimental findings indicated that percentage porosity of 21.771% and 19.18% were obtained for open cell Aluminum foam and for closed cell Aluminium foam, respectively. TiH_2powder as foaming agent was successfully replaced by commercial $CaCO_3$ powder in closed cell Aluminium sponge production. Polystyrene granules as space holders are better utilized for open cell Aluminium sponge production. It is found that the properties of Aluminium sponge significantly depend on its porosity, which means that a desired property can be tailored by the sponge density [30].

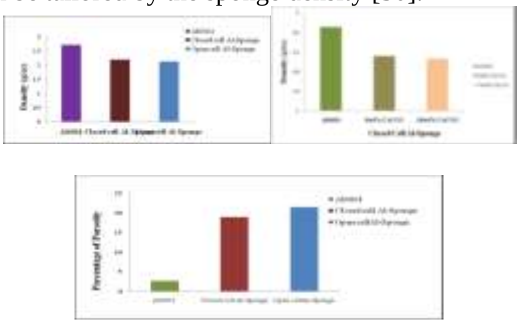


Fig. 2.10 (a): Variation of densities in Al6061 parent metal and developed Al6061 sponges, (b): Variation of density in Al6061 parent metal and developed Al6061 sponge materials with varying percentage of $CaCO_3$ and (c): variation of porosity in Al6061 alloy and developed Al sponge.

A. Seksak and T. Rath used aluminium-titanium hydride with rice husk ash (RHA) particles to produce a foam with improved pore structure. The particles significantly influence the foam structure by increasing the viscosity of aluminium melt, modifying foam microstructure and increasing the cell wall strength, resulting in an improvement in the structure and an increase in energy absorbed, as shown in figure 2.11.

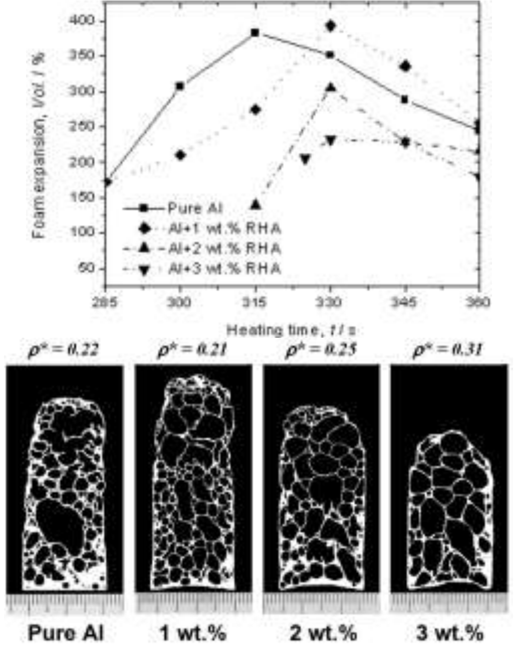
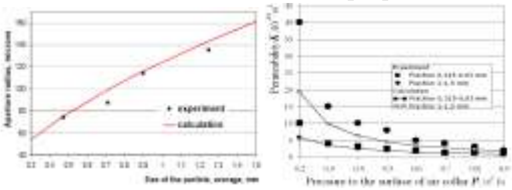


Fig. 2.11: Expansion and pore structure at maximum expansionof Al foams added with rice husk ash at various contents.

Results showed that a larger maximum expansion ofcomposite foams was found at 1 wt.% RHAparticle addition, compared with pure Alfoams, and anincrease in theenergy absorption, for a given strain. These improvement in foam structure areresulted from the increasing viscosity of Almelt, the modification of foam microstructureand the increasing strength in the cell walls atwhich the particles reside [31].

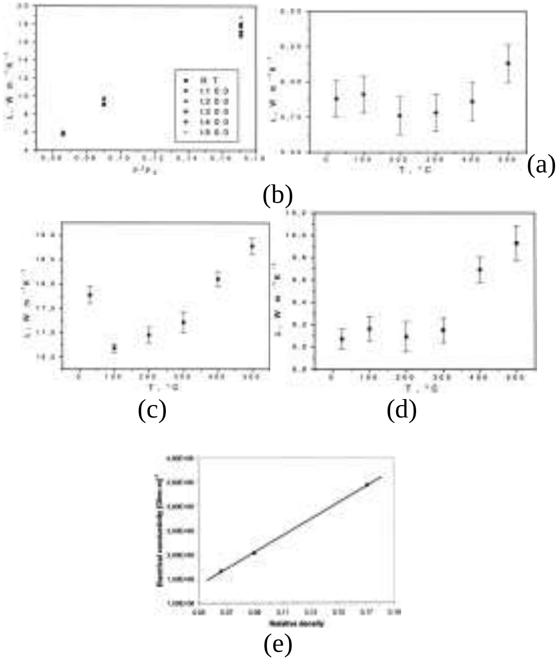
Aluminum foam was produced by replication casting process. Pure sodium chloride of spherical shape with various fractions was used. NaCl bed with porosity ranging from 50% up to 65% was used and the gauge DV8009-Kc of the membrane type with an error of 2.5% was used to estimate thepressure vacuum. In the experimental work, a model describing the interaction between solid particles poorly wetted by molten metal with theassociated formation of an “air collar” was developed. The expression for the permeability of replicated aluminum foam was derived on the basis of the “bottleneck” model of a porous medium also it agrees well with the experimental data. Figures 2.12-a and –b show that the aperture radius increases with increasing NaCl particle size and the permeability of replicated aluminum decreases with increasing pressure to the surface of air collar [32].



(a) (b)

Fig. 2.12 (a): Relation between aperture radius andNaCl particle size (P = 25 kPa) and(b): Permeability of replicated aluminum.

The thermal conductivity of Alporas samples in the functionof the temperature at 30, 100, 200, 300, 400, 500 ^{o}C was determined by using a comparative method. The ratio of thermal conductivity was calculated and shown anincreasing function by the density of the foams. As illustrated in figures 2.13-a, b, -c, -d and –e, findings indicated thatin case of the 0.177 g/cm^3 density samples, the pressure ofthe gas environment did not influence significantly the TCdata. A slight increase of the heat conductivity was found vs. Temperature (in the temperature ranging from RT to 500 ^{o}C) in all the densities. The TC of foam vs. density showedalmost linear behaviour [33].



(a)

(b)

(c) (d)

(e)

Fig. 2.13- (a):Thermal conductivity of different relative density foams atdifferent temperatures, (b):Thermal conductivity in the function of the temperature inthe case of 0.066 relative density, (c):Thermal conductivity in the function of the temperature inthe case of 0.171 relative density, (d):Thermal conductivity in the function of the temperature inthe case of 0.09 relative density, and (e): The measured conductivity values vs. the relative densitiesof the foams.

B. Oana, R. Florea and I.Carceafocused research on Al-Mg alloys with magnesium and silicon carbide (SiC). They used different gas blowing method (N_2, SO_2 and C_4H_{10}). They analyzed the samples obtained by electron microscopy and observed that the best results in terms of pore volume gave blowing with C$_4$H10. Results showed that the viability of the foams obtaining method and that the foam stability was achieved by depositing of some particles (Al_2O_3, and SiC) on pores walls. It is also found thatspherulites distribution and their size significantly influence the increasing the porosity of cellular composites [34].

K.Kitazono examined an impact of superplastic deformation on the solid-statefoaming process of closed-cell aluminum foams. He used a SP5083 aluminum alloy as a model material. The ARB process enabled for manufacturingof preform platecontaining TiH_2 particles. Results indicated that aluminum foams with smalland anisotropic pores were produced under the superplastic foaming condition. Also it was found that the aluminum foams having oblate pores with substantially low thermal conductivity, figure 2.14 [35] .

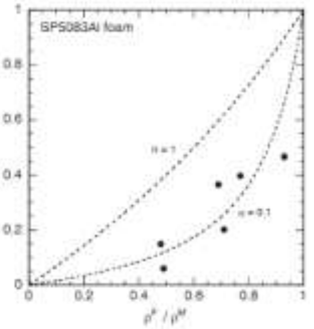
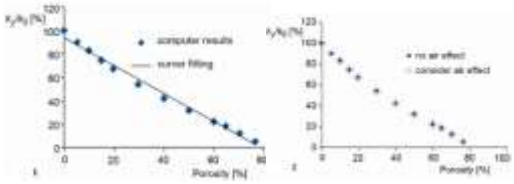
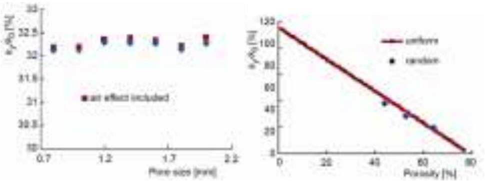


Fig. 2.14: Thermal conductivity of the SP5083 alloy foams measured by the LF method. Broken lines show theoretically calculated values based oncontinuum theory.

Two-dimensional finite element numerical model to get the equivalent coefficient of the thermal conductivity of aluminum foams with different aperture distribution model was used. Simulation results indicated that apparent TC linearly increases with an increasing the porosity, it was also found that the cell sizeand the distribution have negligible influences on the thermal property. Figures 2.15-a, -b and –c illustrated the simulation results obtained from the experiments.



(a)



(b)(c)

Fig. 2.15 (a): Relationship of the effective thermal conductivity and the porosity when aperture size keeps constant and the effects of the air filled in the pore, (b): Relationship of the effective thermal conductivity and the pore size and (c): The relationship of equivalent coefficient of the thermal conductivity and different aperture distribution model.

As shown in illustrated figures, the effective TC of closed-cell foam aluminum materials under low temperature coefficient was mainly influenced by the porosity [36].

III. SUMMARY

From the above introduced extensive literature survey, it can be noticed that worthwhile comprehensive efforts have been reported to evaluate thermophysical properties of cellular Al and AMMCs reinforced with ceramic particles used to meet the needs of modern industrial applications.

Inthe case of aluminium foams, the porosity, cells size and cells size have significantly effect on the thermophysical properties, where it was found that the effective thermal conductivity (TC)increases with an increase of cell size and relative density of foams. TCdecreases with theincreasing of porosity when the pore size unchanged and whenthe aluminium foams having oblate pores. It was noted that the sound absorption of the aluminium with closed cell foam is better than those of the open cell foam.The large contribution of thermal contact resistance (TCR) to the total thermal resistance, this due to a small ratios of contact area to the cross-sectional area.

In the cellular aluminium, theTCR has the large contribution tothe total thermal resistance for relatively lowcompressive loads, this due to the small ratios of contact area to the cross-sectional area.
Thermophysical properties of cellular AMMCs reinforced with ceramic particles basically depend on type, size and geometry of dispersions, as well as the reinforcement volume ratio ”RVR”. It was noticed that an increasing of RVR leads to an increase both porosity and energy absorption capability, and also causes a reducing of relative density andTC. While increasing of reinforcement particles size leads to an enhancement of TC and reducing of both porosity and energy absorption capability.TC can be greater for larger cell size foam.Cell size of the sample foamed increases with increasing particles concentration at constant foaming temperature and cell wall thickness increases with increasing particles concentration constant foaming temperature. It was found that the spherulites distribution and their size substantially influence the increase of cellular composite material porosity. Thermal, electrical conductivity and their ratio increase in the function of relative density.A larger maximum expansion of composite foams depend on the RVR. The improvement in foam structure of the foams are resulted from the increasing viscosity of Al melt. It was also observed that the syntactic foams had lower CTE compared to the matrix. The syntactic foam demonstrated a higher CTE values at higher temperature. By preheating of the mould, the void density can be reduced by increasing the applied pressure. Furthermore an increased infiltration pressure improves metal infiltration through the salt pattern. In these conditions the void density distribution will be more regular and there is a more effective replication of salt particles with a consequent reduced void circularity.

REFERENCES

[1] L. Lefebvre, J. Banhart and D. Dunand, metfoam: porous metals and metallic foams, proc. of the 5th conference, montreal, Canada, 2007.
[2] V. Paserin, J. Shu, A. Liu, B. Yu, L. Renny and M. Groo, commercial production and applications of Ni-based specialty foams, proc. of the 5th international conference on porous metals and metallic alloys, montreal, canada, 2007, 121-124.
[3] S. Sinha, Metal foams - A novel field of metallurgy. Journal of Metallurgy and Materials Science, Vol. 54, No. 3, , July-September 2012,pp. 175-185.
[4] A.Kheder, G. Marahleh and D. Al-Jamea, Strengthening of Aluminum by SiC, Al_2O_3 and MgO. Jordan Journal of Mechanical and Industrial Engineering”. Volume 5, Number 6, Dec. 2011,ISSN 1995-6665.
[5] D. Ramesh, R. Swamy and T.Chandrashekar, Effect of weight percentage on mechanical properties of frit particulate reinforced Al6061 composite. ARPN Journal of Engineering and Applied Sciences. Vol. 5, No. 1, January 2010,ISSN 1819-6608.
[6] M. Surappa, Aluminium matrix composites: Challenges and opportunities. Sadhana, Vol. 28, Parts 1 & 2, February/April 2003, pp. 319–334.
[7] N.Dukhan, Metal Foams: Fundamentals and Applications, DEStech Publications, Technology & Engineering, 2013, pp.432.

[8] B. kheradmand, S. Otroj, Z. Soleimanpour and M. Beigyfar, Comparison between methods used for manufacturing of aluminum foam, Life Science Journal 2013;10(1).

[9] M. Robert, A. Jorge, F. Gatamortaand.R. Silva, Thixoinfiltration: a new approach to produce cellular and other low density metallic materials, Journal of Achievements in Materials and Manufacturing Engineering. Vol. 40, issue 2, June 2010.

[10] N. Taskin, P. Demirhan and I.Mutlu, Manufacturing of composite metal foam by directly foaming at semisolid temperature, International scientific conference 19–20, Gabrovo, November 2010.

[11] W. Ekkapak B. , Yuttanant, and A. Seksak, Microstructural examination and mechanical properties of replicated aluminium composite foams. Elsvier, Trans. Nonferrous Met. Soc. China 22(2012) 1674−1679.

[12] https://en.Wikipedia.org/wiki/Physical_property, 2013, From Wikipedia, the free encyclopedia.

[13] W. Callister, 2007, Materials Science and Engineering, Department of Metallurgical Engineering, The University of Utah, seventh edition. ISBN-13: 978-0-471-73696-7, ISBN-10: 0-471-73696-1.

[14] Department of Defense USA, 2002, Composite Materials Handbook, Vol. 1, Polymer Matrix Composites.

[15] K. U. Kainer, 2006, Basics of Metal Matrix Composites, Metal Matrix Composites. Custom-made Materials for Automotive and Aerospace Engineering, ISBN: 3-527-31360-5.

[16] https://en.wikipedia.org/wiki/Interfacial_thermal_resistance, 2015, From Wikipedia, the free encyclopedia

[17] D. Hasselman and L. Johnson, 1987, Effective Thermal Conductivity of Composites with Interfacial

[18] T. Andritsch, 2010, Epoxy Based Nanocomposites for High Voltage DC Applications. Synthesis, Dielectric Properties and Space Charge Dynamics, PhD thesis, Delft University of Technology,

[19] R. Kochetov, 2012 Thermal and Electrical Properties of Nanocomposites, Including Material Processing, PhD thesis, Delft University of Technology.

[20] N. Chawla and K. Chawla, 2013, Metal Matrix Composites, second edition, pp. 342-344.

[21] C. Zweben, 2006, Thermal Materials Solve, Power Electronics Challenges, Power Electronics Technology, pp 40-47.

[22] M. Robert and A. Jorge, Processing and properties of AA7075/porous SiO_2-MgO-Al_2O_3 composite, Journal of Achievements in Materials and Manufacturing Engineering, Vol. 54, issue 1, September 2012.

[23] E. Sadeghi, S Hsieh and M. Bahrami, Thermal conductivity and contact resistance of metal foams, Journal of Physic D: Appl. Phys. 44, 201, 125406 (7pp).

[24] K. Bokhyun, K. Kiyoung, L. Byungminand N. Jaesoo, Heat Transfer and Acoustic Properties of Open Cell Aluminum Foams, J. Mater. Sci. Technol., Vol.24 No.1, 2008.

[25] J. Cox, D. Luong, V. Shunmugasamy and others, Dynamic and Thermal Properties of Aluminum Alloy A356/Silicon Carbide Hollow Particle Syntactic Foams, Metals 2014, 4, 530-548.

[26] N. Babcsán, C. Kadar, N. Hegman, I. Meszaros and E. Maire, Characterization of thermal and electrical properties ofaluminum foams, J. Banhart, N.A. Fleck: Cellular Metals and Metal Foaming Technology, © MIT-Verlag 2003.

[27] H. Osman, A. Omran2, A. Atlam and M. Moatasem, Fabrication of aluminum foam from aluminum scrap, Int. Journal of Engineering Research and Applications, ISSN : 2248-9622, Vol. 5, Issue 2, (Part -5) February 2015, pp.109-115.

[28] M. Malekjafarian, S. Sadrnezhaad, M. Abravi, and others, Manufacturing Aluminum Foams by Melt Gas Injection Process, 7th International Conference on Porous Metals and Metallic Foams, 2011.

[29] A. Boschetto, L. Bottini, F. Campana and L. Consorti, Morphological characteristics of aluminium foams producedby replication casting, A. Boschetto et alii, Roma, Italia, 1-3 Luglio 2013; ISBN 978-88-95940-47-2.

[30] B. Kumar, C. Kumar and V. Reddy, Production of Low Cost Aluminium Foams, International Journal of Current Engineering and Technology, April 2014, ISSN 2277 – 4106.

[31] S. Asavavisithchai and T.Rath, On the Production of Aluminium Foams StabilisedUsing Particles of Rice Husk Ash, Chiang Mai J. Sci. 2009; 36(3) : 302-311.

[32] E. Furman, A. Finkelstein and M. Cherny, Permeability of Aluminium Foams Produced byReplication Casting, Metals 2013, 3, 49-57,ISSN 2075-4701.

[33] N. Babcsan, Meszaros and N. Hegman, Thermal and Electrical ConductivityMeasurements on Aluminum Foams, Mat.-wiss. u. Werkstofftech, 2003, 34, 391–394.

[34] O. Balţatescu, R. Florea and I. Carcea, Studies on Metal Matrix Composite Based On AlMg Alloys, IJRES, ISSN (Print): 2320-9356, Vol. 1, Issue 5, Sep. 2013, PP.73-78.

[35] K. Kitazono, Superplastic Forming and Foaming of Cellular Aluminum Components, Materials Transactions, Vol. 47, No. 9 (2006) pp. 2223 to 2228.

[36] L. Guo-Yun, S. Bu-Yun, L. Zhi-Qiang and others, Thermal Properties of Closed-Cell Aluminum Foam with Circular Pores, Thermal Science, 2014, Vol. 18, No. 5, pp. 1619-1624.