International Journal For Technological Research In Engineering
Volume 6, Issue 7, March-2019 *ISSN (Online): 2347 - 4718*

A CRITICAL REVIEW ON LOW TEMPERATURE CRYOCOOLER REGENERATOR MATERIALS

B.P.Patel[1], N. B. Parmar[2] , G.S.Kharadi[3], D.S.Thanki[4]
[1,2,3,4]Assistant Professor
[1]Polytechnic in Agricultural Engineering, Targhadia,
[2,3,4]College of Agricultural engineering & Technology
Junagadh Agricultural University, Junagadh, Gujarat, India

Abstract: The regenerator has a significant influence on the development of refrigerators for Cryogenic application. It is a key component in every Cryocooler because it efficiently cools and heat supply the gas as it flows between the compressor and the expansions place and vice versa. An essential Para meter in the regenerator design is the heat capacity ratio. "In addition, the pressure drop across the regenerator must be minimized to achieve maximum p-V work in the expansion space. This paper Describe the Regenerators of various customized shapes, geometrical and structural characteristics to ensure desirable end properties may be produced. The patentedtechnique offers a possibility to fabricate Cryocooler regenerators with controlled surface area andlow fluid flow resistance from any powder materials including brittle magnetic intermetallics. Mechanical stability of the regenerators is expected to be much better than that of beds packed withspheres. It is anticipated that the cost of manufacture using the MCS technology will be significantly lower because of much higher yieldscompared to the traditional sphere production andspherical regenerator beds packing
Keywords: Regenerator, Cryocooler

I. INTRODUCTION

The large demand for compact, energy efficient and powerful Cryocooler is driven by recent developments in infrared sensor detection technology, conductive cooling of conventional super-conducting magnets for MRI systems, and wireless communications, where further increases of tower capacity and transmission quality require superconducting-electronics based filters and preamplifiers. Current applications of cryogenic regenerative materials and regenerative heat exchangers include small cryogenic refrigerators (cryocoolers), such as Stirling, Gifford-McMahon, and pulse tubes to reach and maintain temperatures between 4.2 and 100 K at cooling powers ranging from100 mW to100W.

Regenerators are exceptionally suitable for conditions that occur in heat engines and cryogenic coolers. The three most important requirements to regenerator matrix are: 1) a maximum thermal storage capacity; 2) a maximum surface heat transfer area; and 3) a minimal hydraulic resistance to the fluid flow.

Thermal storage capacity of a cryogenic regenerator matrix is proportional to the heat capacity of a regenerator material and, therefore, successful candidate materials must have large heat capacity. The heat capacities of conventional solid regenerator materials such as stainless steel or bronze or lead rapidly decrease with decreasing temperature below ~70 K. This limits practical application of stainless steel and bronze to temperatures above ~50 K and lead to temperatures above ~10 K.

The critical parameter defining the effectiveness of a regenerator packing is the ratio of the heat transfer surface area to the fluid pressure drop. In theory, the best design for regenerators is a matrix with multiple micro channels. It has a highest ratio of heat transfer area to pressure drop. An attemptto use this approach has been utilized in ribbon regenerators, where the channels are formed by either dimpling or embossing the ribbon and then winding it on a mandrel. Unfortunately, the advantages of higher thermal efficiency never have been practically achieved with the ribbon re-generator because of channel tortuosity and associated maldistribution of the flow through the channels. If the core passages are uniform and the flow is laminar, the regenerator compactness can be expressed as

$$C = (4\,p\,Nu)/D^2 \tag{1}$$

Where,

p = core porosity (dimensionless)

Nu= h D / k, the appropriateNusselt number for laminar flow (dimensionless)

$D=4A_{ff}/\Pi$,the hydraulicdiameter of a core passage (m)

A_{ff}=free-flow area of the passage (m)

Π=wetted perimeter of the passage (m)

Equation (1) shows an inverse-squared dependence of core compactness on the passage hy-draulic diameter. This means that if everything else is held constant, the regenerator compactnesswill increase dramatically as the diameter of core passages is decreased.

If the regenerator is made as a solid block with straight microchannels or regularly stackedseries of perforated plates, its effectiveness may be significantly increased. The problem is thatthere are no techniques for fabricatingsuch kind ofstructures from brittle magnetic intermetallics Should the technique bedeveloped, it may result in the creation ofhigher efficiency low tempera-ture (near and below 10 K) regenerators.The objective of this work is to demonstratea novel approach for fabrication ofhigh-efficiencymicrochannel cryocooler regenerators from rare-earth magnetic intermetallics and other materials.

II. EXPERIMENTAL TECHNIQUES

Fresh ingots of LM25 of about 600 gms weight were meltedin crucible type electrical resistancefurnace. Melting was carried out under cover flux. Just prior to pouring N2 was used as degaser.Lime coated clean iron tools were used. The molten metal was stirred by graphite rods and waspoured in metal mould to 200^0 C in order to overcome chilling effect. Finally metal mouldcasting was obtained. Then after Solution treatment was carried out at $540+5^0$C for 4 hours.Samples were quenched in water and ageing was carried out at 160^0C for 12 hrs. Samples formetallographic observation were prepared by grinding on emery paper using kerosene as lubricant. Those were then polished on sylvtan cloth with Al_2O_3 abrasive powder. Samples werethen etched with 0.5%HF solution. Etched samples were then observed at 250X and 500 Xmagnifications on Neophot-2. The samples prepared for Metallography studies were also usedfor hardness testing. Hardness was measured on vicker hardness. Tensile test was measured onUniversal tensile testing. UTS was found with the help of initial diameter of samples.

III. RESULTS

Table.1Tensile Test &hardness of as cast and heat treated unalloyed A356

Samples	Ultimate Tensile strength Kg/mm2	%Elongation	Hardness VHN	Q index
A356 (Unalloyed)	165.4	2.30	72	219.65
A356 +T6	237.1	1.48	88.33	262.63

Microstructure Observation:

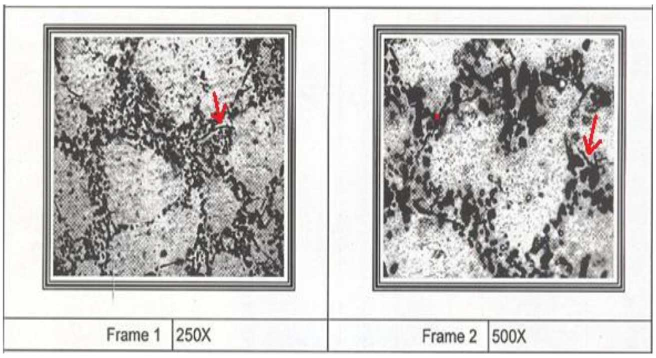

Figure 1: Unalloyed A-356

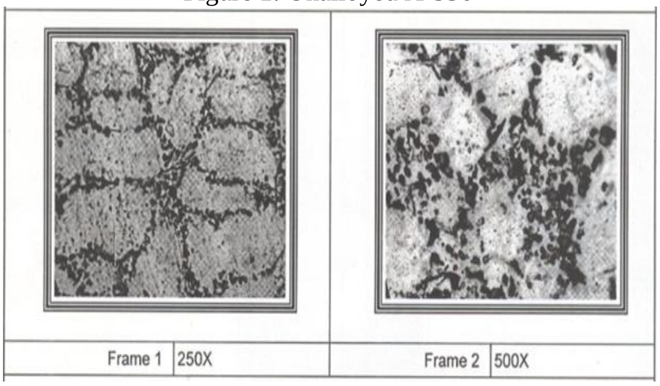

Figure 2.: A356 with 12 hrs Ageing

Microstructural Observation By Scanning Electron Microscope:

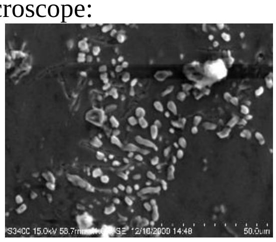

Fig 3:A356 as cast1.00k

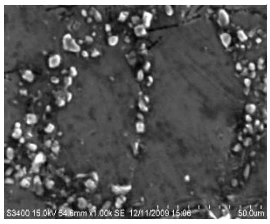

Fig 4:A356 12hrs ageing 1.00k

Microstructure Of Tensile Fracture Samples Using Sem:

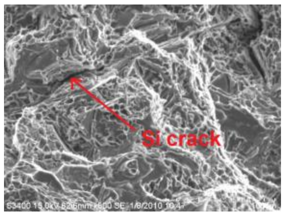

Fig 6: A356 500x

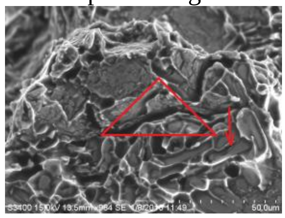

Fig 7:A356after ageing 1.00k

Result discussion

The results of ultimate tensile, hardness and elongation measurement are shown in above table1. Here we can observe that after 4 hrs of solution treatment and 12 hrs of ageing process ultimate tensile strength and hardness increases. In A356 pure alloy the value of ultimate tensile strength (UTS) increases from 165.4 to 237.1 Kg/mm2 and hardness increases from 72VHN to 88.33VHN as compared to as cast A356. In unalloyed 356 because of lower alloying elements that contributing to the formation of precipitates during aging process such as Mg, aging process did not high effect on the improvement of the mechanical properties clearly state the units for each quantity in an equation.

Fig. 1 consists of dendrite of primary α-Al phase together with interdendritic Al-Si irregular eutectic. Due to rapid rate of casting in metal mould, the majority of the eutectic silicon phase exhibits a modified morphology which is fibrous, and a small fraction of eutectic silicon phase has a coarse acicular shape. Intermetallic phase such as iron-rich phase may be observed at 500 X (indicated by arrowed in fig. 2). After a solution treatment at 5400 C for 4 hrs all the fibrous silicon particles are transformed in to spherical shape as shown in fig.2.the dendrite arm spacing is to be reduced after ageing.

Fig.3 shows microstructure of A356 sample without heat treatment at different magnification alloy without addition of grain refiner/modifier inoculants. It is clear from the Fig.3 at 1000 X that the microstructure consists of coarse α-Al dendrites (~50 μm in size) together with large plate like eutectic silicon needles in the interdendritic regions. It is well-known that this kind of microstructure is detrimental to the mechanical properties of the A356 alloy. After 12 hrs of ageing microstructure indicates uniform distribution rounded Si particles and its spherodisation (fig.4).

To better understand the failure mechanism of the castings under various loading conditions, the fracture surface of each specimen was examined with a scanning electronic microscope. The SEM of the tensile test specimen of the three cast alloy with and without heat treatment is shown in fig 6. Fracture surface are mainly composed to ductile fracture and cleavage fracture region are hardly observed in fig 6. There are some siliconcracks indicated by a mark in fig 6. in as cast unalloyed 356. Before heat treatment a number of small dimples, which is a typical characteristic of the ductile fracture, can be easily recognized. Studies have found that the fracture of cast aluminium alloys is often initiated by the cracking of silicon particles. [6]. Hence Si size, shape and distribution plays major role in the properties of Al-Si alloy.

IV. CONCLUSION

Mechanical Properties improved after ageing process. The SDAS after solidification have an influence on when the aging peak isachieved. A small value of SDAS provides a faster time for the alloy to reach theaging peak.

REFERENCES

[1] Liu Yao-hui"High temperature friction and wear behaviour of Al2O3 and/orcarbonshortfibre reinforced Al–12Si alloy composites,2004,pp.275-285.
[2] U.S geological survey http://minerals.usgs.gov/ds/2005/140/aluminium.pdf H.
[3] On the uniform elongation of cast Al–7%Si–0.6%Mg (A357) alloysNikolaos D. Alexopoulosa, Murat Tiryakio˘glubJ.
[4] Aluminium die casting alloys: alloy compostion and microstructure, andproperties –preformence relationship. L. Wang, M. Makhlouf, and D. Apelian
[5] Microporosity formation in Al-Si-Cu-Mg casting alloyG.A Edwards, G.K Sigworth, C.H Caceres, D.H ST John, J Barresi
[6] M.N.Mazlee, Study of fracture of recycled aluminium alloys from automotive component,Feb 2007.

