Thermal stability of cast Aluminium-Cerium based alloys

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Abstract

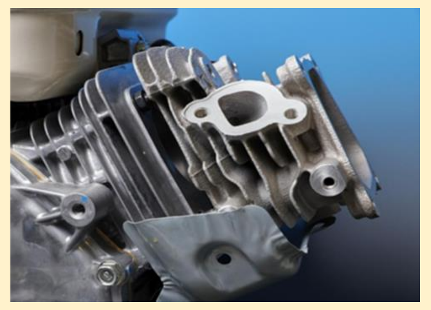
The present study deals with the investigation of thermal stability of Aluminium-Cerium based alloys produced by two different casting routes - gravity casting and suction casting. This class of cast aluminium alloys have generated interest due to its excellent castability and good mechanical properties at elevated temperatures. In the present study, aluminium alloys with cerium as the primary alloying element was developed. Silicon and Magnesium were added to Al-Ce alloy to form ternary alloys (Al-Ce-Mg and Al-Ce-Si) and quaternary alloys (Al-Ce-Mg-Si). The quaternary alloy exhibited significantly higher hardness as compared to ternary alloys for both the casting routes. It was observed that quaternary alloy responds to isothermal T6 heat treatment with the alloy showing a peak hardness. On the other hand, the ternary alloys did not show any significant change in hardness implying thermal stability at the temperatures investigated. The thermal stability of alloys were investigated in the temperature range of 100 - 400 °C and discussed in light of various intermetallic compounds formed in the alloys.

Introduction

For more than three decades, development of aluminium alloy with improved strength at high temperatures has been a continuing goal. Aluminium has wide applications in automotive industry owing to its low weight. Due to the availability and the price fluctuation currently available high-performance permanent magnet are of high concern. Recent research works have shown that binary Aluminum-Cerium (Al-Ce) and ternary Al-Ce-Mg alloys can be used for high temperature applications in automotive industry.

Important properties: expected

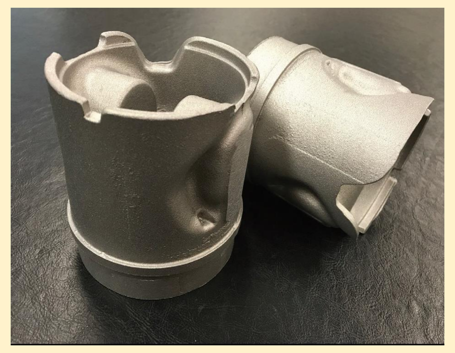
Higher Operating Temperatures,Castability,High strength, High corrosion resistance, good Mechanical Properties



(a) Cylinder head cast using the Al-Ce alloy

(b) Rotary engine rotor

(c) An engine cylinder using Al-Ce alloy



(d) Pistons

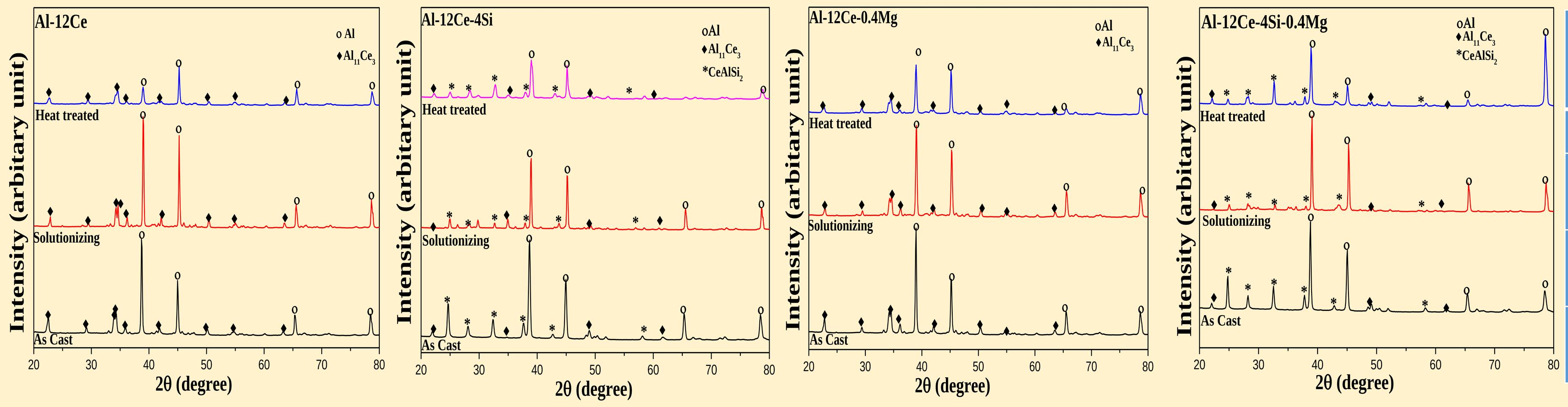
Experimental Details

S.NO	Alloys	Master alloys
1	Al-12Ce	CPAL+ Al-20Ce
2	Al-12Ce-4Si	CPAL+ Al-20Ce+ Al-52Si
3	Al-12Ce-0.4Mg	CPAL+ Al-20Ce+ Al-20Mg
4	Al-12Ce-4Si-0.4Mg	CPAL+ Al-20Ce+ Al-52Si+ Al-20Mg

- CPAl+ Ce
- Melted in a graphite crucible (785 ºC)
- Mild Steel mould
- Heat treated at 537 ºC for 8 h, water quenching and aging at 155 ºC for 0,2,4 and 8 hours respectively
- Characterization by optical microscopy and Vickers hardness
- Metallography and characterization by optical microscopy, XRD and FESEM
- Vickers hardness, Load=100gf, dwell time=10s

Results and Discussion: XRD

XRD of Cast, Solutionising and heat treated Al-12Ce-X alloy:



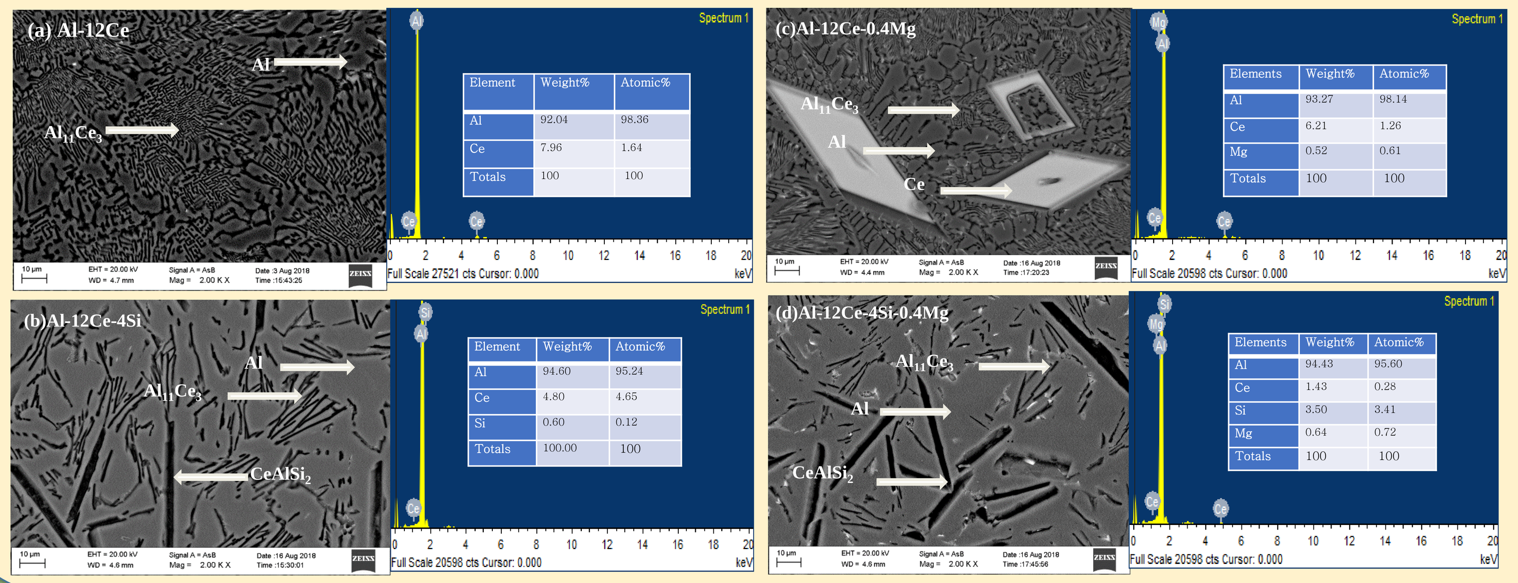
Phase fraction of cast and heat treated Al-Ce-X alloys:

Sl. No	Alloy	f_{Al}		$f_{Al11Ce3}$		$f_{CeAlSi2}$	
		AC[a]	HT[b]	AC	HT	AC	HT
1	Al-12Ce	0.81	0.76	0.18	0.23	--	--
2	Al-12Ce-4Si	0.72	0.69	0.03	0.06	0.24	0.23
3	Al-12Ce-0.4Mg	0.82	0.76	0.17	0.30	--	--
4	Al-12Ce-4Si-0.4Mg	0.70	0.71	0.04	0.05	0.25	0.23

- After heat treatment, the phase fraction of $Al_{11}Ce_3$ value increases while the phase fraction of Al is observed to decrease.
- The alloy Al-12Ce-4Si-0.4Mg doesn't varies much. However, a very high peak shift is found towards the end.

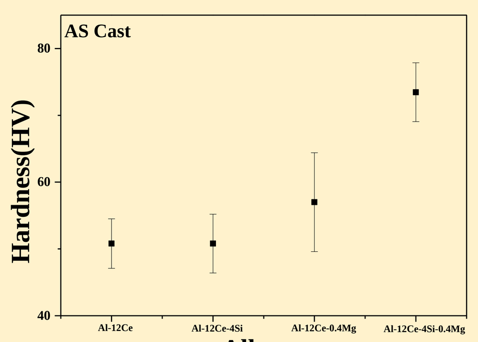
Results and Discussion: Microstructure and Hardness

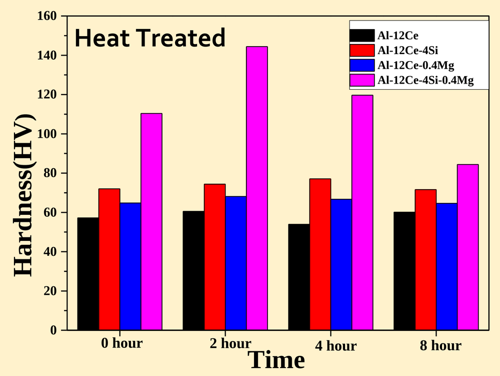
Microstructure and EDX of Al-12Ce-X alloys:



- Al-Ce shows Al matrix as well as eutectic intermetallic $Al_{11}Ce_3$ in a Chinese script like structure.
- EDX confirms the presence of Al and Ce
- Addition of silicon- one new inter- metallic is formed as $CeAlSi_2$ as acicular (needle like) eutectic structure
- The Mg does not forms any intermetallics, but is found to be in precipitate state.
- Addition of both Mg and Si, the microstructure is observed to change a little, with white spots attributing to the presence of Mg in precipitate form

As cast and heat treated microhardness of (a) Al-12Ce (b) Al-12Ce-4Si (c) Al-12Ce-0.4Mg (d) Al-12Ce-4Si-04 Mg





	Al-12Ce	Al-12Ce-4Si	Al-12Ce-0.4Mg	Al-12Ce-4Si-0.4Mg
As cast condition	50.8±3.8	57.1±7.4	50.9±4.4	73.5±4.4
Solutionised condition	57.2±3.0	72±4.2	64.8±5.5	110.4±11.0
Ageing at 155 ^{0}C for 2h	60.5±3.5	74.4±7.4	68.1±5.6	114.4±9.3

- Ageing at 155^{0}C for 2 hours- slight increase in the hardness.
- With heat treatment at different temperatures and longer times- increase the hardness of the alloys.

Conclusions

- The combined addition of Silicon and Magnesium to binary Al-12Ce alloy results in maximum increase in hardness.
- The alloy is characterized by the presence of intermetallics like $Al_{11}Ce_3$ and $CeAlSi_2$ as confirmed by the XRD.
- On the other hand, EDX confirms the presence of Al, Ce, Si and Mg. Also, it can be concluded that the time to attain peak hardness in alloys depend on alloy composition.

References

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