The ?-al grains. figure 2: identification of

The addition of Al-5Ti-1B master alloy (2 wt.%, 4 wt.% and 6wt.%) effectively modify and refine both the ?-Al and eutectic Si phase (Fig. 1(b)-1(d)). The alloy with 2 wt.

% Al-5Ti-1B master alloy has some globular ?-Al grains with dendritic morphology and a fibrous eutectic Si phase with large spacing (Fig. 1(b)). Further, theAl-7.

6Si-4 wt.% Al-5Ti-1B alloy has more amount of globular ?-Al grains and a fine fibrous eutectic Simorphology with least spacing compared to the 2 wt.% Al-5Ti-1B added alloy (Fig. 1(c)) The average size ofthe ?-Al grains are decreased and roundness (degree of sphericity (DOS)) of the ?-Al grain increases, when theconcentration of the Al-5Ti-1B master alloy is increased from 2 wt.% to 4 wt.% (Fig. 3).

The average ?-Al grainsize and DOS were measured by ImageJ image analysis software and calculated according to the equation (1)and (2) 21-22. Grain Diameter (GD) = 2 Ag ? (1)Roundness (R) = ? 4? Ag Pg2 ? (2)Where Ag and Pg are the area and perimeter of the ?-Al grains. Figure 2: Identification of eutectic Si by SEM based EDS spot analysis in the Al-7. 6Si alloy.

But, the alloy with 6 wt.% Al-5Ti-1B master alloy has more dendritic ?-Al grains with less roundness and thespacing of fibrous eutectic Si is more as compared to the Al-7. 6Si-4 wet.% Al-5Ti-1B alloy (Fig.

1(d)). Theaverage size of the ?-Al grains is also comparatively large and roundness is less (Fig. 3).

This may cause ofover modification of the alloy. Figure 3: The roundness and average diameter of ?-Al grains variation of Al-7. 6 Si alloy with differentadditions of Al-5Ti-1B grain refiner. Furthermore, the X-ray diiffratoragram of the Al-7. 6Si alloy (Fig.

4(a)) and the Al-7. 6Si-6 wt.%Al-5Ti-1Balloy (Fig. 4(b)) shows the presence of ?-Al and Si peaks, while the 6 wt.

% Al-5Ti-1B master alloy added alloyhas the peaks of titanium boride (TiB2) apart from the ?-Al and Si peaks. The TiB2 processes HCP structurewith a lattice parameter aTiB2 = bTiB2= 3. 034 Å cTiB2= 3.

226 Å 23 and the crystal structure of aluminium is FCCwith a lattice parameter aAl = 4. 0497 Å 24. The FCC aluminium matrix has (111) closed packed planematching with (0001) closed packed plane of the HCP TiB2. The closed packed direction on (0001) plane is2110 and the interatomic distance is aTiB2. Further, interatomic distance in close-packed 110 direction on(111) plane is aAl 2 and misfit parameter or disregistry is 0. 056. Therefore, the TiB2 will act as potentialnucleation sites of ?-Al grains during solidification.

The modification and the refinement of both the phasesoccur due to the formation of the TiB2 in the grain refined alloy. Figure 4: The XRD pattern of (a) Al-7. 6Si alloy and (b) Al-7. 6%Si-6 wt.% Al-5Ti-1B alloy. 3. 2 HardnessThe bulk hardness of the alloys and composites generally depends on the morphology and the volume fractionof different phases of the alloys 25. Figure 5 shows the bulk hardness of the devolved alloys as a function ofAl-5Ti-1B concentration.

The bulk hardness of unmodified alloy is approximately 46 VHN, but the modifiedalloys have a bulk hardness around 65VHN to 74VHN. This increase in hardness is caused by themicrostructural morphology changed, such as globular ?-Al grains and fibrous eutectic Si phase formation inthe modified alloy. The Al-7. 6Si-4. wt% Al-5Ti-1B alloy has high hardness compare to other modified alloybecause it has more globular fine ?-Al grains and fibrous eutectic Si phase with low spacing. Figure 5: Bulk hardness variation of Al-7. 6 Si alloy with different additions of Al-5Ti-1B grain refiner.

3. 3 Mechanical propertiesFigure 6 shows the UTS and percentage elongation of the Al-7. 6Si alloy as a function of Al5Ti-1B grain refinerconcentration. The un-modified Al-7. 6Si alloy has UTS value of 108MPa and % elongation value of 6. 60 %. The grain refinement of Al-7. 6Si alloy by the addition of 2.

0 wt.% Al-5Ti-1B grain refiner resulted in 33. 3%and 47. 5% improvement of UTS and % elongation values.

The 4 wt.% Al-5Ti-1B refined alloy has relativelymore improved UTS (58. 3%) and elongation (101.

5%). But, further increase in the Al-5Ti-1B refinerconcentration to 6 wt.% the UTS and elongation values are slightly decreased compared to previouscomposition but, much higher than the unrefined alloy.

This improvement of the UTS and ductility attribute tomicrostructural refinements such as fine globular ?-Al grains and fibrous eutectic Si phase with low spacing (asdiscussed in section 3. 1)Fig. 6: UTS and % elongation of Al-7. 6 Si alloy as a function of Al-5Ti-1B grain refiner concentration.

Figure 7: Secondary electron images of the fractured surface (a) Al-7. 6Si (b) Al-7. 6Si-2 wt. % Al-5Ti-1B (c)Al-7. 6Si-4 wt. % Al-5Ti-1B and (d) Al-7.

6Si-6 wt. % Al-5Ti-1B alloy. 3. 3 Fracture SurfaceFigure 7 exhibits the fracture surface of the developed alloys. In the present study, various structural defects(micro-porosity and microcrack) and sharp corners of eutectic Si are the suitable sites for failure initiation(Figure 7(a)-(d)).

Then the crack propagates through the eutectic Si particles by means of cleavage fracture ofthe eutectic Si particles (Figure 7(a)-(d)). However, a combined mode of brittle and ductile fracture with dimpleformation has been found in the fracture surface of the developed alloys. The factrograph of the unmodifiedalloy has mainly cleavage facets of coarser and dendritic eutectic Si particles (Figure 7(a)).

Whereas, the grainrefined alloys have a very less number of cleavage fracture of eutectic Si as the plate-like and needle-likeeutectic Si transformed into fibrous morphology. The decohered particles are observed in the grain refined alloyand the dimple formation is increased (Figure 7(c)-(d)). The fracture surface factrograph has a great agreementwith the microstructural morphology and mechanical properties of the developed alloys. 4. ConclusionEffect of the Al-5Ti-1B grain refiner addition on the microstructure, mechanical properties and fracturebehavior of the hypoeutectic Al-7. 6Si alloy has been studied and following conclusion are drawn:? The cast unmodified hypoeutectic Al-7. 6 Si alloy consisting of a needle and rod-like eutectic Siparticles with very sharp corners inside the ?-Al phase and the ?-Al phase is present as like a matrixphase.

? The grain refined alloys have globular ?-Al grains and a fibrous eutectic Si phase.? The bulk hardness, ultimate tensile strength (UTS) and elongation (%) of the modified alloy areincreased as compared to the unmodified alloy.? Addition of 4 wt.% of Al-5Ti-1B grain refiner to the Al-7. 6Si alloy gives the smallest grain size andhighest roundness of ?-Al grains compare to the 2 wt.

% and 6 wt.% Al-5Ti-1B added alloy. As aresult, the Al-7. 6Si alloy with 4 wt. % Al-5Ti-1B grain refiner has the highest strength (171 ? 2), ductility (13. 3 ? 0. 4) and hardness (73. 8 ? 0. 5)? The cleavage fracture and brittle fracture are reduced in the modified alloy and fine dimple formation isincreased.