Microstructure and Mechanical Properties of DC Cast 7065 Aluminum Alloy

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Abstract. The microstructure and mechanical properties of 7065 alloy was investigate in this present work. The main intermetallic phases of the 7065 alloy identified by EDS analysis were \((\text{Mg,Cu})_2\text{Zn}, \text{Al}_2\text{Cu}\) and \(\text{Al}_7\text{Cu}_2\text{Fe}\). The microstructure of the 7065 alloy after hot rolling mainly consists elongated fibrous grains containing sub-grains, indicating that dynamic recovery is the primarily mechanism during hot rolling. The 7065 alloy has lower quench-sensitive and higher mechanical properties than that of the 7050 alloy.

1. Introduction
The 7000 series alloys, typically as 7075, 7050, 7055 and 7085 alloys, are based on the Al-Zn-Mg system. They have a combination of high strength and fracture toughness as well as resistance to stress corrosion cracking by proper heat-treatment. These alloys are very useful in the aircraft and aerospace industry applications [1-3]. 7050 alloy is the most popular aluminum material among which for structural parts. Recently, a novel 7065 alloy was developed based on these alloys, which exhibits higher comprehensive properties such as strength, toughness, corrosion resistance, lower quench sensitive, etc. However, the investigation on the microstructure and mechanical properties of the 7065 alloy is seldom being reported. The aim of this present investigation is to study the microstructure and mechanical properties of a DC cast 7065 alloy.

2. Experimental procedure
The 7065 alloy (nominal chemical composition is listed in Table 1) was prepared using 99.94wt% pure Al, 99.92wt% pure Mg, 99.99wt% pure Zn, Al-49.7wt%Cu, Al-5wt%Zr and Al-5wt%Ti master alloys. The alloys were melted in an induction furnace and DC cast to produce slabs 200mm×600mm in cross-section with a pouring temperature of 780°C and casting velocity of 2.5 mm/s. After degassing, certain amount of Al-5wt%Be master alloy was added to the melt at the temperature of 800°C, then held for 20 min before casting. The slabs were homogenized at 470°C for 14h and follow by air cooling. The slabs were scalped to 190mm in thickness, then heated to 440°C and hot-rolled to plates with thickness of 76mm. The plates were solution heat-treated at 473°C for 2h, quenched in room
temperature water, and aged at 163℃ for different times (4h, 8h, 12h, 16h).

Table 1. Nominal chemical composition of the 7065 alloy (wt.\%)

| Alloy  | Zn  | Cu  | Mg  | Zr  | Others |
|--------|-----|-----|-----|-----|--------|
|        |     |     |     |     | each  |
| 7065   | 7.6 | 2.1 | 1.7 | 0.1 | 0.05   |
|        |     |     |     |     | total  |
|        |     |     |     |     | 0.15   |
|        |     |     |     |     | Balance|

The metallographic samples were mechanically ground and polished using standard routines. The deformed specimens were observed on the mid-thickness along the plane formed by the rolling (RD) and normal (ND) directions (RN plane). Samples were electropolished using 5\% perchloric acid in methanol at 0℃ and 20V. Microstructures were examined by scanning electron microscopy (SEM) using a ZEISS EVO 18 instrument operated on secondary electron and backscattered electron model. EBSD measurements with step size of 1 \( \mu \)m were carried out using a ZEISS EVO 18 instrument with HKL channel 5 software. In the data presented, high angle boundaries (HABs) were defined as having misorientations greater than or equal to 10\(^\circ\) and low angle boundaries (LABs) were defined as having misorientations of 2\(^\circ\)~10\(^\circ\).

Room temperature tensile test specimens with 10 mm in diameter and 50 mm in gage length were machined according to the standard of ASTM B557-06. A SANS CMT testing machine was used for the tensile test at a constant crosshead speed of 1 mm/min. The tensile property data for each condition was the average from the measurements of three specimens.

3. Results and discussion

3.1 Microstructure

The SEM micrograph (in back-scattered electrons mode) of the as-cast and homogenized 7065 alloy are shown in Fig.1(a), (b) and Fig.1(c), (d), respectively. The as-cast microstructures comprise \( \alpha \)-aluminum dendrite with Al-Cu-Mg-Zn eutectics and coarse intermetallic compounds segregated into the interdendritic regions. Fig. 1(b) exhibits that the extremely fine intermetallic phases are light gray in color. The main intermetallic phases identified by EDS analysis were (Mg, Cu)\(_2\)Zn, Al\(_2\)Cu and Al\(_2\)Cu\(_2\)Fe. As is shown in Fig.1 (c) and Fig.1 (d), after homogenization, the \( \alpha \)-aluminum dendrite transforms to equiaxed crystals, and the coarse intermetallic compounds dissolve into the \( \alpha \)-aluminum, extensive fine particles precipitated into the \( \alpha \)-aluminum matrix during cooling from homogenization.

In order to evaluate the result of homogenization, image tool was used to calculate the second phase volume. Fig.2(a) and Fig.2(b) shows the second phases grabbed by the image tool in the as-cast and homogenized states, respectively. The second phase (larger than 20\( \mu \)m) volume of the as-cast is 3.455\%, while the homogenized state is 0.088\%. 

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Figure 1. Microstructure of the 7065 alloy: (a) and (b) as-cast; (c) and (d) homogenized

Figure 2. Second phase volume of the 7065 alloy: (a) as-cast and (b) homogenized

The microstructure of the alloy after rolling is shown in Fig. 3. It can be seen from Fig. 3(a) that the equiaxed α-aluminum crystals transformed to elongated fibrous grains structure after hot rolling. In high magnification of Fig. 3(b) we can see that there are extensive fine grains, about 2 to 10 μm in length, distributed in the matrix, which seems that the process of dynamic recrystallisation occurred during hot rolling.
Figure 3. Microstructure of the 7065 alloy after hot rolling:
(a) low magnification; (b) high magnification

The grains and the boundaries nature of these fine grains generated by hot rolling are analyzed by EBSD technique shown in Fig.4. In the maps, HABs (≥10º) and LABs (2-10º) are represented by dark and light lines, respectively. It can be seen that there are lots of LABs in the matrix, indicating that the structures in Fig.3(b) are sub-grains rather than recrystallized-grains. It is generally believed that dynamic recovery instead of dynamic recrystallization commonly occurred during hot deformation of Al and its alloys as a result of their high stacking fault energy. However, observation of DRX was reported in Al and its alloys [4-7]. In the present study, the microstructure after hot rolling mainly consists elongated fibrous grains containing sub-grains, indicating that dynamic recovery is the primarily mechanism during hot rolling.

Figure 4. EBSD typical all Euler image maps of the 7065 alloy samples on RN plane:
(a) as-rolled; (b) after heat treated

3.2 Tensile properties
The tensile properties of the 7065 alloy as a function of aging time is shown in Fig.5. As can be seen, the strength of the alloy aged at 163°C increases with increasing aging time and achieves peak value of ultimate tensile strength of 590 MPa after 12 h of aging, and then the tensile strength gradually decreases with the increasing aging time. In contrast, the elongation of the alloy decreases with the increase of aging time from 4 h to 24 h. As is well known, the strength and the plasticity of a material are usually contradictable.

Tensile properties of the 7065 alloy compare with that of the 7050 alloy is shown in Fig.6. These two alloys were produced with the same method and underwent the same heat treatment, tensile
samples were cut from mid-thickness the of the plate. The ultimate tensile strength of the 7065 alloy is 40MPa higher than that of the 7050 alloy, while the yield strength of the 7065 alloy is 50MPa higher than that of the 7050 alloy, indicating that the 7065 alloy has lower quench-sensitive and higher mechanical properties than that of the 7050 alloy.

Figure 5. Tensile properties of the 7065 alloy aged at 163°C for different aging times

Figure 6. Tensile properties of the 7065 alloy compare with that of the 7050 alloy

4. Conclusions
Microstructure and mechanical properties of 7065 alloy was investigated, the conclusions are given as below:

1. The main intermetallic phases of the 7065 alloy identified by EDS analysis were (Mg,Cu)\textsubscript{2}Zn, Al\textsubscript{2}Cu and Al\textsubscript{2}Cu\textsubscript{2}Fe.

2. The microstructure of the 7065 alloy after hot rolling mainly consists elongated fibrous grains containing sub-grains, indicating that dynamic recovery is the primarily mechanism during hot rolling.

3. The 7065 alloy has lower quench-sensitive and higher mechanical properties than that of the 7050 alloy.

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References
[1] Immarigeon J P, Holt R T, Koul A K, Zhao L, Wallace W, Beddoes J C 1995 Mater. Charact. 35 41
[2] Heinz A, Haszler A, Keidel C, Moldenhauer S, Benedictus R, Miller W S 2000 Mater. Sci. Eng. A 280 102
[3] Williams J C, Starke E J A 2003 Acta Mater. 51 5775
[4] Yamagata H 1992 Scripta Metall Mater 27 201
[5] Kaibyshev R, Shipilova K, Musin F, Motohashi Y 2005 Mater. Sci. Eng. A 396 341
[6] McQueen H J, Evangelista E, Bowles J, Crawford G 1984 Met. Sci. 18 395
[7] Gholinia A, Humphreys F J, Prangnell P B 2002 Acta Mater. 50 4461