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Effects of Magnesium on Precipitated Phase in 7150 Aluminum Alloy Based on Thermodynamics

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Abstract: This paper has systematically investigated the effect of magnesium on the amount of major precipitated phases in 7150 aluminum alloy by Calculation of phase diagram based on thermodynamics. From the phase diagrams of different Zn content that are drawn in temperature (℃) and magnesium (wt %) Cross-section, it can be found that the diagrams do not change basically when the content of Zn is small, but when the content of Zn gets to 6.4(wt%) the phase diagram appearance changes a lot . The results indicate that with the content of Mg increase, the mass of the primary phase $MgZn_2$ rises lightly at first and descend quickly, the mass of SPHASE phase increases to the top value then fall, the mass of $CuAl_2$ and $AlZr_3$ change trend is resemble, they all have liner relationship with the content of Mg. The amount of the QPHASE phase rises all the time until attain to a top point. These results can be used to design the chemical composition of 7xxx aluminum alloy.

Key words: *Magnesium; CALPHAD; Precipitated phase*

1. Introduction

The 7000 series alloys, based on the Al–Zn–Mg system, have a combination of high strength and fracture toughness, as well as resistance to stress corrosion cracking that renders them very useful in the aircraft and aerospace industry applications [1-3]. Increased strength of these alloys was anticipated by increasing Zn, Mg, and Cu concentration, as these are the principal basis of precipitation strengthening, but at the same time lowers the hot workability [4]. 7150 aluminum alloy, higher fracture toughness, SCC resistance and strength than that of 7050 alloy, has been developed [1,5]. As we all known, the performance of alloy is determined by its microstructure while microstructure is mostly determined by its composition, so how to select the components and the mass of the components of the alloy is very important to design an excellent alloy.

Magnesium in the aluminum alloy is a strengthening element, magnesium in the aluminum solid solution in a great degree, and the atomic radius of Mg is13% larger than that of aluminum. When a lot of magnesium element dissolves into the aluminum alloy, it can make α (Al) lattice larger distortion, so it has a high solid solution strengthening role [6]. Therefore on the composition design of 7xxx aluminum alloy, the design of magnesium is a very important aspect. In this study, through the thermodynamic calculation of phase diagram from the thermodynamic point of view to discuss the content of magnesium in 7150 aluminum alloy how to effect on the amount of the precipitation.

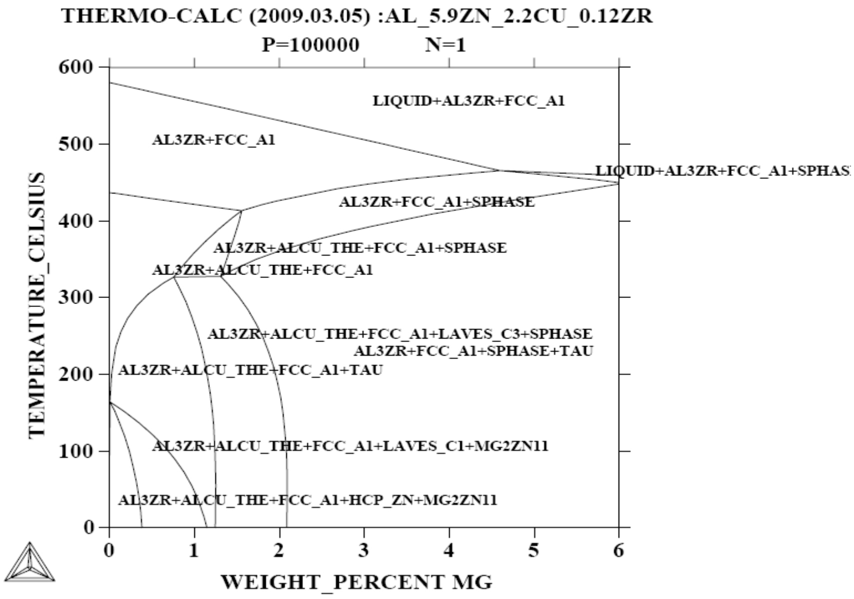
2. CALPHAD

In this paper all the calculations are taken by the thermodynamic software Thermo-Calc. In this software all the calculation is under the conditions that the sum of the alloyed elements is 1 mol, the pressure intensity is 1 standard atmosphere pressure .and mass is used for the amount of the precipitated phases. Furthermore in this system thermo-chemical properties of substances and phases are described with variable composition for temperatures from 273.15K. At the same time in this software the phases which structures are determined will generally be expressed with their structure, for example, the MgZn2 phase is showed as LAVES, and the FCC_A1 is used for α-Al[7]. All the value to use this thermodynamic calculation is in the 7150 aluminum alloy constitute range. Table1 is the 7150 chemical compositions.

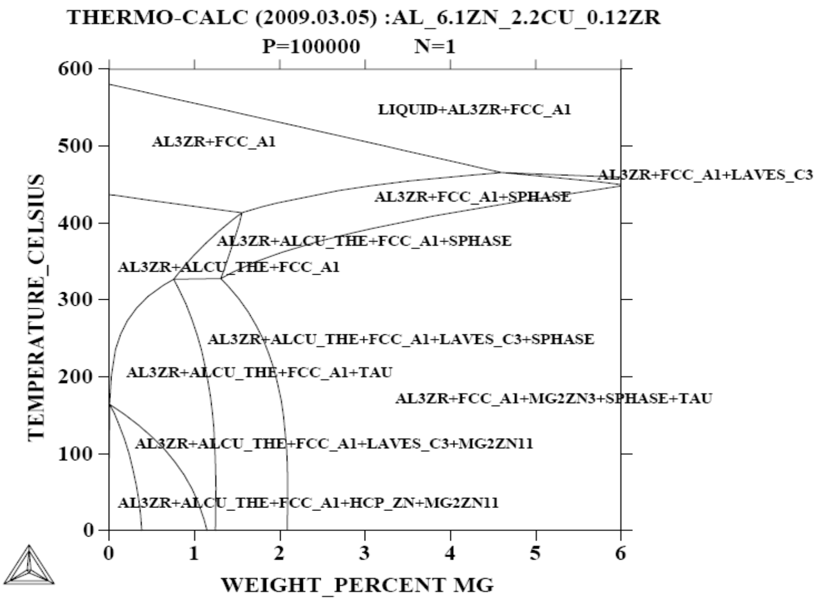
Table 1 Chemical compositions of aluminum alloy 7150 (wt %)[8]

Chemical	Zn	Mg	Cu	Zr	Fe	Si	Al
W (%)	5.9～6.9	2.0～2.7	1.9～2.5	0.08～0.15	≤0.15	≤0.12	余量

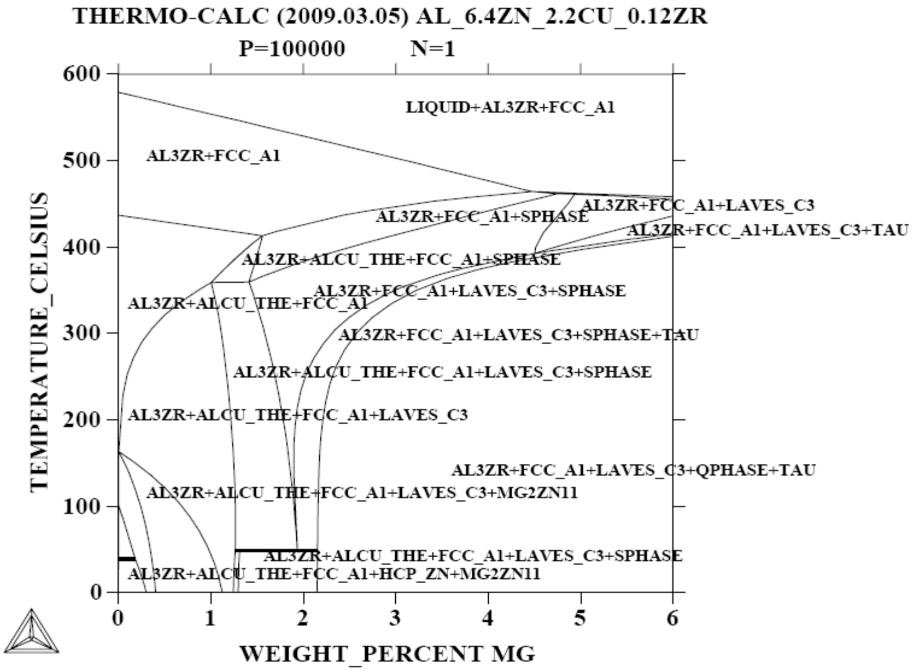
The following are the phase diagrams of different zinc content. They are drawn in temperature (℃) and magnesium (wt %) Cross-section (Fig.1). Element content is expressed as mass percentage.



(a)



(b)


THERMO-CALC (2009.03.05) AL_6.4ZN_2.2CU_0.12ZR
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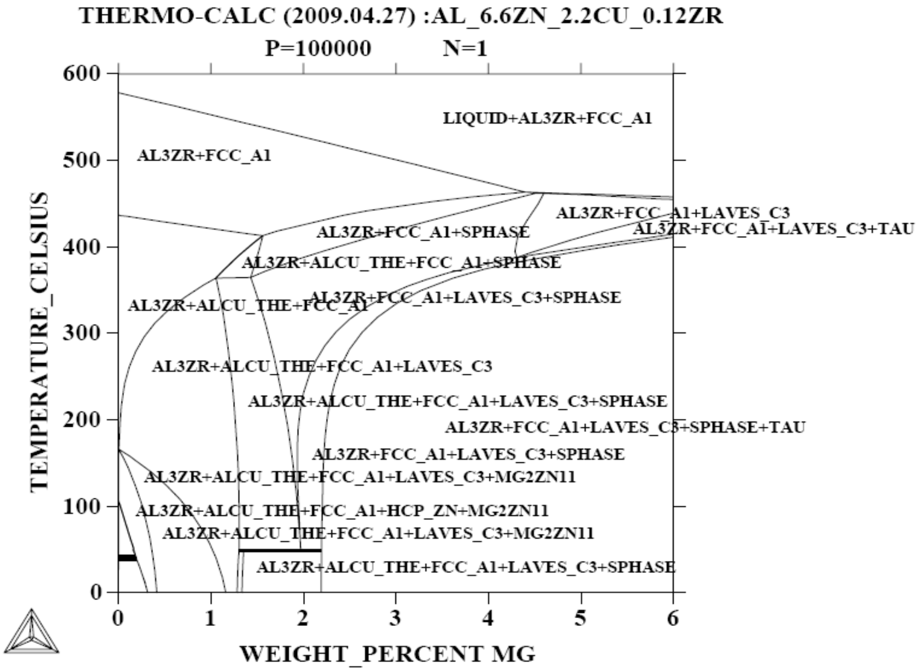
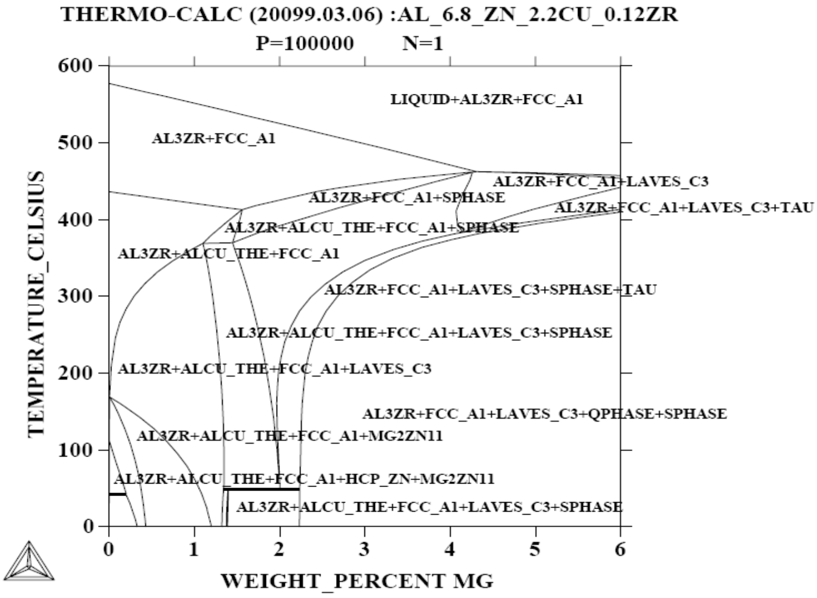
TEMPERATURE_CELSIUS
WEIGHT_PERCENT MG
0
100
200
300
400
500
600
1
2
3
4
5
6
LIQUID+AL3ZR+FCC_A1
AL3ZR+FCC_A1
AL3ZR+FCC_A1+SPHASE
AL3ZR+FCC_A1+LAVES_C3
AL3ZR+FCC_A1+LAVES_C3+TAU
AL3ZR+ALCU_THE+FCC_A1+SPHASE
AL3ZR+FCC_A1+LAVES_C3+SPHASE
AL3ZR+ALCU_THE+FCC_A1
AL3ZR+FCC_A1+LAVES_C3+SPHASE+TAU
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3+SPHASE
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3
AL3ZR+FCC_A1+LAVES_C3+QPHASE+TAU
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3+MG2ZN11
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3+SPHASE
AL3ZR+ALCU_THE+FCC_A1+HCP_ZN+MG2ZN11

(c)


THERMO-CALC (2009.04.27) :AL_6.6ZN_2.2CU_0.12ZR
P=100000 N=1
TEMPERATURE_CELSIUS
WEIGHT_PERCENT MG
0
100
200
300
400
500
600
1
2
3
4
5
6
LIQUID+AL3ZR+FCC_A1
AL3ZR+FCC_A1
AL3ZR+FCC_A1+LAVES_C3
AL3ZR+FCC_A1+SPHASE
AL3ZR+FCC_A1+LAVES_C3+TAU
AL3ZR+ALCU_THE+FCC_A1+SPHASE
AL3ZR+ALCU_THE+FCC_A1
AL3ZR+FCC_A1+LAVES_C3+SPHASE
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3+SPHASE
AL3ZR+FCC_A1+LAVES_C3+SPHASE+TAU
AL3ZR+FCC_A1+LAVES_C3+SPHASE
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3+MG2ZN11
AL3ZR+ALCU_THE+FCC_A1+HCP_ZN+MG2ZN11
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3+MG2ZN11
AL3ZR+ALCU_THE+FCC_A1+LAVES_C3+SPHASE

(d)



(e)

Fig.1 the diagrams of 7150 alloy with different Zn content ((a)5.9Zn (b)6.1Zn (c)6.4Zn (d)6.6Zn (e)6.8Zn)

From Fig.1 we can find that the diagrams do not change basically when the content of Zn is small, but when Zn content gets to 6.4(wt%) the phase diagram appearance changes a lot .If comparing the phase diagram, we can find that the diagram of more Zn content appears AL3ZR+FCC_A1+LAVES_C3,AL3ZR+FCC_A1+LAVES_C3+TAU,AL3ZR+FCC_A1+LAVES _C3+SPHASE+TAU, AL3ZR+ALCU_THE+FCC_A1+LAVES_C3+SPHASE phase field while the less content of Zn cannot find these fields, and with the content of Zn increment the whole phase diagram moves to right slightly. And at room temperature, the phase fields are sequentially AL3ZR+ALCU_THE+FCC_A1+HCP_ZN+MG2ZN11, AL3ZR+ALCU_THE+FCC_A1+LAVES _C3+MG2ZN11,AL3ZR+ALCU_THE+FCC_A1+LAVES_C3, AL3ZR+ALCU_THE+FCC_A1+ LAVES_C3+SPHASE, AL3ZR+FCC_A1+LAVES_C3+QPHASE+TAU with the increment of the content of Mg.

3. Result and discussion

The curves are drawn in order to research the effect of Mg on the precipitated phases in 7150 aluminum alloy, in which that the amount of the phases is counted at 298K and in the alloys the content of Cu and Zr are constant.

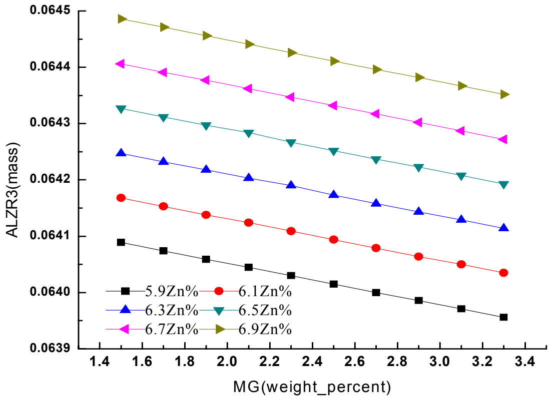


Fig 2 the variation of the amount of the phase $AlZr_3$ with the variation of the content of Mg

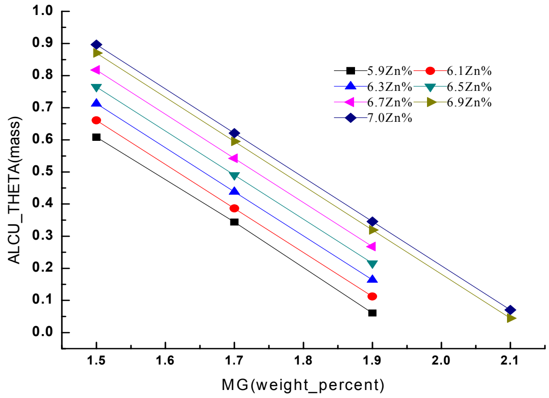


Fig. 3 the variation of the amount of the phase $CuAl_2$with the variation of the content of Mg

As can be seen from Fig.2 the mass of the $AlZr_3$ is with strong linear relation to the content of Mg .The amount of AlZr3 decreases monotonously with the increment of the content of Mg if the Zn content is definite. At the meantime if the content of Zn is higher, the phase amount is higher. This variation relation is very simple.

The Fig.3 shows that the amount of $CuAl_2$ change trend with the content of Mg increase is resemble to the $AlZr_3$. This change has a liner relationship with the content of Mg increase. For a definite Zn when the content of Mg increment, the mass of $CuAl_2$ decline. For the different content of Zn, the more Zn content, the more mass of $CuAl_2$.

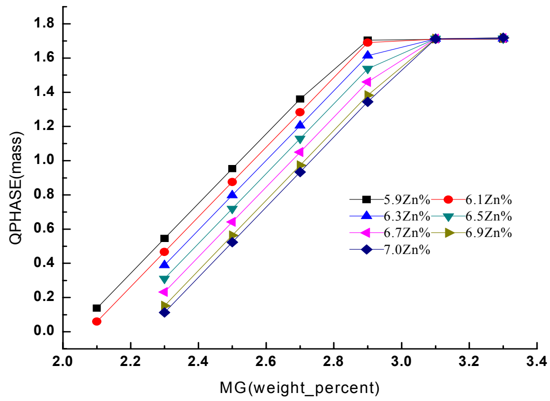


Fig. 4 the variation of the amount of the phase QPHASE with the variation of the content of Mg

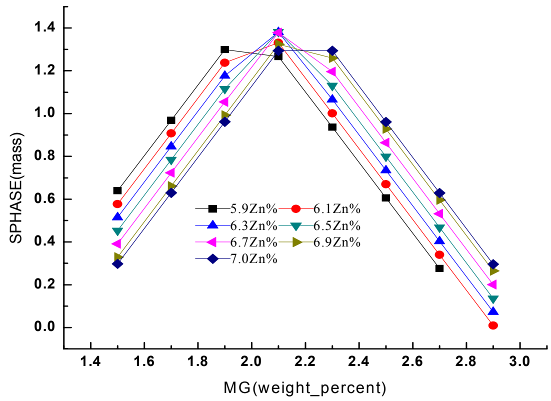


Fig. 5 the variation of the amount of the phase SPHASE with the variation of the content of Mg

From Fig.4 it can be seen that when the content of Mg increment the mass of QPHASE phase increase for a definite content of Zn, but this increase has a greatest value. For the different content of Zn but the content of Mg is certain, the amount of QPHASE is higher when the content of Zn is lower. At last all the conditions have a similar biggest value, all of the curves converge to one point.

As can be seen from Fig 5, the curve of SPHASE phase variation is discrepancy with the above phase change curves. The amount of SPHASE increment with the content of Mg increase when the content of Mg is relatively small. But when the content of Mg gets to approximately 2.2, the amount of SPHASE attains to the max, then the change trend become opposite when the content of Mg continue to increase. Another characteristic of this figure is that when the curves ascend, for the higher content of Zn the mass of phase is lower, after the largest value the higher content of Zn the mass of phase is higher.

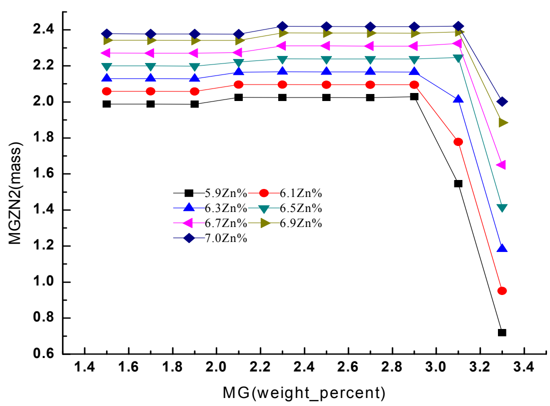


Fig. 6 the variation of the amount of the phase $MgZn_2$ with the variation of the content of Mg

Fig.6 shows the curves that the amount of the phase $MgZn_2$ various with the variation of the content of Mg, while the content of Zn is different. At any Zn content the phase mass keep a certain amount then has a slightly increase reaches to the biggest value and keep, at last the curves decline. In alloys the utmost mass of the phase $MgZn_2$ depends on the content of Zn, if the content of Zn is higher, the mass of the phase $MgZn_2$ is higher.

We all know that the chemical composition range of 7150 aluminum, but when product the alloy, we must select the optimal composition. The above thermodynamic calculation can give a guidance to solve this problem.

4. Conclusion

It can be concluded as follows through the systematic thermodynamic calculation of 7150 aluminum alloy.

(1)The amount of the phase $AlZr_3$ and $CuAl_2$ variety trend is resemble, they all decrease with the content of Mg increase.

(2)The amount of the phase QPHASE increases steadily with the increase of the content of Mg until reach to the top point and then invariant.

(3)The amount of the phase SPHASE increases to the maximum value then decreases with the content of Mg increase for the definite Zn content. When the content of Mg is definite the Zn content is more the mass of SPHASE is more before the amount of SPHASE gets to maximum then the condition became opposite.

(4)The amount of the primary precipitated phase $MgZn_2$ remain a certain value and has a little growth then decline with the content of Mg increase.

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