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Modeling of Dentrite Cooling Rate between the Temperature and the Secondary Dendrite Arm Space in Tial Intermetallic Compounds

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Abstract

According to the secondary dendrite arm space L and composition at solid and liquid interface in solidification the line model of temperature and composition in dentrite has been established. The equation is gained as T=-44,260/L to follow last study on telationship between temperature and composition. Meantime the cooling rate and the secondary arm space has been discussed. In the intersection the cooling rate of solid and liquid ΔT is gained. According to dentrite therefore the composition can determine temperature. According to Y changing from pure X to pure Y ie. The temperature will change from maximum to minimum at Al composition in materials like TiAl. The period one of cooling rate is from 10K/s to 77 K/s in speed of 4860mm/hr at the solidified length to be 50mm. For engineering use the speed is better when the speed is higher like 8,860mm/h when the cooling rate attains from 25K/s to 145K/s with the secondary arm space increasing with the maximum value. When cooling rate is 8,860mm/hr the biggest one in these three conditions will happen with 145K/s when it is 15μm. When DS is 2.4J/(mol·K) the DG changes from 1200J to -1200J with the temperature increases same in TiAl.

Keywords: Modelling; TiAl; Dentrite; The secondary arm space; analysis; Temperature; Cooling rate; Composition difference; Gibbs free energy

Introduction

The change of temperature in the solid and liquid in solidification transformation can deduce the related formula. The curve expresses its trend better. From this relation their secondary dendrite arm space composition will change when the transformation happens. It is known that the temperature in solidification can solve their relationship. In this study in terms of these equations the deduction and analysis is done and the error analysis to them is done. Here the solid and liquid equation is explored within line and find the simple formula which make us to calculate the cooling rate rapidly [1]. Therefore in this study the model of temperature and composition has been established to observe the trend and intrinsic relationship between them. Then the error is checked with variance to both of constant. TiAl as a promise materials has been searched and developed for many years. However the cooling rate with compositions is not much yet, so in this study the equation is established through temperature and composition according to the phase diagram. It is modelled with cooling rate and composition difference too in directional solidification test. The detail value is combined through phase equilibrium line and it is compared with thermal dynamics. The research scope is from 0 to pure Al here [1,2]. On the other side the relationship with cooling rate and energy difference & temperature has been investigated according to varied speed and ΔS respectively for the application. According to the solidified crystalline and phase diagram the application will be known. In addition relationship between cooling rate and energy difference & temperature are drawn for further research in this study. To calculate the cooling rate is our destination in the end in terms of the composition in TiAl alloys. Therefore the establishment equation between temperature and cooing rate in terms of the equilibrium diagram [3-6].

Calculation and Discussion

The relationship between the secondary dendrtie space and temperature

I It is supposed that

T=C/L -- (1)

C is constant, L is the second dendrite arm space.

Then C=TL

Since $T=aC_{com}+b$ [1]--(2)

Substitute (2) into (1) it has

$C= (aC_{com}+b) L$ -- (3)

And supposed that

Ccom =0.06, L=20µm --- (4)

Because it has

C=44260 Kµm. --- (5)

So T=44260/L ---- (6)

This is the temperature equation with L which is the secondary dentrite arm space.

At solidified length ls it has

C rate=T/t --- (7)

And t=ls/v --- (8)

So the function between cooling rate Crate and ls as below

C rate=T·v/ (3600·ls) --- (9)

Discussion

As seen in Figure 1 the relationship between temperature and secondary dendrite space is exhibited according to the equation above. When the temperature increases from 15 µm to 110µm the temperature will decrease from 3000K to 400K in TiAl. The bigger space expresses that low temperature. So the whole dendrite may be expressed in terms of the whole space changing. Because it is supposed that C_{com} =0.06 and L=20µm the whole space and temperature will change a certain with the two parameter changing. At the tip of dentrite the temperature attains high value and then temperature will become low (Figure 1).

As seen in Figure 2 (a~e) when the drawing speed increases from 4860~8860mm/hr the cooling rate will increase from 75K/s, 95K/s, 110K/s, 130K/s and 145K/s at the place of 15µm to 10K/s, 15K/s, 18K/s,19K/s and 25K/s at the same one of 110µm in TiAl at the solidified length to be 50mm. It expresses that the cooling rate decreases with the drawing speed becomes bigger (Figure 2).

From Figure 3 DG decreases with temperature increasing. It decreases with entropy DS increasing from 2 to 2.4J/mol/K. It's decreasing means cooling rate increases along the dendrite. This is the result of concentration of liquid and solid in terms of composition. When DS is 2J/ (mol·K) the DG changes from 1600J to 600J with the temperature increases from 850K to 1900K respectively. When DS is 2.4J/ (mol·K) the DG changes from1200J to -1300J with the temperature increases same. It means that in TiAl when DS becomes big the DG will decrease. G is Gibbs free energy and DH is enthalpy. [3] It is supposed that enthalpy is constant in this study. It means that when DS becomes big the Gibbs free energy DG will decrease.

$\Delta G=\Delta H-T\Delta S$ (11)

In Ti-Al ΔH and ΔS are to be

ΔH=3.3KJ/mol, ΔS=1.2 J/mol/K at 1492℃ [4] (Figure 3).

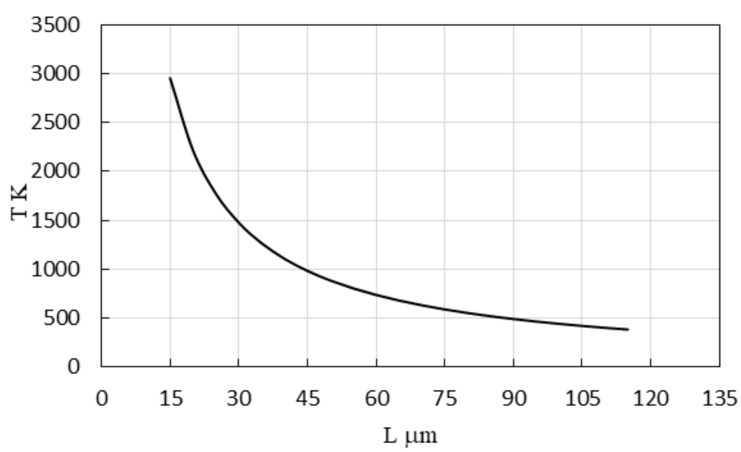
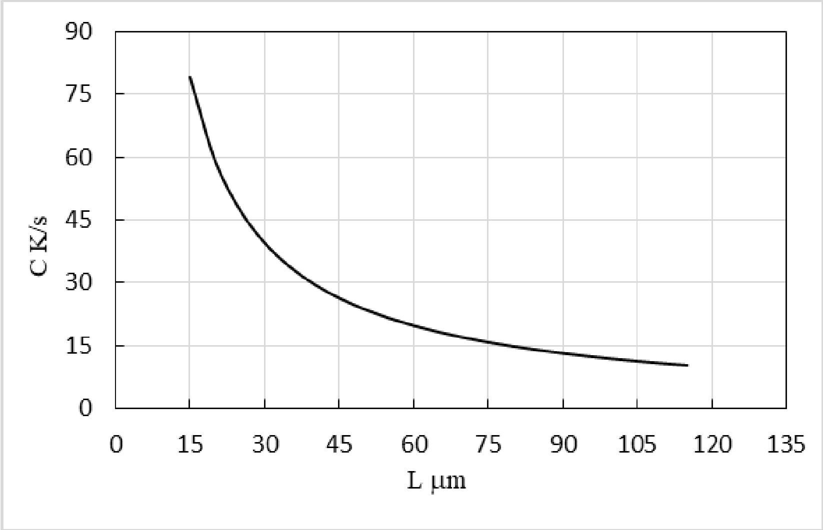
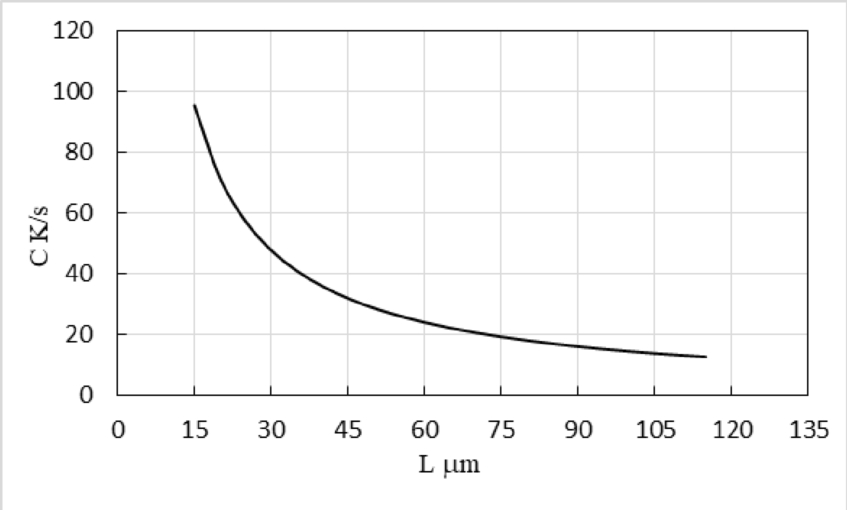


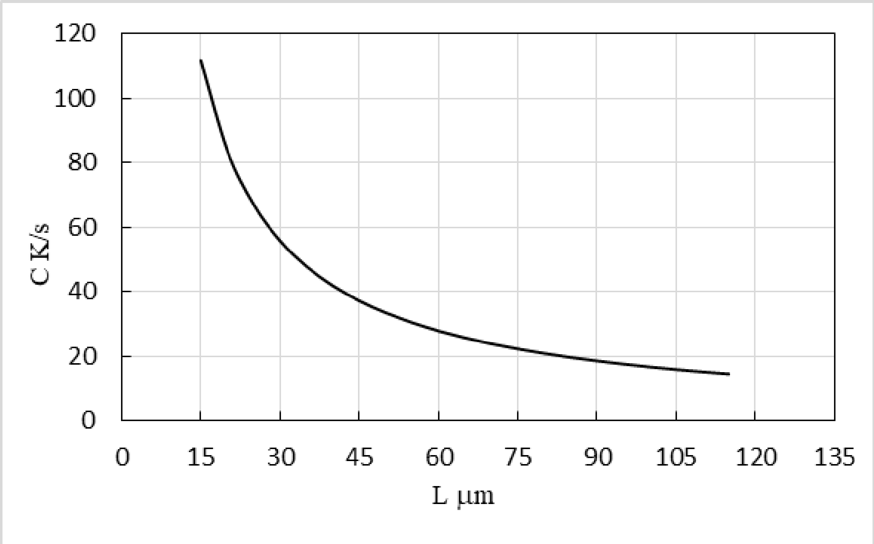
Figure 1: *The relationship between temperature and dentrite second space in TiAl.*



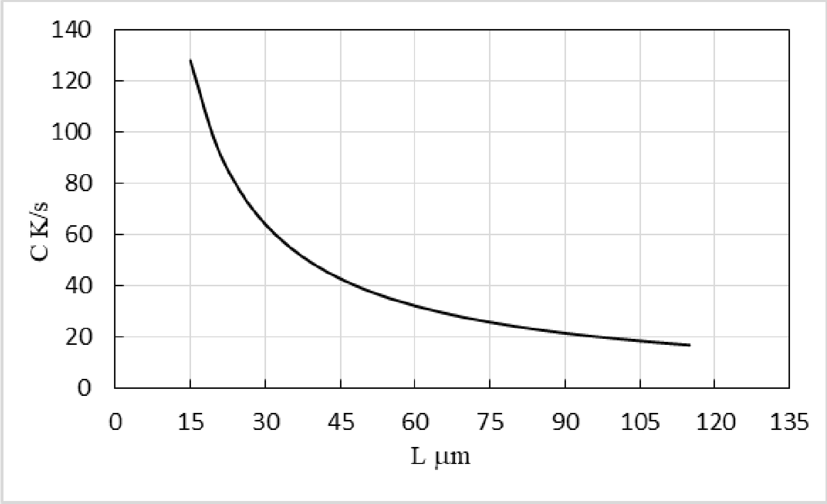
(a) v=4,860mm/hr



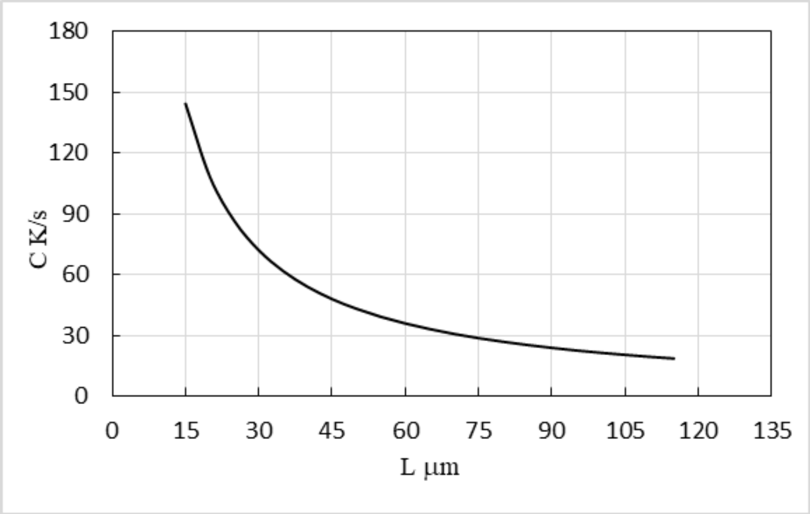
(b) v=5,860mm/hr



(c) v=6,860mm/hr

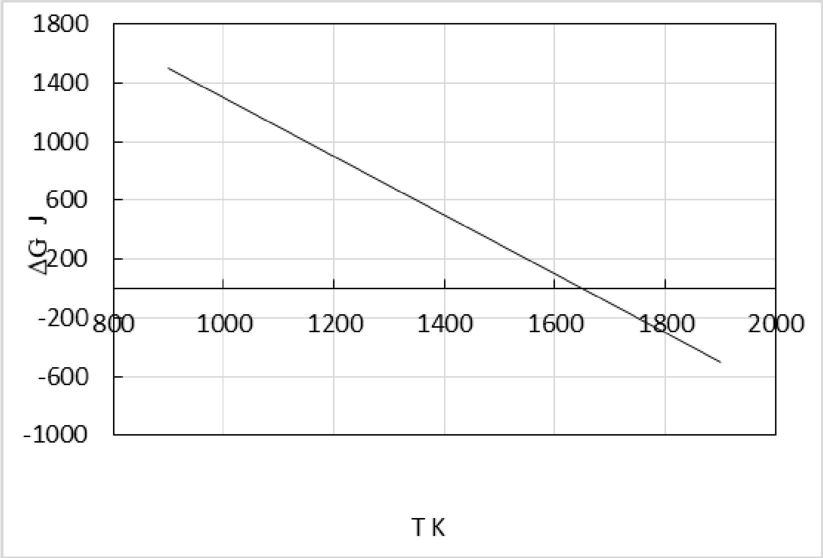


(d) v=7,860mm/hr

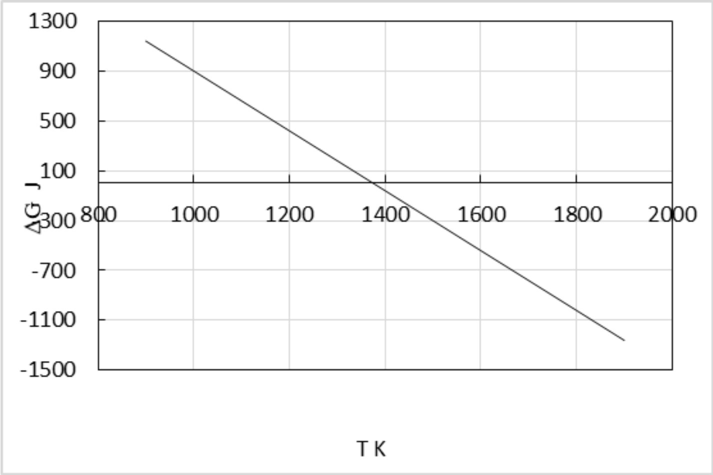


(e) v=8,860mm/hr

Figure 2: *The relationship between cooling rate and dentrite second space at the solidified length Ls= 50mmin TiAl.*



(a) ΔS=2J/(mol•k)



(b) *ΔS=2.4J/(mol•k)*

Figure 3: *The relationship between ΔG and temperature T in TiAl.*

Conclusions

- According to composition at solid and liquid interface in solidification the line model of temperature and dentrite secondary arm space in solidified course has been established. The equation is gained as T=44260/L. Meantime the cooling rate and secondary arm space L has been discussed. In the intersection the cooling rate of solid and liquid ΔT is gained. Composition difference has been deduced and analyzed according to dentrite therefore the dentrite secondary arm space can determine temperature. When the secondary arm space in dentrite is from 15 to 110μm the temperature changes from 3,000K(2727℃) to 450K(177℃). Y changes from pure X to pure Y the temperature will change from maximum to minimum with increasing secondary arm space in materials like TiAl at solidified length to be 50mm.
- The period one of cooling rate is from 25K/s to 145 K/s in speed of 8,860mm/hr. For engineering use the speed is better when the speed is higher like 7,860mm/h when the cooling rate attains from 20K/s to 77K/s with the secondary arm space increasing to minimum value 4860mm/hr. When cooling rate is 8860mm/hr the biggest one in these three conditions will happen with 145K/s mentioned above.
- When DS is 2J/(mol·K) the DG changes from1500J to -500J with the temperature increases same. It means that in TiAl alloys when DS becomes big the DG will decrease. From diagram the concentration of Al is measured to be 1.6at% in 46Al at%. The calculation value is thought to be phase forming element due to the minus. That has been the low concentration with solid solution in TiAl.

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