



# The Modelling of Cooling Rate between Solidification Speed and Dendrite Secondary Arm Space in TiAl Intermetallic Compounds III

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## Abstract

The simulation of cooling rate and temperature & solidified speed has been established for the sake of searching their intrinsic relationship. It is observed that the temperature will become low with speed to be increased firstly. It fits to the principle well. The cooling rate increases with the solidified speed becomes bigger secondly. At last in dendrite the cooling rate of solidification has been high with decreasing temperature. That fits to principle well according to the tendency of three parameters in this paper. For further research the deeper relationship need to be studied further as this paper's destination. In addition the cooling rate will increase from 2K/s to 58K/s when the secondary arm space changes from 10 $\mu$ m to 250 $\mu$ m in dendrite of TiAl.

**Keywords:** Modelling; TiAl; Dendrite; 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 their 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 [1,2]. 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 [3]. On the other side the relationship with cooling rate and energy difference & temperature has been investigated according to varied speed 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 cooling rate in terms of the equilibrium diagram [3-6].

## Calculation and Discussion

### Simulation

It is supposed that  
 $C_{rate} = K_v \dots (1)$

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Here  $v$  is the solidified speed, mm/s;  $K$  is coefficient;  $C_{rate}$  is the cooling rate, K/s.

Since  $v=0.21$  mm/s,  $C_{rate}=4.5$ K/s within  $L_s=210$ mm

$L_s$  is the solidified length.

Substitute them into (1) it has been calculated

$K=22$  K/mm

So it has  $C_{rate}=22v$  --- (2)

It is supposed that

$T=K1/v$  --- (3)

Substitute them above into (3) it has

$T=440/v$  -- (4)

Here  $K1 = 440$ Kmm/s

Substitute  $C_{rate}=22v$  into (4) it has

$T=9,680/C_{rate}$  --- (5)

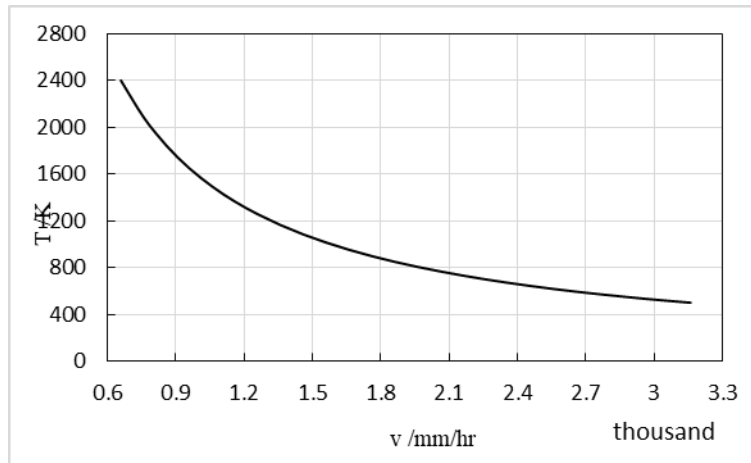
Since  $T=44,260/L$

Here  $L$  is secondary arm space in dendrite. Substitute it into (5)

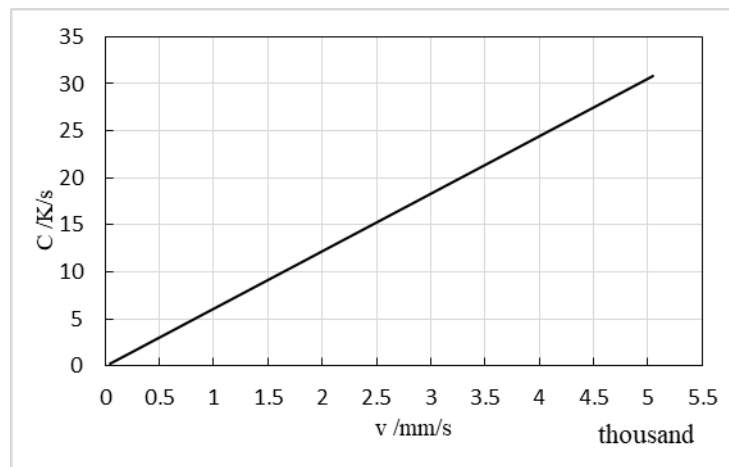
It has  $C_{rate}=219*L$  --- (6) (Figure 1).

## Discussion

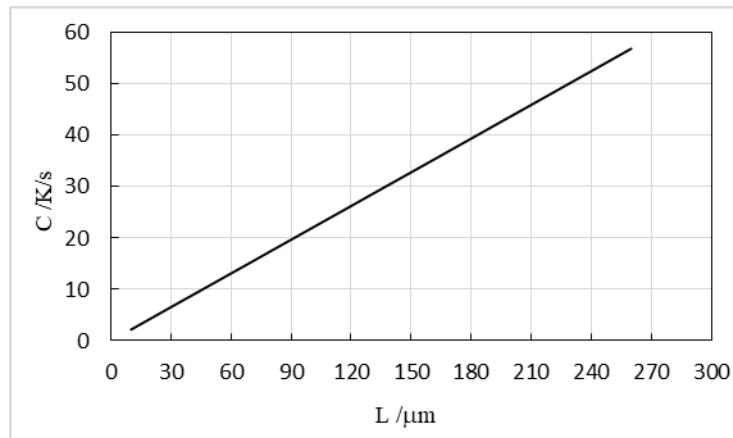
In Figure 1 the curve between temperature and solidified speed has been expressed. It is observed that with speed increasing from 600mm/hr to 3,200mm/hr the temperature will decrease from 2,400K to 600K. The temperature will become low with speed to be increased. It fits to the principle well. As seen in Figure 2 the relationship between cooling rate and solidified speed is exhibited according to the equation above. When the solidified speed increases from 0 to 5,000mm the cooling rate will decrease from 0°C/s to 30°C/s in TiAl with solidification. The bigger solidified speed expresses that higher cooling rate. It fits to principle very well. So the whole cooling rate will change a certain with the parameter of speed changing. It expresses that the cooling rate increases with the solidified speed becomes bigger.



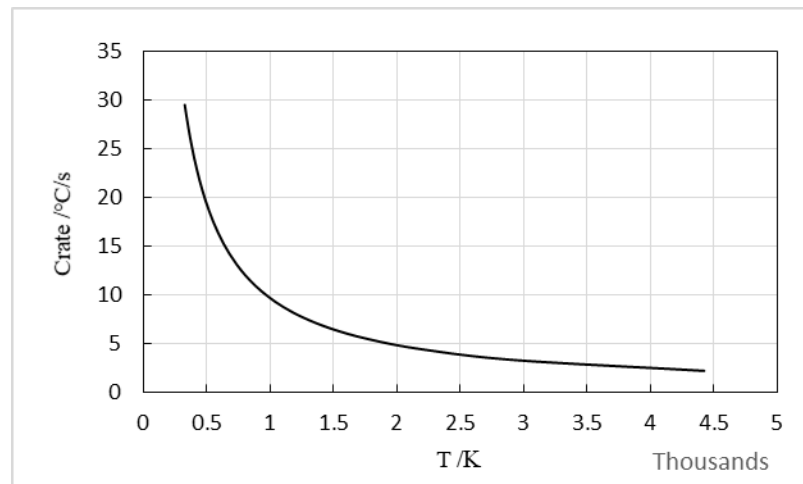
**Figure 1:** The relationship between temperature and speed in metal.



**Figure 2:** The relationship between cooling rate and dendrite secondary arm space in TiAl.



**Figure 3:** The relationship between cooling rate and temperature in TiAl.



**Figure 4:** The relationship between cooling rate and temperature in TiAl.

In Figure 3 the cooling rate will increase from 2K/s to 58K/s when the secondary arm space changes from 10 $\mu$ m to 250 $\mu$ m in dentrite of TiAl. It explains that the bigger secondary arm space will be if the cooling rate is bigger too. It fits to the principle well too. As seen in Figure 4 when the solidified cooling rate decreases from 30K/s to 3K/s the temperature will increase from 350K to 4,500K. So the maximum cooling rate is 30K/s under 350K. In dentrite the cooling rate of solidification has been high with decreasing temperature. In short only if the temperature decreases the cooling rate will increase which fits to the theory well. So for the sake of increasing the cooling rate the controlling temperature is necessary (Figure 2,3).

## Conclusions

When the solidified speed in dentrite is from 600mm/hr to 3,200mm/hr the temperature changes from 2,400K to 500K. The period one of cooling rate is from 0K/s to 30 K/s in increasing speed from 0 to 5,000mm/hr. When cooling rate increases from 30K/s to 3K/s the speed changes from 400K to 4,400K in TiAl.

Meantime the cooling rate increases with the solidified speed becomes bigger.

## Foundation

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## References

1. Cai X. Fundamentals of Materials Science and Engineering. Shanghai Jiao Tong University. 2017; 174-175.
2. Hao S. Materials Thermal Dynamics. Chemical industry Press. 2004; 101.
3. Xu R. Kim Y. A study on cooling rate modelling of dentrite between the temperature and composition in TiAl Intermetallic Compounds. SunText Review Material Sci. 2022; 3: 123.
4. Xu R. A study on directional solidification and deformation behaviors by calculation in titanium aluminides. Gyeongsang National University. Metallurgical Materials Engineering Dept. PhD thesis dissertation. 2009; 12: 7.



5. Wang YM, Li S. Study on homogeneous structure DD6 in directional solidification of Single crystalline high temperature Acta Metallurgica Sinica. 2015; 51: 1039.
6. Xu R. Effects of the composition on structures and mechanical properties of TiAl base intermetallic compounds. Gyeongsang National University. Metallurgical Materials Engineering Dept. Master thesis dissertation. 1999; 5.