University of Alberta
Oversea research report

Weian Lin, Patricio Mendez
CCWJ

Relationship between Enthlaphy and temperature by thermo-calc simulation

1 Preliminary

Form 8 Aug. 2018 to 3 Sep. 2018, around 27 days oversea research has been conducted at University of Albert, and content will be reported below.

2 Research topic

In our laboratory, the hot-wire system is widely been used, however, due to di erent materials' characteristics phenomenon, cause the melting behavior is hard to predict, so, in the University of Albert, the simulation of hot-wire behavior has already been conducted for a while, in this term experiment, by using the thermo-cal simulation method to understand various material under di erent stats and temperature is the prior task.

3 Schedule

8 Aug. 2018 Departure

9 Aug. 2018 2 Sep. Experiment

3 Sep. 2018 Arrived

4 School information

School: University of Alberta

Location: Edmonton, Alberta state, Canada

Supervisor: Professor Patricio Mendez

5 Research content

5.1 Introduction

The phase behavior of the material is critical for the di erent the welding process, especially, the hot-wire system, because the wire needs to be pre-heated below the melting point, the required energy seems to be important in contrast, the simple illustration is showed at Fig 1, and by Dakota's draft report the necessary heat resource equation is calculated as

$$q_{in} - q_{out} + q_{gen} = q_s \tag{1}$$

$$q_{st} = m' U_c (i_{liq} - i_0) \tag{2}$$

Equation 1 is the heat system in the welding process,$q_{in}, q_{out}, q_{gen}, q_s$ mean heat input, heat lost, heat generate, and heat stored respectively, the parameters above can determined, however, for the heat stored can be seen in equation 2, m' and U mean the mass amount of time and cross-section of the wire, but for the$i_{liq} and i_0$, the enthalpy at liquid state and at room temperature, these numbers only can be determined by experiments data or

simulation method, so, in order to gure out this problem, thermo-calc simulation can help to predict it easily and precisely, so in this time experiment, the main target is to simulate the enthalpy-temperature graph which could improve to predict the required energy for the di erent material to melt it down from the room temperature by the thermo-calc software.

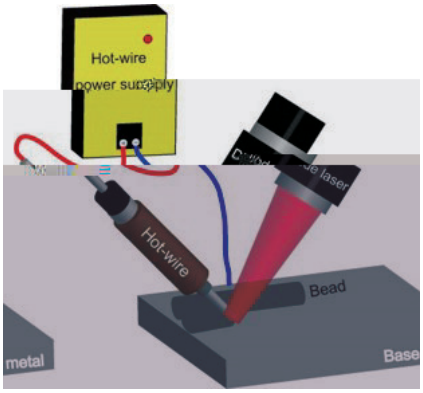

Figure 1: Illustration of hot-wire welding system

5.2 Materials

In this term, the various metal like ER705-6 low carbon steel, 304 stainless steel, aluminum ER4047, Copper 6560, Titanium Ti-6Al-4V will be conducted respectively and their chemical composition are showed at Table 1.

Table 1: Chemical composition

Material	Fe	C	Mn	Si	P	S	Cr	Ni
ER705-6	Bal.	0.06-0.15	1.4-1.85	0.8-1.15	0.025			
SS304	Bal.	0.08	2.0	0.75	0.045	0.03	18-20	8-10.5

Material	Al	Si	Mn	Fe	Mg	Cu	Zn
Al-ER4047	Bal.	11-13	0.15	0.8	0.1	0.3	0.2

Material	Cu	Si	Mn	Fe	Sn	P	Pb	Zn	Al
Cu-6560	Bal.	2.8-4.0	0.5-1.5	0.5	0.2	0.05	0.02	0.4	0.02

Material	Ti	Al	V	Fe	C
Ti-6Al-4V	Bal.	6.0	4.0	0.05	0.15

5.3 Simulation condition

For the simulation, the software is thermo-calc 2017 A version, in the simulation condition database SSOL4:SGTE Alloy Solutions Databases v4.9g will be used to simulate all the material of the relationship between Enthalpy and temperature.

5.4 Results

After the simulation each state of material can be observed detailed, in this term, there are four spots are determined, 20°C, T_S, T_L, and refered temperature(1000°C,1600°C2500°C) which are mean temperature at room temperature, solidus, liquidus, and completely melting respectively and the slopes of solid state without transformation and completely melting will also be obtained, which are calculated by least square and the equation is shown below,

$$y = ax + b \tag{3}$$

a = (

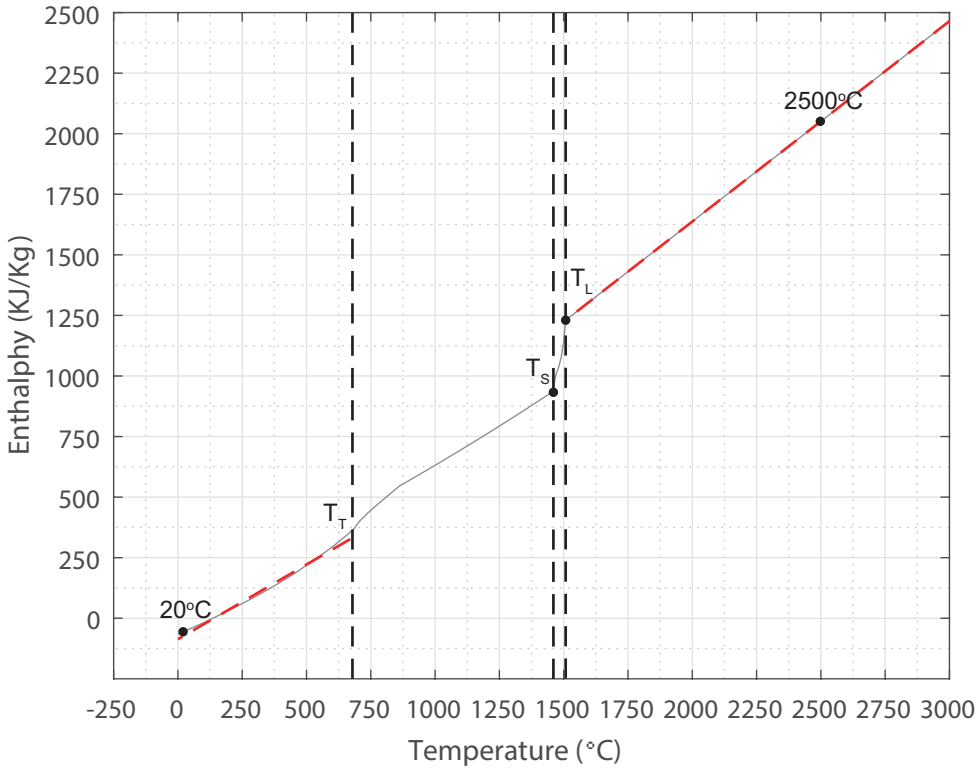

Figure 2: Relationship between Enthalpy and temperature of the ER705-6 steel

Table 2: Results of each parameter

Temperature (°C)	h (KJ/Kg)	Slope
20°C	-55.8	0.62
T_S	934.2	
T_L	1230.3	
2500°C	2051.1	0.83

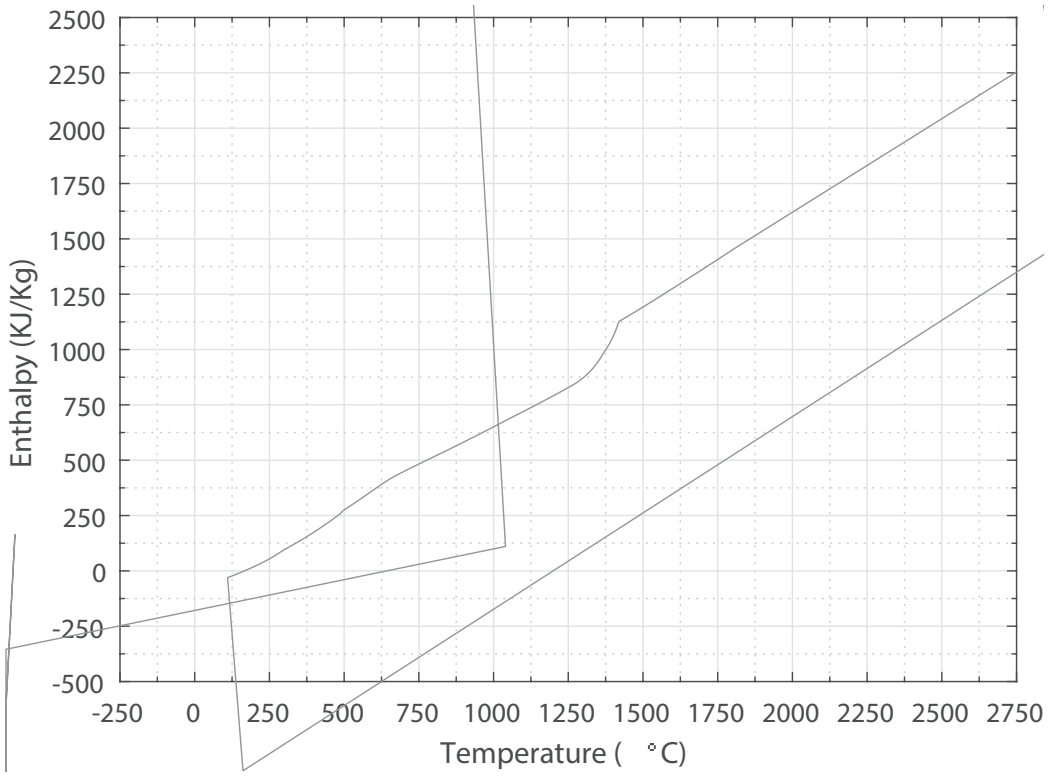

Figure 3: Relationship between Enthalpy and temperature of the ss304

Table 3: Results of each parameter

Temperature (°C)	h (KJ/Kg)	Slope
20°C	-74.65	0.58
T_S	985.09	
T_L	1126.42	
2500°C	2042.9	0.85

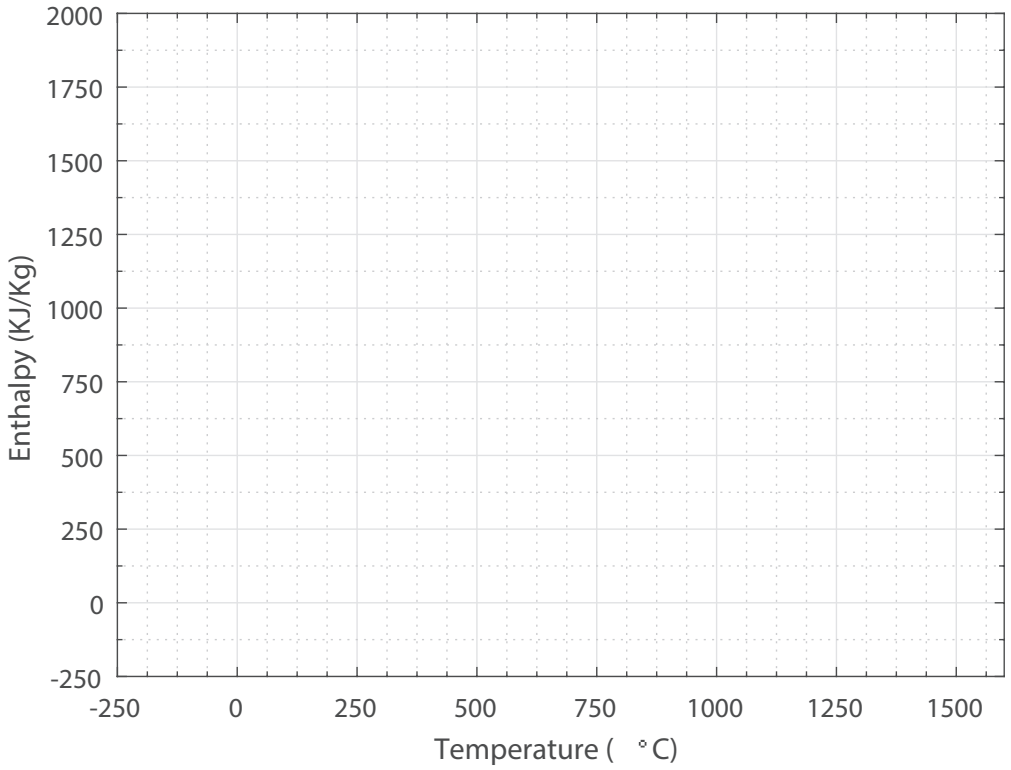

Figure 4: Relationship between Enthalpy and temperature of the Aluminum 4047

Table 4: Results of each parameter

Temperature (°C)	h (KJ/Kg)	Slope
20°C	-29.1	1.02
T_S	542.3	
T_L	1075.7	
1000°C	1536.1	1.14

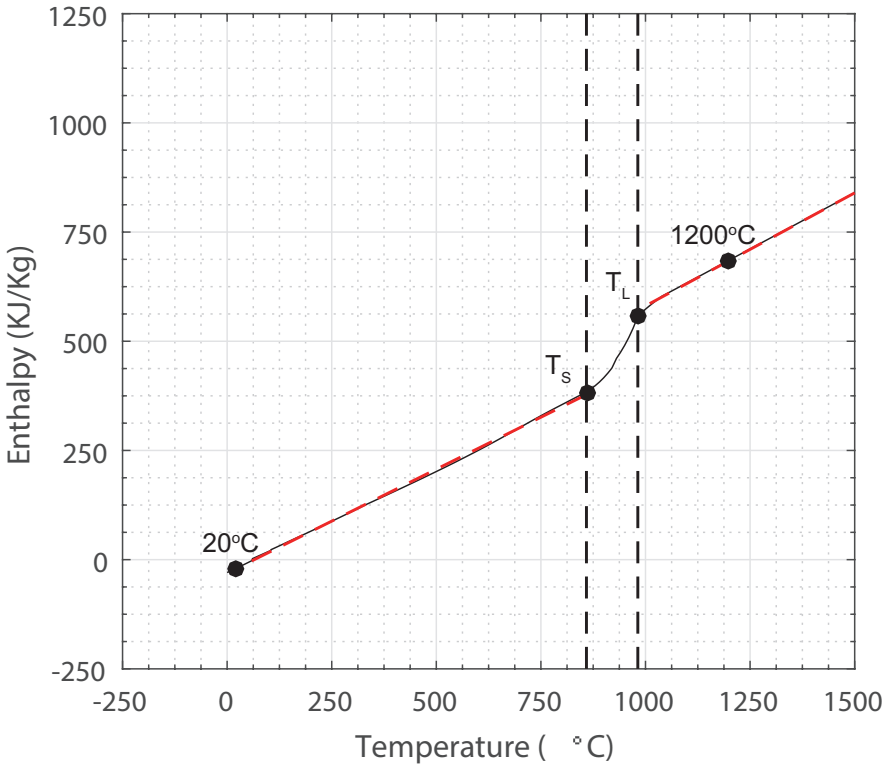

Figure 5: Relationship between Enthalpy and temperature of the Copper 6560

Table 5: Results of each parameter

Temperature (°C)	h (KJ/Kg)	Slope
20°C	-20.59	0.48
T_S	436.67	
T_L	603.25	
1200°C	685.6	0.52

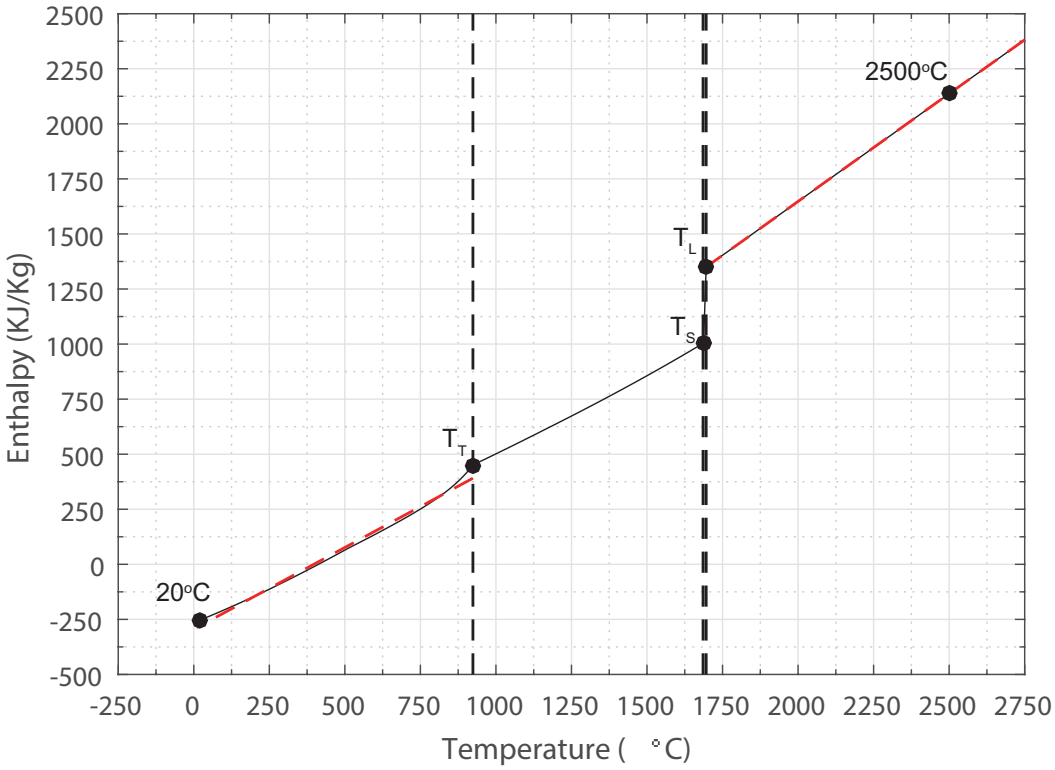

Figure 6: Relationship between Enthalpy and temperature of the Ti-6Al-4V

Table 6: Results of each parameter

Temperature (°C)	h (KJ/Kg)	Slope
20°C	-253.54	0.74
T_S	-1003.11	
T_L	1350.49	
2500°C	2136.79	0.98

6 Summary

6.1 Conclusion

In the conclusion, the complete results can be performed by simulation, and each stage of material also can be known, so in the practical experiment, for instance, the hot-wire system welding, the required heat resource from room temperature to melting point could precisely be calculated, this can give a great advantage for the further process, by thermo-calc simulation no matter what kind of material all can be done by this method.

6.2 Future target

From the perspective, the actual experiment should be conducted, in order to see whether the real result corresponds to the simulation also can observe the error.

7 Acknowledge

Firstly for the Japan side, I would like to thank the professor Yamamoto who gave me this valuable opportunity, and really thanks to all the sta s who supported me.

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