



PRACTICAL SOFTWARE FOR MATERIAL PROPERTIES

JMatPro 계산사례

(주)솔루션랩

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- ◆ JMatPro for **Al Alloy**
- ◆ JMatPro for **Ni Alloy**
- ◆ JMatPro for **General Steel**
- ◆ JMatPro for **Cast Iron**
- ◆ JMatPro for **Stainless Steel**
- ◆ JMatPro for **Mg Alloy**
- ◆ JMatPro for **Ti Alloy**
- ◆ JMatPro for **Zr Alloy**
- ◆ JMatPro for **Solder Alloy**
- ◆ JMatPro for **Copper Alloy**
- ◆ JMatPro for **Cobalt Alloy**



General Steel

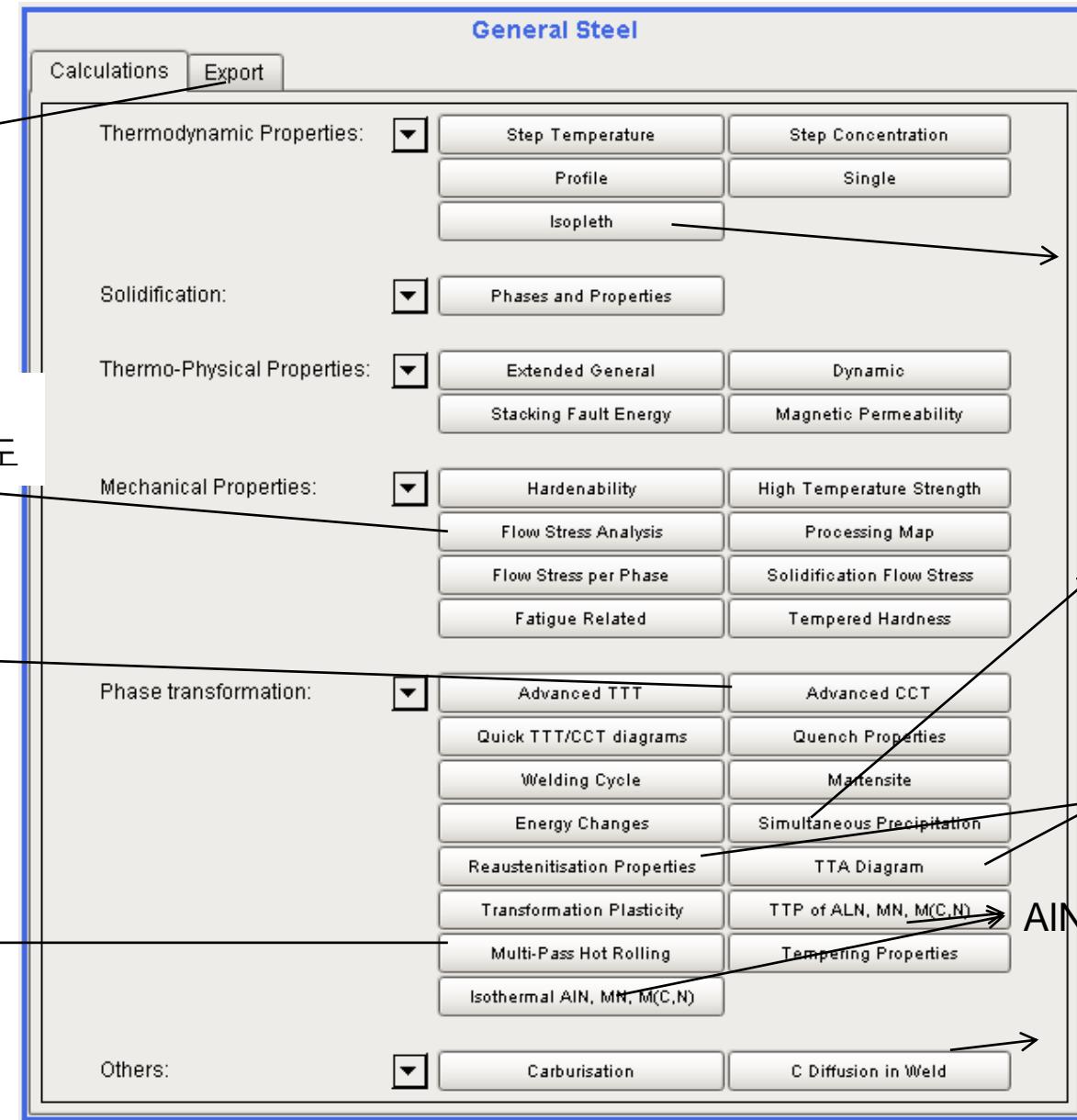
JMatPro 13 버전

열간성형/열처리/주조/
용접 해석용 물성 작성

온도/변형율속도에
따른 응력-변형률선도

Advanced TTT
Advanced CCT

제어압연시
결정립 변화 계산
(결정립크기,
재결정분율, 하중)



바이너리 상태도
계산 기능 향상

템퍼링시 석출상
거동/강도계산

가열시 변태특성

AlN, MN, M(C,N) 석출 거동

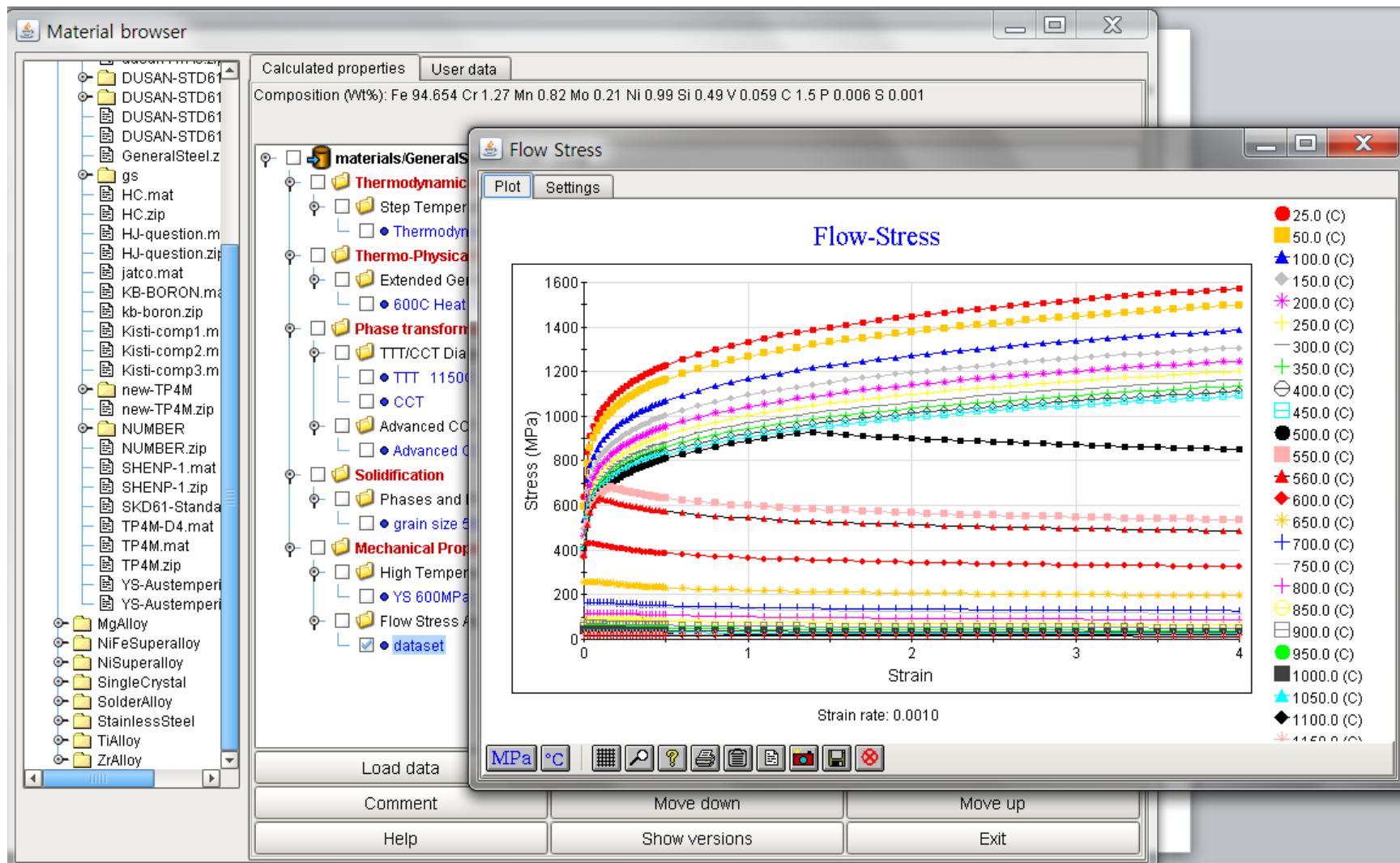
이종재질 용접에서 C
확산분포

General Steel 모듈 기능 개요

구분	기능	활용분야/기타
열역학계산	<ul style="list-style-type: none"> 평형상분율 계산 상태도 계산(isopleth) 	<ul style="list-style-type: none"> 상태도 관련 정보추출 열처리 기준 온도 설정 생성상을 제어하기 위한 합금설계
응고물성 계산	<ul style="list-style-type: none"> 응고분율 계산 및 물성계산 	<ul style="list-style-type: none"> 응고시뮬레이션 물성계산 응고구간 거동 정보 추출 잠열 계산
열물리적 물성 계산	<ul style="list-style-type: none"> 열역학계산 기반의 상분율을 가정한 물성계산 투자율 계산 	<ul style="list-style-type: none"> 열물성, 탄성계수, 열팽창계수, 밀도변화, 점성, 잠열 및 비열 등 계산 유도가열 해석에 필요한 투자율 정보 계산
기계적 물성 계산	<ul style="list-style-type: none"> 고온 항복강도 계산 온도별/변형율 속도별 유동응력 선도 조미니 경화능 선도 피로 시험 관련 계산 기능 템퍼링시 온도/시간에 따른 경도변화 	<ul style="list-style-type: none"> 상온 강도 정보로부터 고온 응력선도 추출 템퍼링계산 기능은 저합금강/저탄소강에 유효
상변태 관련 기능	<ul style="list-style-type: none"> TTT/CCT 계산기능 냉각사이클에 따른 각종 물성계산 용접물성 계산 기능 가열시 상변화 거동 및 물성계산 템퍼링시 석출상 거동 계산 마이크로 합금강에 대한 석출상 거동 및 압연시 거동 계산 침탄공정/용접경계의 C확산 계산기능 	<ul style="list-style-type: none"> 냉각프로파일에 따른 상분율 및 강도/물성 계산 마이크로 합금 압연시 결정립크기 및 재결정분율 계산 가능 상변태 해석 물성 추출 용접해석 물성 추출 열간압연해석 물성 추출

Material Browser

매우 쉽고 직관적인 계산결과 정리



Main GUI for General Steel

기본 조성 입력창 및 기능 전체구성

	Wt %
Fe	100.0
Al	0.0
Cr	0.0
Cu	0.0
Co	0.0
Mn	0.0
Mo	0.0
Nb	0.0
Ni	0.0
O	0.0
Si	0.0
Ta	0.0
Ti	0.0
V	0.0
W	0.0
B	0.0
C	0.0
N	0.0
P	0.0
S	0.0

General Steel

Calculations Export

Thermodynamic Properties:

Solidification:

Thermo-Physical Properties:

Mechanical Properties:

Phase transformation:

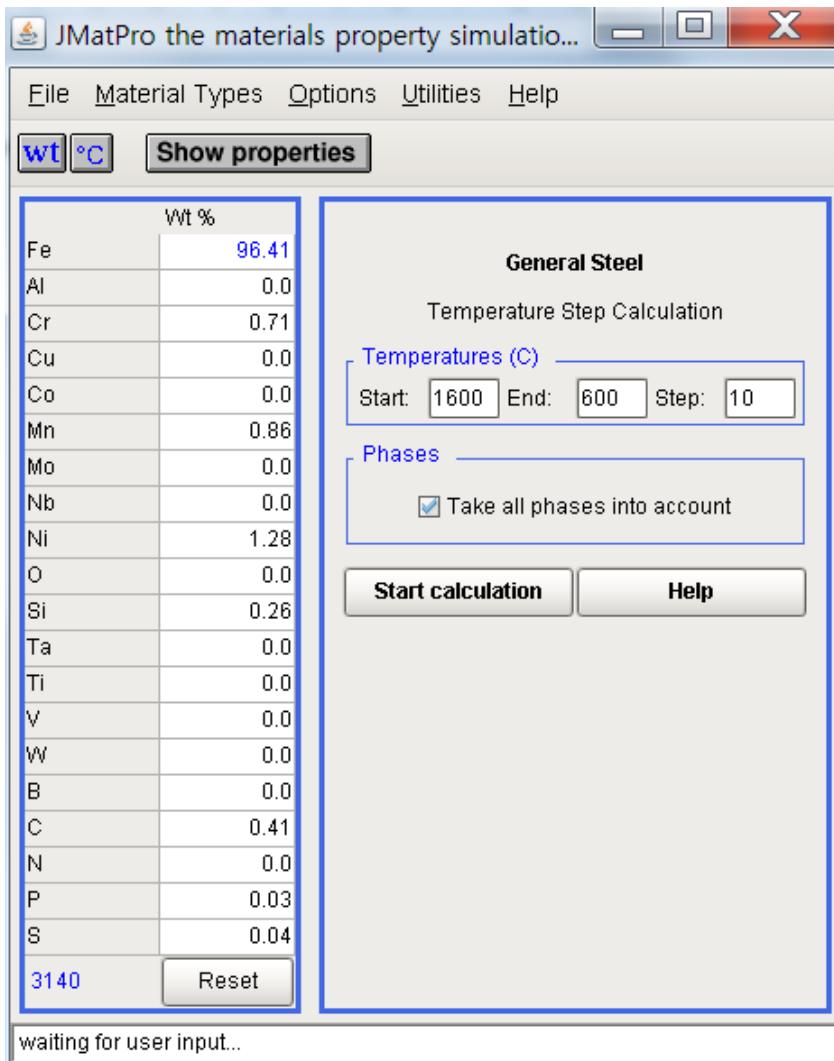
Others:

열역학계산

- Step Temperature : 온도별 안정상 계산
- Step Composition : 조성별 안정상 계산
- Profile : 여러 조성을 동시에 변경하며 열역학 계산
- Isopleth Calculation: 상태도 계산

Temperature Step Calculation

기본 입력사항 및 계산에서
고려하는 상의 목록

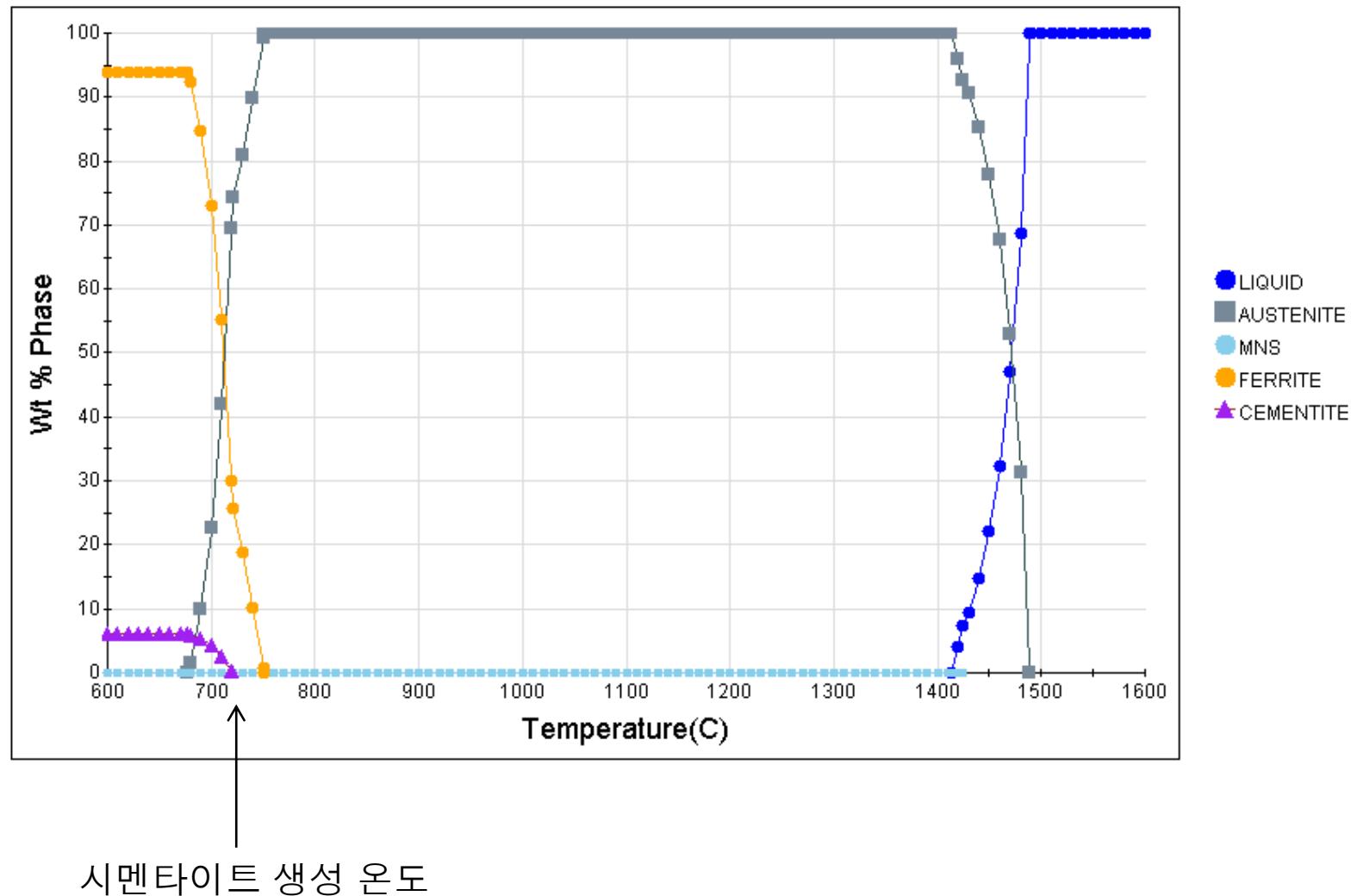


Choice of phases for: General Steel	
<input checked="" type="checkbox"/> LIQUID	<input checked="" type="checkbox"/> AUSTENITE
<input checked="" type="checkbox"/> FERRITE	<input checked="" type="checkbox"/> CEMENTITE
<input checked="" type="checkbox"/> M2(C,N)	<input checked="" type="checkbox"/> M(C,N)
<input checked="" type="checkbox"/> MN	<input checked="" type="checkbox"/> M23C6
<input checked="" type="checkbox"/> M6C	<input checked="" type="checkbox"/> M7C3
<input checked="" type="checkbox"/> ALN	<input checked="" type="checkbox"/> BN
<input checked="" type="checkbox"/> LAVES	<input checked="" type="checkbox"/> CHI
<input checked="" type="checkbox"/> G_PHASE	<input checked="" type="checkbox"/> PI_PHASE
<input checked="" type="checkbox"/> Z_PHASE	<input checked="" type="checkbox"/> CU
<input checked="" type="checkbox"/> M2P	<input checked="" type="checkbox"/> M3P
<input checked="" type="checkbox"/> MS_B81	<input checked="" type="checkbox"/> MNS
<input checked="" type="checkbox"/> M3B2	<input checked="" type="checkbox"/> MB2_C32
<input checked="" type="checkbox"/> FE2B	<input checked="" type="checkbox"/> CR2B
<input checked="" type="checkbox"/> FE3B	<input checked="" type="checkbox"/> M2O3
<input checked="" type="checkbox"/> M2SiO4	<input checked="" type="checkbox"/> M3O4
<input checked="" type="checkbox"/> MO_B2	<input checked="" type="checkbox"/> MULLITE
<input checked="" type="checkbox"/> SiO2	<input checked="" type="checkbox"/> SPINEL_AB2O4
<input checked="" type="checkbox"/> Ti4C2S2	<input checked="" type="checkbox"/> KAPPA

Temperature Step Calculation

평형상태에서의 상분율 계산

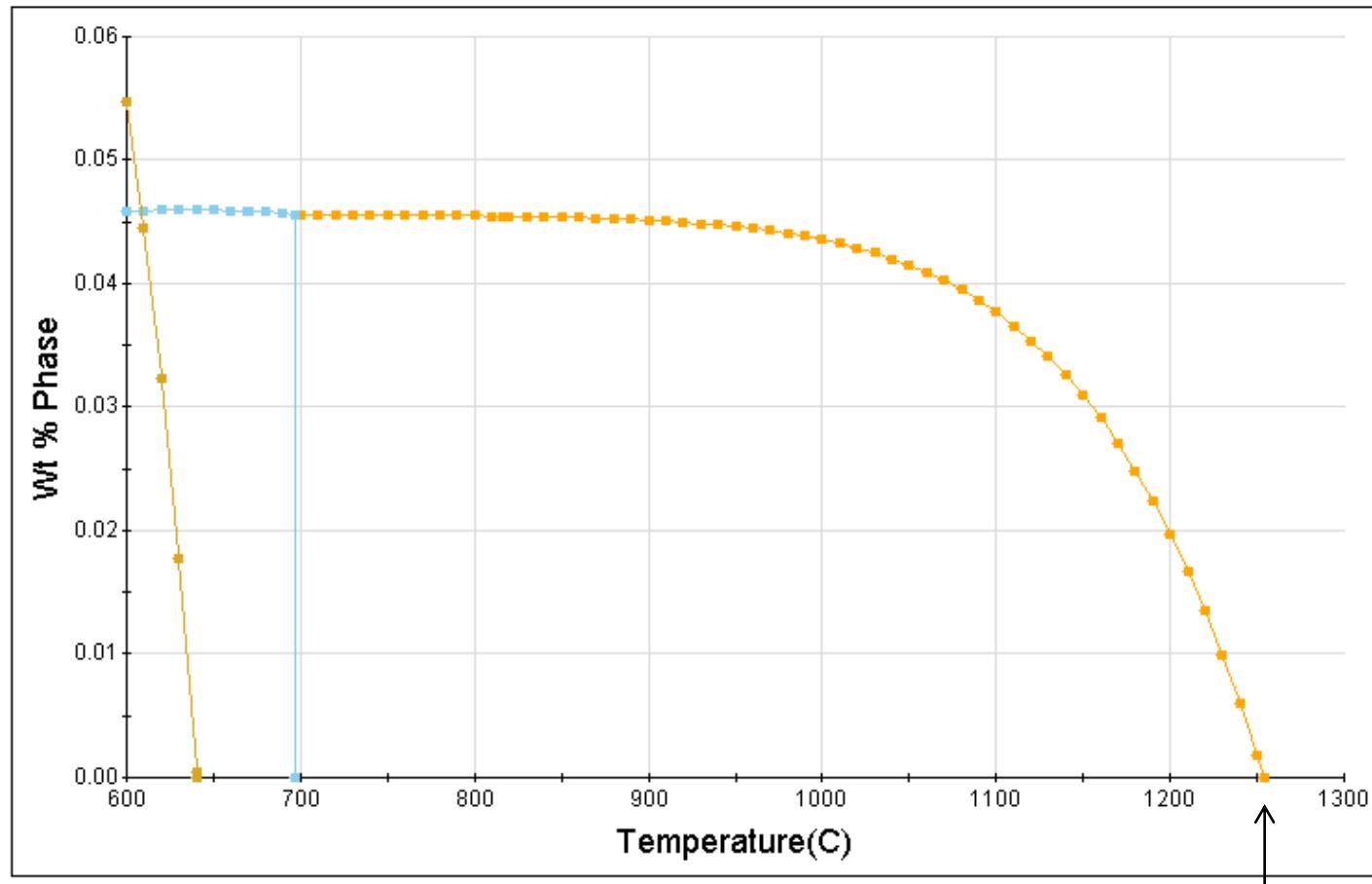
Fe-0.71Cr-0.86Mn-1.28Ni-0.26Si-0.41C-0.03P-0.04S wt(%)



Temperature Step Calculation

평형상태에서의 상분율 계산

Fe-1.35Mn-0.04Nb-0.31Si-0.17C-0.011N wt(%)

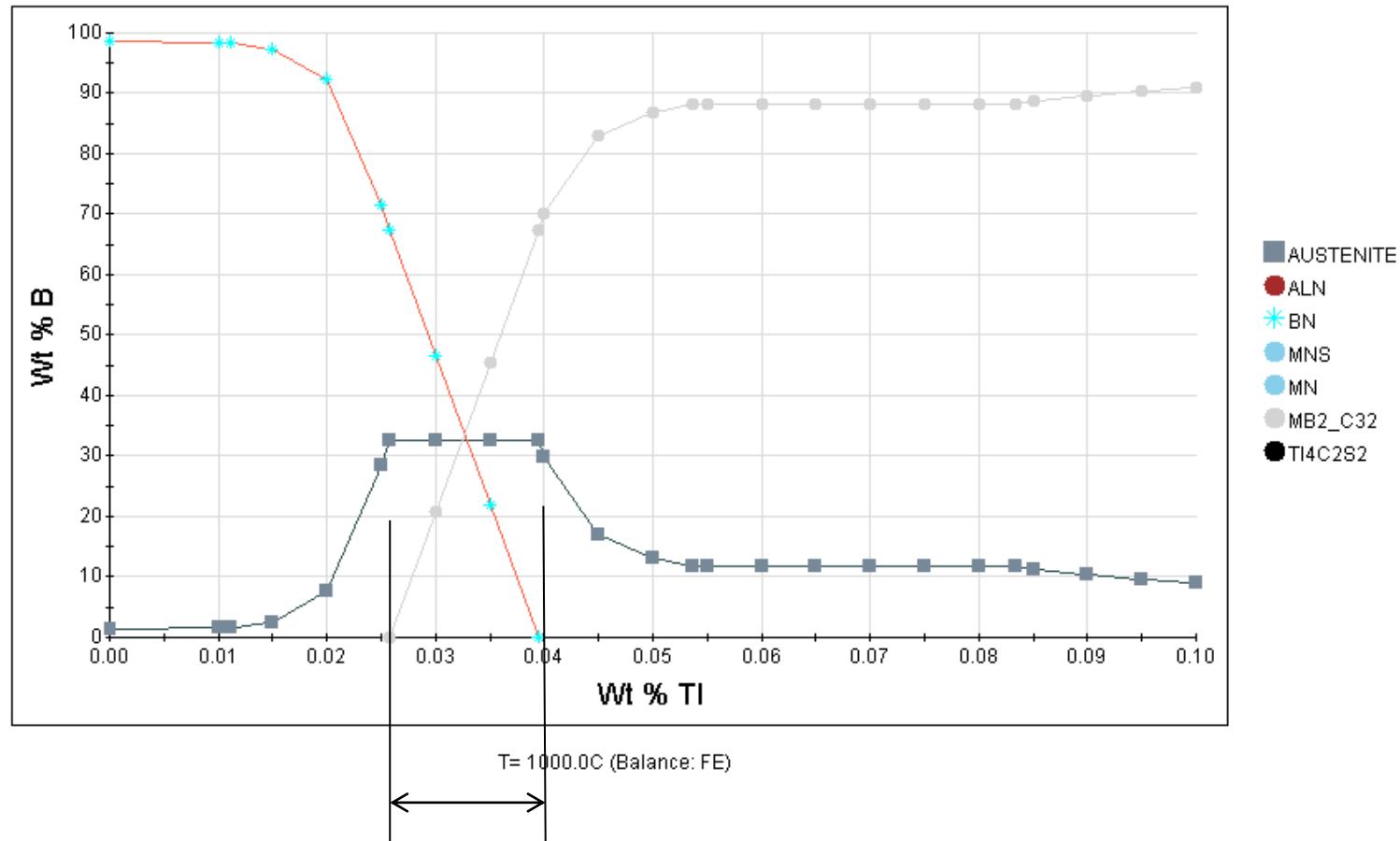


MX carbonitride 생성온도

Concentration Step Calculation

특정온도에서의 합금조성 변화에 따른 상분율 변화 계산

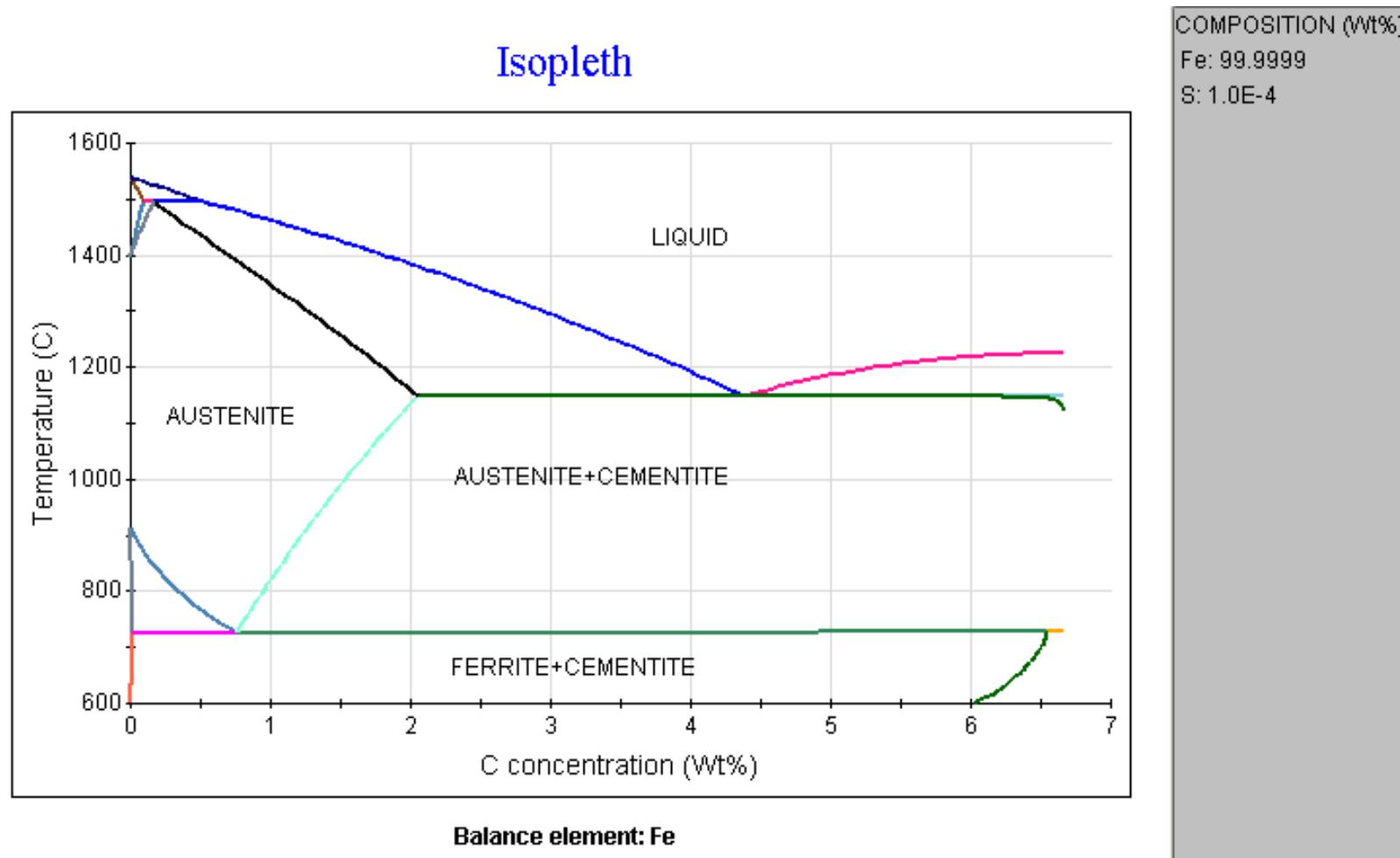
Fe-0.02Al-1.0Cr-0.3Cu-1.8Mn-0.1Mo-0.2Ni-0.2Si-0.0Ti-0.003B-0.15C-0.01N-0.007P-0.01S wt(%)



보론강 오스테나이트 상에 B를 최대로 녹이기 위한
Ti 합금원소 조성범위

Isopleth Phase Diagram

2원계 상태도 계산

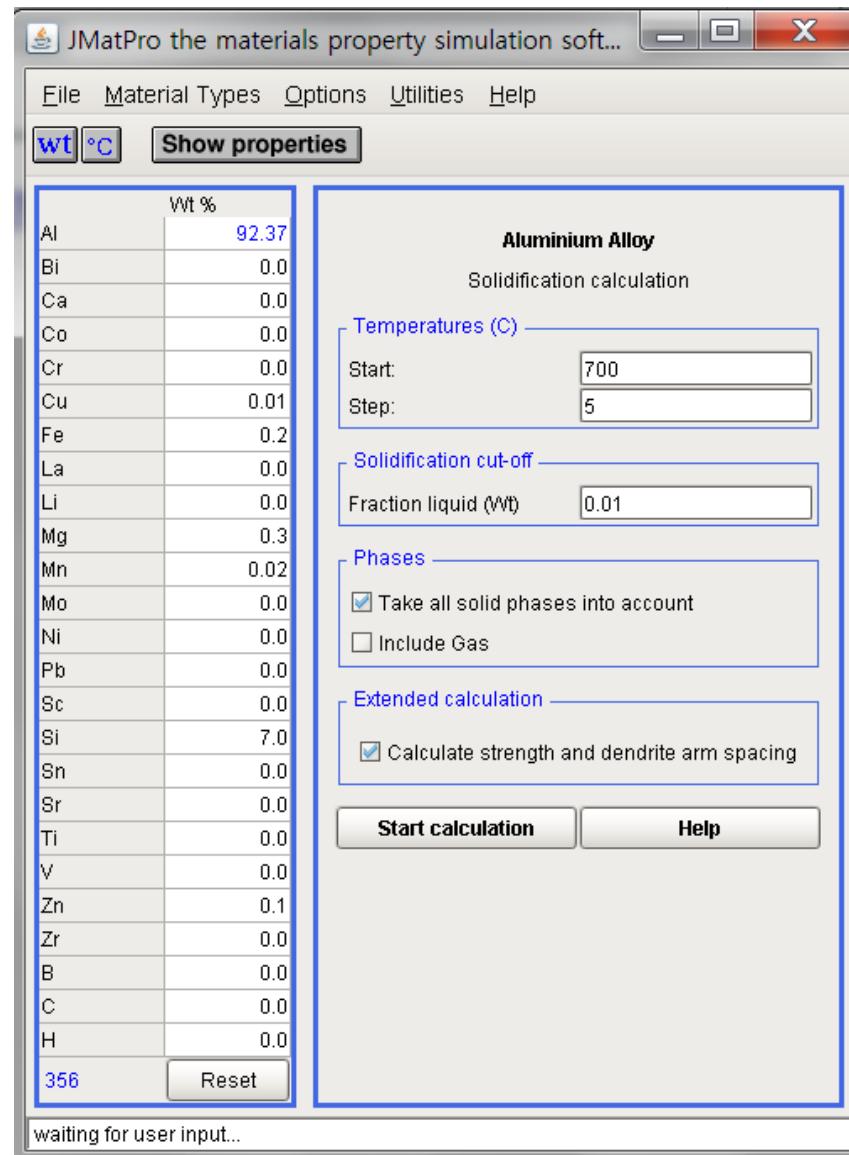


응고물성 계산

- Fraction Solid: 온도별 응고분율
- Material Properties during Solidification : 밀도, 점도, 열전도 등

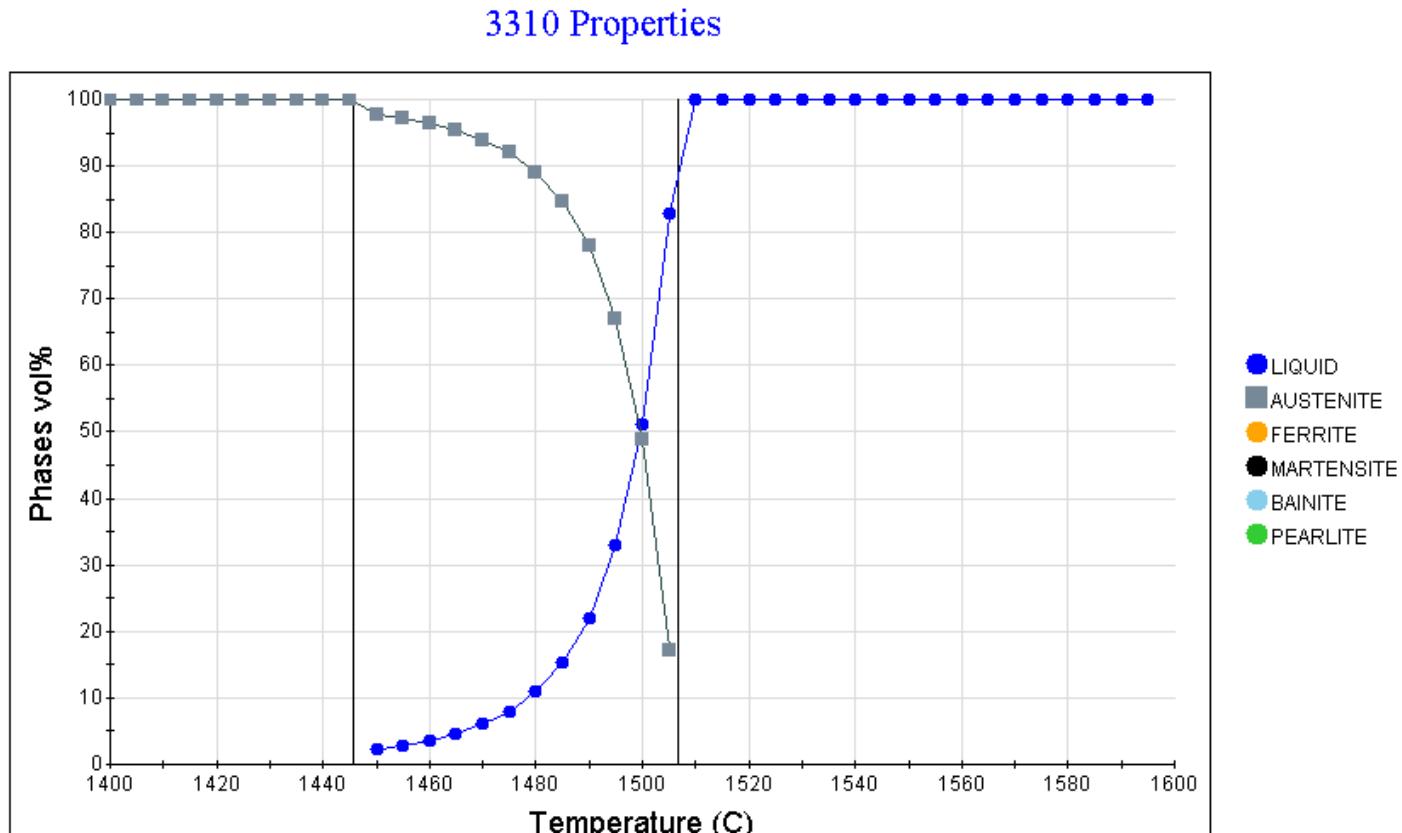
Solidification Calculation

응고물성 계산을 위한 입력창



Solidification Calculation

온도별 응고분율외 각종 물성
계산



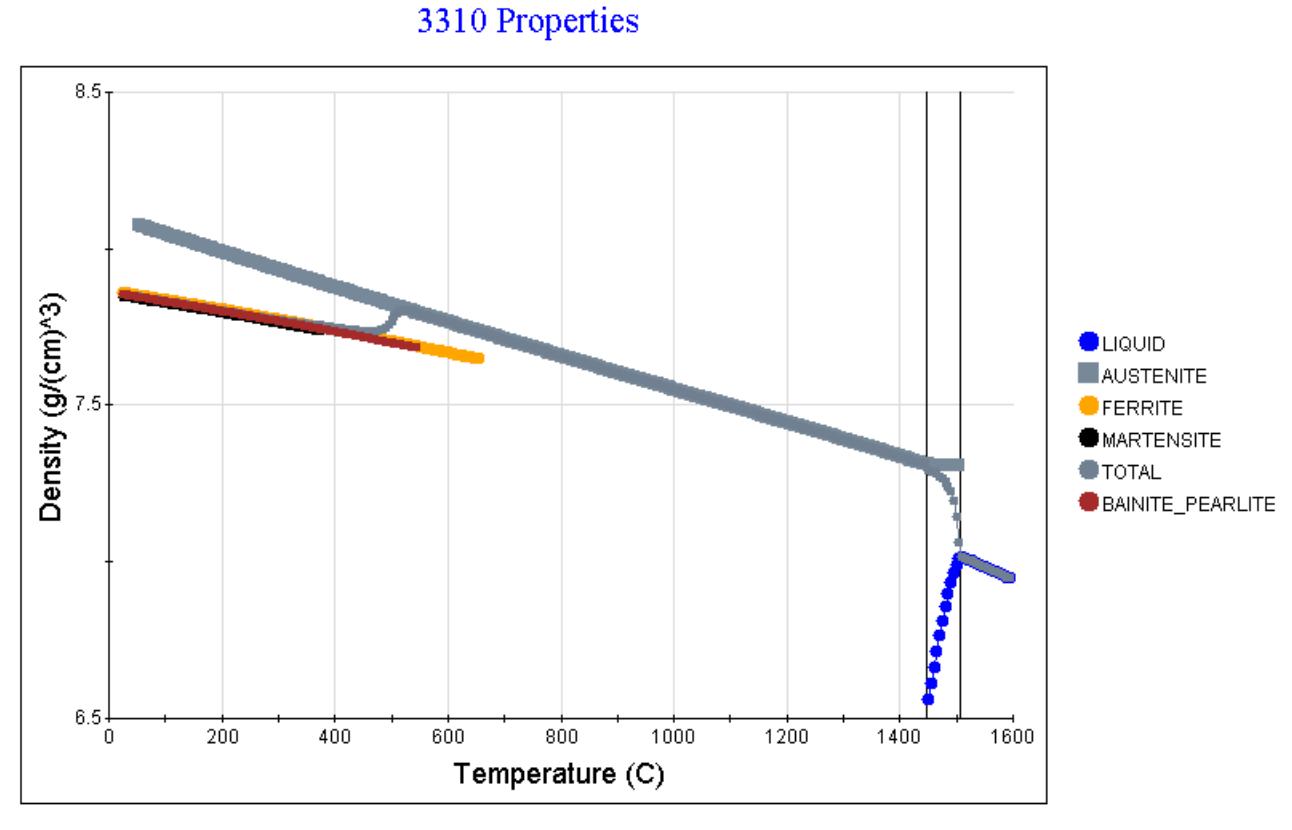
Grain size: 500.0 microns

온도별 응고분율

Solidification Calculation

온도별 각상의 밀도변화와

- Phases %
- Density
- Molar volume
- Linear expansion
- Average expansion coeff.
- Thermal conductivity
- Electrical resistivity
- Electrical conductivity
- Young's modulus
- Bulk modulus
- Shear modulus
- Poisson's ratio
- Liquid viscosity
- Total viscosity
- Yield Stress
- Tensile Stress
- Hardness
- Enthalpy
- Specific heat
- Latent heat
- Density



기계적 물성 계산

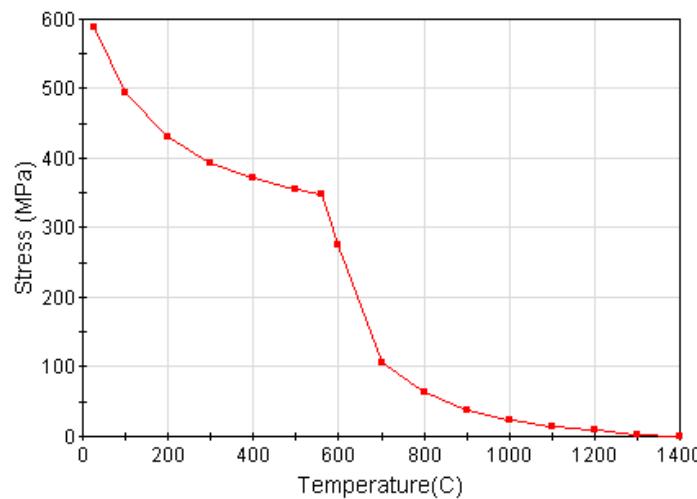
- High Temperature Strength: 온도별 항복강도
- Flow Stress : 온도별/각상별/변형률속도별 응력-변형률선도
- Jominy Curve: 조미니 경화능 선도
- Tempering Hardness: 저탄소강 템퍼링 강도 예측

High Temperature Strength Calculation

고온 항복강도 계산

SHENP-1 Strength

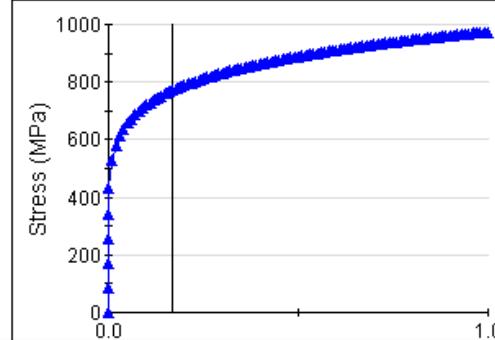
High Temperature Strength



Fixed strain rate: 1.0E-5 (1/s)

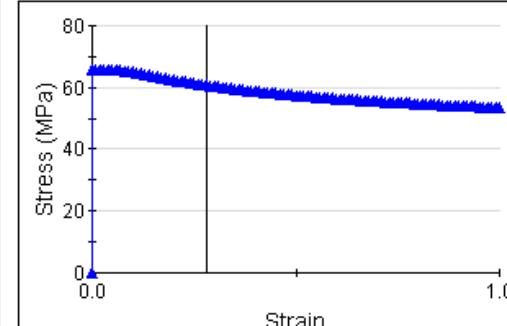
wt °C MPa μm

Stress-Strain Curve



COMPOSITION (Wt%)
Fe: 94.654
Cr: 1.27
Mn: 0.82
Mo: 0.21
Ni: 0.99
Si: 0.49
V: 0.059
C: 1.5
P: 0.0060
S: 0.0010

Stress-Strain Curve



COMPOSITION (Wt%)
Fe: 94.654
Cr: 1.27
Mn: 0.82
Mo: 0.21
Ni: 0.99
Si: 0.49
V: 0.059
C: 1.5
P: 0.0060
S: 0.0010

0.2% Proof Stress: 64.3 MPa
Strain rate: 1.0E-5 (1/s)
Test temperature: 800.0 C

Display data above elongation

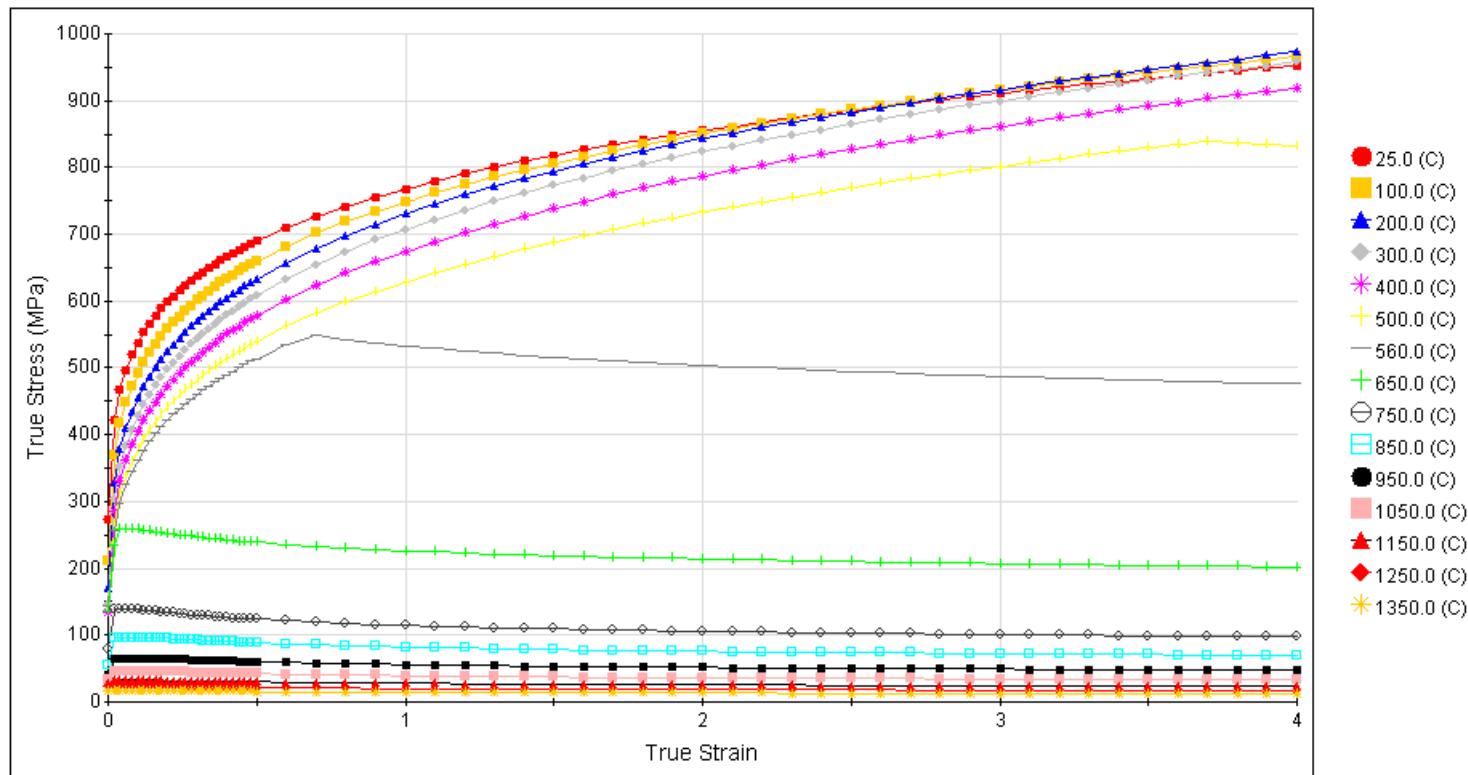
Stress : True MPa Strain : True

wt °C MPa μm

Strength Calculation

온도별/변형율 속도별 유동응력선도

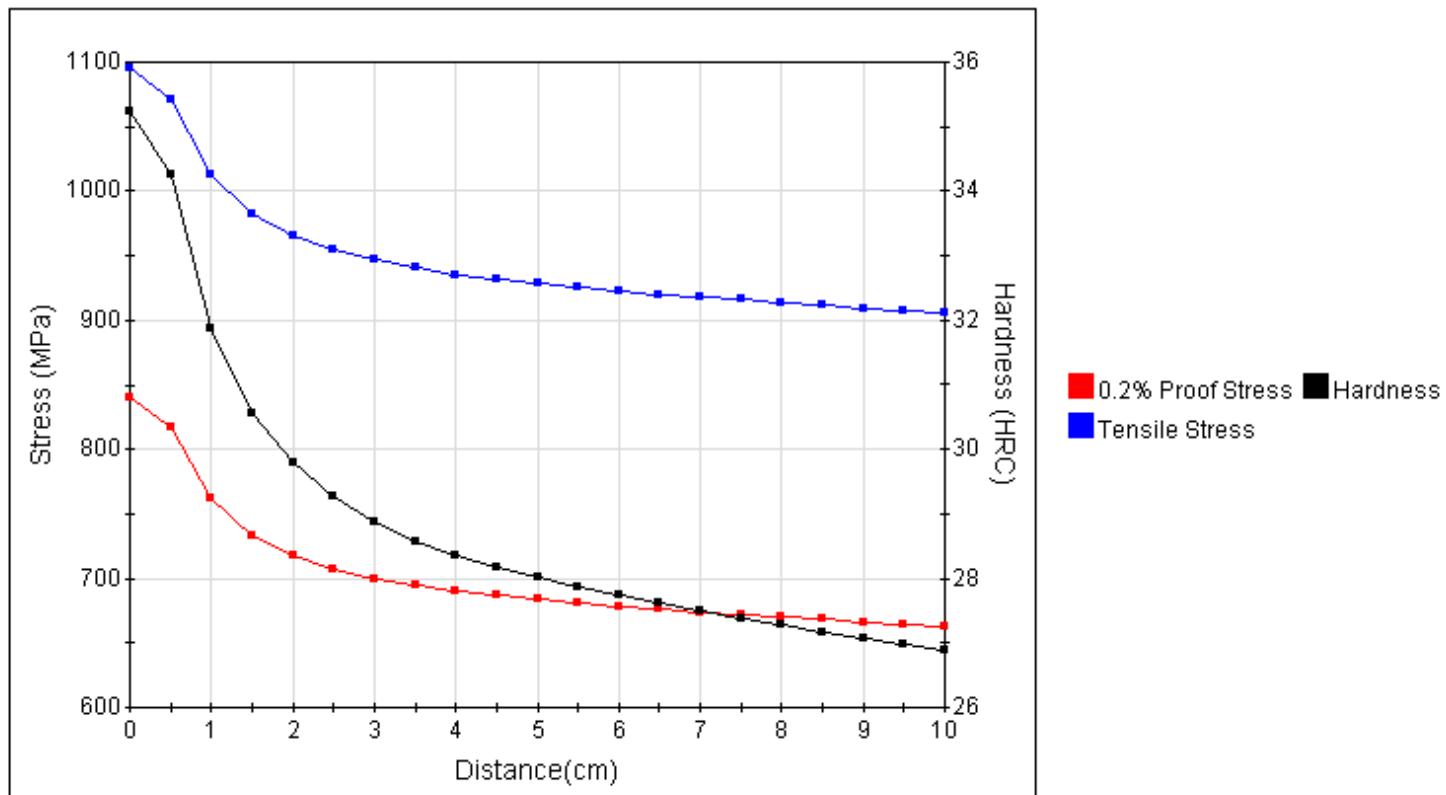
Flow-Stress



Jominy Hardenability Calculation

조미니 경화능 선도

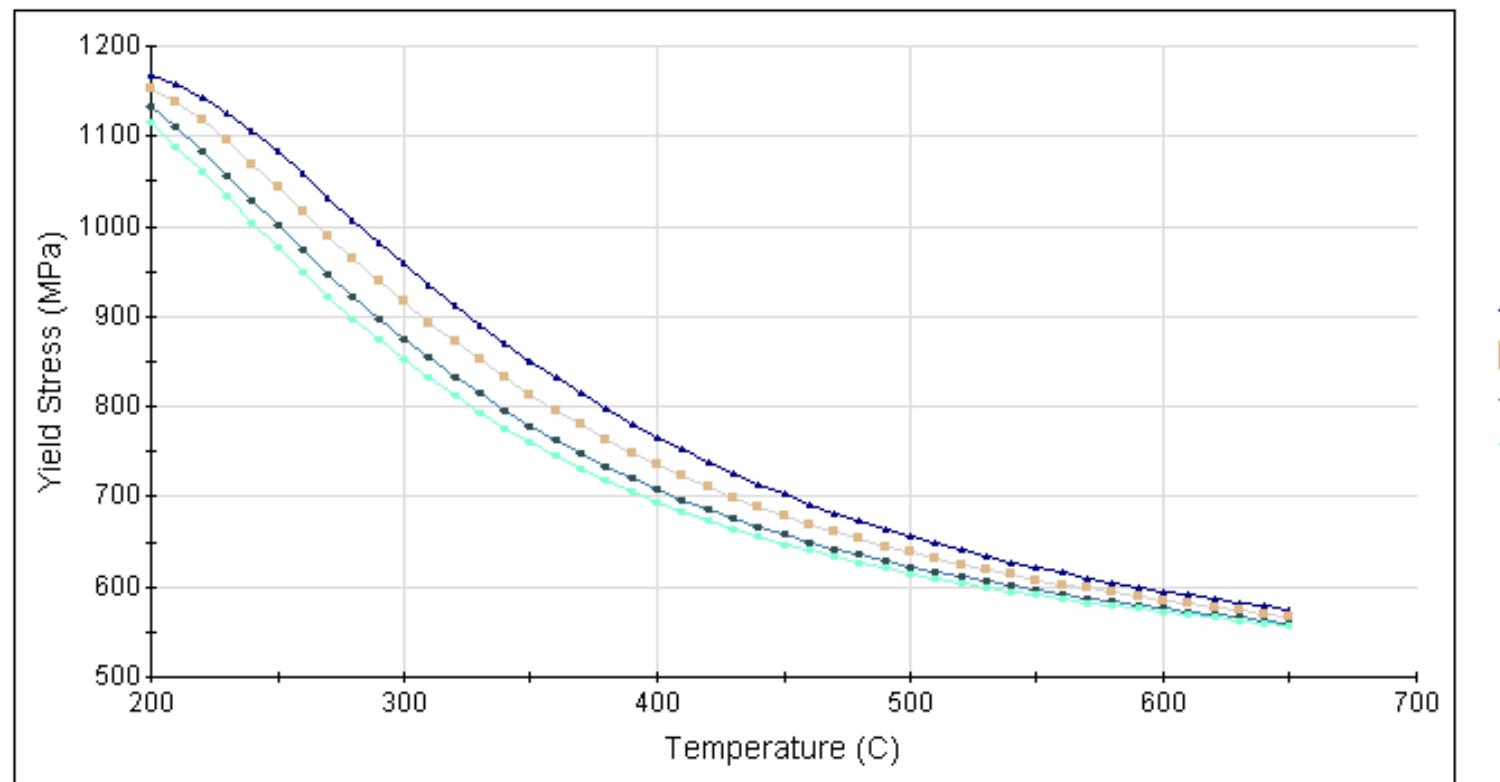
Jominy Hardenability



Grain size : 9 ASTM
Austenitisation : 820.0 C

Tempered Hardness

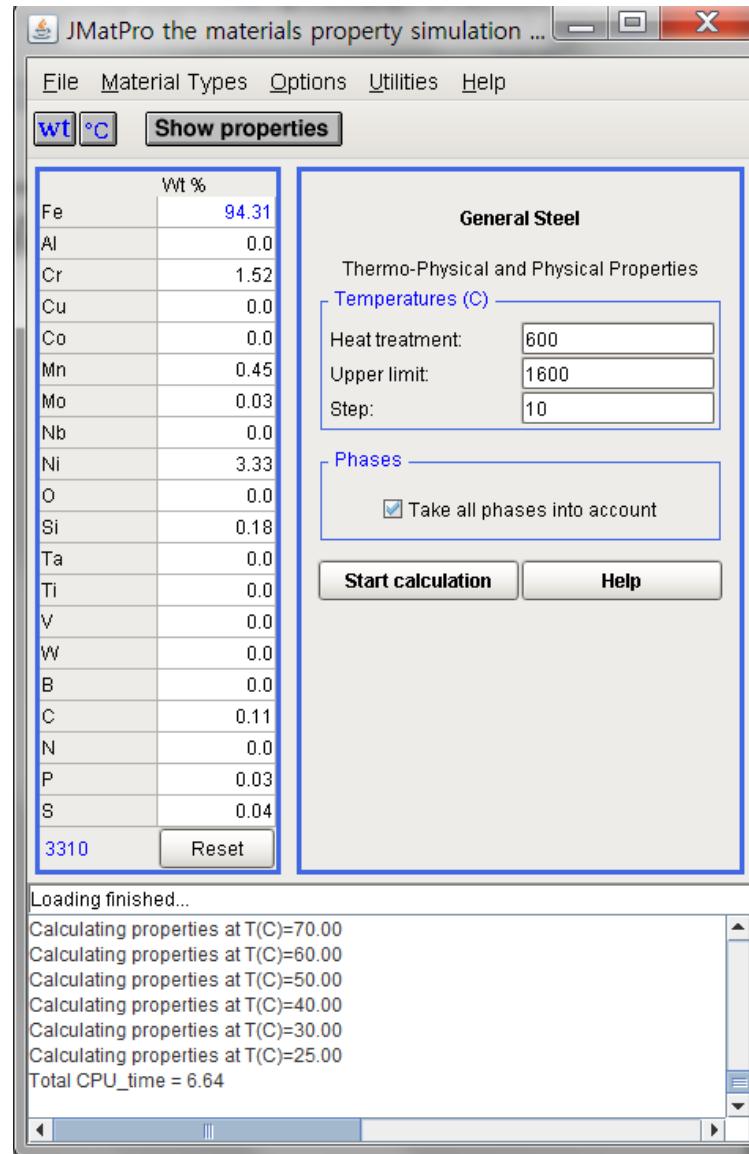
시간에 따른 강도/경도 계산



열물리적 물성 계산

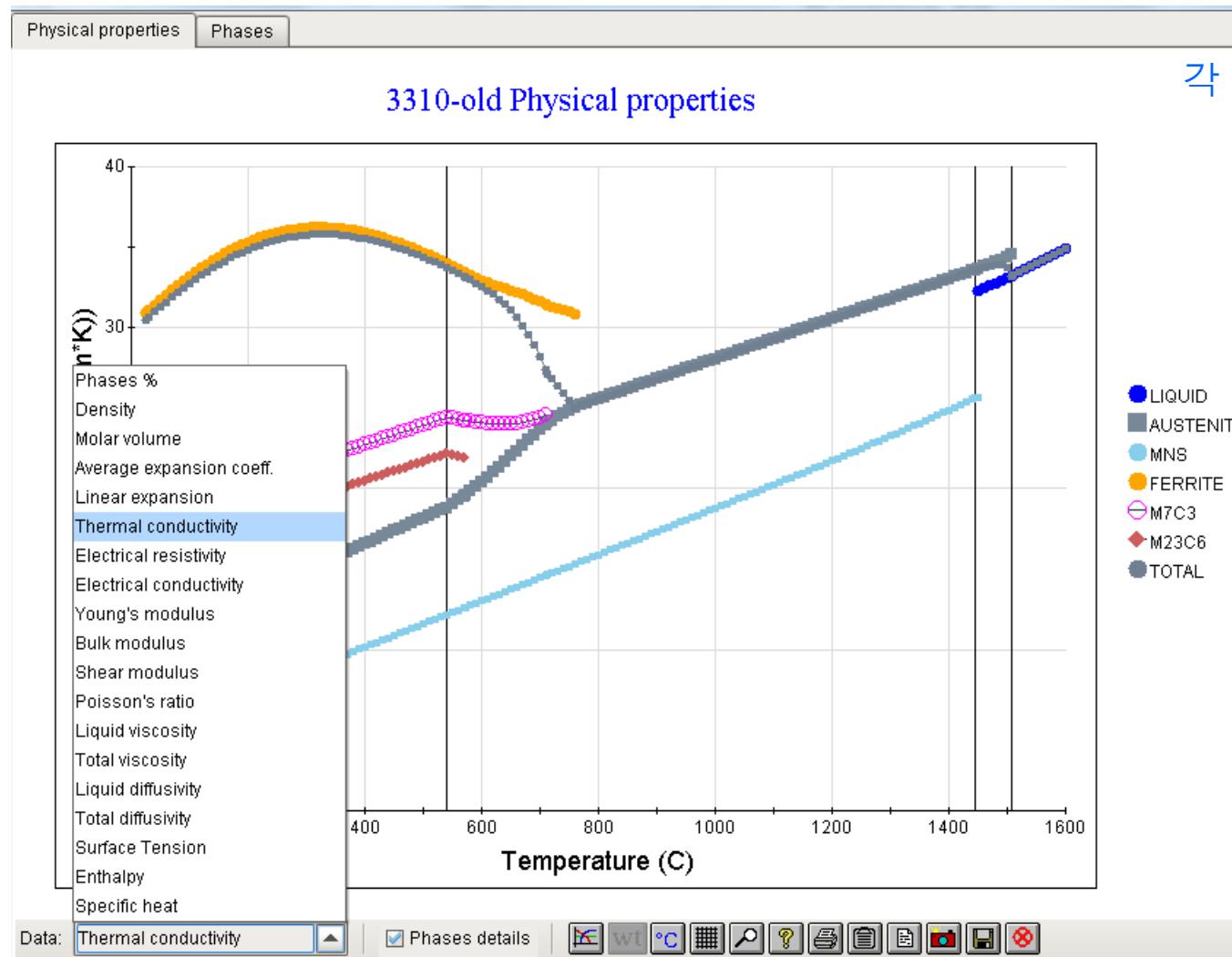
- 밀도, 열전도도, 전기전도도/비저항, 탄성계수, 프와송비, 열팽창계수, 표면장력, 비열 등

Thermo-physical Properties Calculation



열역학 계산에 기반한 상분율을
가정하여 물성계산수행

Thermo-physical Properties Calculation

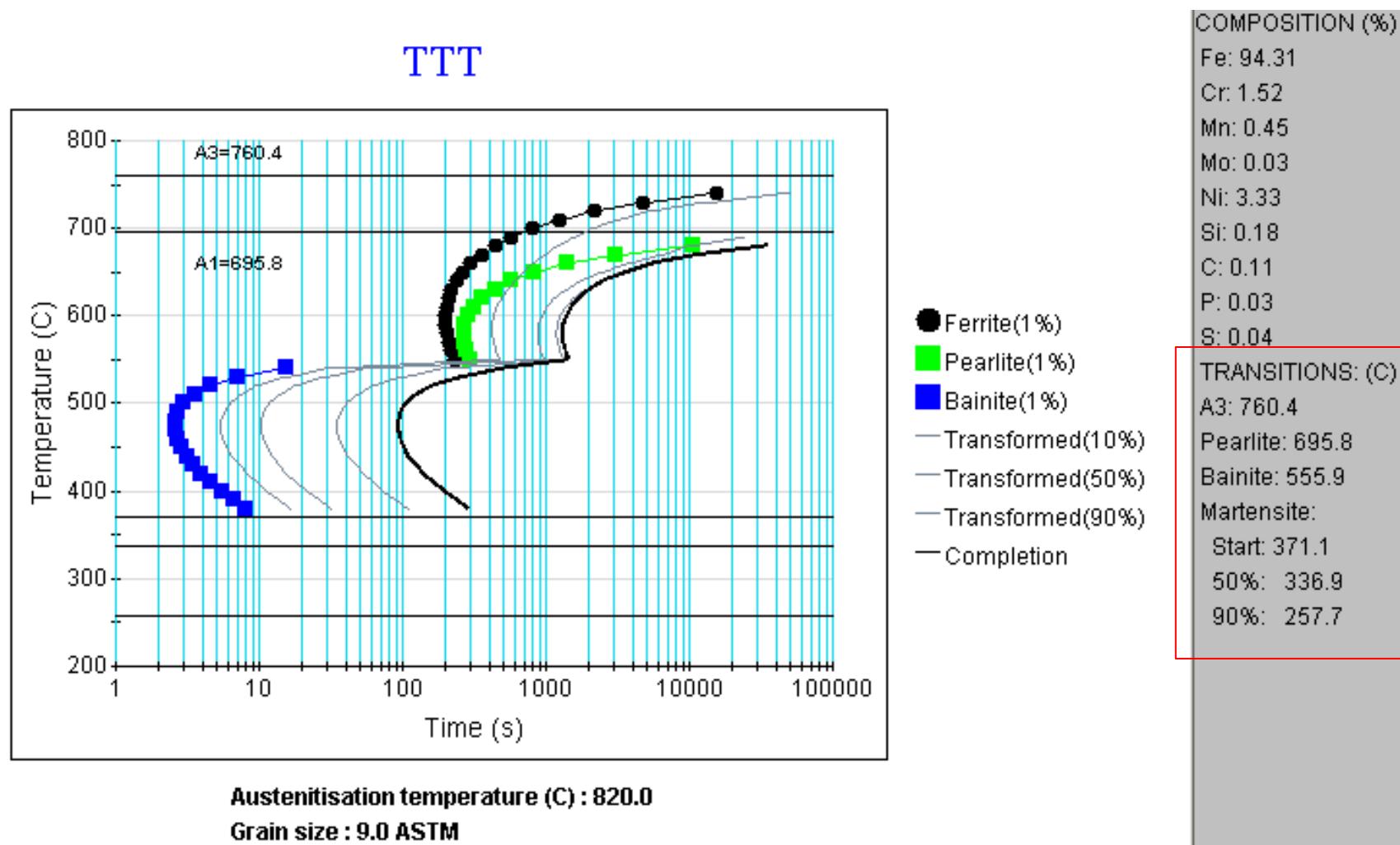


상변태 물성 계산

- TTT/CCT: 냉각시 상변태
- TTP: MN, AlN, M(C,N)
- TTA: 가열시 상변태
- Welding Cycle: 용접시 물성변화
- Simultaneous Precipitation: 템퍼링시 석출상의 크기/분율
- Quench Properties: 임의 냉각선도에서의 상분율 및 물성 계산

TTT/CCT Calculation

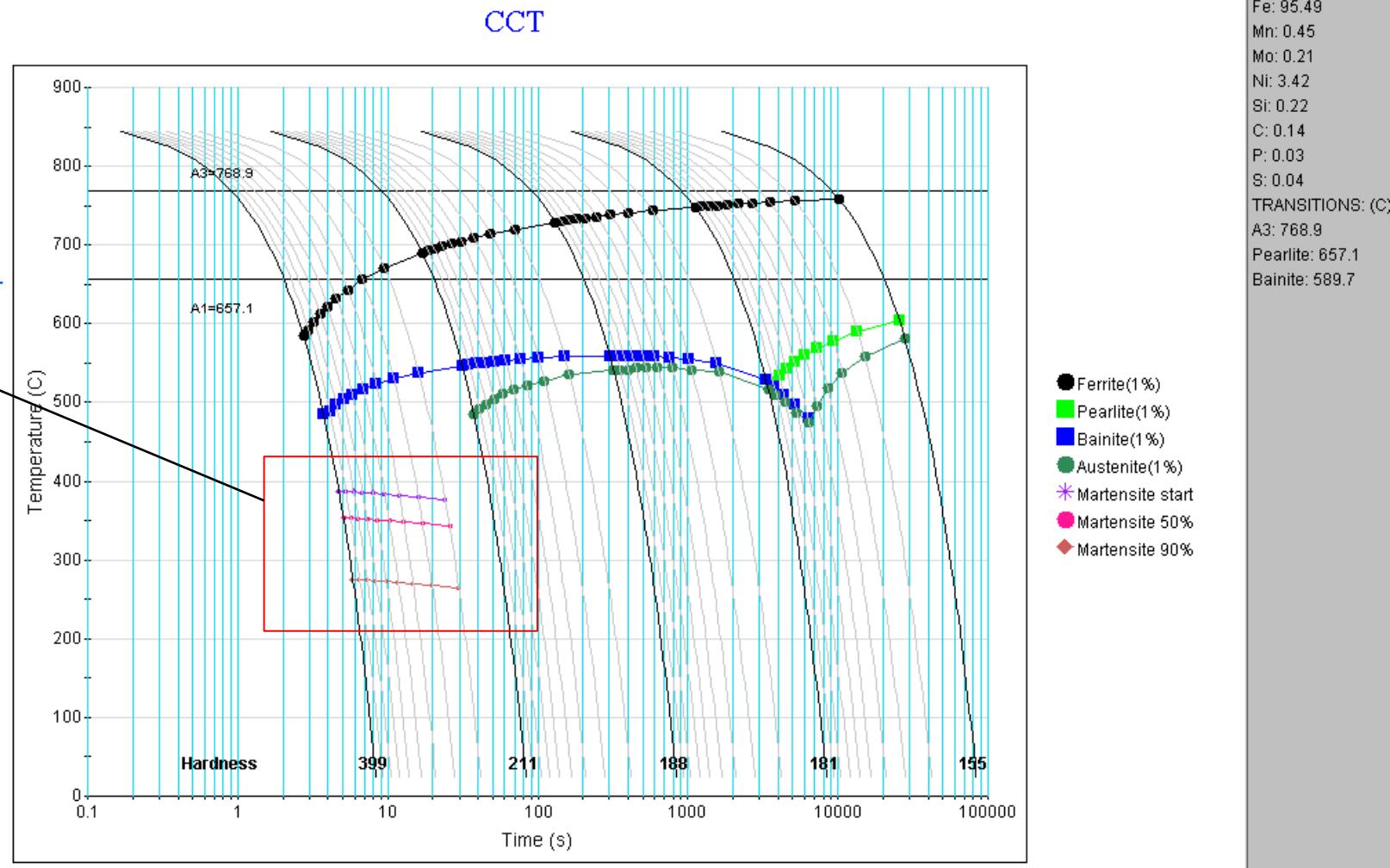
TTT/CCT 선도



TTT/CCT Calculation

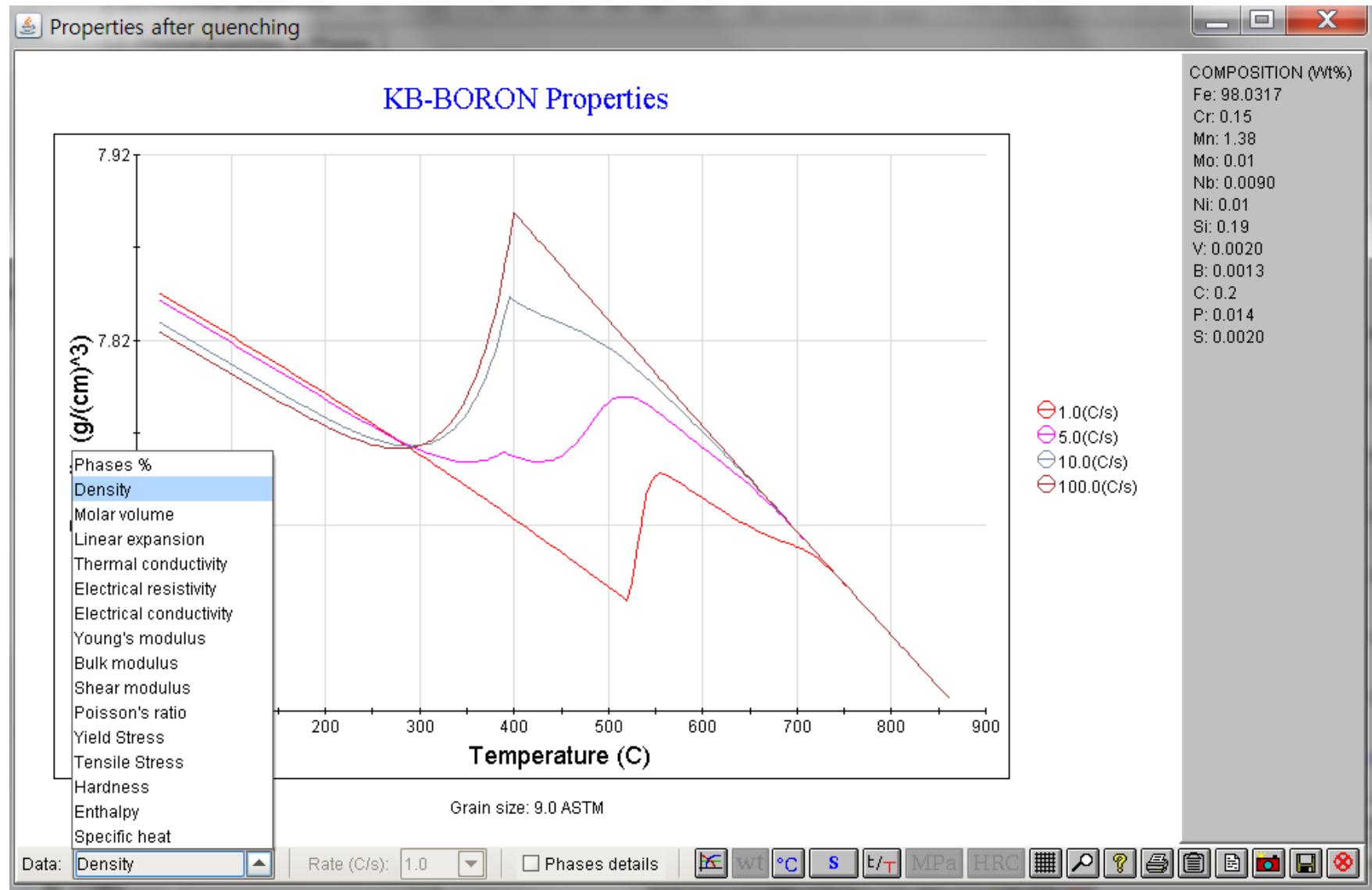
TTT/CCT 선도

오스테나이트
의 조성이 실시
간으로 변화하
는 것을 반영하
여 변태계산



Quench Properties Calculation

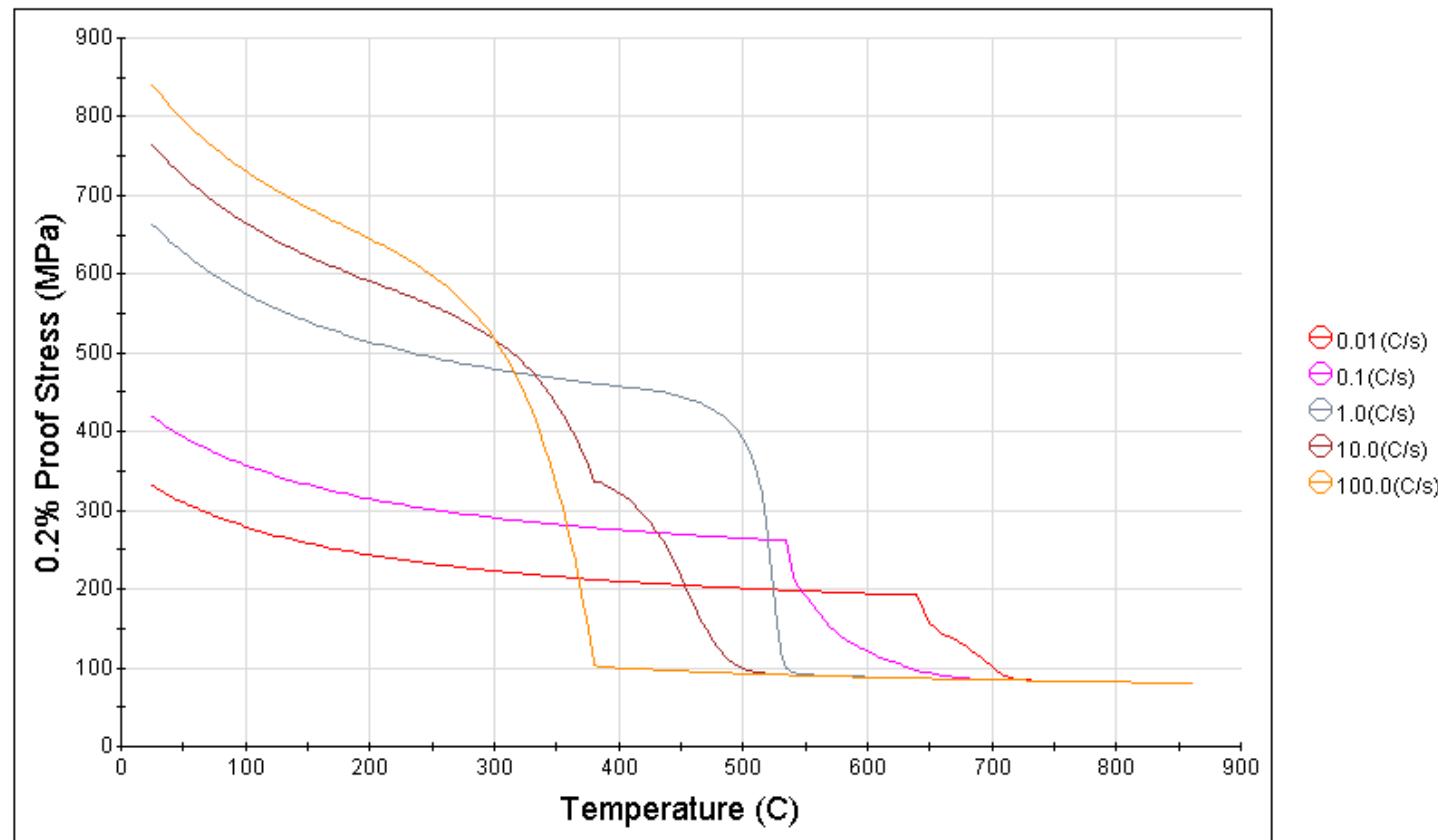
임의 냉각프로파일에 따른
상변화/물성변화 계산



Quench Properties Calculation

냉각속도에 따른 상온 강도 예측

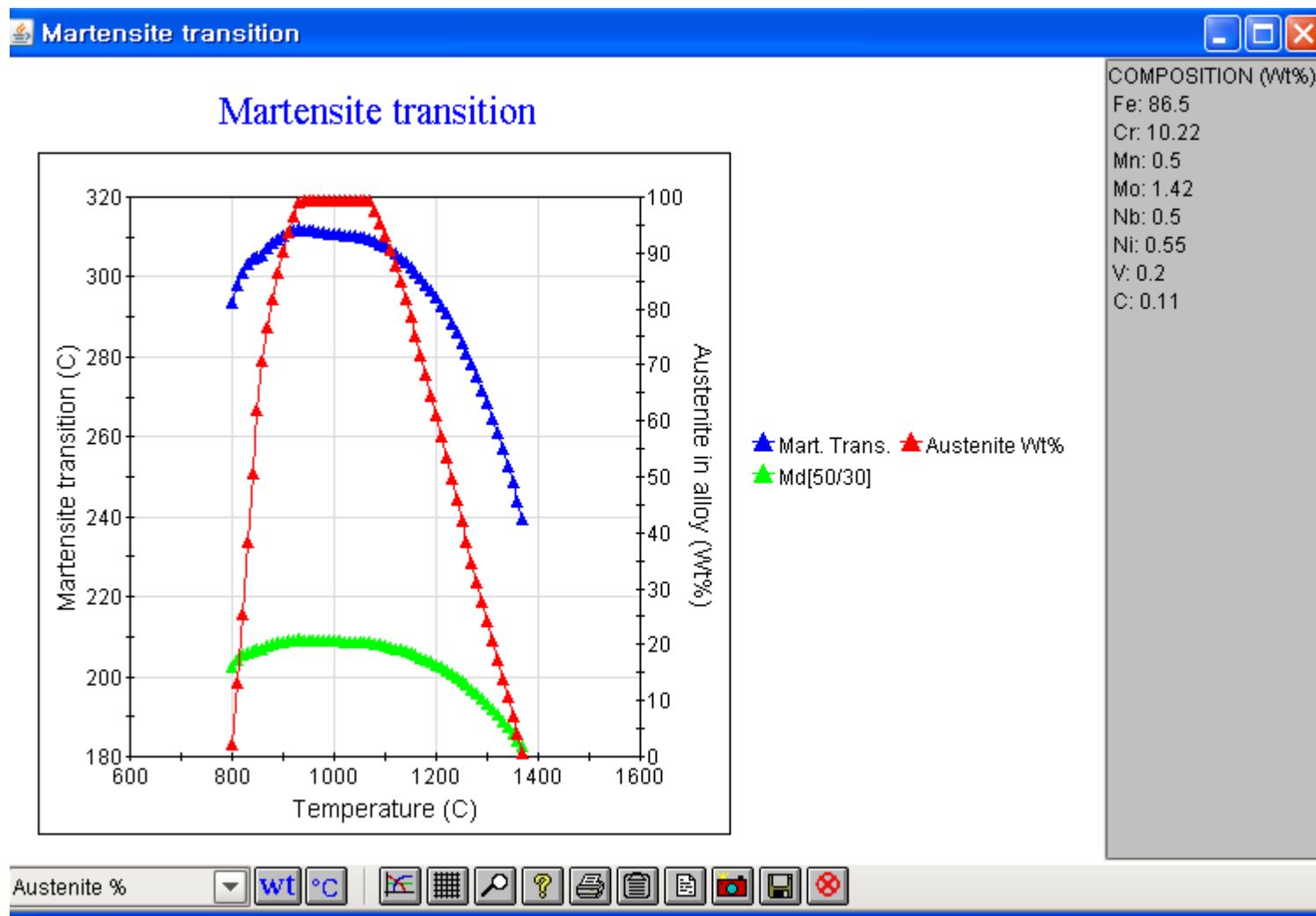
3310 Properties



Grain size: 9.0 ASTM

Martensite Transition Calculation

웬칭 온도에 따른 마르텐사이트 변태온도 변화



Tempering Precipitation Calculation

템퍼링시 온도/시간에 따른 석출상 크기 및 분율계산

General Steel
Simultaneous Precipitation

Steel type
 Carbide-strengthened Maraging

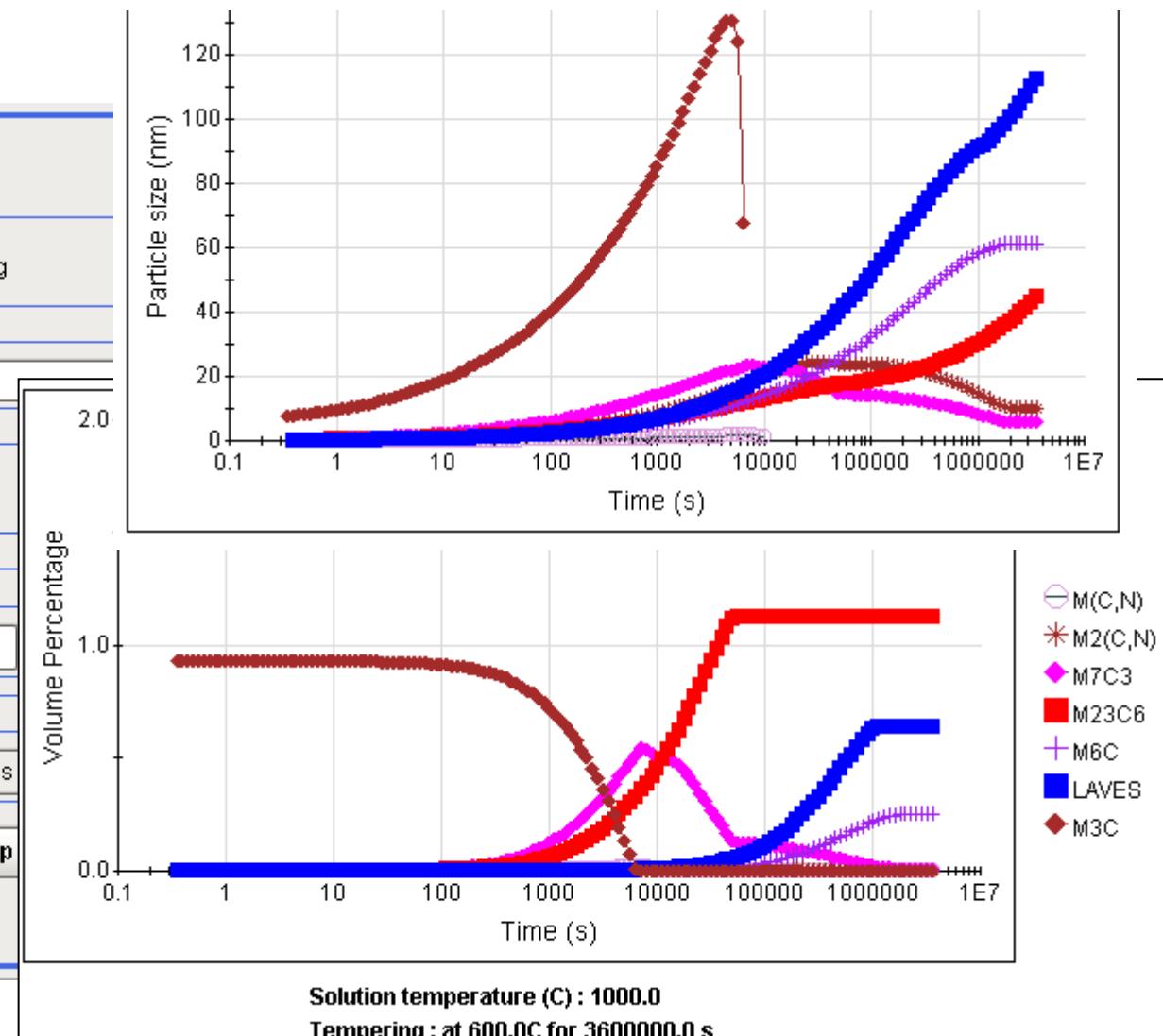
Solution treatment
 Temperature (C)

Second tempering stage
 add second tempering stage

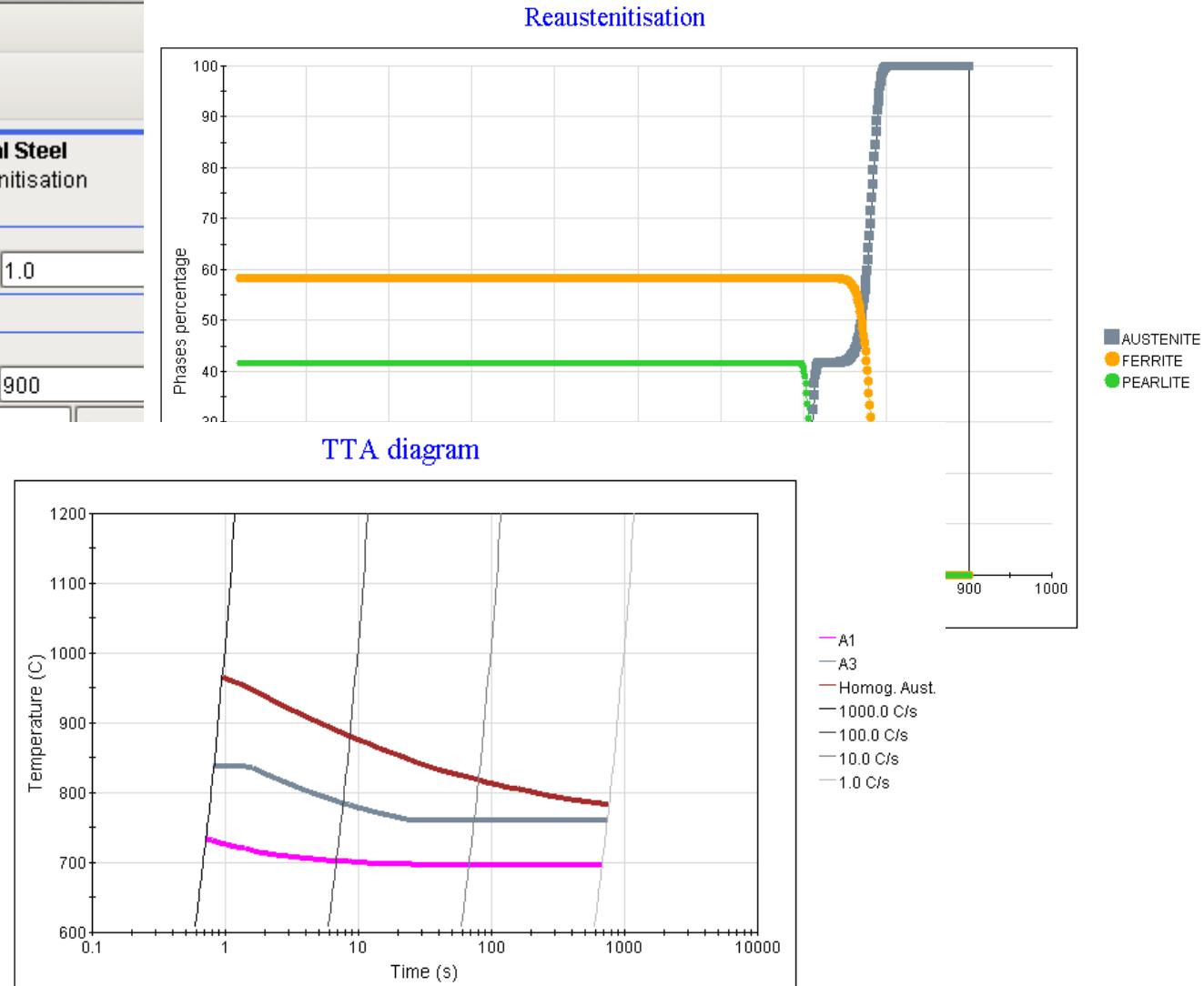
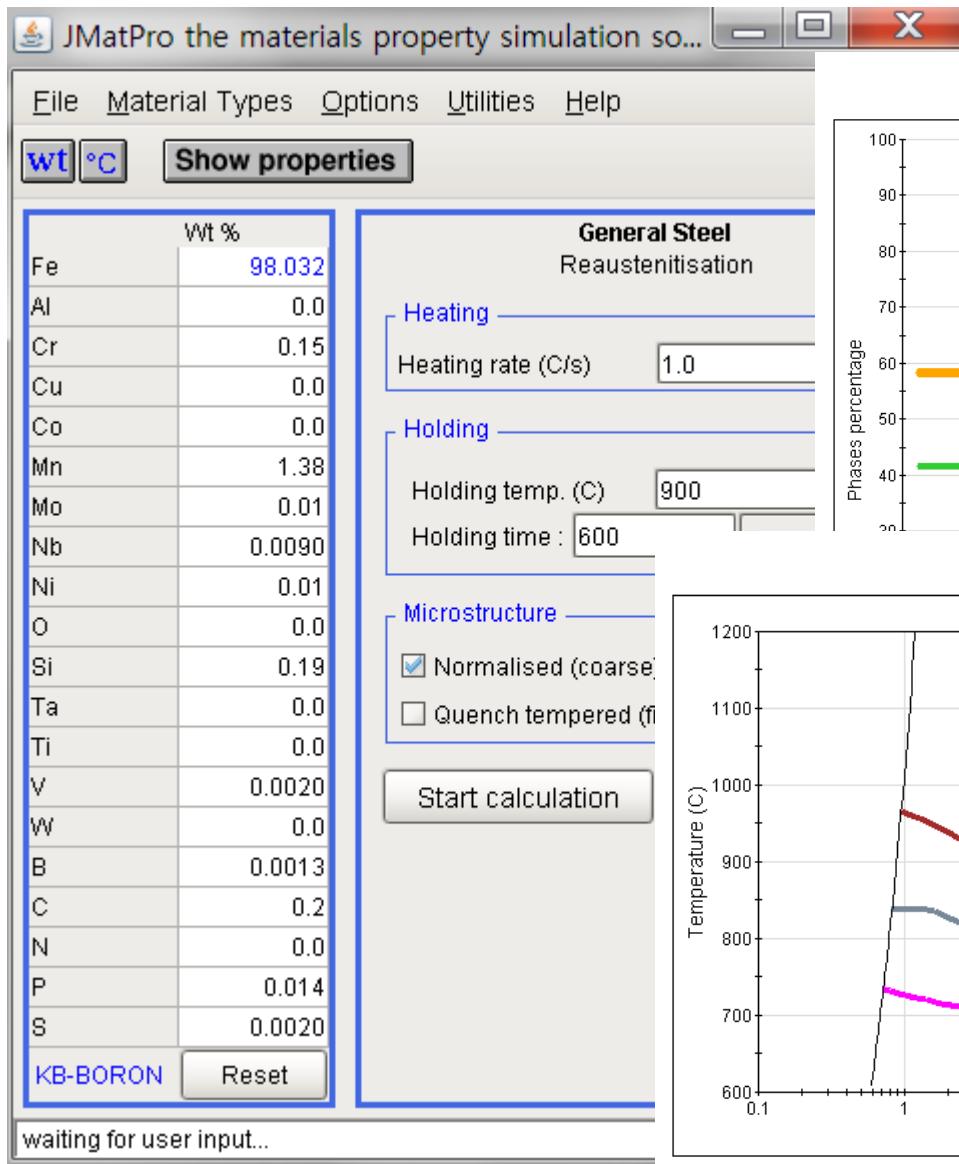
Tempering
 Temperature
 Temp. (C) Time
 Time :

Final matrix grain size
 Size microns

Start calculation **Help**



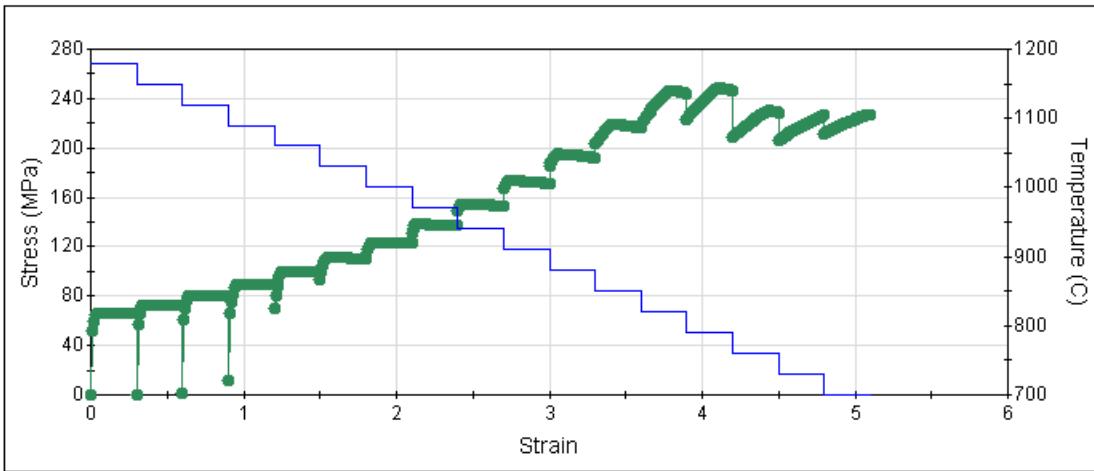
Reaustenization Calculation



가열 속도에 따른 오스테나이트 변태온도 구간 계산

Multi-pass Hot Rolling

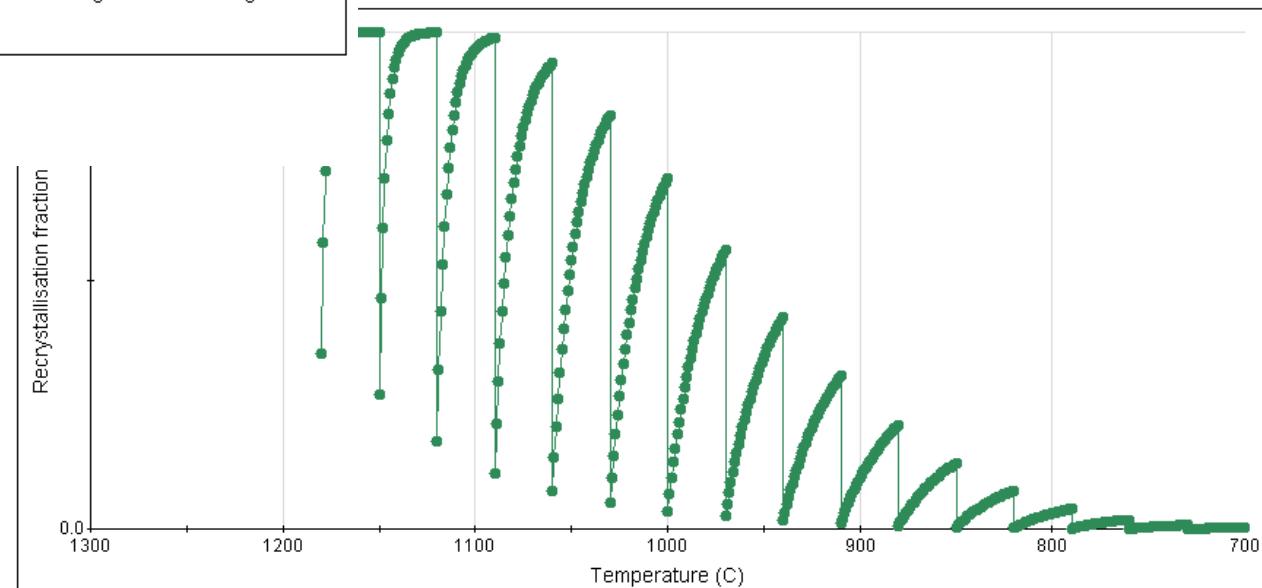
Hot Rolling



Annealing temperature : 1300.0 C
Initial cooling rate : 1.0 C/s
Initial grain size : 200 micron

다단 열간압연시 재결정분율/결정립크기/하중 변화 계산(micro_alloyed_steel)

Hot Rolling

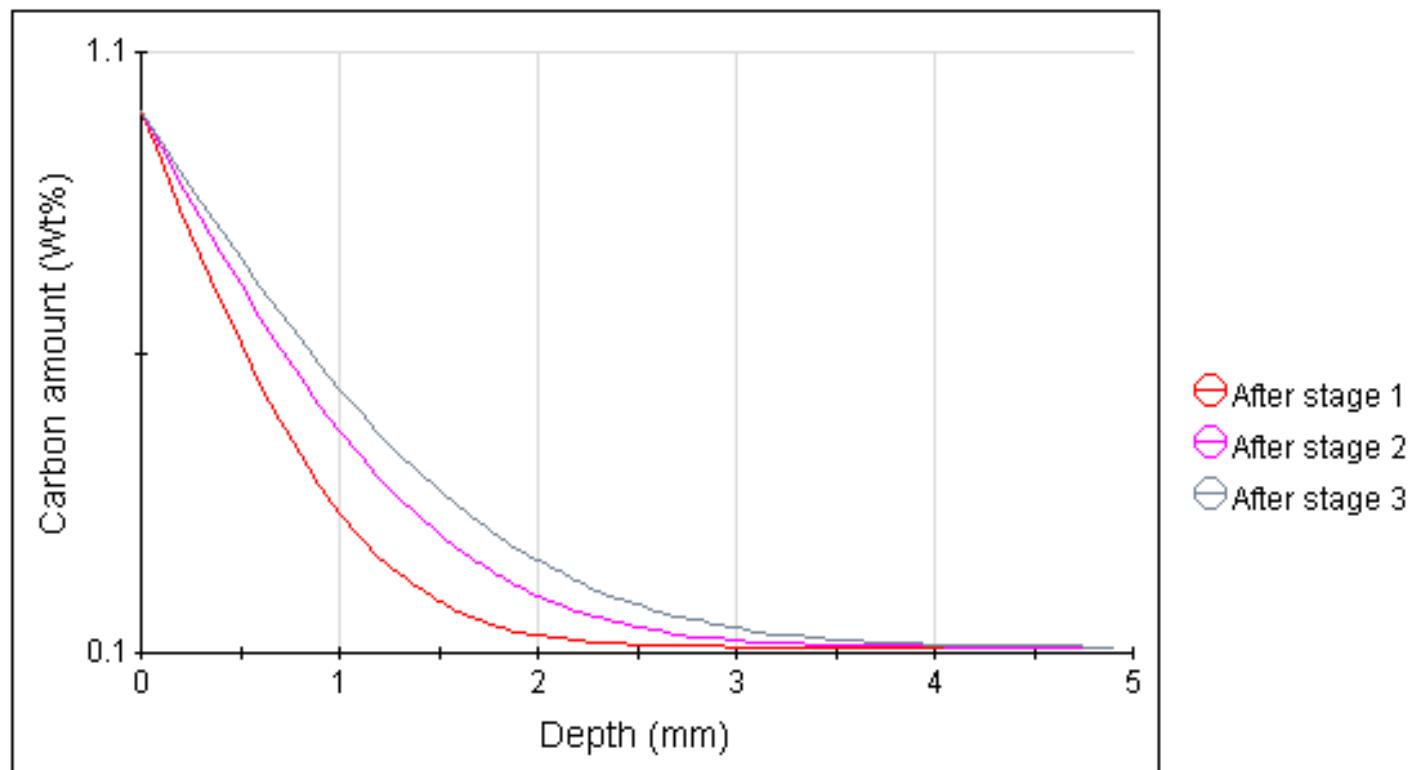


Quenching temperature : 1300.0 C
Initial cooling rate : 1.0 C/s
Initial grain size : 200 micron

Carburization (General Steel)

침탄 조건에 따른 농도
변화 계산

Carburisation



Carburisation in 3 stages:

At 900C for 10.0hr with surf. C 1.0wt%

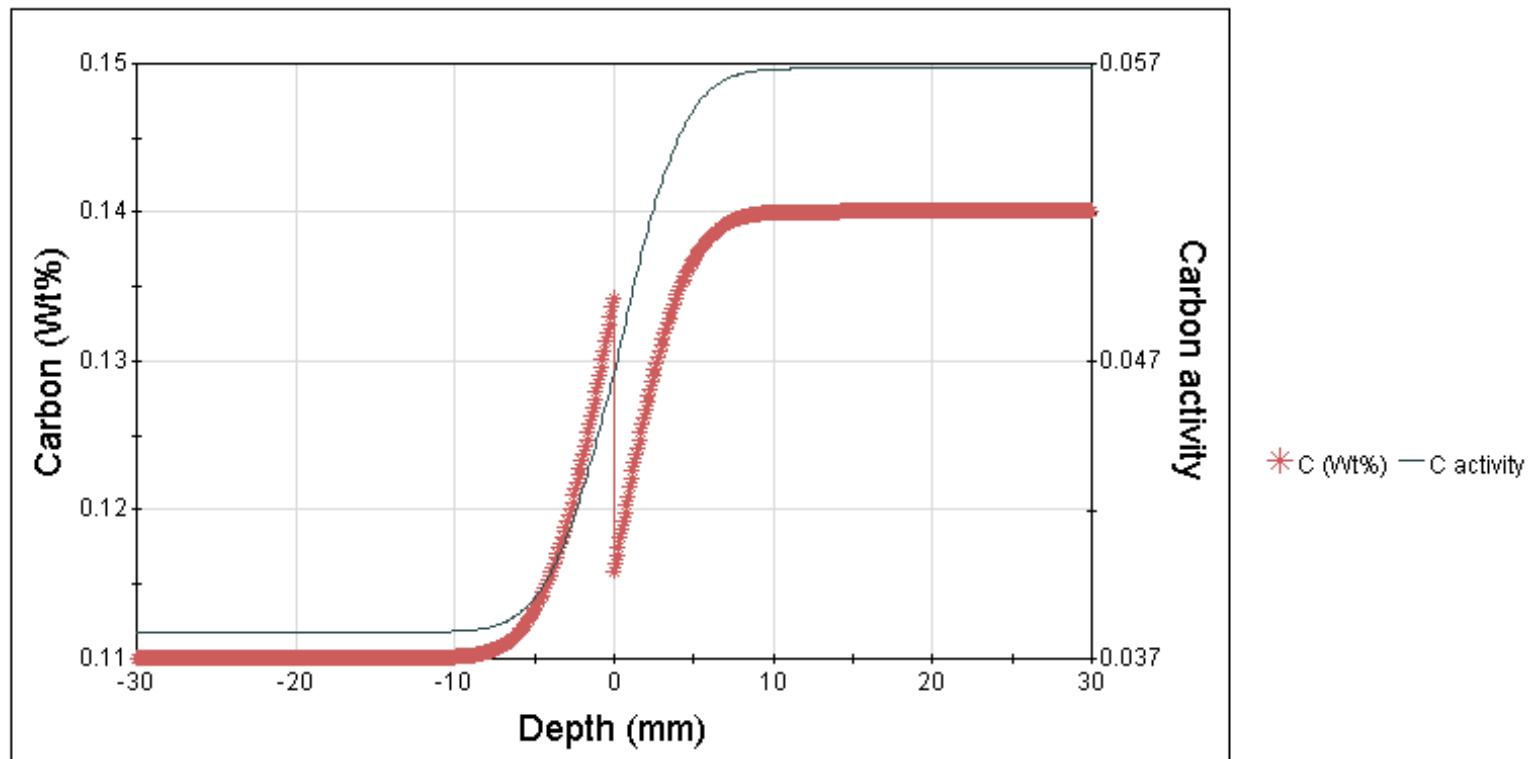
At 890C for 10.0hr with surf. C 1.0wt%

At 880C for 10.0hr with surf. C 1.0wt%

C diffusion in Weld(General Steel)

용접 인근영역에서의
C 확산

C diffusion in weld



Holding temperature (C) : 1050.0

Holding time (h) : 30.0

Left alloy elts: Fe Cr Mn Mo Ni Si C P S

Left alloy (wt%): 94.31 1.52 0.45 0.03 3.33 0.18 0.11 0.03 0.04

Right alloy elts: Fe Mn Mo Ni Si C P S

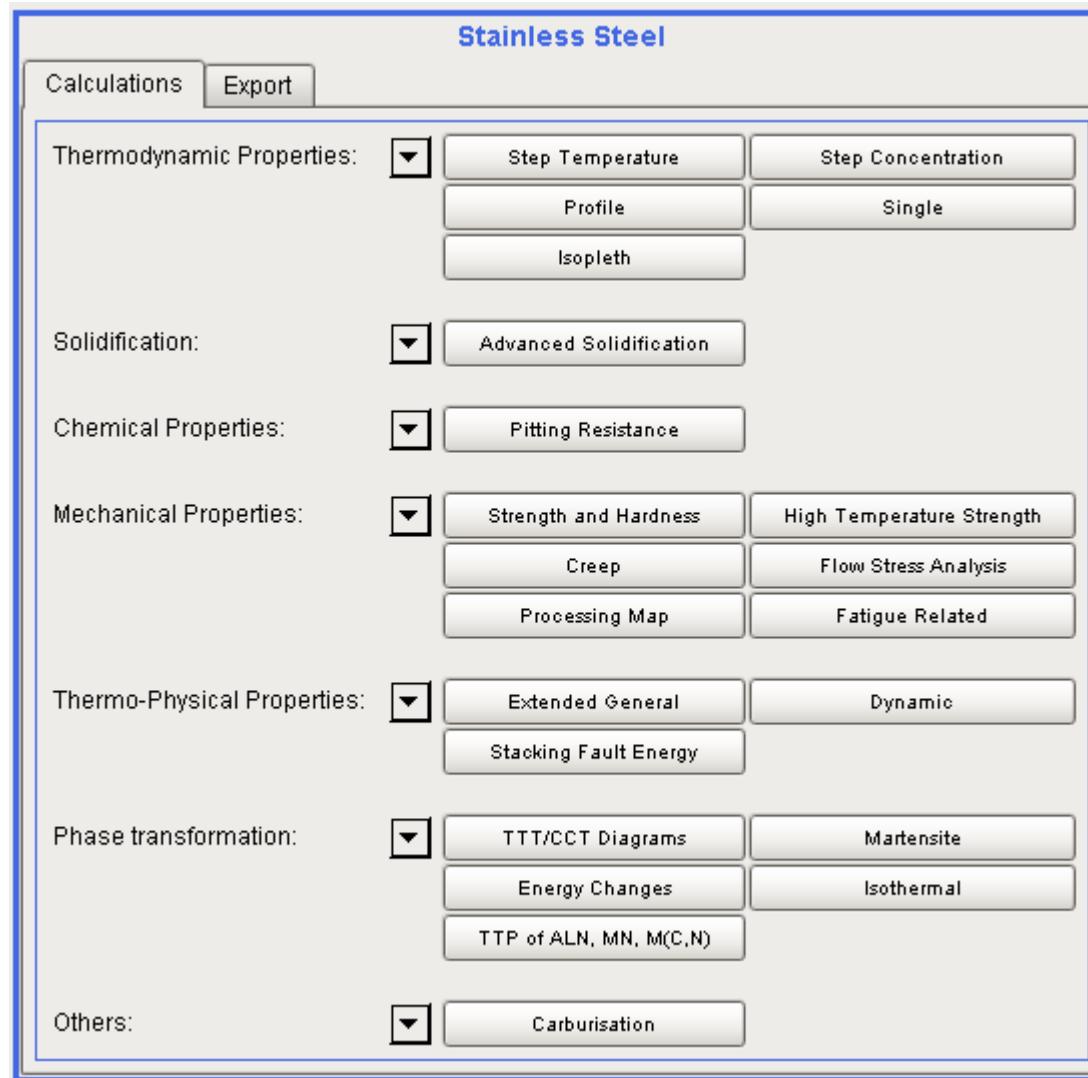
Right alloy (wt%): 95.49 0.45 0.21 3.42 0.22 0.14 0.03 0.04

Stainless Steel

Stainless Steel모듈 기능 개요

구분	기능	활용분야/기타
열역학계산	<ul style="list-style-type: none"> 평형상분율 계산 상태도 계산(2원계) 	<ul style="list-style-type: none"> 상태도 관련 정보추출 열처리 기준 온도 설정 생성상을 제어하기 위한 합금설계
응고물성 계산	<ul style="list-style-type: none"> 응고분율 계산 및 물성계산 	<ul style="list-style-type: none"> 응고시뮬레이션 물성계산 응고구간 거동 정보 추출 잠열 계산
열물리적 물성 계산	<ul style="list-style-type: none"> 열역학계산 기반의 상분율을 가정한 물성계산 PRE Number 계산 	<ul style="list-style-type: none"> 열물성, 탄성계수, 열팽창계수, 밀도변화, 점성, 잠열 및 비열 등 계산 부식 관련 정보
기계적 물성 계산	<ul style="list-style-type: none"> 고온 항복강도 계산 온도별/변형율 속도별 유동응력 선도 피로 시험 관련 계산 기능 크립 계산 기능 	<ul style="list-style-type: none"> 열처리 온도정보로부터 상온강도/고온 유동응력선도 추출 피로/크립물성/파단수명 등 예측
상변태 관련 기능	<ul style="list-style-type: none"> TTT/CCT 계산기능 Isothermal Holding 계산기능 침탄 계산 기능 	<ul style="list-style-type: none"> 열간성형해석용 물성 추출 응고해석용 물성 추출

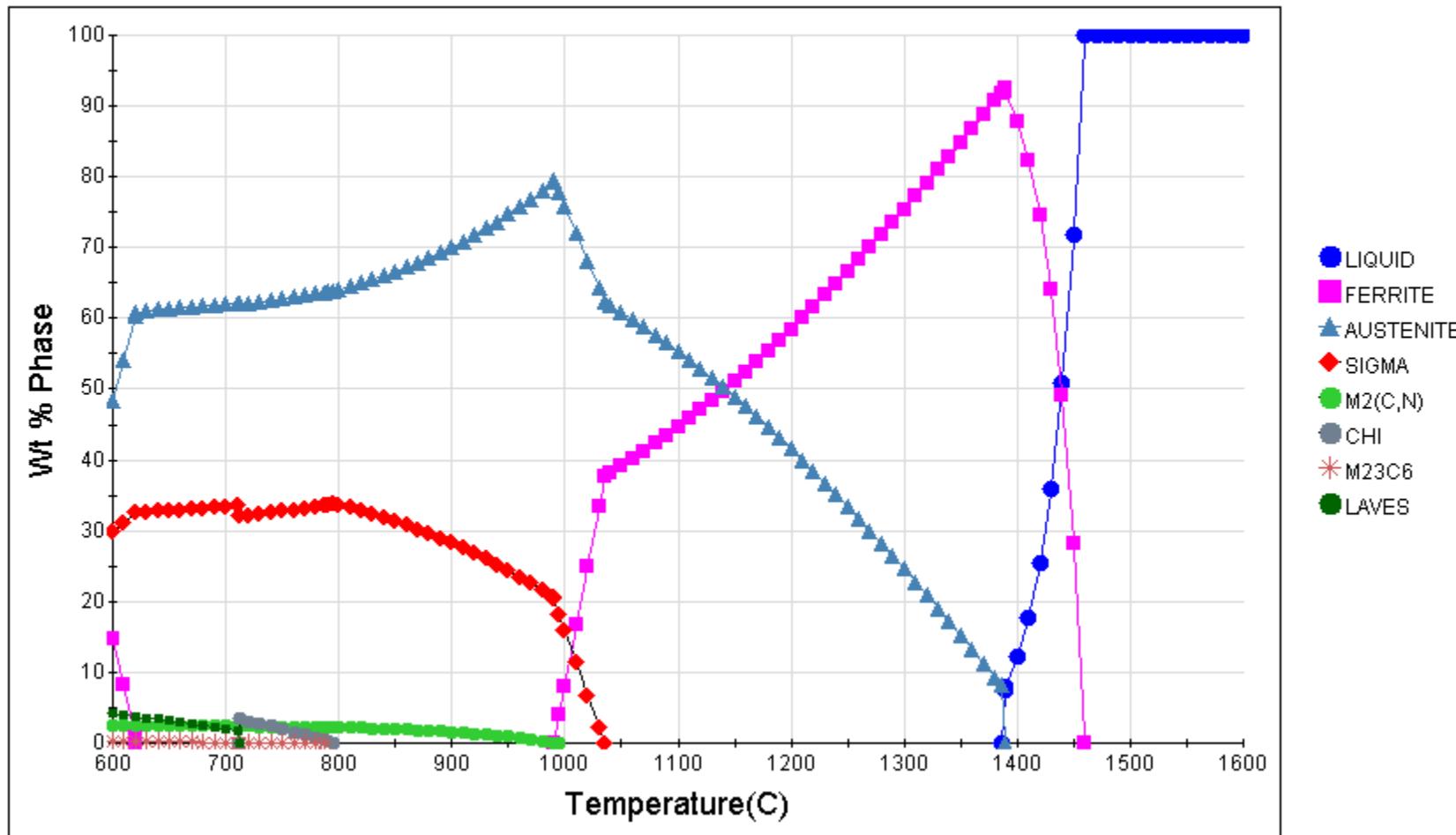
Main GUI for Stainless Steel



Thermodynamic Calculation

SAF2507 온도별 평형상분율

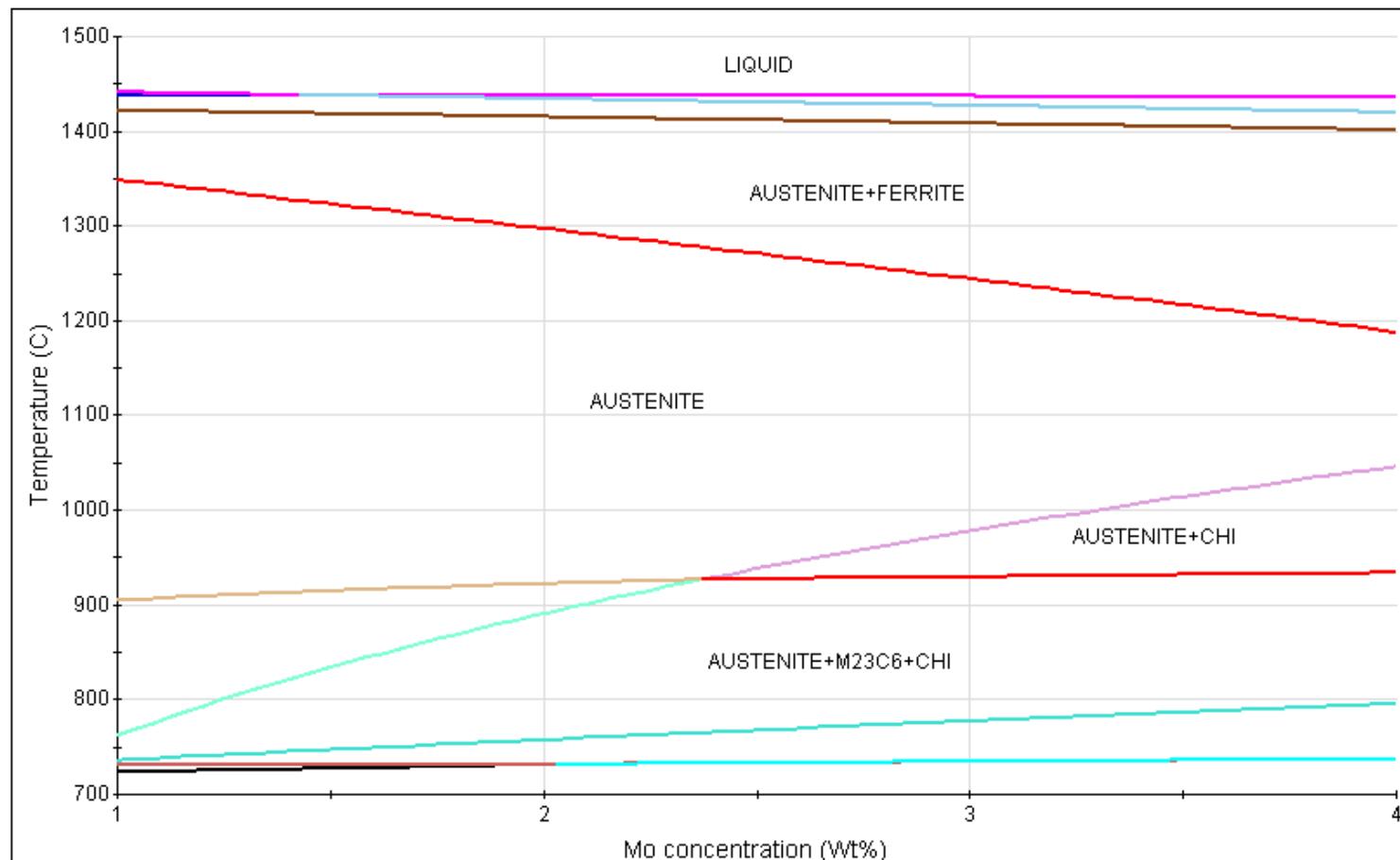
Fe-25.0Cr-1.0Mn-3.8Mo-7.0Ni-0.4Si-0.01C-0.28N wt(%)



Isopleth Phase Diagram

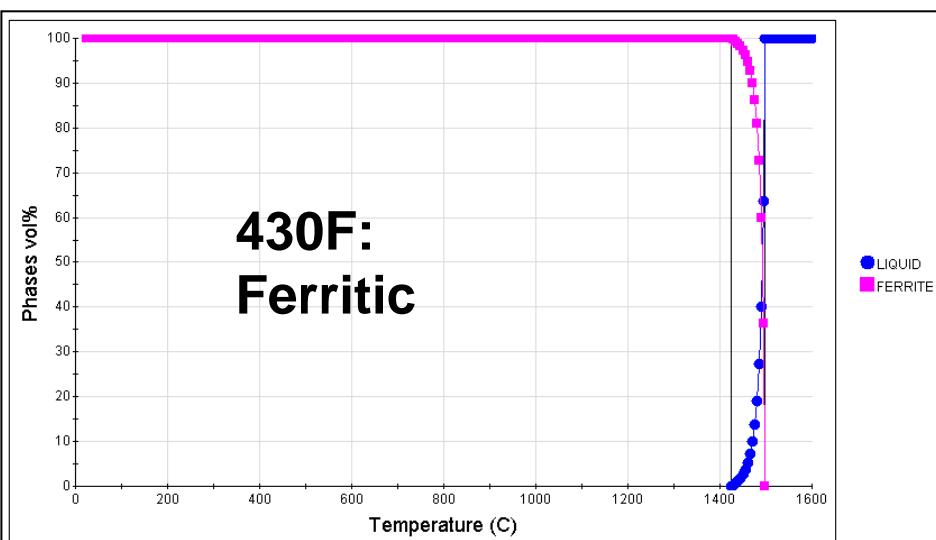
Mo 첨가에 따른 생성상 변화

Isopleth

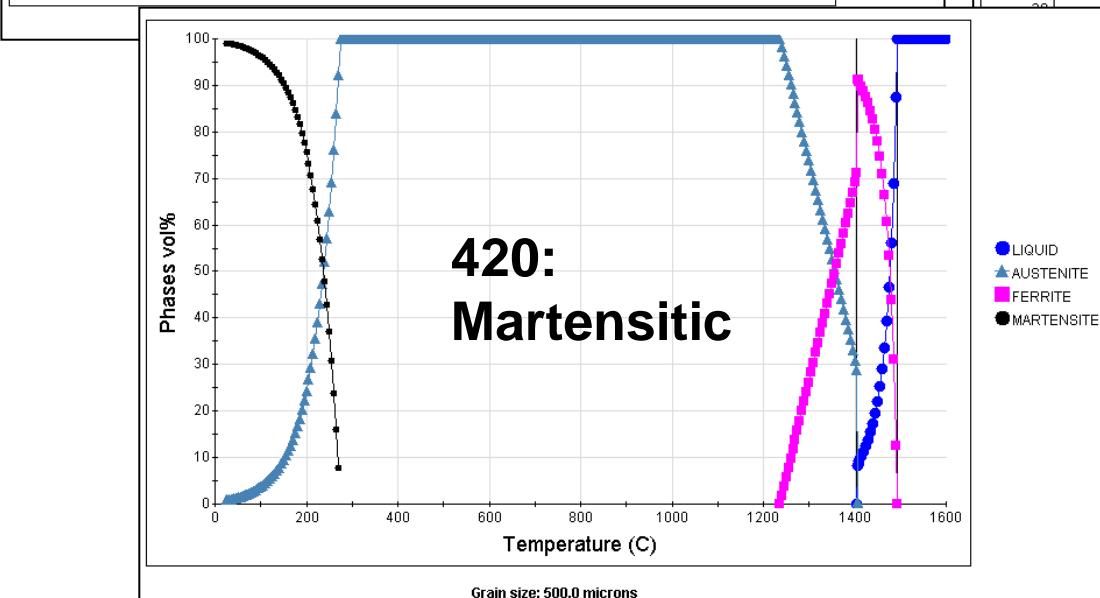
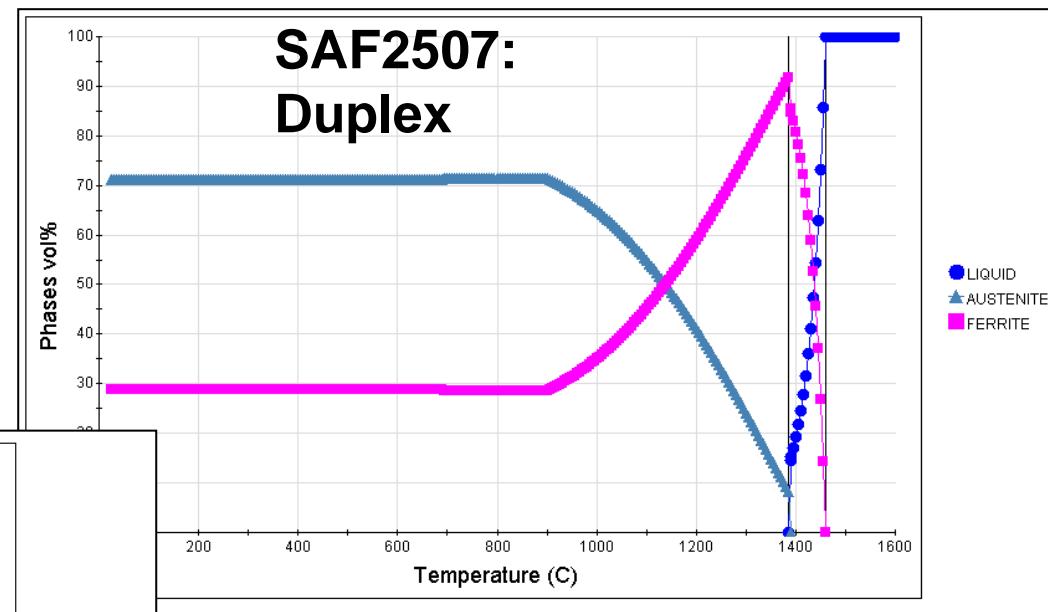


Balance element: Fe

Advanced Solidification



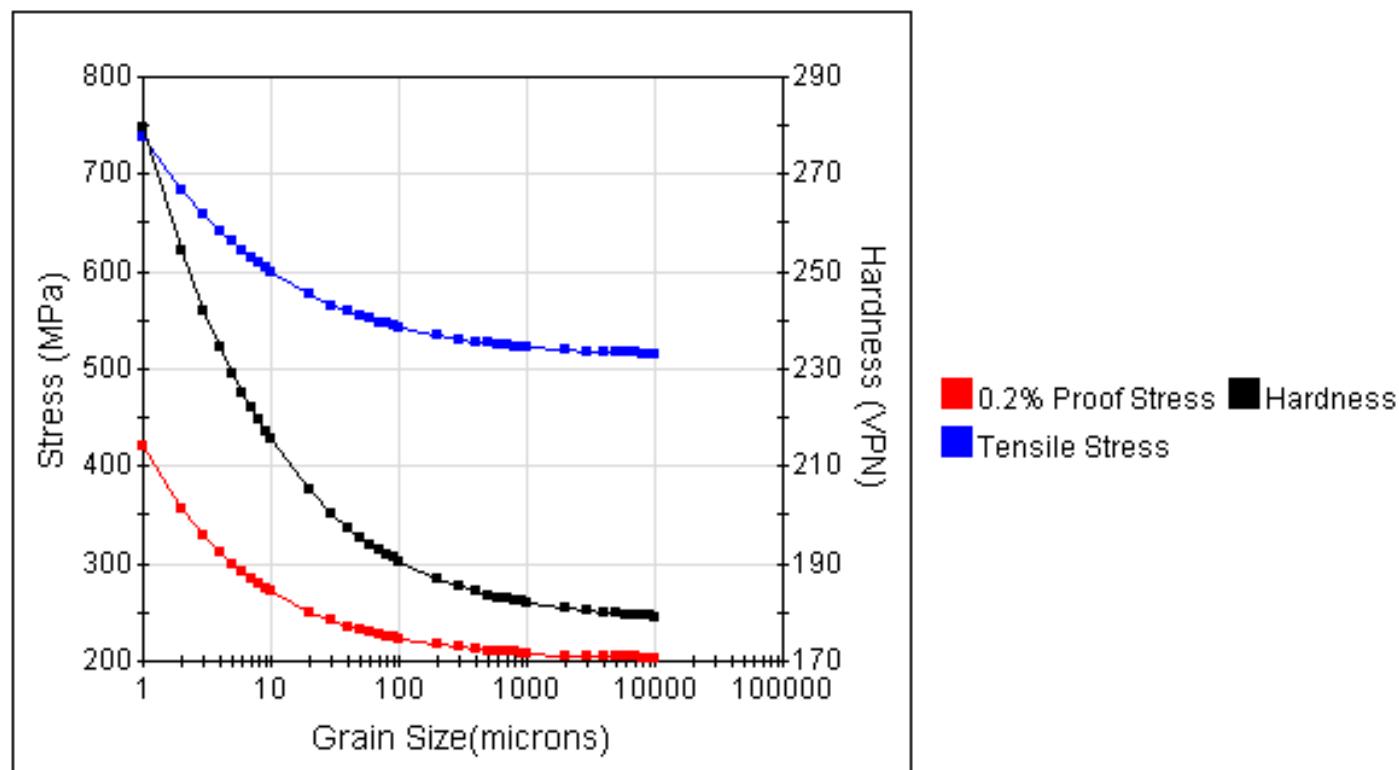
Type별 응고거동 모사



Solution Hardening

결정립크기 및 고용체 강화 고려한 강도계산

Solution hardening



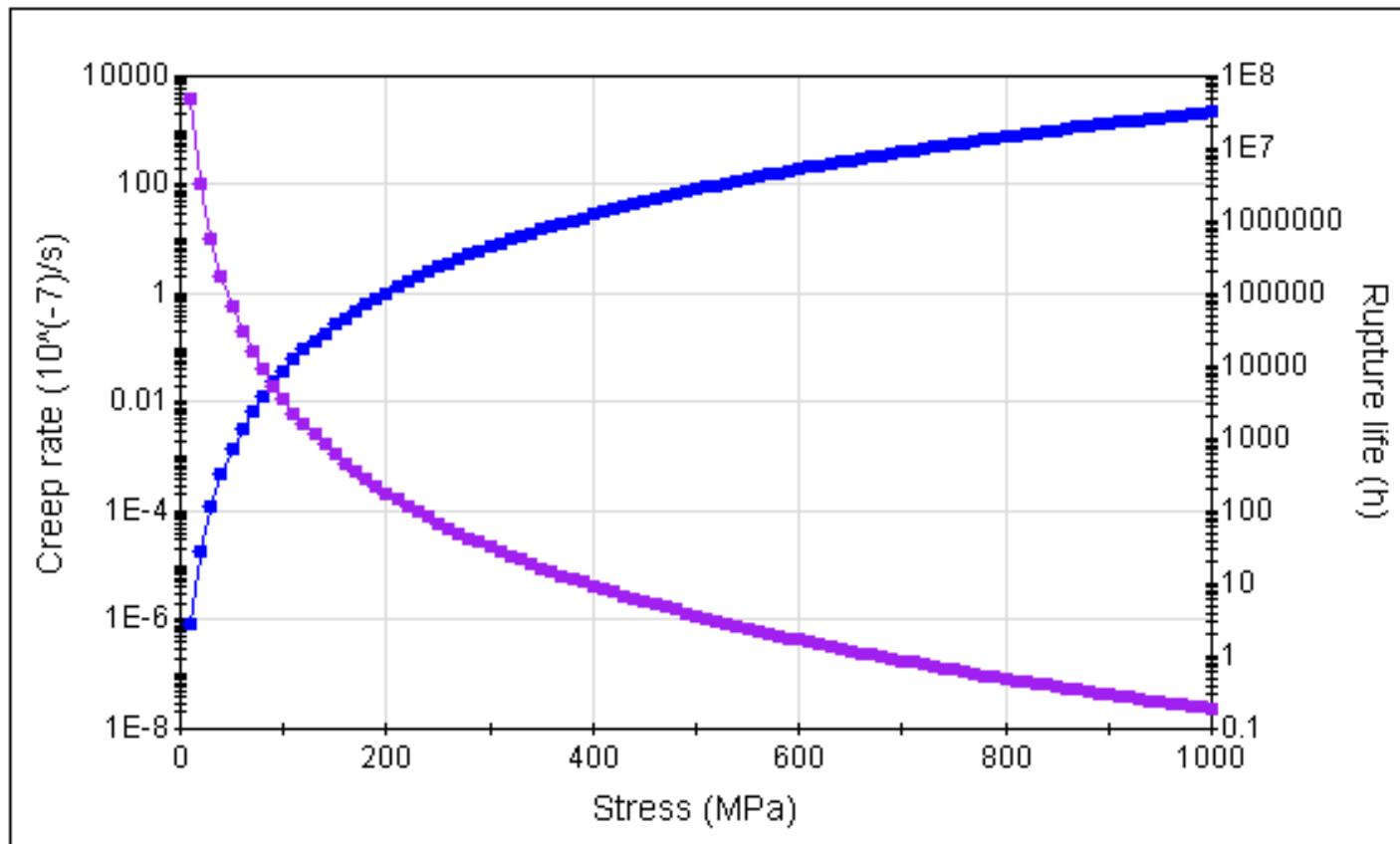
Heat treatment : 1000.0 C

AUSTENITE 100.0%

Hall-Petch : $0.22 \text{ MN/m}^{3/2}$

Creep/Fracture life

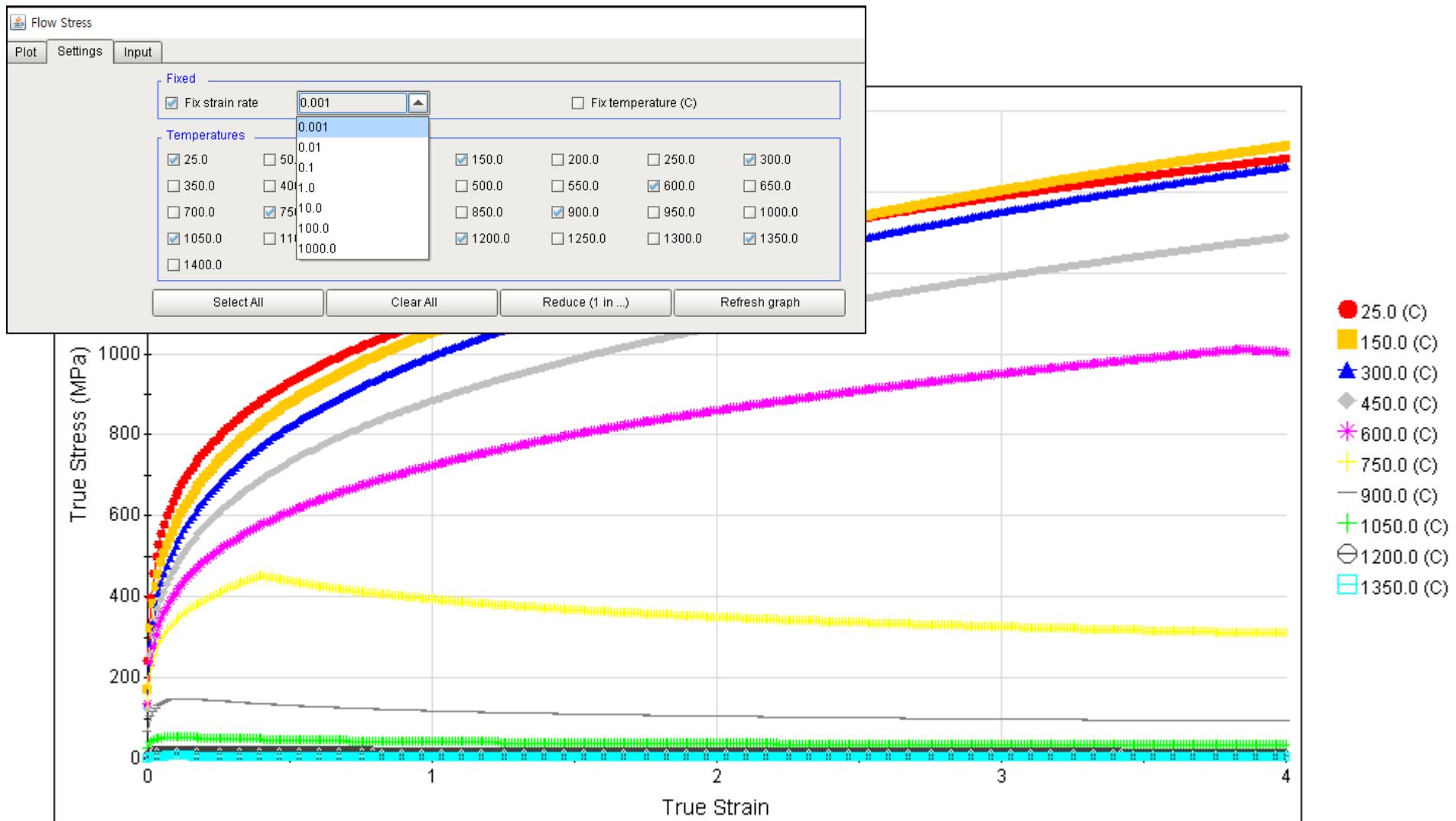
Creep calculation

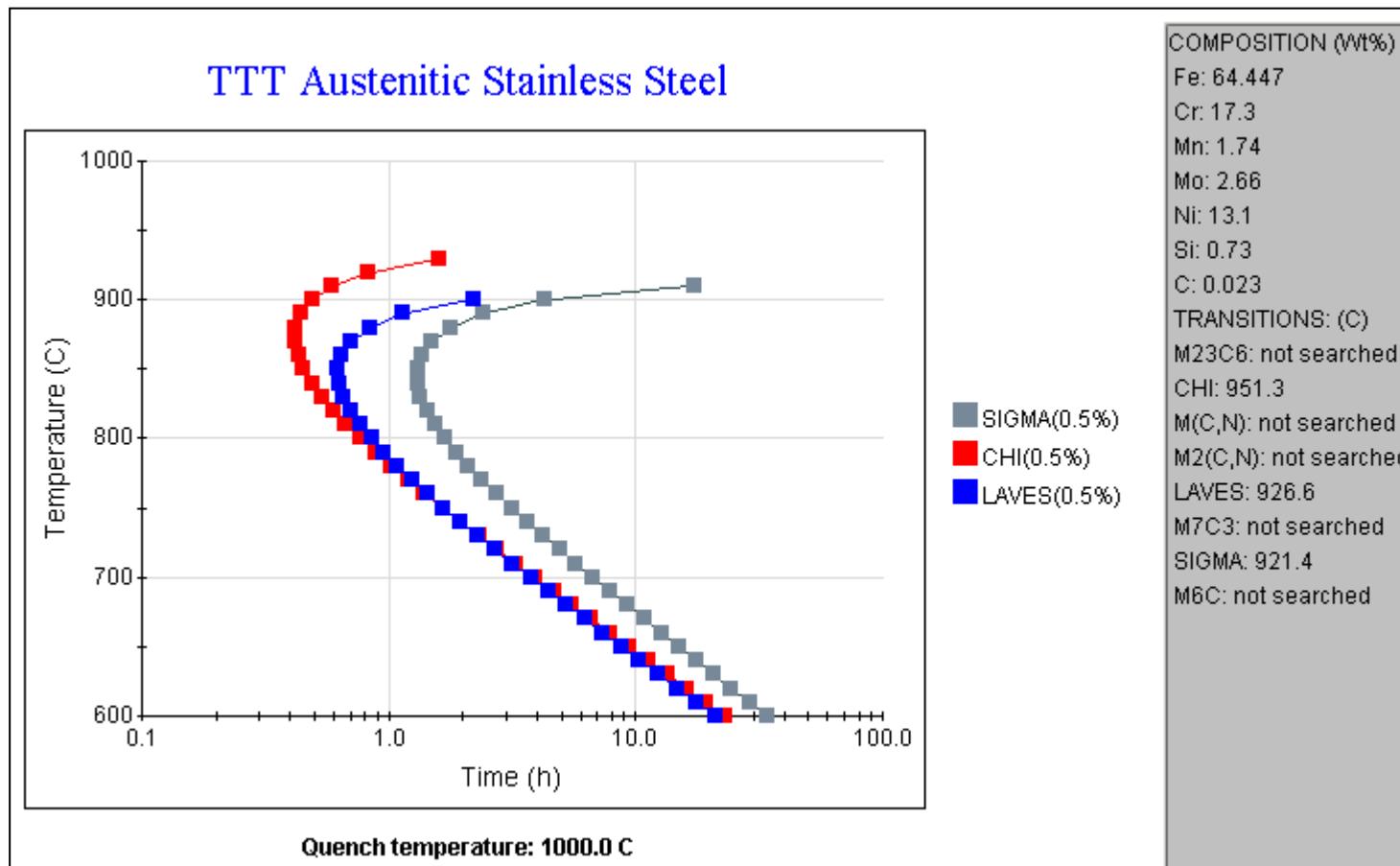


Test temperature : 650.0 °C

AUSTENITE 99.26%

Flow Stress Analysis

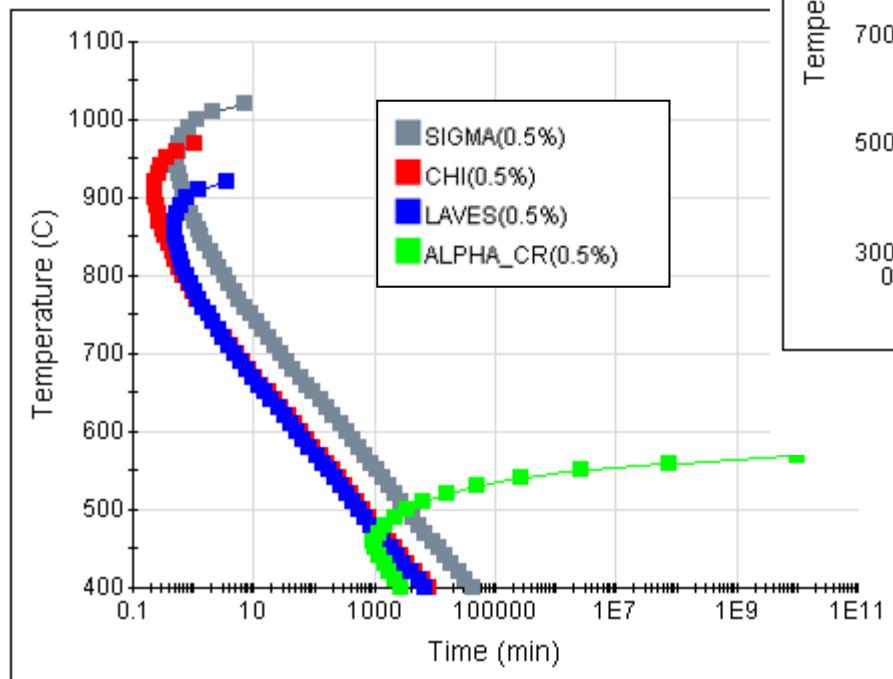


TTT

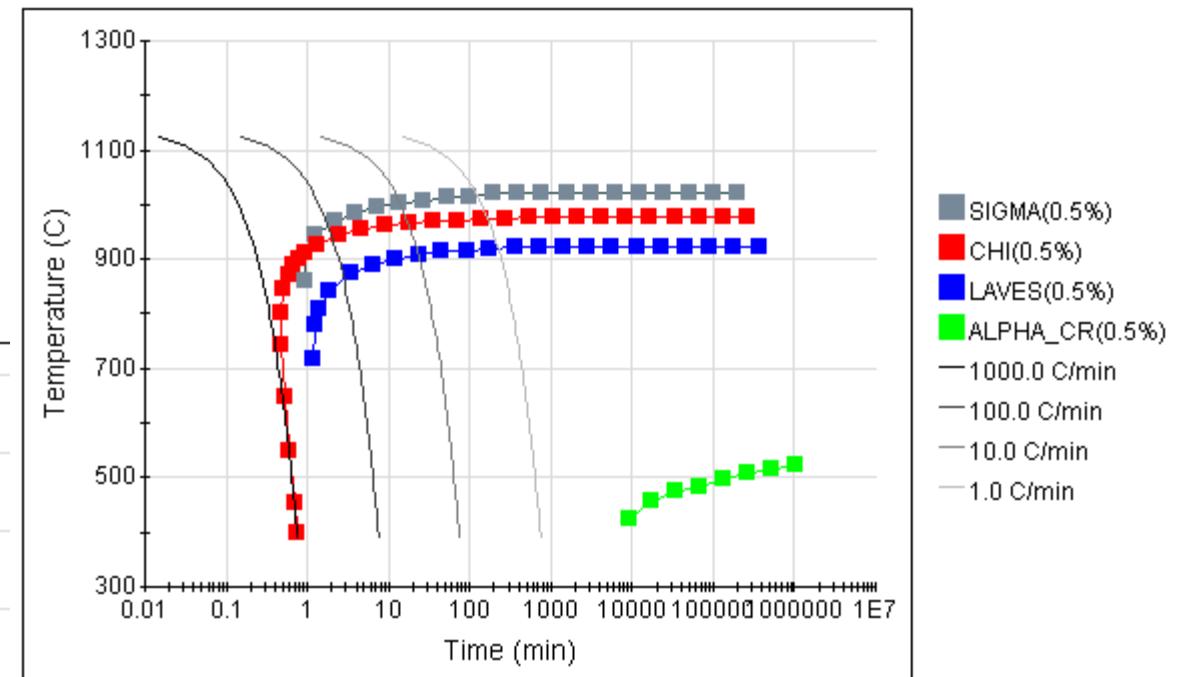
TTT/CCT

CCT Duplex Stainless Steel

TTT Duplex Stainless Steel

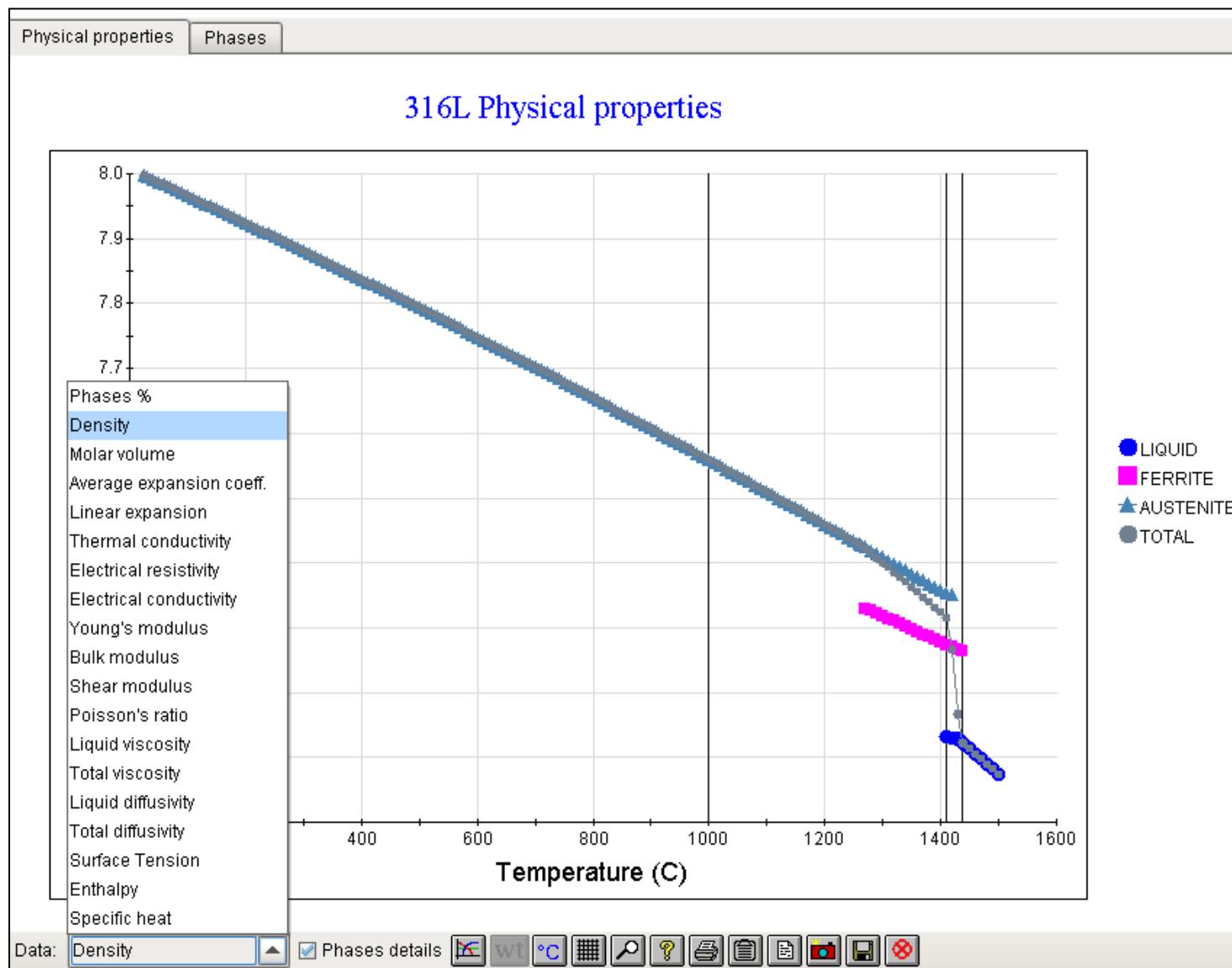


Heat treatment:
T=1140.0 C AUSTENITE 50.69 FERRITE 49.31



Heat treatment:
T=1140.0 C AUSTENITE 50.69 FERRITE 49.31

Thermo-physical Properties



Nickel based Superalloy

Nickel Alloy 모듈 기능 개요

구분	기능	활용분야/기타
열역학계산	<ul style="list-style-type: none"> 평형상분율 계산 	<ul style="list-style-type: none"> 상태도 관련 정보추출 열처리 기준 온도 설정 생성상을 제어하기 위한 합금설계
응고물성 계산	<ul style="list-style-type: none"> 응고분율 계산 및 물성계산 균질화 열처리 	<ul style="list-style-type: none"> 응고시뮬레이션 물성계산 잠열 계산 균질화 열처리 설계
열물리적 물성 계산	<ul style="list-style-type: none"> 열역학계산 기반의 상분율을 가정한 물성계산 Gamma/Gamma' mismatch SFE 	<ul style="list-style-type: none"> 열물성, 탄성계수, 열팽창계수, 밀도변화, 점성, 잠열 및 비열 등 계산
기계적 물성 계산	<ul style="list-style-type: none"> 고온 항복강도 계산 온도별/변형율 속도별 유동응력 선도 크립물성/파단수명 관련 계산 기능 피로수명 관련 기능 	<ul style="list-style-type: none"> 고온 응력선도 추출 피로/파단수명 예측
상변태 관련 기능	<ul style="list-style-type: none"> TTT/CCT 계산 기능 열처리시 석출상 거동 계산 Coarsening 계산 	<ul style="list-style-type: none"> 열처리 설계

Main GUI for Nickel alloy

Nickel Based Superalloy

Calculations Export

	Wt %
Ni	100.0
Al	0.0
Co	0.0
Cr	0.0
Cu	0.0
Fe	0.0
Hf	0.0
Mn	0.0
Mo	0.0
Nb	0.0
O	0.0
Pt	0.0
Re	0.0
Ru	0.0
Si	0.0
Ta	0.0
Ti	0.0
V	0.0
W	0.0
Zr	0.0
B	0.0
C	0.0
N	0.0

Reset

Thermodynamic Properties: ▾ Step Temperature Step Concentration
Profile Single
Isopleth

Solidification: ▾ Phases and Properties Homogenisation

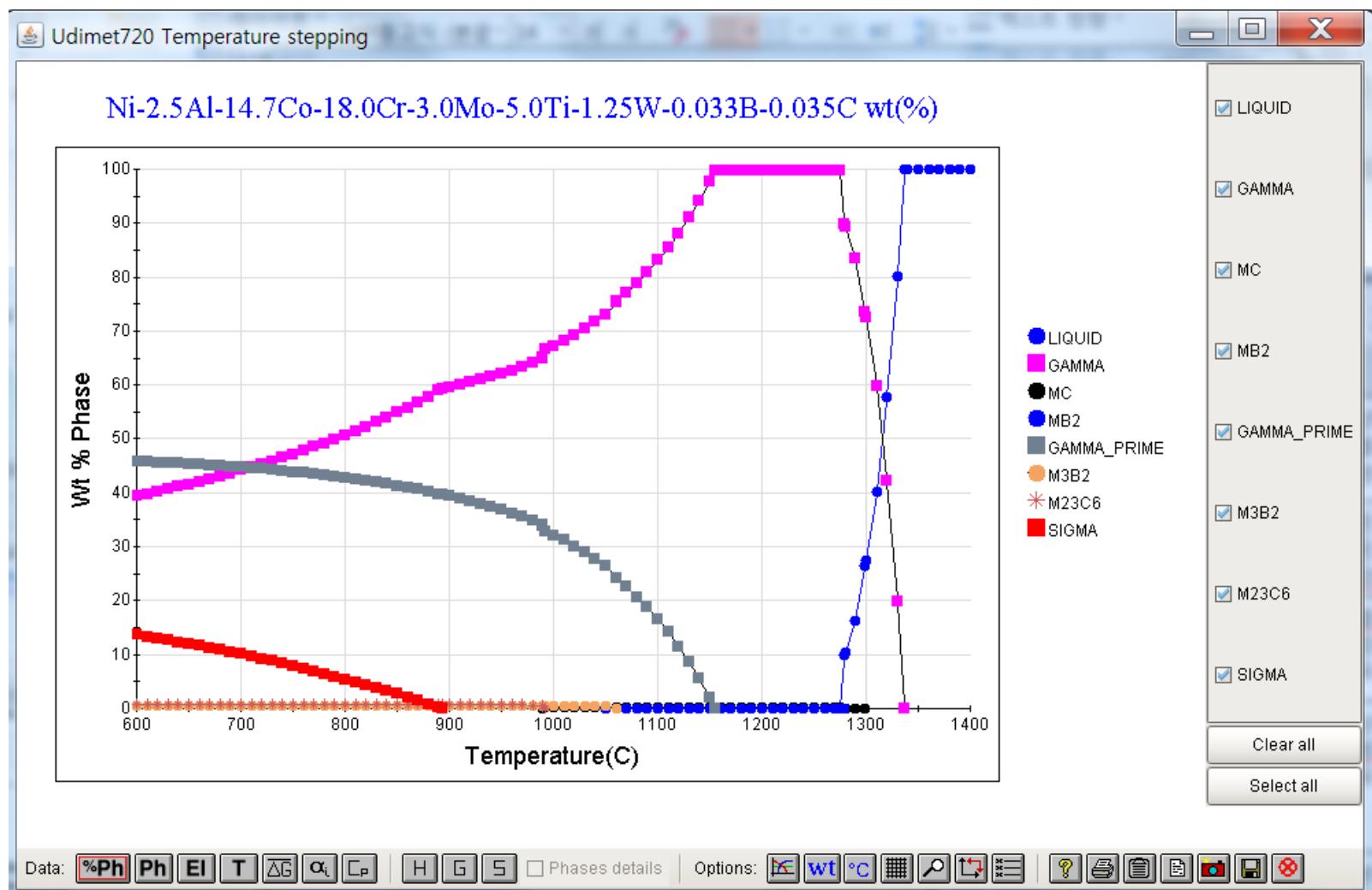
Mechanical Properties: ▾ Strength and Hardness High Temperature Strength
Creep Flow Stress Analysis
Processing Map Fatigue Related

Thermo-Physical Properties: ▾ Extended General Dynamic
Gamma/Gamma' Mismatch Stacking Fault Energy

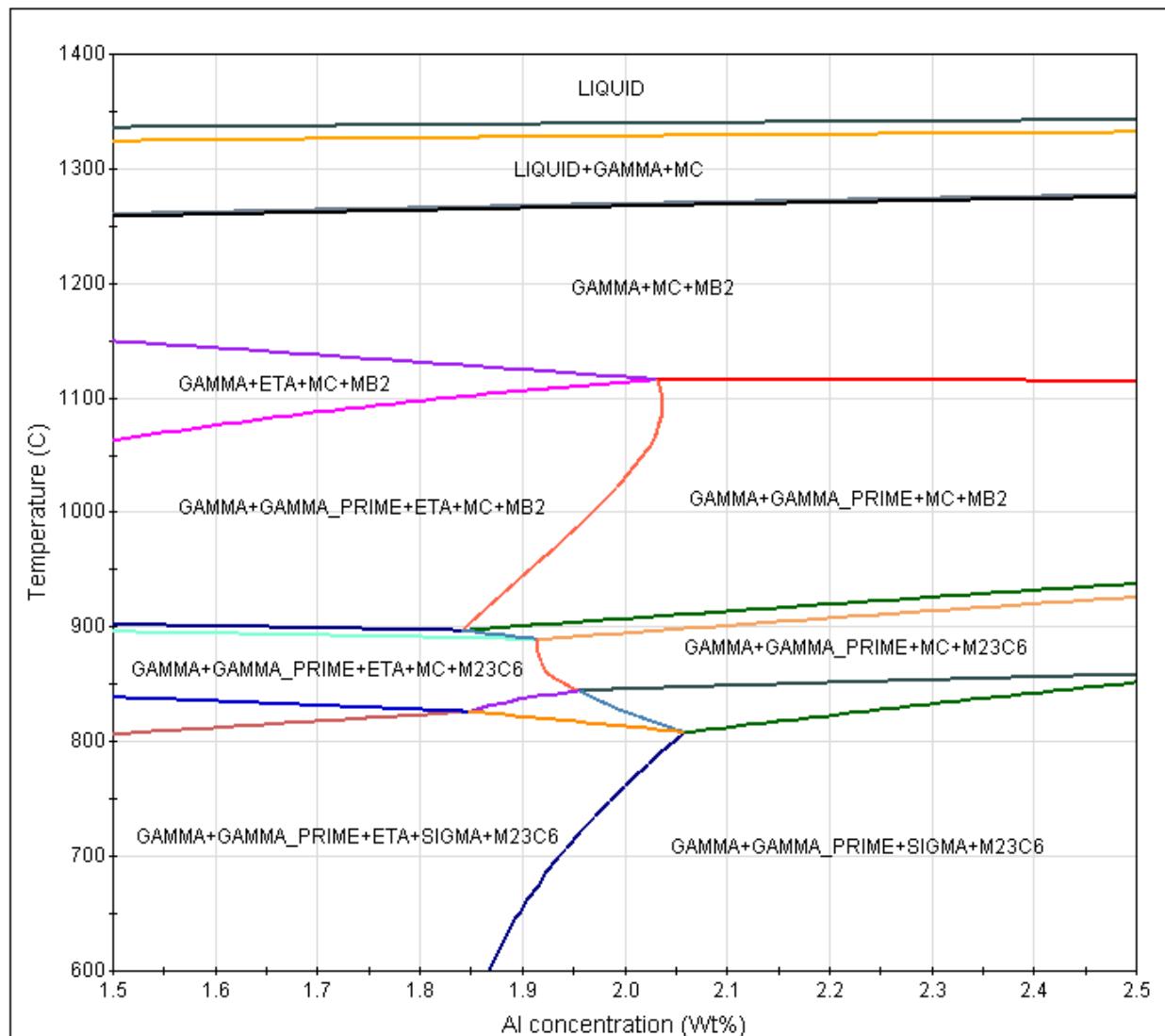
Phase transformation: ▾ TTT/CCT Diagrams Coarsening
Energy Changes Isothermal
Heat Treatment

Others: ▾ Dissimilar Metal Welds

열역학계산

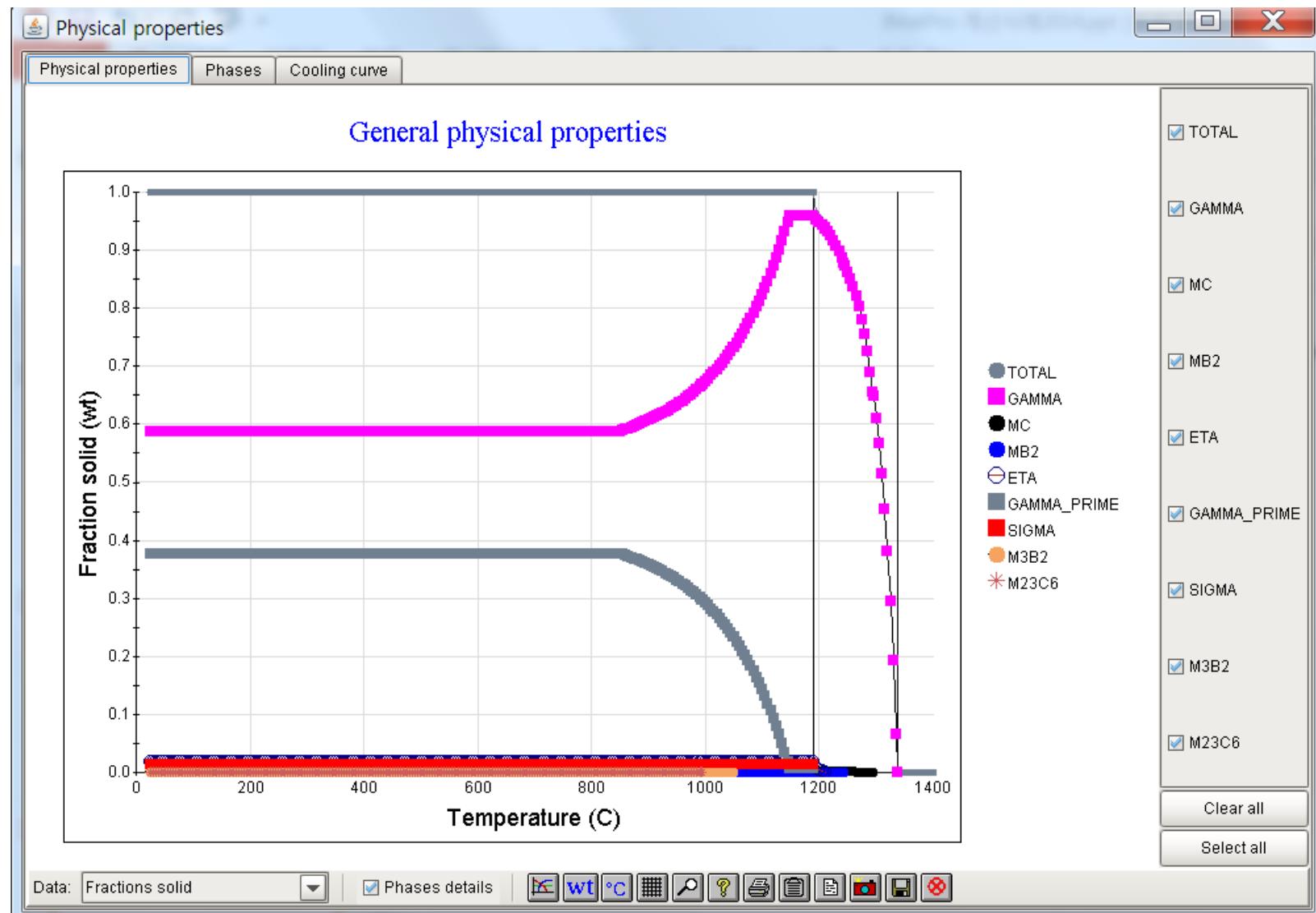


Isopleth

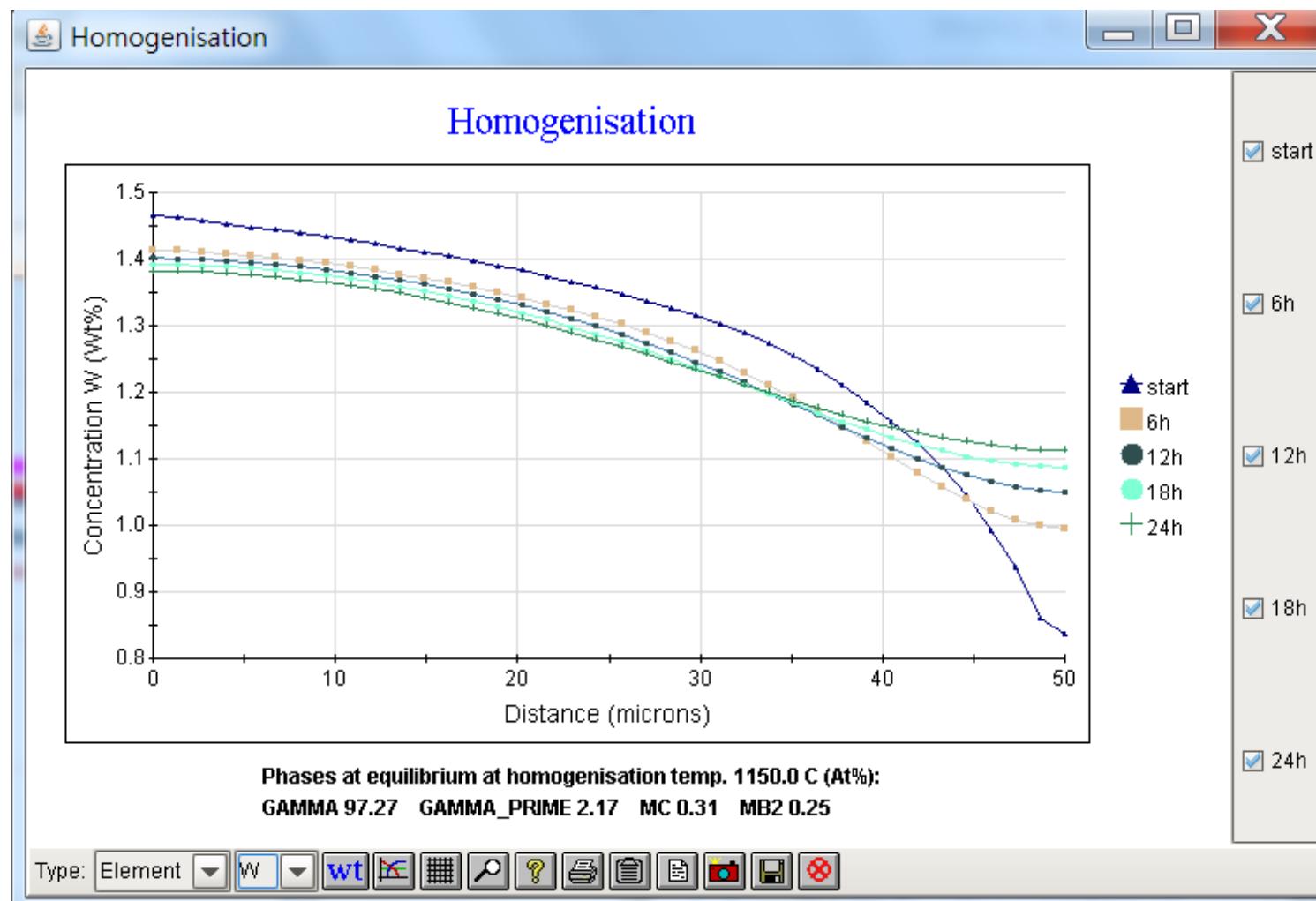


Balance element: Ti

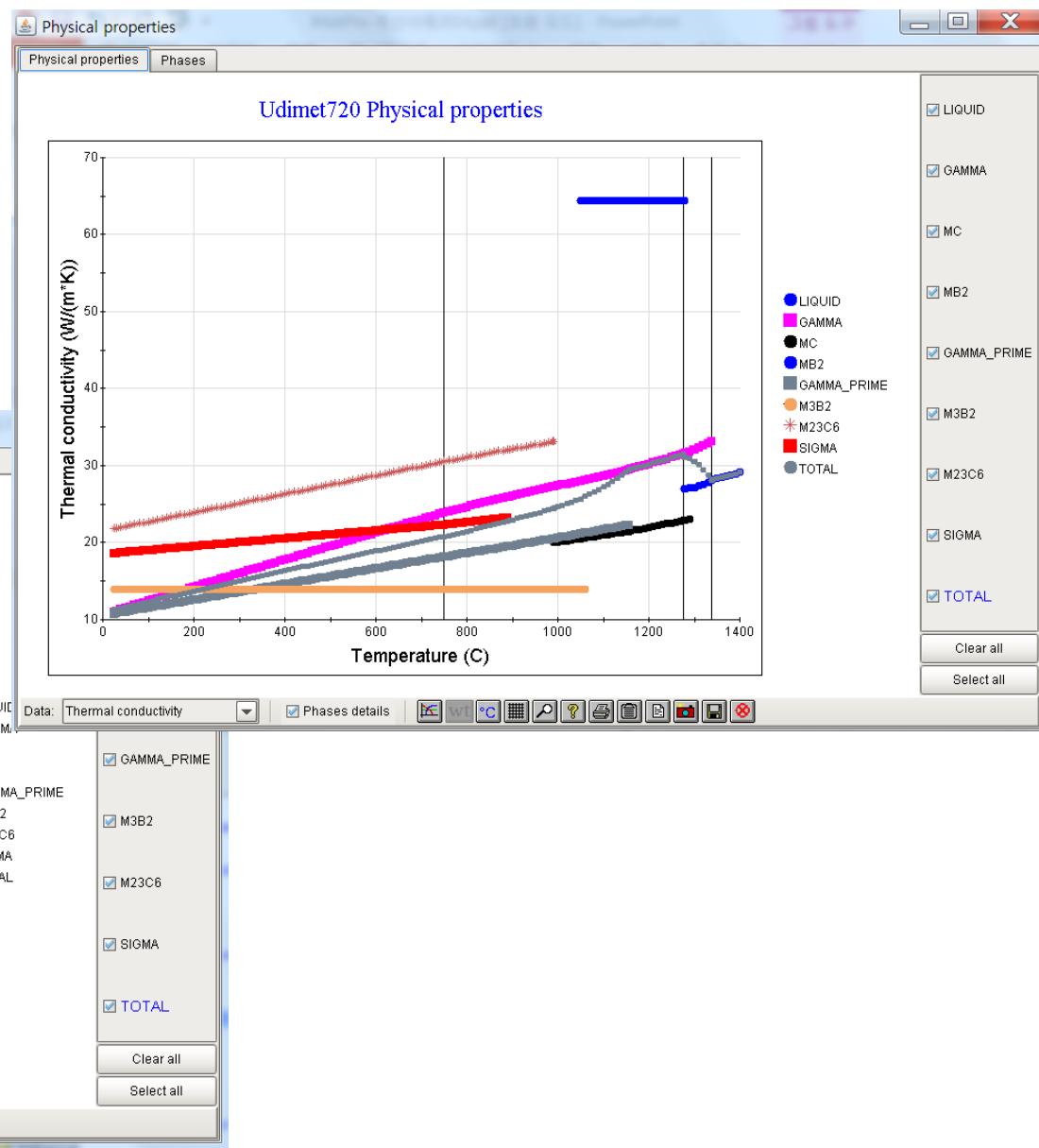
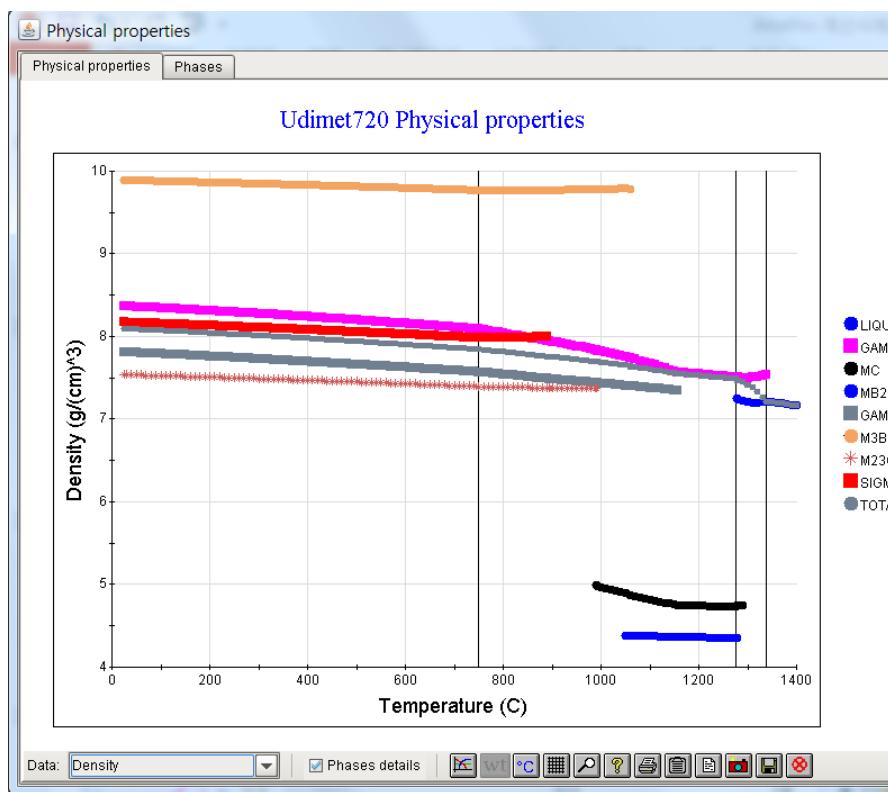
응고물성 계산



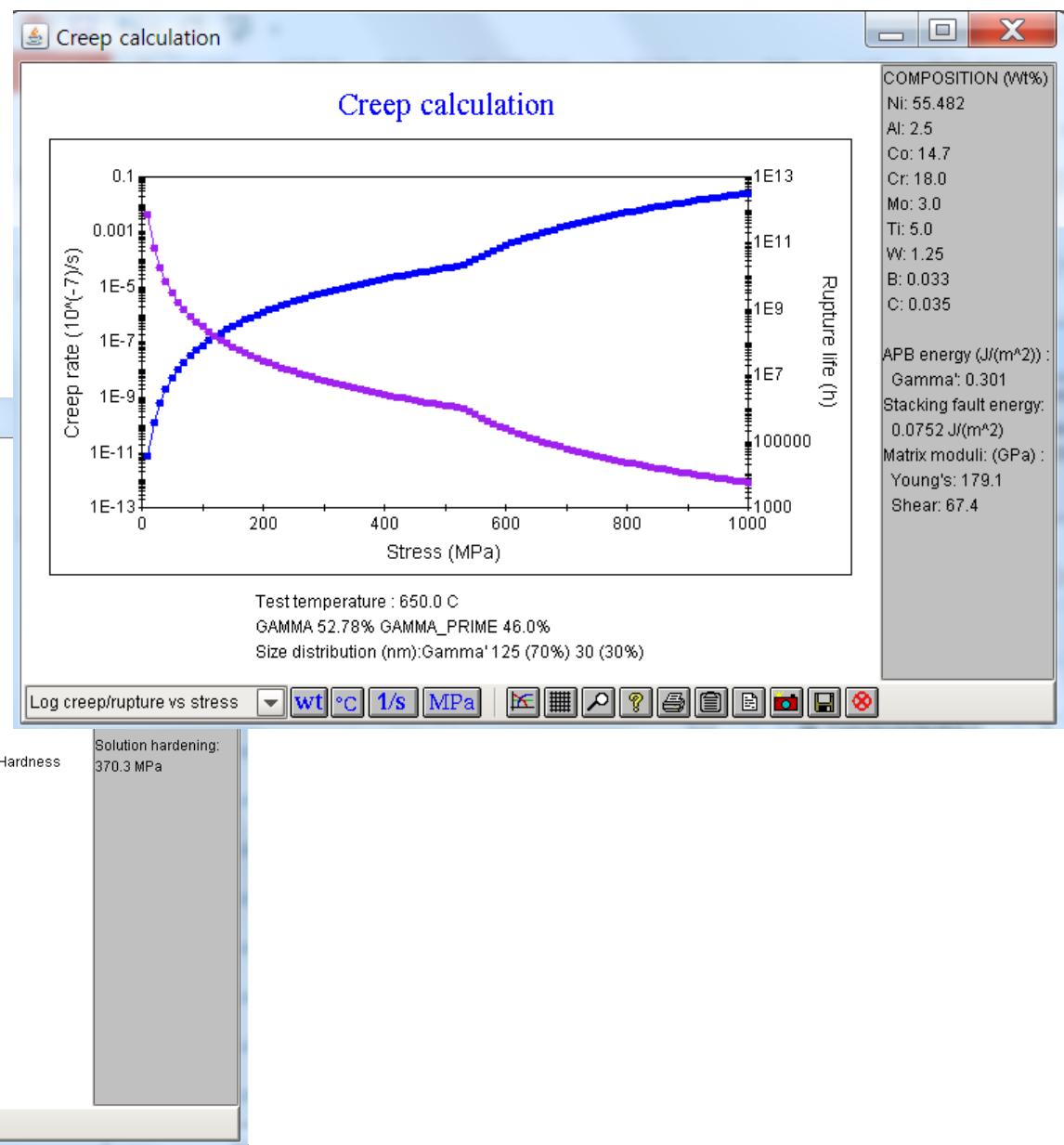
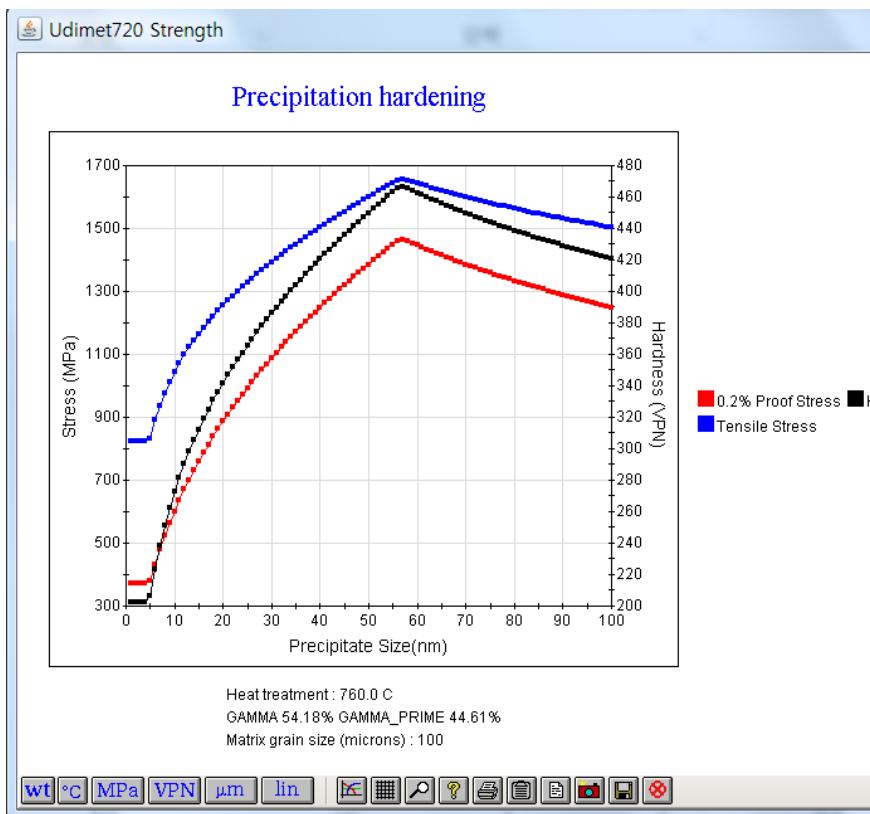
균질화 열처리 기능



열물리적 물성 계산

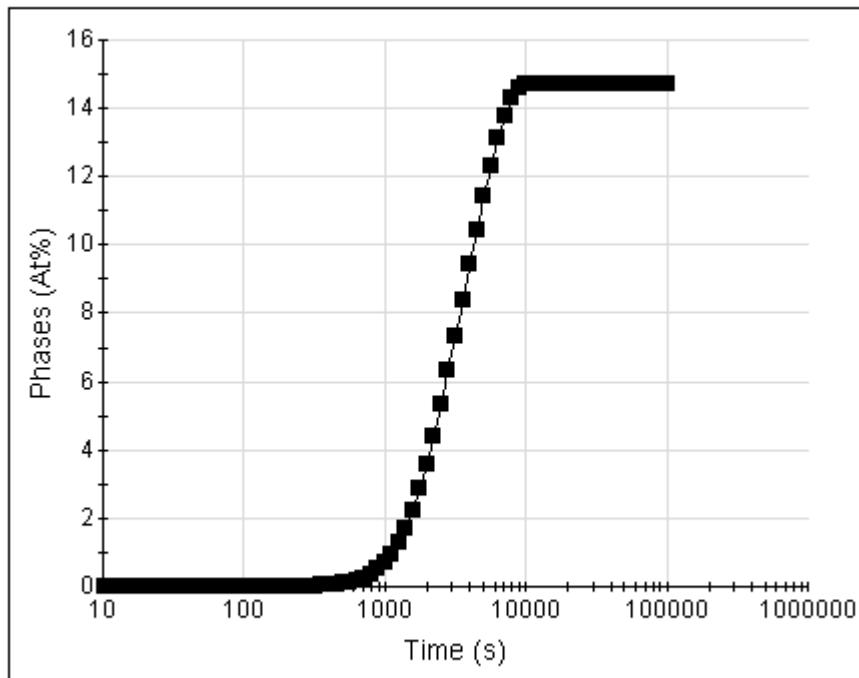


기계적 물성 계산

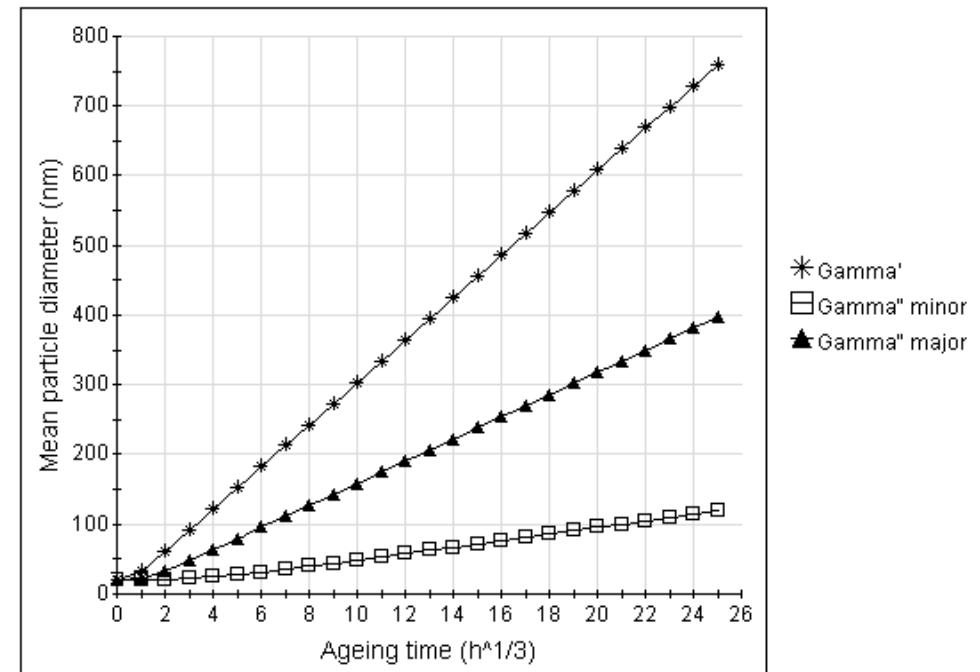


상변태 물성 계산

Phase evolution_Gamma_Prime



Coarsening graph



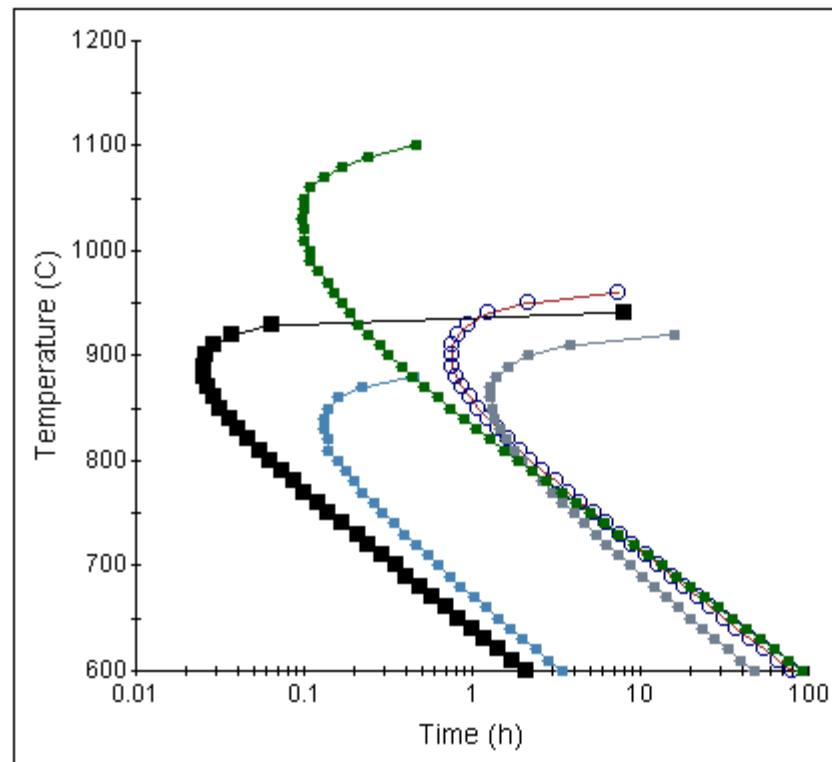
Holding temperature (C) : 720.0

Quench temperature (C) : 1100.0

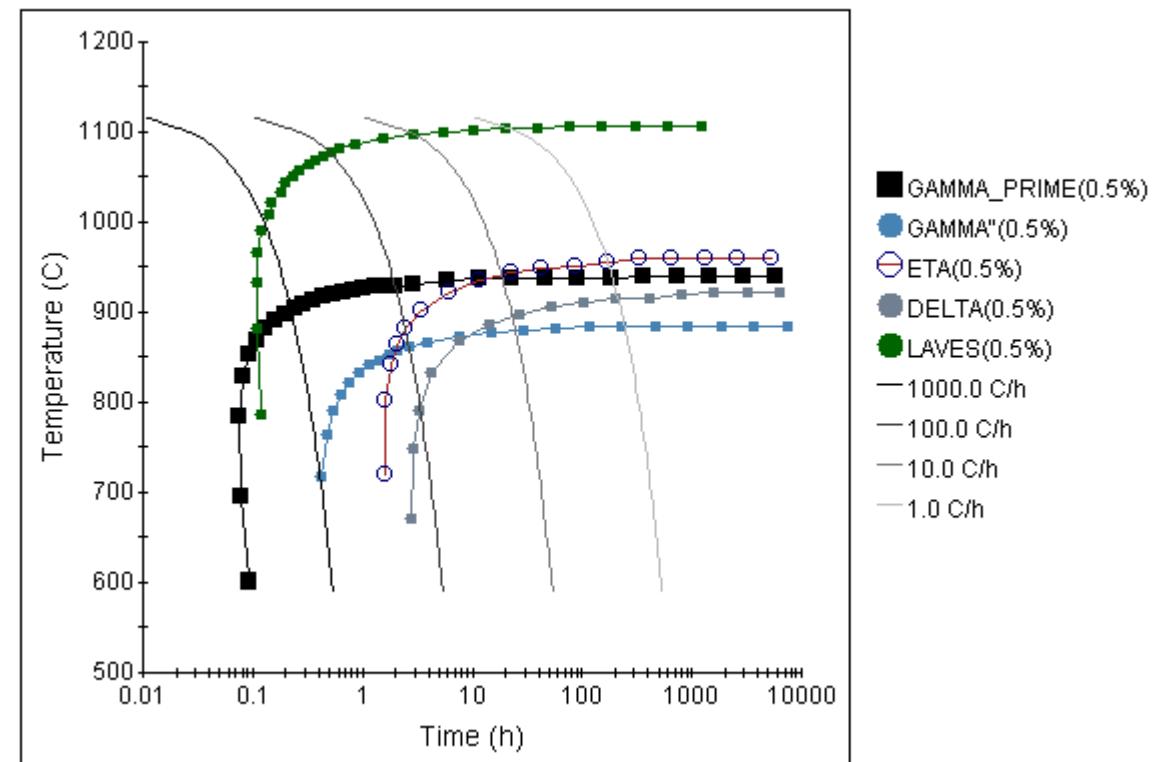
Data: Temperature 750.0 C wt °C (h)^{1/3} lin

상변태 물성 계산

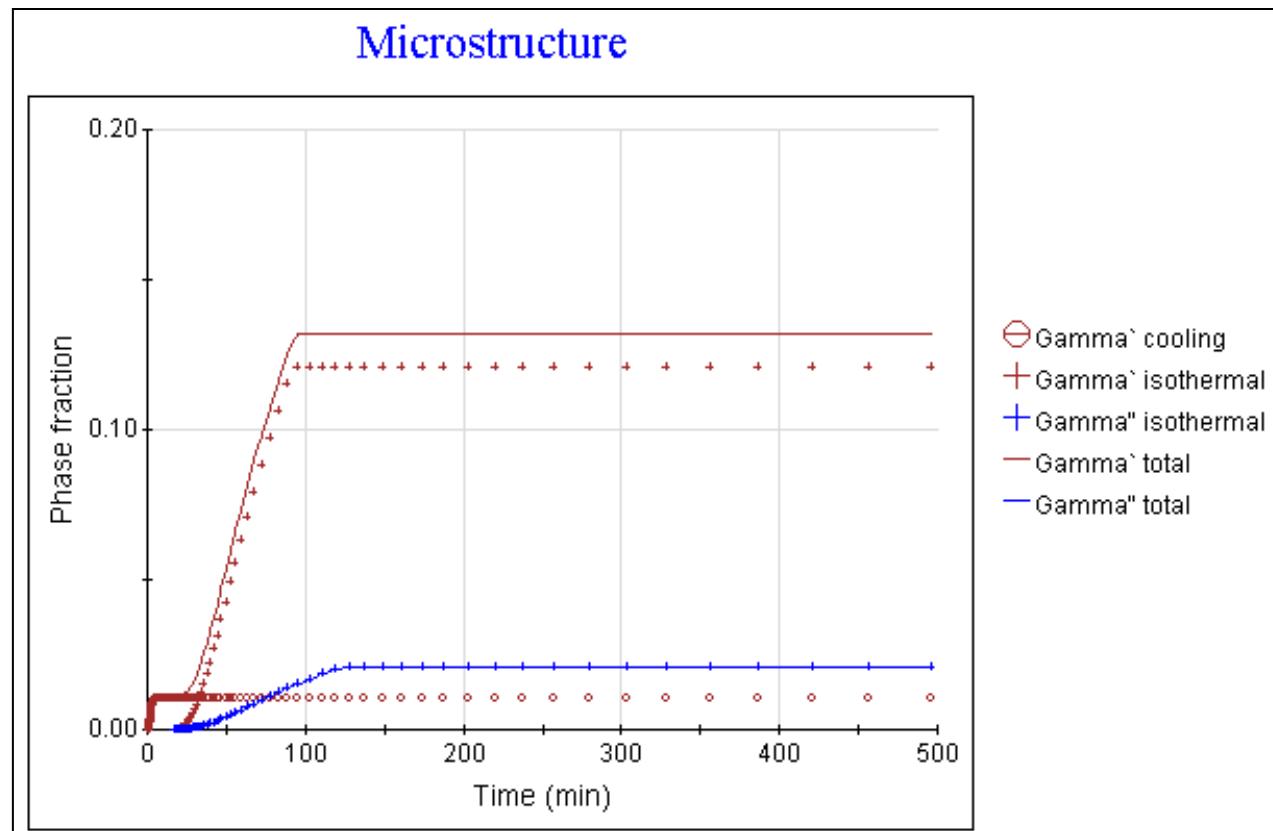
TTT NiFe Based Superalloy



CCT NiFe Based Superalloy

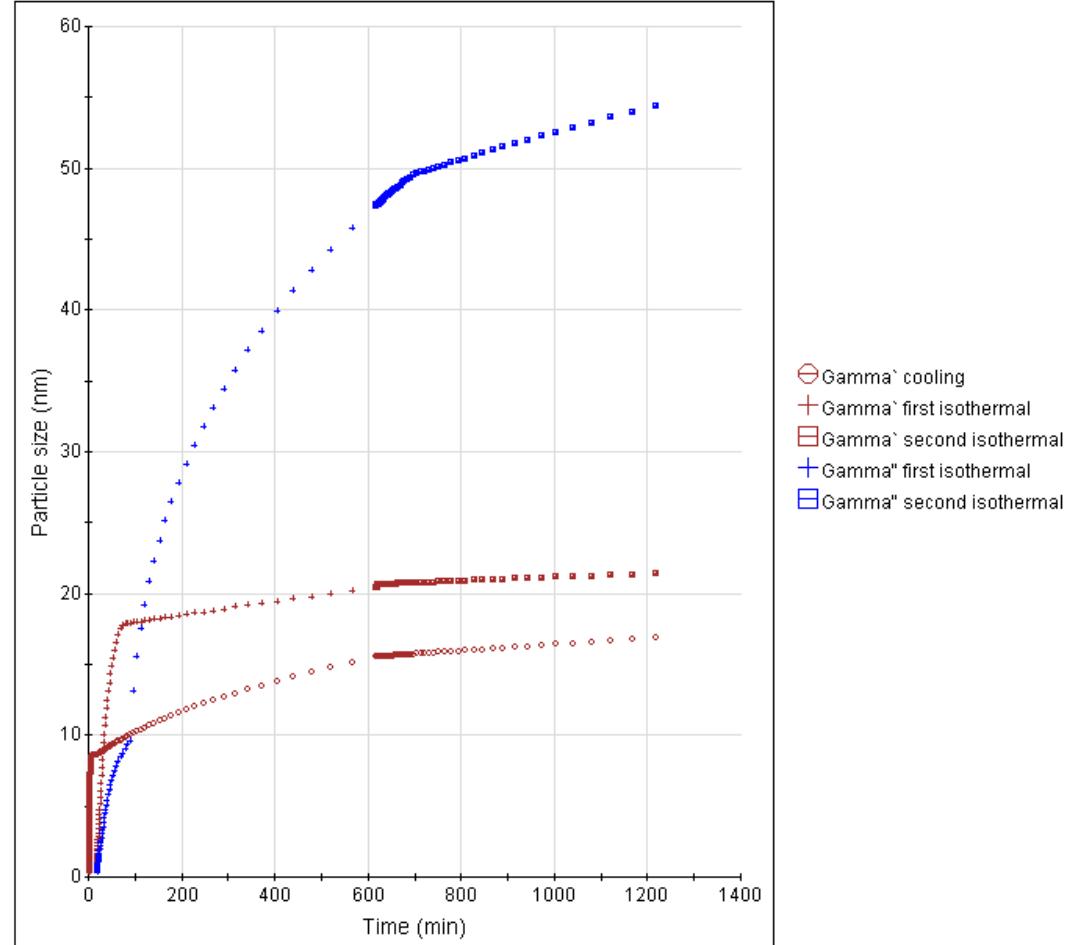
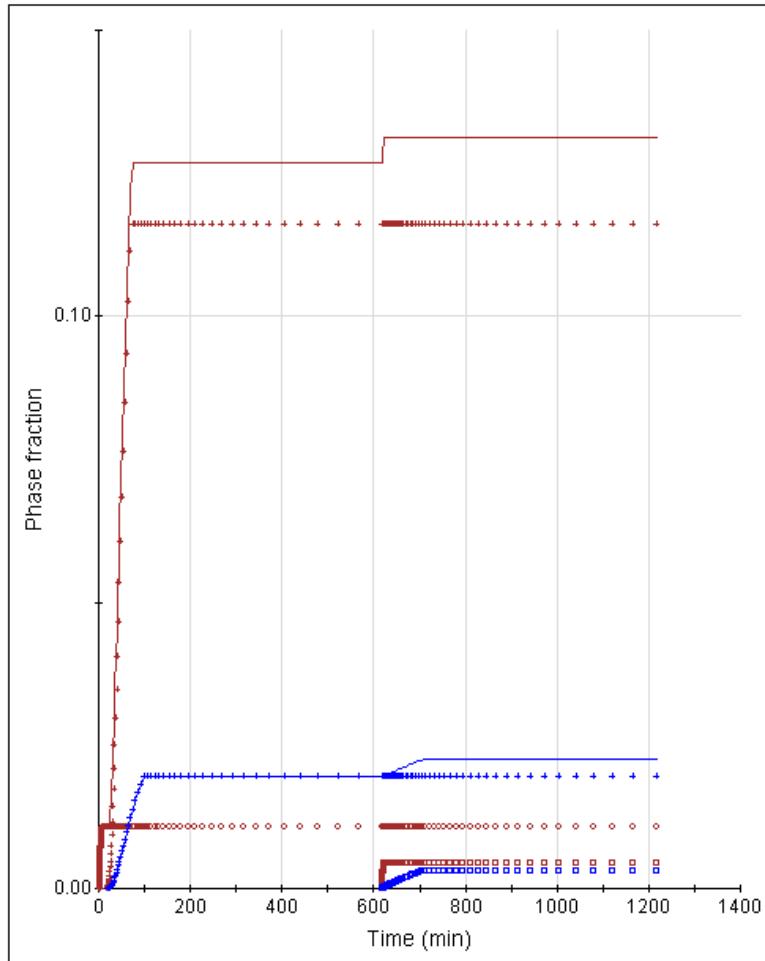


상변태 물성 계산



Input and end results	Evolution
INPUT:	
Initial heat treatment: 970 C	
Cooling rate: 1.0 C/s	
Isothermal holding at 730 C for: 8 h	
Gamma grain size: 4.5 ASTM	
RESULTS:	
Gamma' fraction at sub-solvus: none	
Gamma' fraction formed after cooling: 0.0107	
with final size: 12.24 nm	
Gamma' Fraction formed during isothermal holding: 0.12	
with final size: 18.95 nm	
Gamma" fraction at sub-solvus: none	
Gamma" fraction formed after cooling: none	
Gamma" fraction formed during isothermal holding: 0.0211	
with final size: 34.43 nm	
0.2% Proof Stress: 909.58 MPa / 131.94 ksi	
Tensile Stress: 1270.13 MPa / 184.24 ksi	
Hardness: 346.89 VPN / 35.38 Hrc	

상변태 물성 계산



Al alloy

AI Alloy모듈 기능 개요

구분	기능	활용분야/기타
열역학계산	<ul style="list-style-type: none"> 평형상분율 계산 준안정상 계산 	<ul style="list-style-type: none"> 상태도 관련 정보추출 열처리 기준 온도 설정 생성상을 제어하기 위한 합금설계
응고물성 계산	<ul style="list-style-type: none"> 응고분율 계산 및 물성계산 균질화 열처리 	<ul style="list-style-type: none"> 응고시뮬레이션 물성계산 잠열 계산 균질화 열처리 설계
열물리적 물성 계산	<ul style="list-style-type: none"> 열역학계산 기반의 상분율을 가정한 물성계산 	<ul style="list-style-type: none"> 열물성, 탄성계수, 열팽창계수, 밀도변화, 점성, 잠열 및 비열 등 계산
기계적 물성 계산	<ul style="list-style-type: none"> 주조후 강도 계산 냉각속도 별 SDAS 계산 T4/T5/T6/T8/O/H 열처리후 강도 계산 온도/변형율속도별 유동응력선도 	<ul style="list-style-type: none"> 강도 향상을 위한 열처리 설계
상변태 관련 기능	<ul style="list-style-type: none"> TTT/CCT 계산 기능 등온 열처리 계산 	<ul style="list-style-type: none"> 열처리 설계

Main GUI for Al alloy

	Wt %
Al	100.0
Bi	0.0
Ca	0.0
Co	0.0
Cr	0.0
Cu	0.0
Fe	0.0
Ce	0.0
La	0.0
Li	0.0
Mg	0.0
Mn	0.0
Mo	0.0
Ni	0.0
Pb	0.0
Sc	0.0
Si	0.0
Sn	0.0
Sr	0.0
Ti	0.0
V	0.0
Sc	0.0
Zn	0.0
Zr	0.0
B	0.0
C	0.0
H	0.0
O	0.0

Aluminium Alloy

Thermodynamic Properties:

Step Temperature	Step Concentration
Profile	Single
Metastable Phases	Isopleth

Solidification:

Phases and Properties	Homogenisation
-----------------------	----------------

Mechanical Properties:

Cast Strength	RT Strength
Age Hardening	High Temp. Strength
Flow Stress Analysis	Processing Map
Fracture Toughness	

Thermo-Physical Properties:

Extended General	Dynamic
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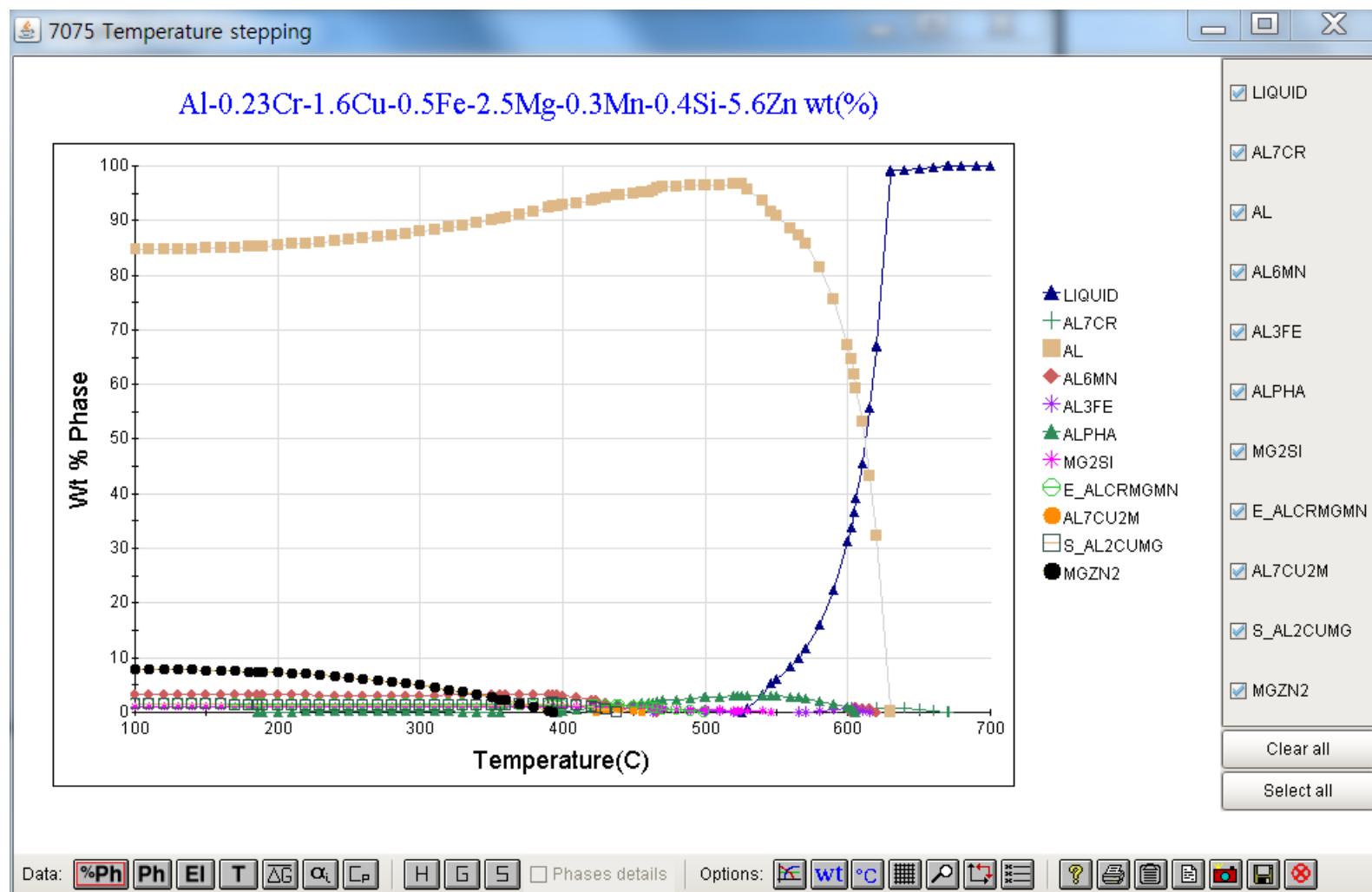
Phase transformation:

TTT	CCT
Isothermal	

Others:

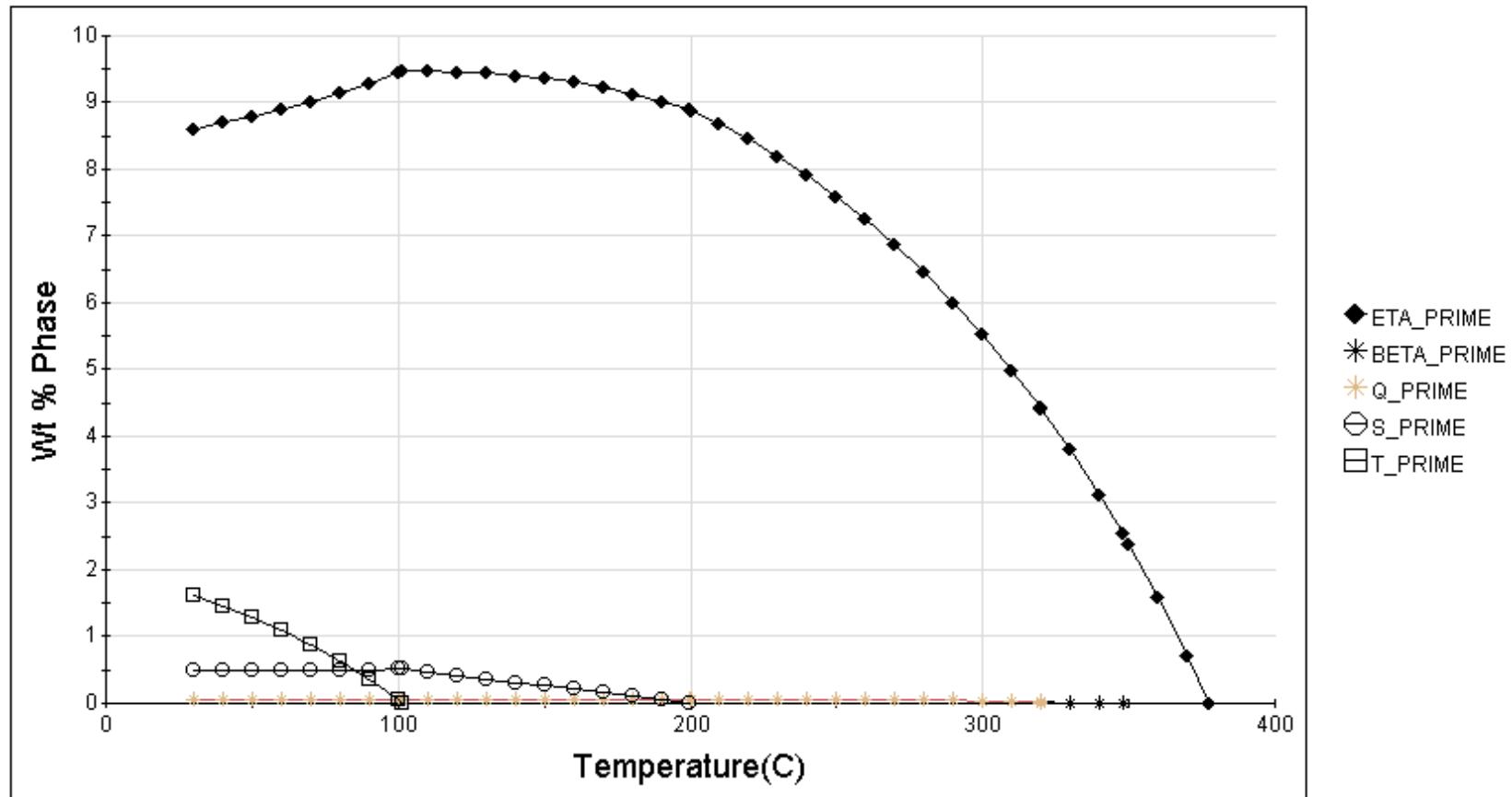
Dissimilar Metal Welds

열역학계산



열역학계산(준안정상)

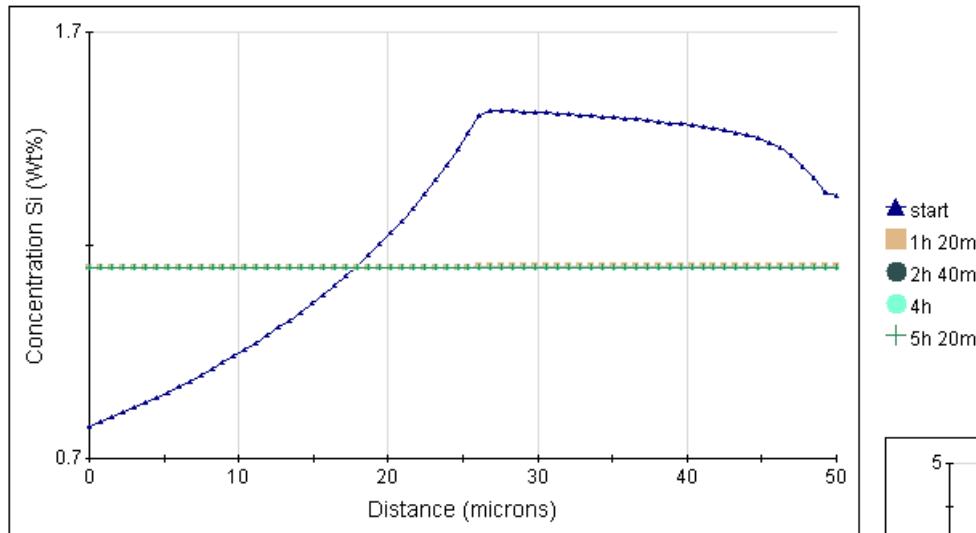
Metastable phases



Heat treatment: 470.0 C

균질화 열처리

Homogenisation

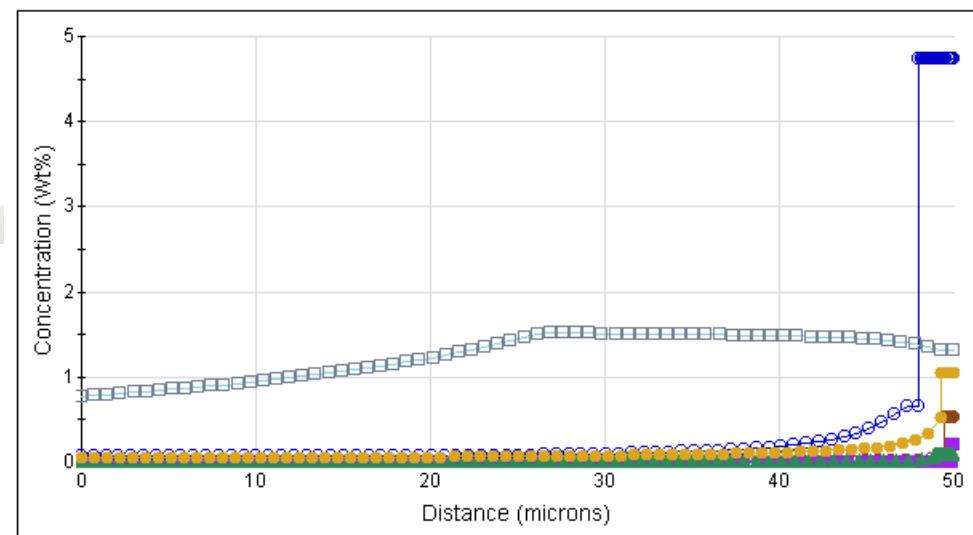


Multi temperature step homogenisation:

510.0C for 1h 20min - 520.0C for 1h 20min - 530.0C for 1h 20min - 540.0C for 1h 20min

Type: Element ▼ Si ▼ wt □

Homogenisation

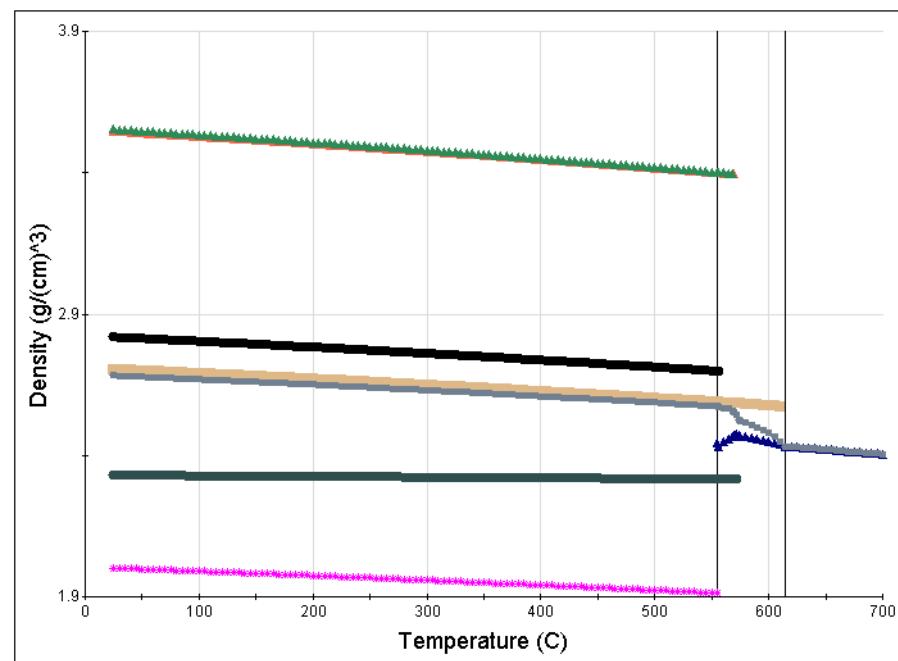


Multi temperature step homogenisation:

510.0C for 1h 20min - 520.0C for 1h 20min - 530.0C for 1h 20min - 540.0C for 1h 20min

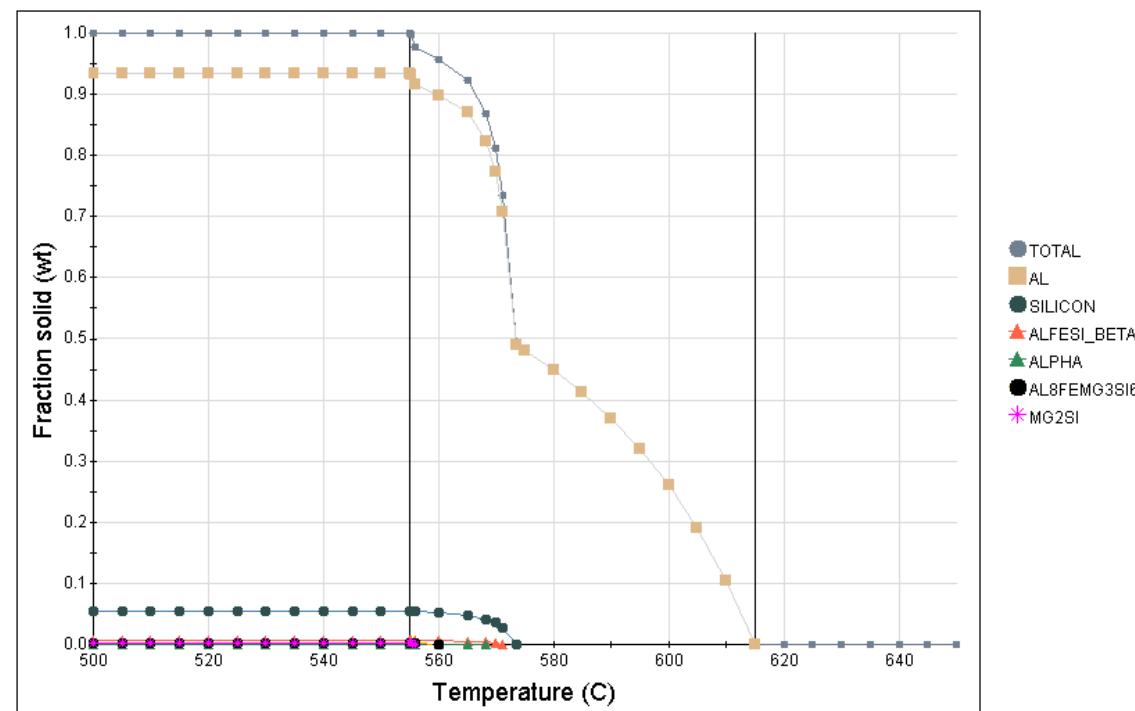
Type: Time ▼ start □

응고물성

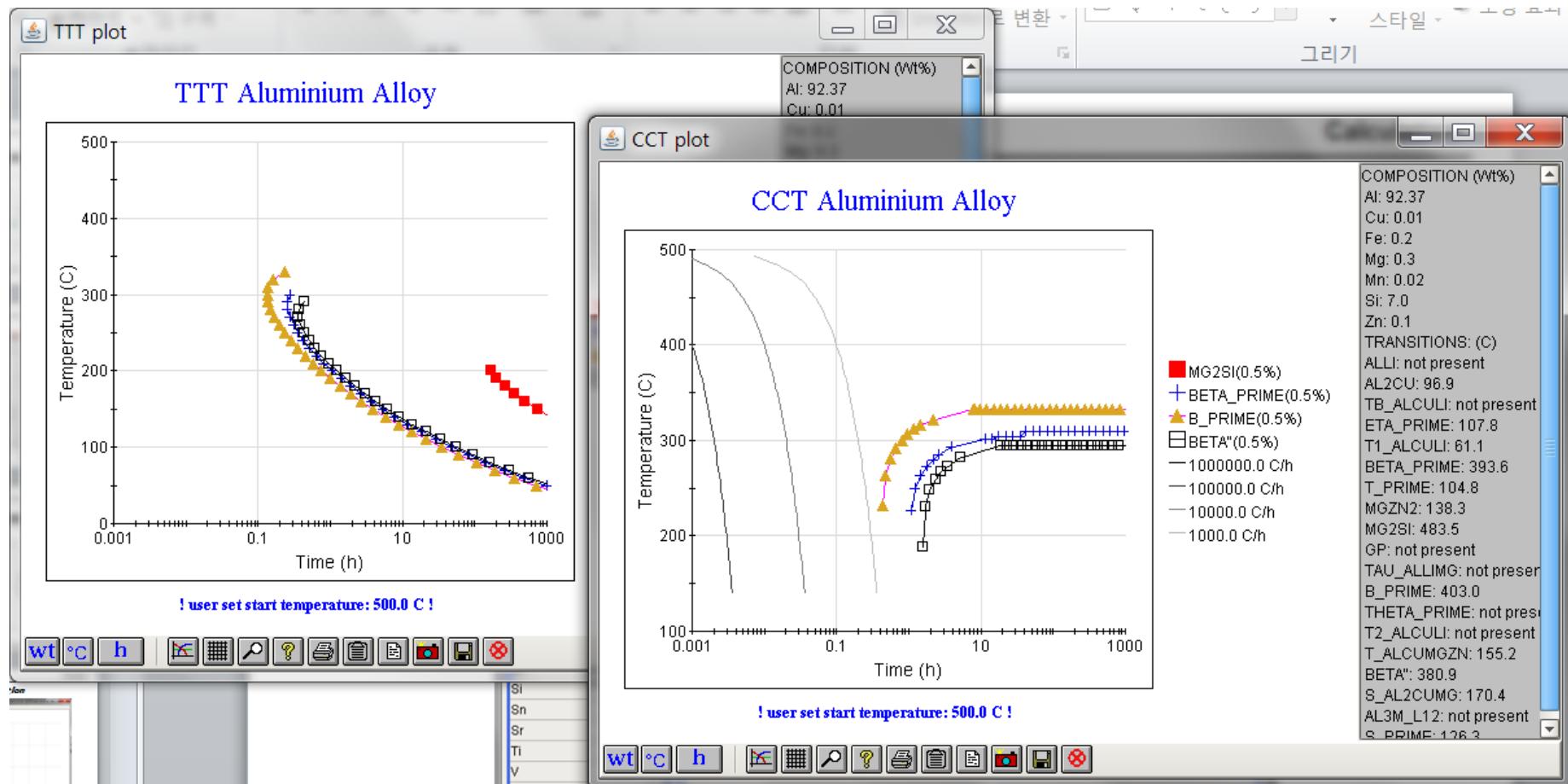


▲ LIQUID
 ■ AL
 ● SILICON
 ▲ ALFESI_BETA
 ▲ ALPHA
 ● AL8FEMG3SI6
 * MG2SI
 ○ TOTAL

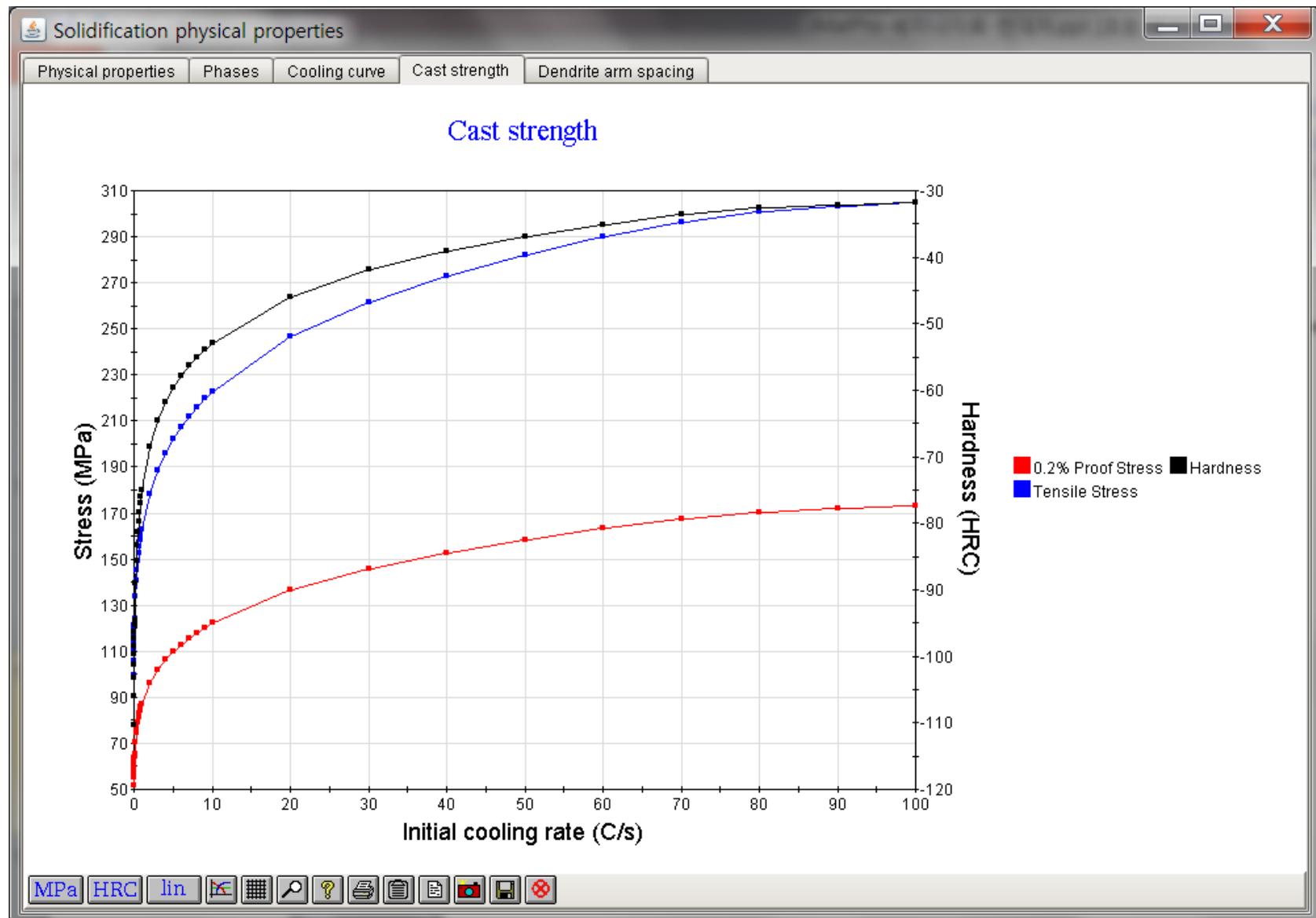
General physical properties



상변태 물성



기계적 물성



기계적 물성

INPUT:

Wrought alloy

Temper designation: T6

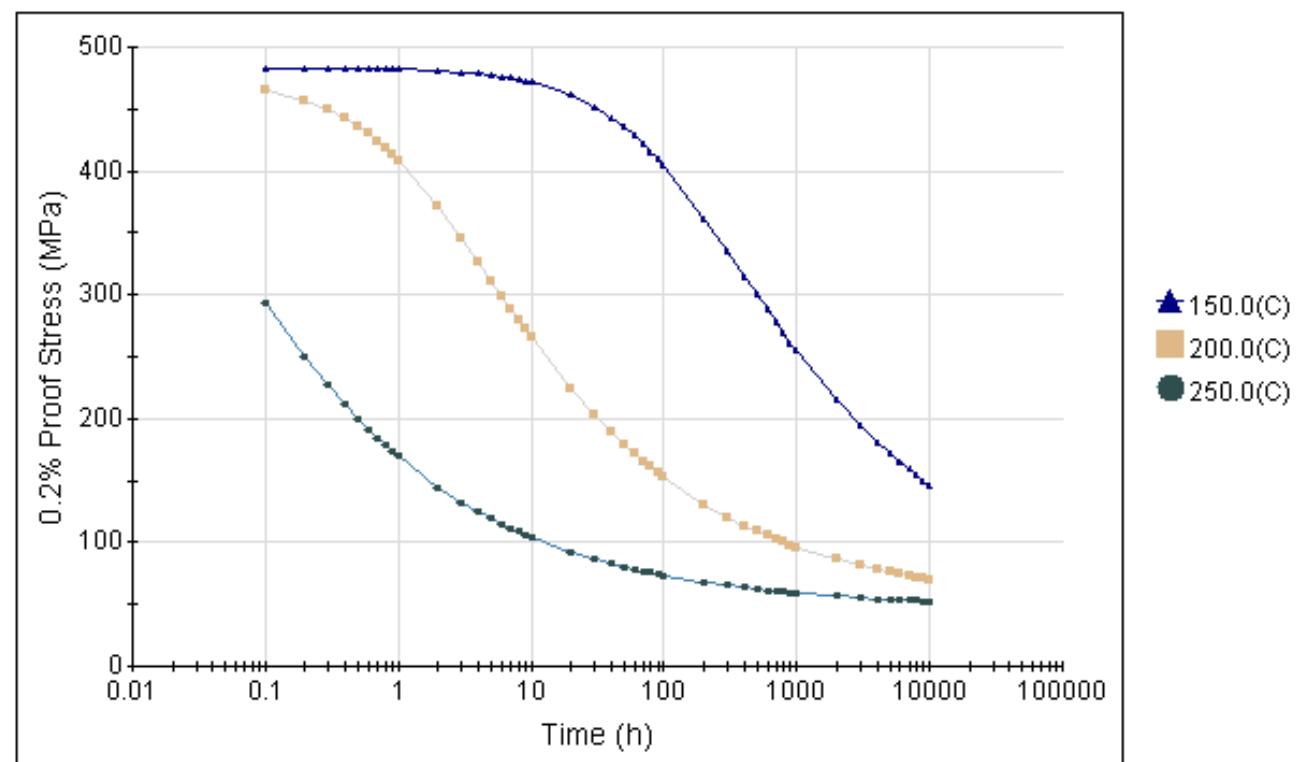
Solution treatment temperature: 500.0C

Ageing temperature: 150.0C

Grain size: 50 microns

Additional thermal history: Isothermal
for 10^4 h

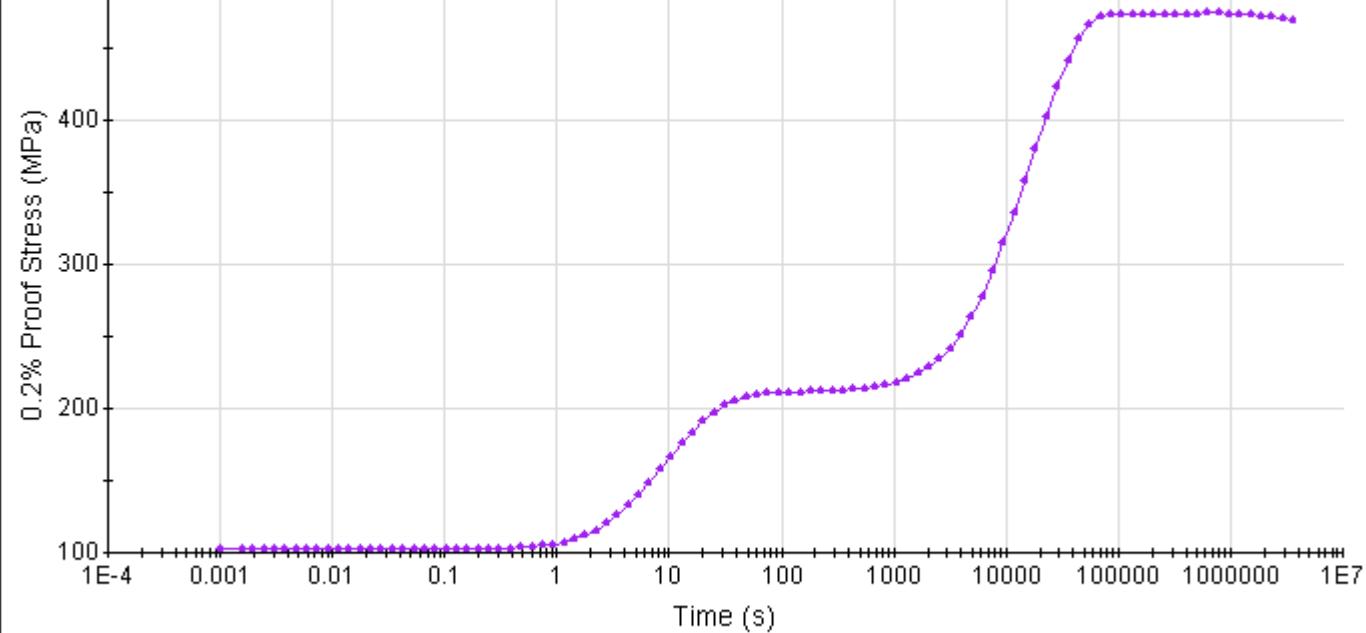
Al alloy strength



기계적 물성

INPUT:
Wrought alloy
Temper designation: T4/T6
Solution treatment temperature: 475.0C
Cooling rate from solution treatment temperature: 1000.0 (C/s)
Ageing temperature: 120.0C
Ageing time: 1000 h
Grain size: 50 microns

Al alloy strength



Data: 0.2% Proof Stress

MPa

VPN

°C

s

log



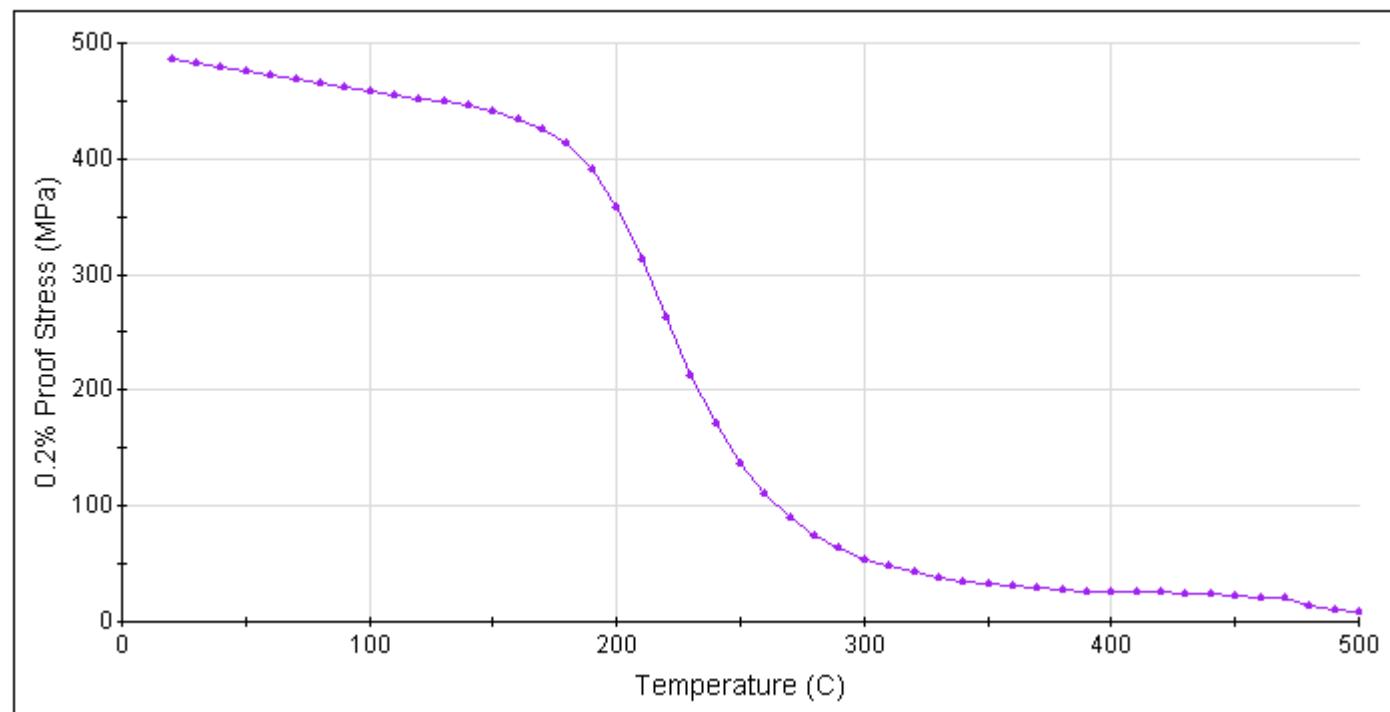
기계적 물성

INPUT:
Wrought alloy
Temper designation: T6
Solution treatment temperature: 500.0C
Ageing temperature: 150.0C
Grain size: 50 microns

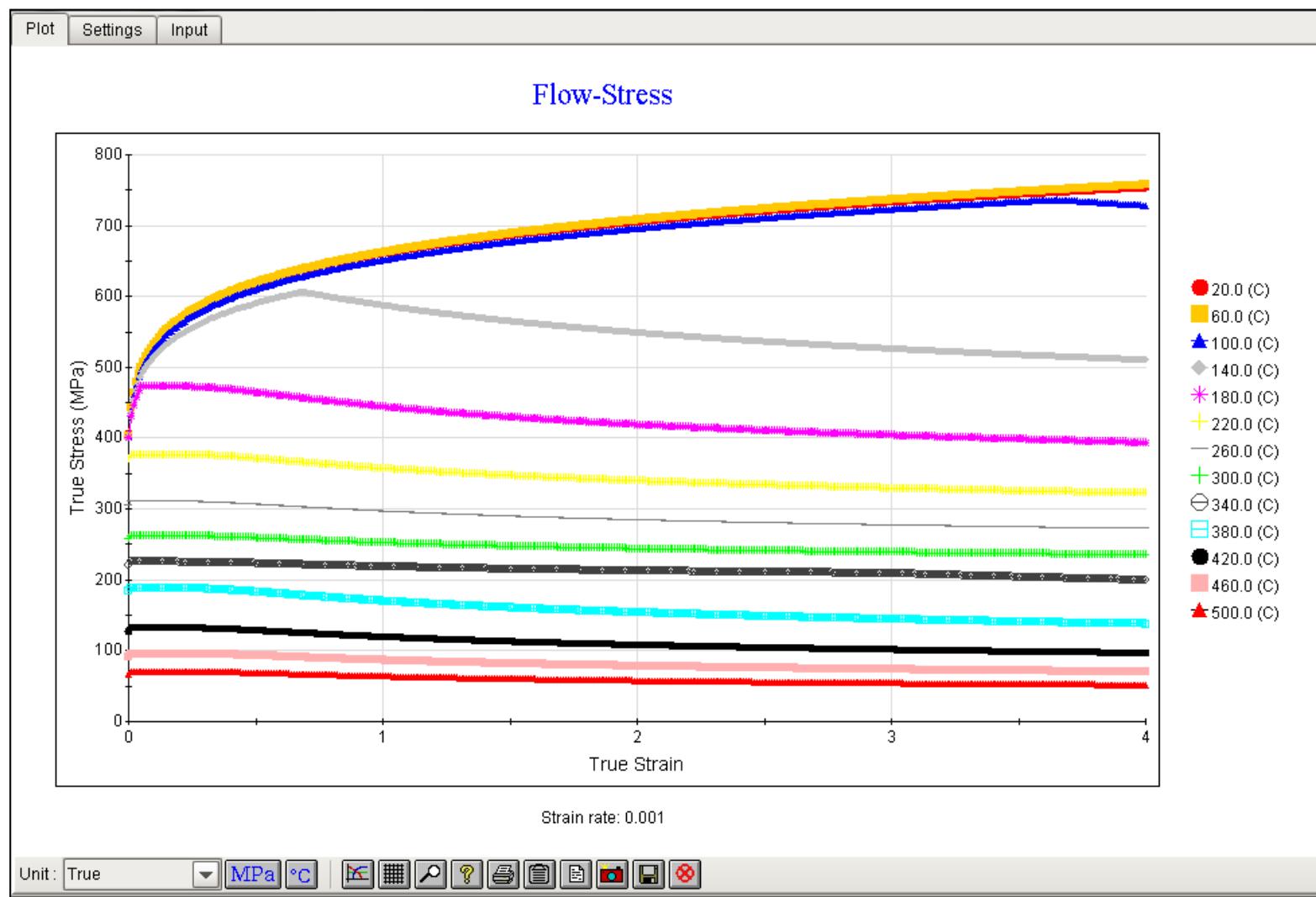
Additional thermal history: None

Time before testing: 1.0 h
Tested at constant strain rate: 1.5E-4 (1/s)

Al alloy strength



기계적 물성



Ti alloy

Ti Alloy 모듈 기능 개요

구분	기능	활용분야/기타
열역학계산	<ul style="list-style-type: none"> 평형상분율 계산 상태도 계산(isopleth) 	<ul style="list-style-type: none"> 상태도 관련 정보추출 열처리 기준 온도 설정 생성상을 제어하기 위한 합금설계
응고물성 계산	<ul style="list-style-type: none"> 응고분율 계산 및 물성계산 균질화 열처리 	<ul style="list-style-type: none"> 응고시뮬레이션 물성계산 잠열 계산 균질화 열처리 설계
열물리적 물성 계산	<ul style="list-style-type: none"> 열역학계산 기반의 상분율을 가정한 물성계산 	<ul style="list-style-type: none"> 열물성, 탄성계수, 열팽창계수, 밀도변화, 점성, 잠열 및 비열 등 계산
기계적 물성 계산	<ul style="list-style-type: none"> 상온강도/결정립크기 별 고온강도 예측 온도/변형율속도별 유동응력선도 온도/응력별 크립물성 고온피로 시험 관련 물성 제공 	<ul style="list-style-type: none"> 강도 향상을 위한 열처리 설계 크립 공정 시뮬레이션을 위한 물성 확보
상변태 관련 기능	<ul style="list-style-type: none"> TTT/CCT 계산 기능 등온 열처리 계산 냉각속도에 따른 변태 정보 	<ul style="list-style-type: none"> 열처리 설계

Main GUI for Ti alloy

Wt %

Ti	100.0
Al	0.0
Cr	0.0
Cu	0.0
Fe	0.0
H	0.0
Mn	0.0
Mo	0.0
Nb	0.0
Ni	0.0
Re	0.0
Ru	0.0
Si	0.0
Sn	0.0
Ta	0.0
V	0.0
Zr	0.0
C	0.0
O	0.0
N	0.0
B	0.0

Reset

Titanium Alloy

Calculations Export

Thermodynamic Properties: ▾ Step Temperature Step Concentration
Profile Single
Isopleth

Solidification: ▾ Phases and Properties Homogenisation

Mechanical Properties: ▾ Strength and Hardness High Temperature Strength
Creep Flow Stress Analysis
Processing Map Fatigue Related
Fracture Toughness

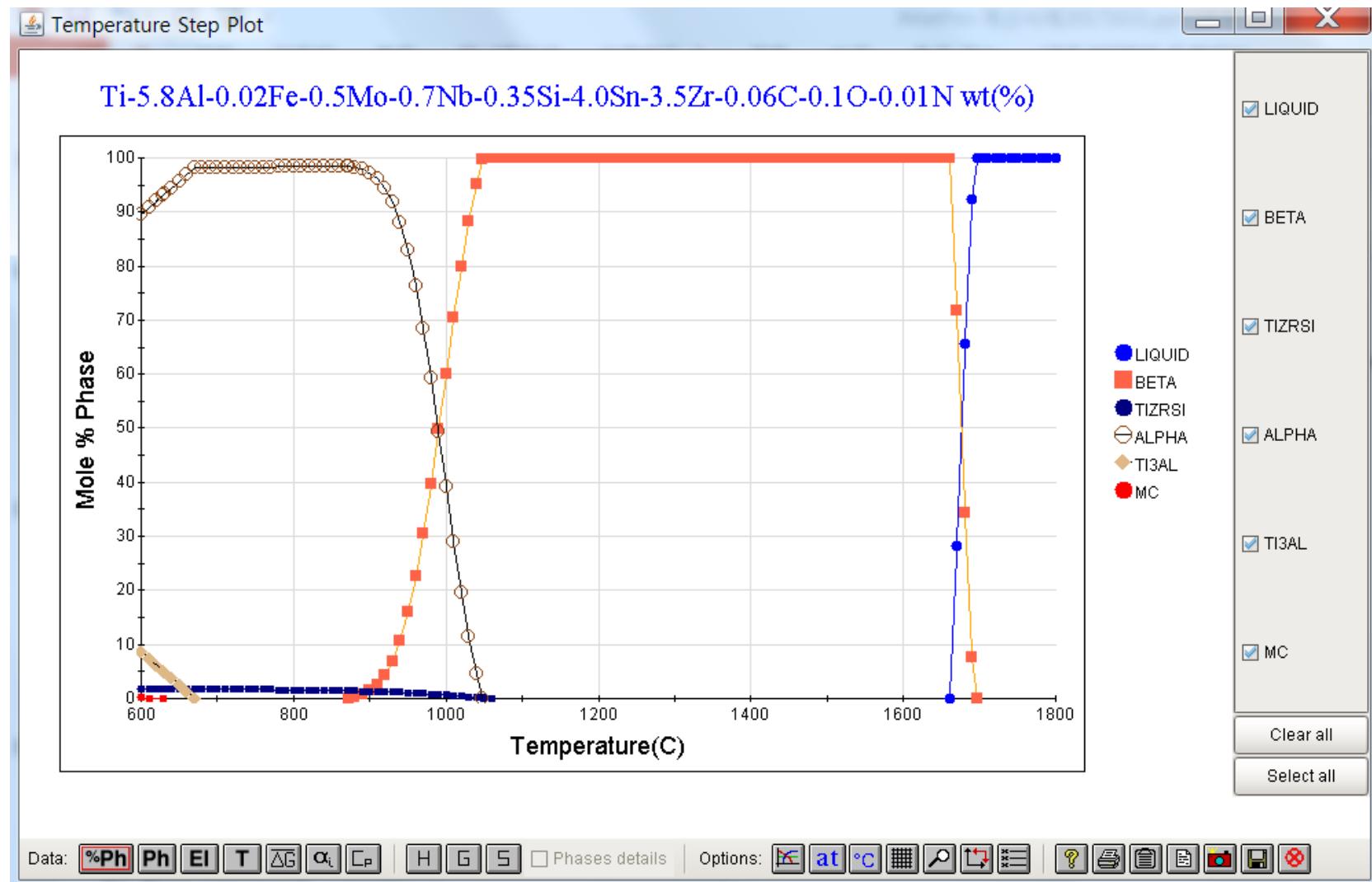
Thermo-Physical Properties: ▾ Extended General Dynamic

Phase transformation: ▾ TTT/CCT Diagrams Cooling Phases
Cooling Properties Energy Changes
Isothermal

Others: ▾ Dissimilar Metal Welds

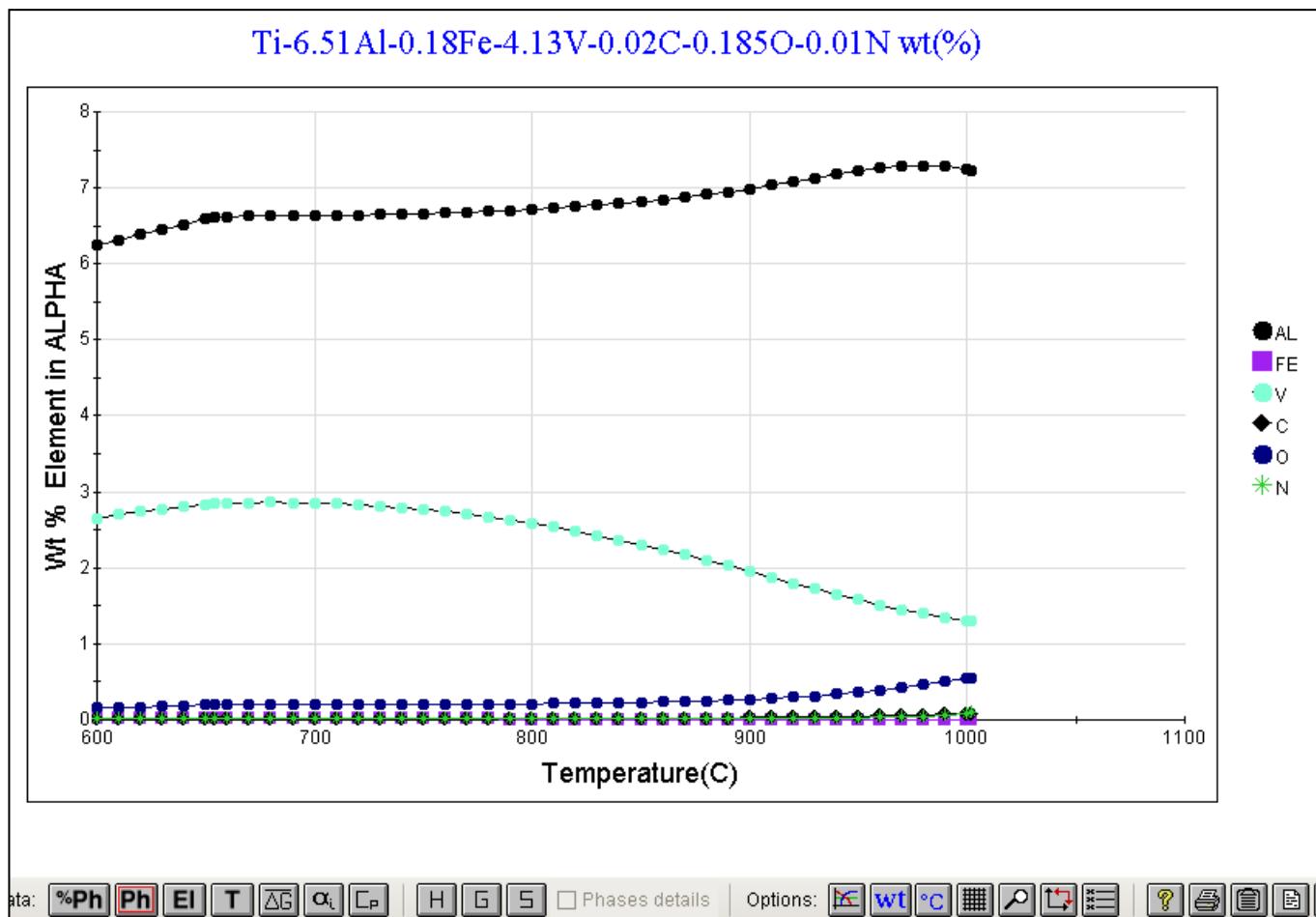
열역학계산

상분율 계산, 각상의 조성 계산, 엔트로피, 엔탈피, 비열 등 계산



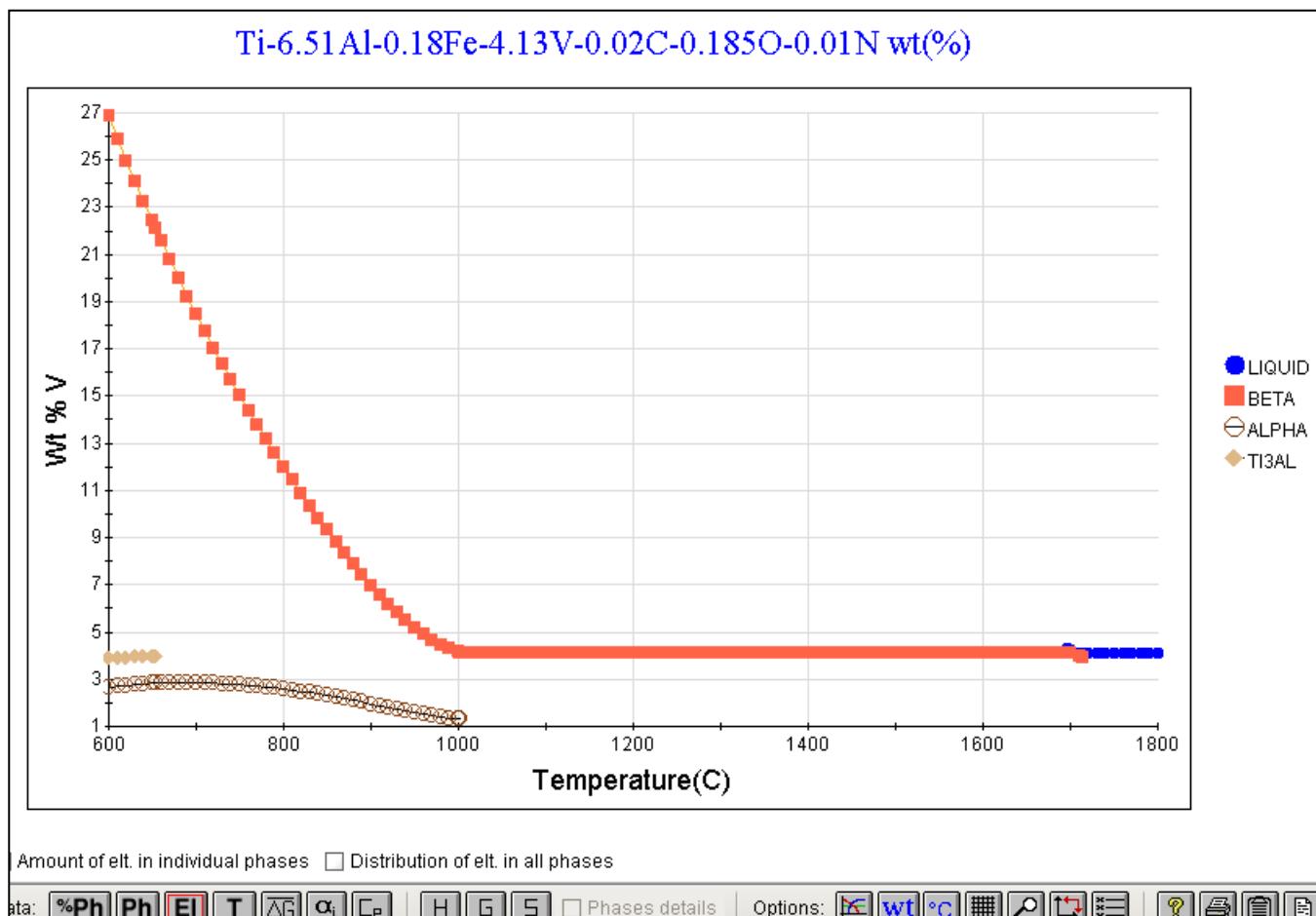
열역학계산

온도별 평형상의 분율 계산-Alpha상의 합금성분 변화



열역학계산

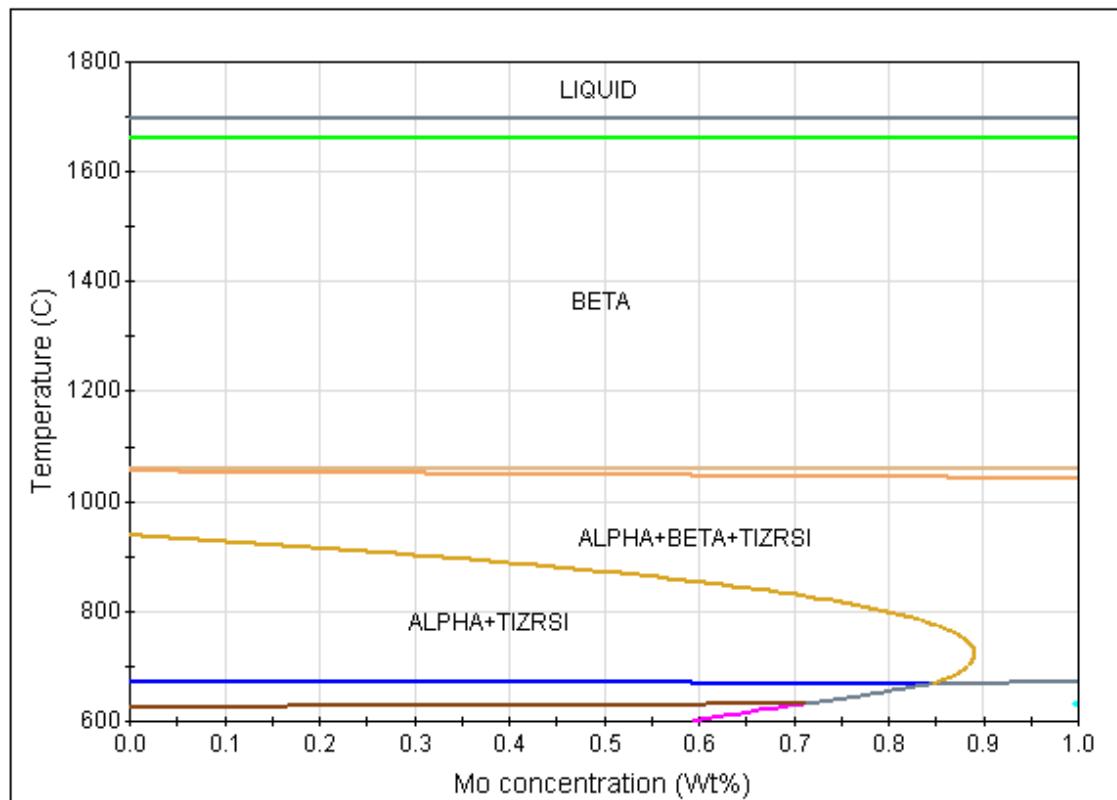
각 상에서의 V의 무게분율



열역학계산

이원계 상태도

Isopleth



Balance element: Ti

균질화 열처리

Titanium Alloy

Homogenisation

Homogenisation type

Single temp. Multi temp.

Initial solidification

Allow back diffusion

Cooling rate (C/s) 0.1

Secondary dendrite arm spacing (micron)

Estimate from cooling rate 353.0

Homogenisation temperature

Temperature (C) 1100

Homogenisation time

Time : 400 min

Steps

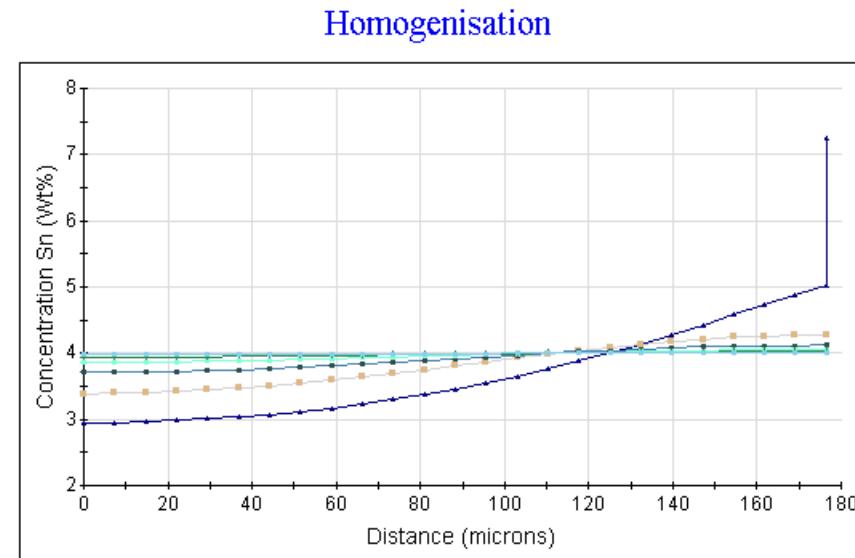
Number of steps 5

Elements to homogenise

Al Fe Mo Nb
 Si Sn Zr C
 O N

Select All Clear All

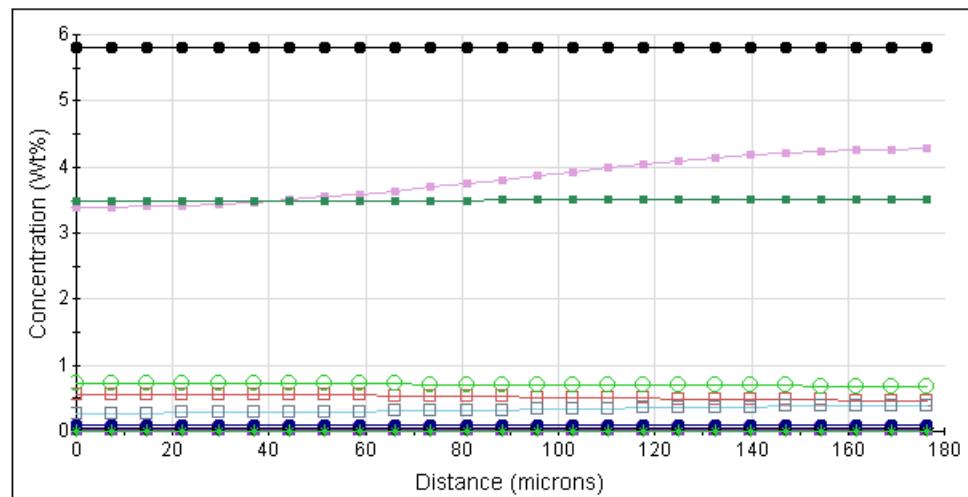
Start calculation Help



Phases at equilibrium at homogenisation temp. 1100.0 C (At%):

BETA 100.0

Initial cool



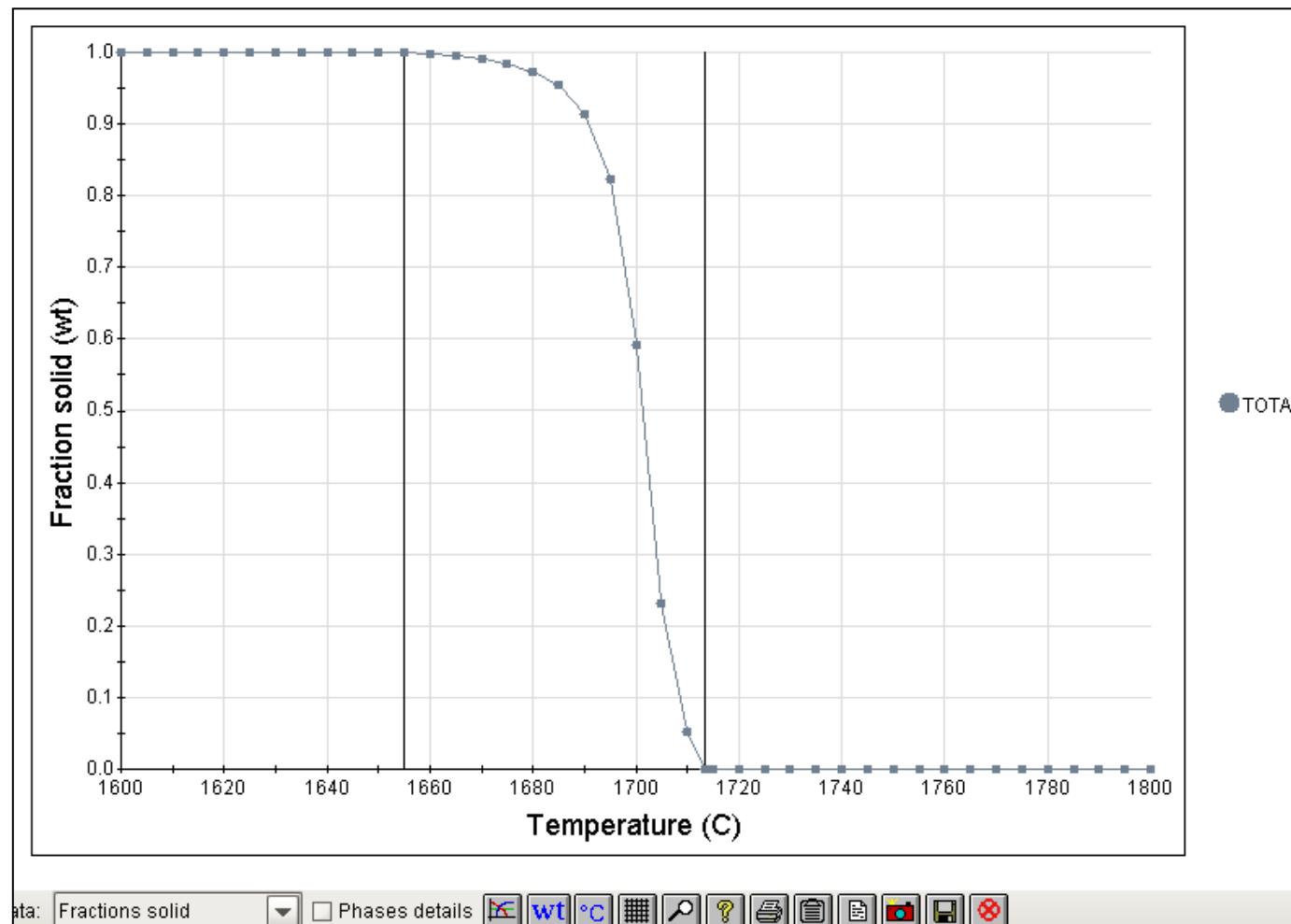
Phases at equilibrium at homogenisation temp. 1100.0 C (At%):

BETA 100.0

Initial cooling rate: 0.1 C/s

응고물성

응고분율



응고물성

응고구간 물성

Titanium Alloy

Solidification calculation

Temperatures (C)

Start: 1800

Step: 5

Solidification cut-off

Fraction liquid (Wt) 0.01

Back diffusion

Allow back diffusion

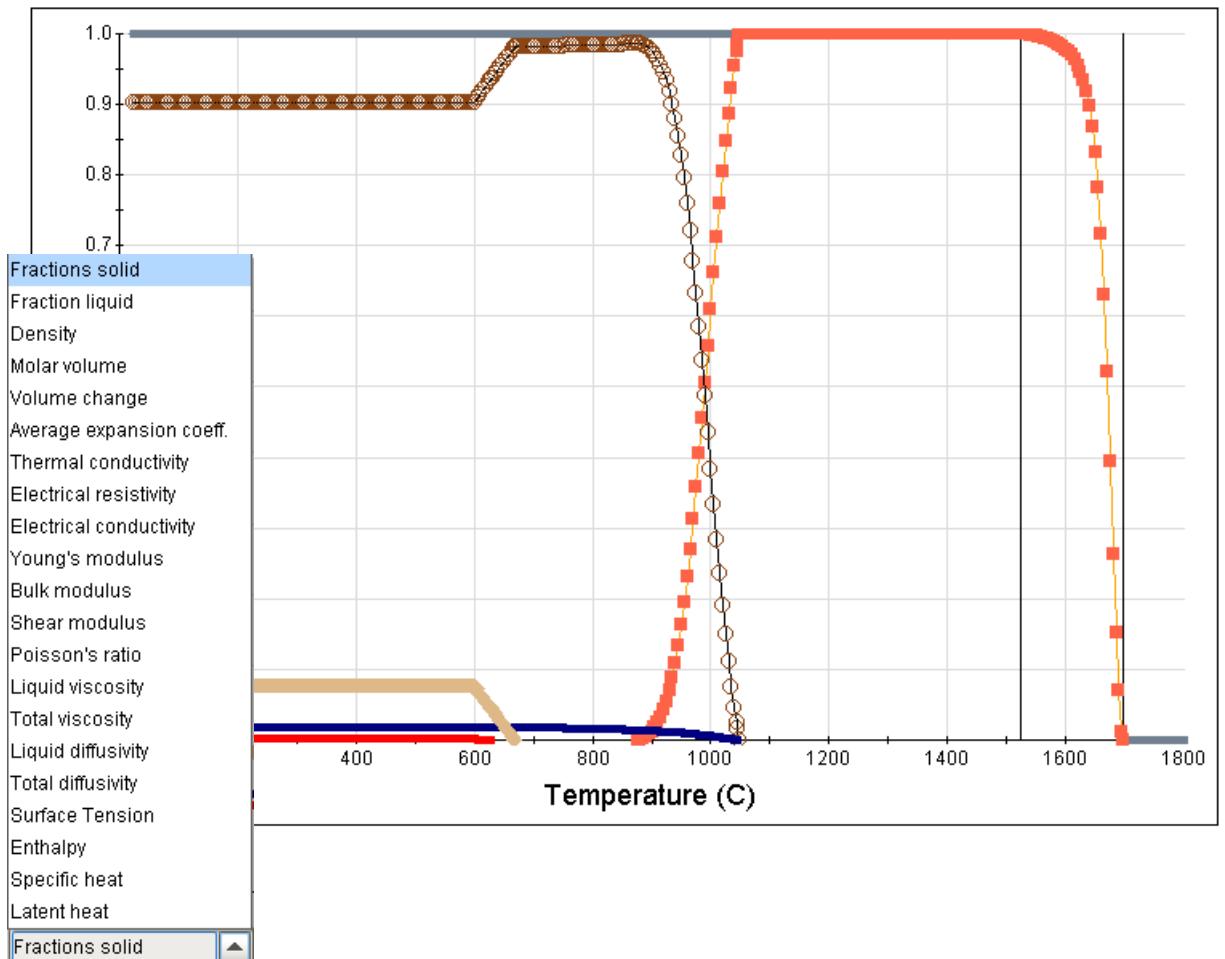
Phases

Take all solid phases into account

Phase Boundaries

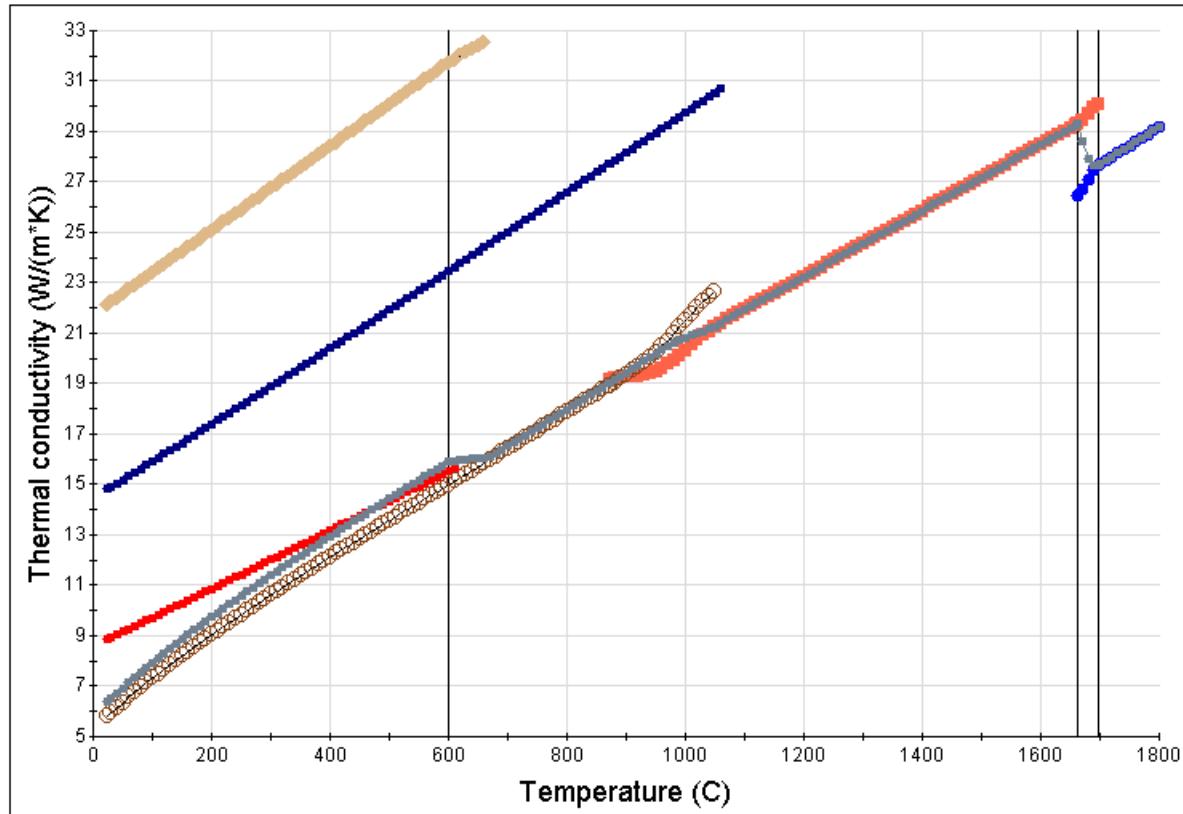
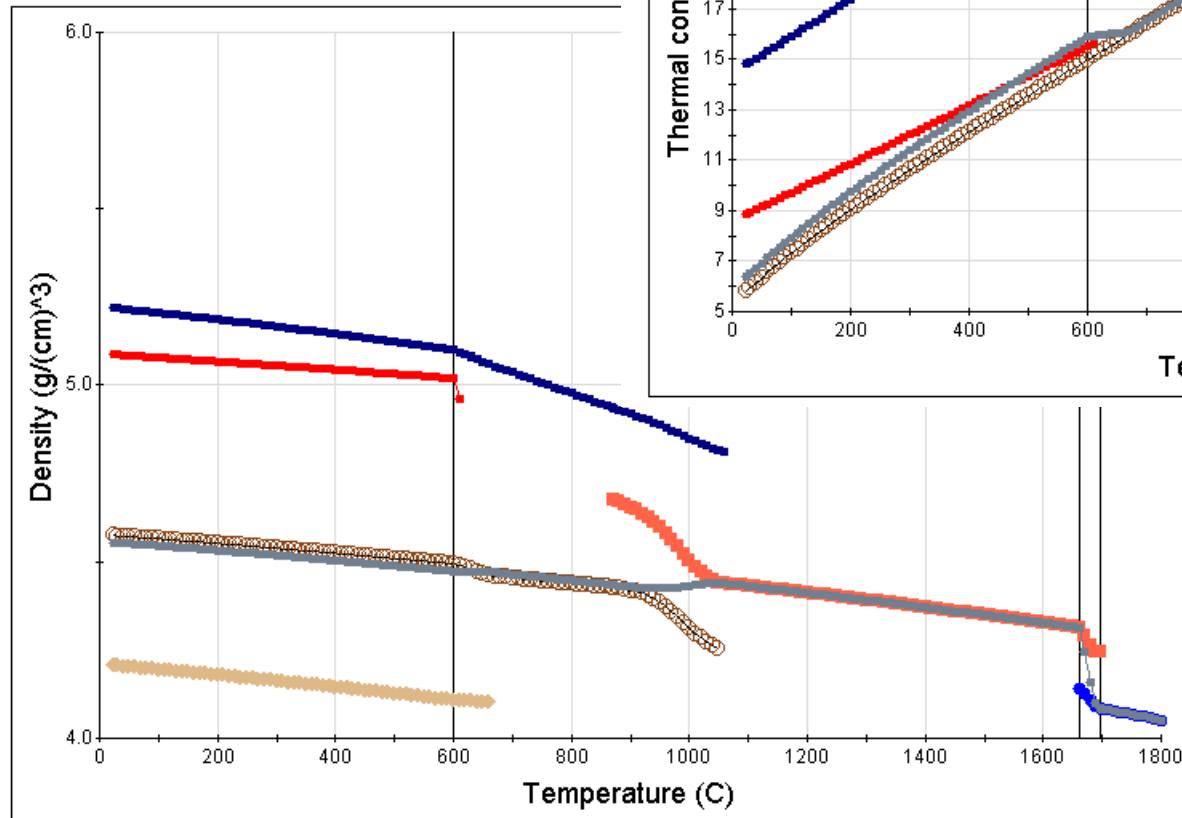
Locate phase boundaries

Start calculation **Help**



열물리적 물성

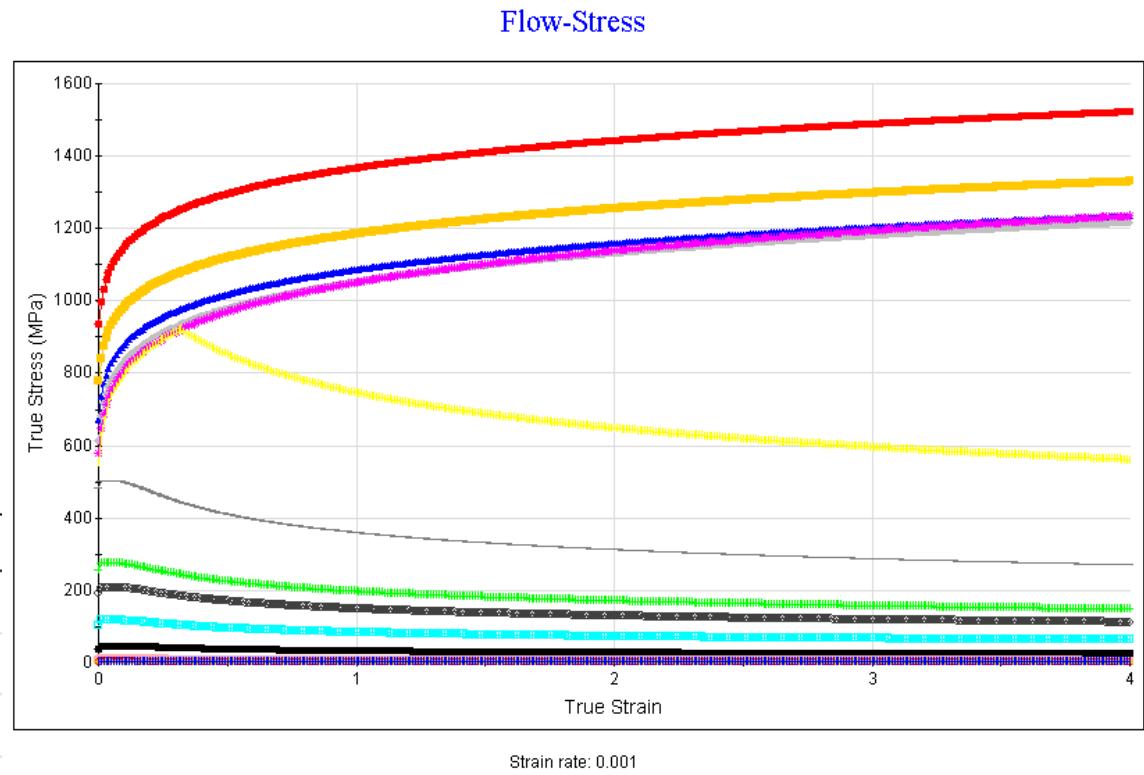
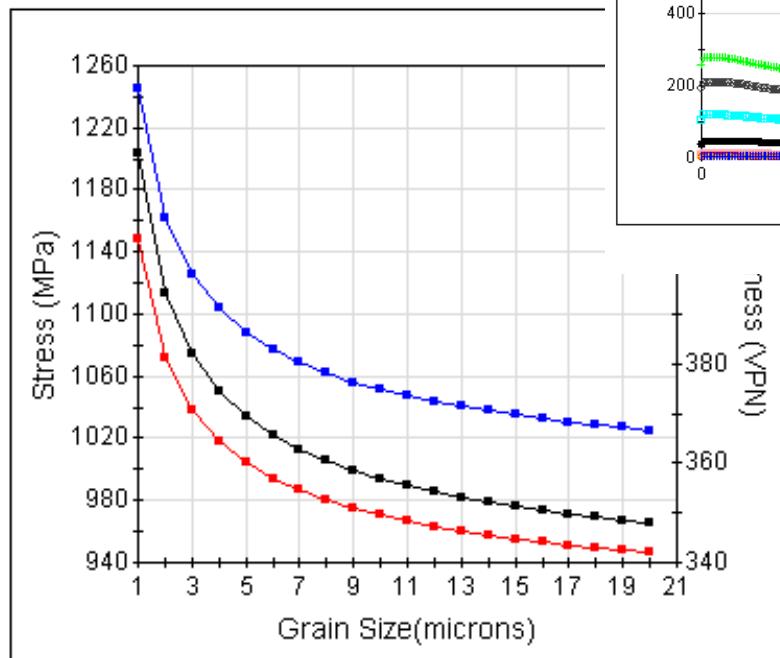
다양한 열물리적 물성



Ti3AL
MC
TOTAL

기계적 물성

Solution hardening



Heat treatment: 720.0 C

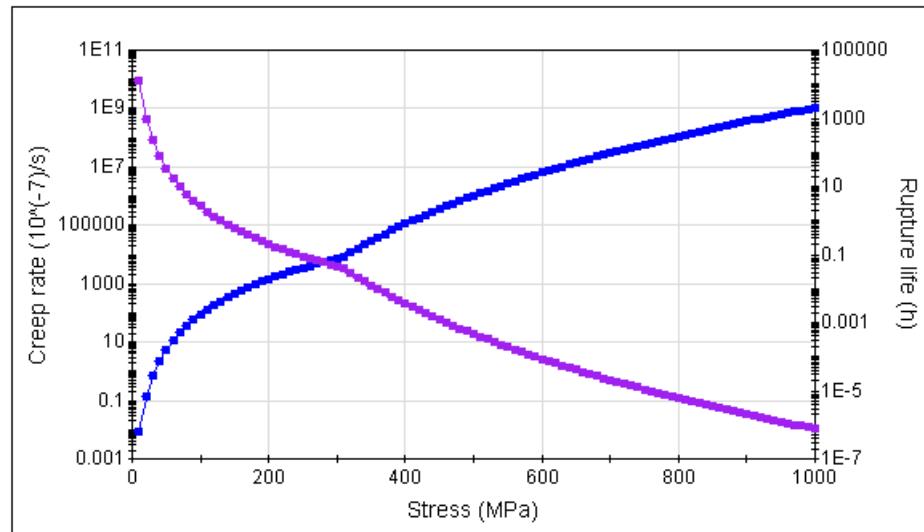
ALPHA 98.29%

Hall-Petch : 0.26 MN/m^{3/2}

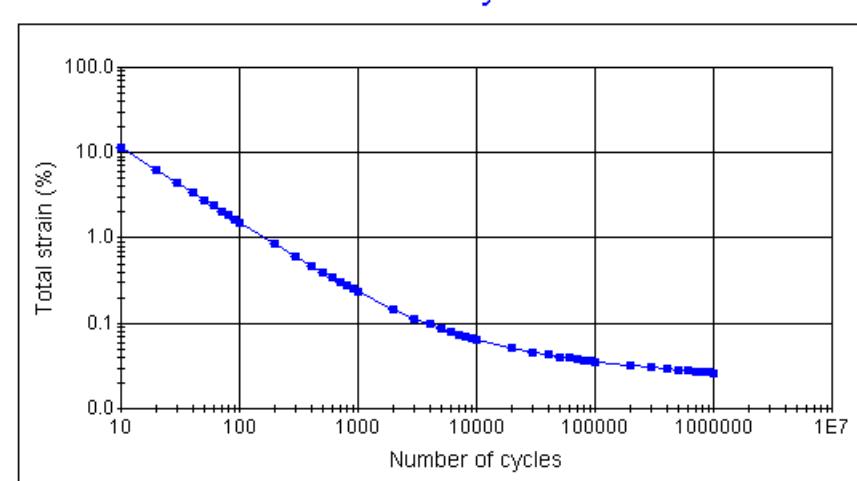
기계적 물성

크립물성

Creep calculation



고온 피로 관련 물성

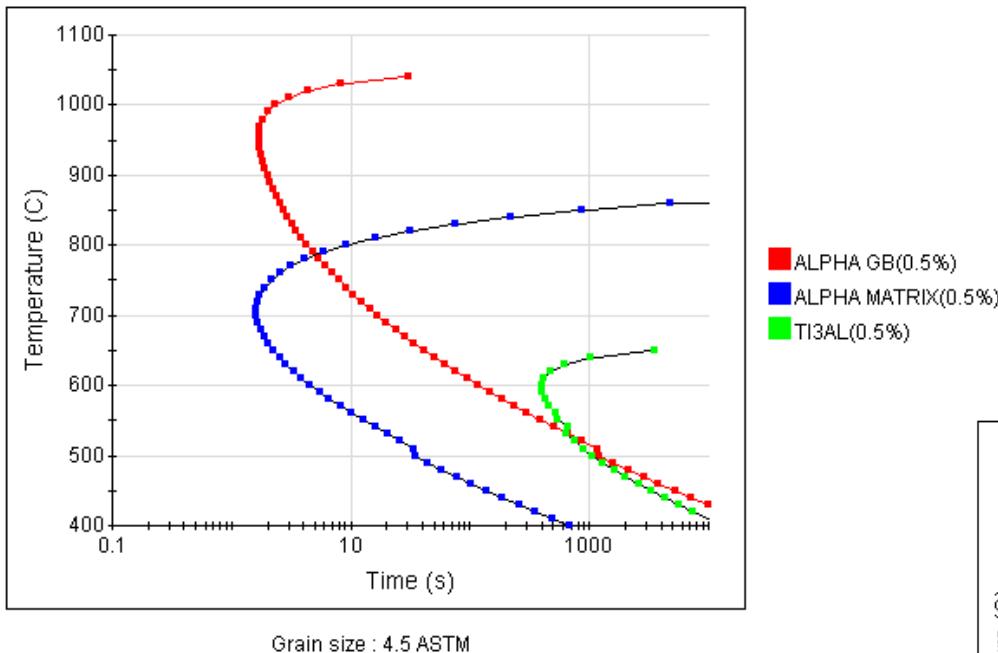


b: -0.1 c: -0.9 $^{\circ}\text{C}$

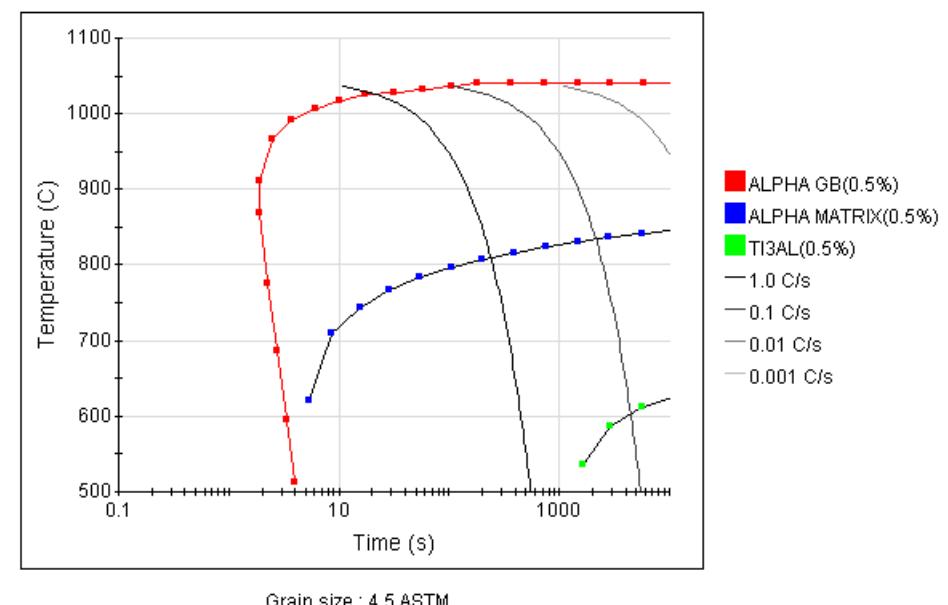
상변태 물성

TTT/CCT

TTT Titanium Alloy



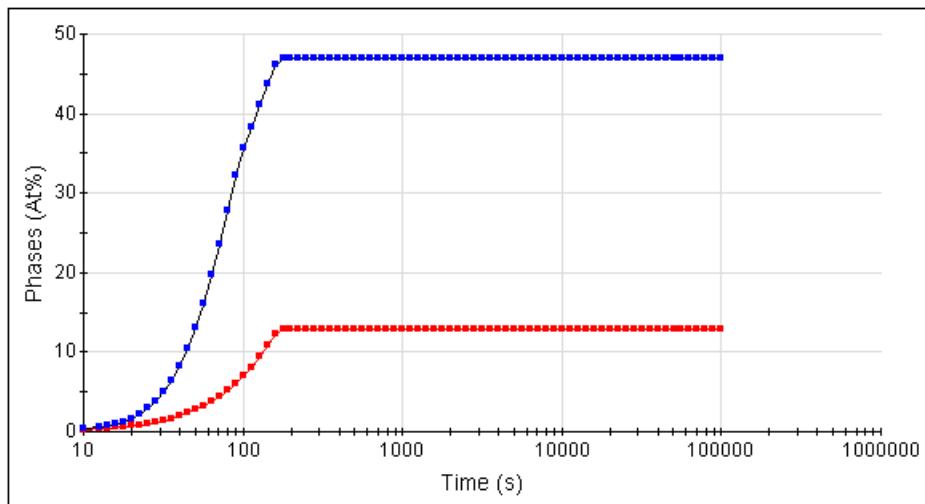
CCT Titanium Alloy



상변태 물성

Isothermal heat treatment

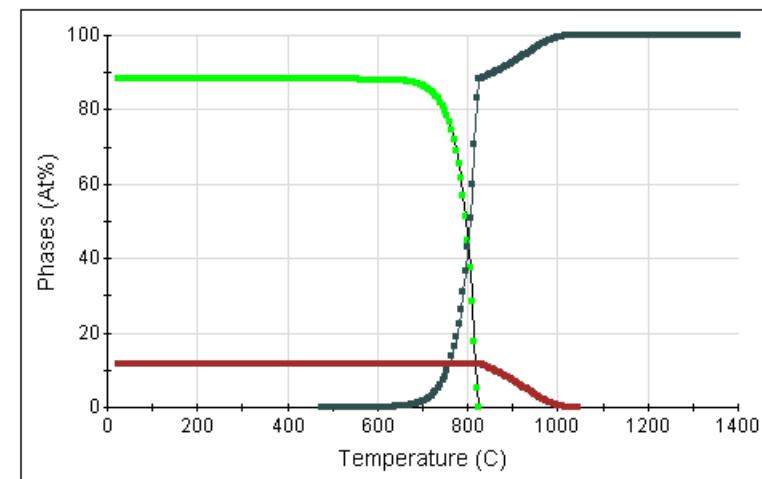
Phase evolution



Holding temperature (C) : 750.0
Quench temperature (C) : 1000.0
Grain size : 4.5 ASTM

Continuous cooling transformation

Phase evolution



Start temperature (C) : 1400.0
Cooling rate (C/s) : 10.0
Grain size : 4.5 ASTM
Martensite transition: 821.79 C

기계적 물성

Fracture toughness

Fracture toughness

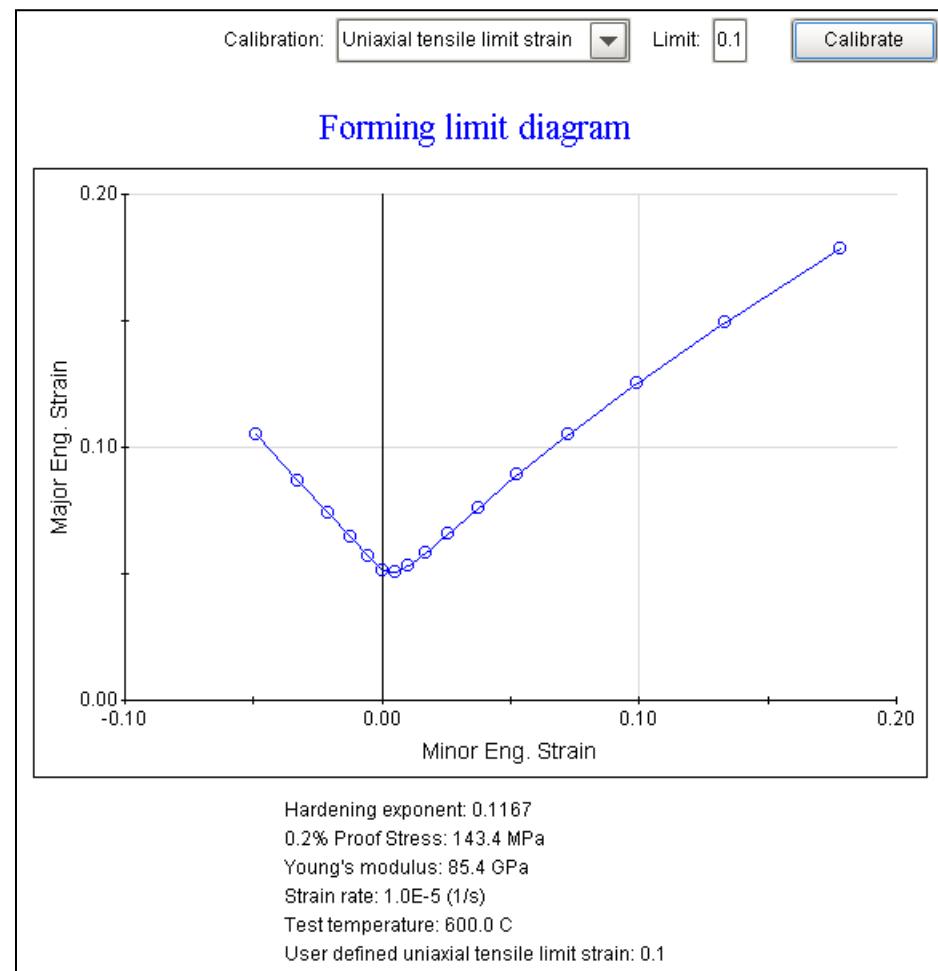
INPUT:

Heat treatment temperature: 710.0C
ALPHA: 91.34Wt% 91.55At%
BETA: 8.66Wt% 8.45At%
RT 0.2% proof stress: 1000.0MPa / 145.0ksi

CALCULATION RESULTS:

Plane strain fracture toughness KIC:
If ALPHA morphology is acicular: 61.6(MPa*m^0.5) / 56.1(ksi*in^0.5)
If ALPHA morphology is equiaxed: 52.1(MPa*m^0.5) / 47.5(ksi*in^0.5)
Charpy V-notch impact energy CVN:
If ALPHA morphology is acicular: 15.8(J) / 11.7(ft/lbs)
If ALPHA morphology is equiaxed: 14.2(J) / 10.5(ft/lbs)

FLD



Cu alloy

Cu Alloy 모듈 기능 개요

구분	기능	활용분야/기타
열역학계산	<ul style="list-style-type: none"> 평형상분율 계산 상태도 계산(isopleth) 	<ul style="list-style-type: none"> 상태도 관련 정보추출 열처리 기준 온도 설정 생성상을 제어하기 위한 합금설계
응고물성 계산	<ul style="list-style-type: none"> 응고분율 계산 및 물성계산 	<ul style="list-style-type: none"> 응고시뮬레이션 물성계산 잠열 계산
열물리적 물성 계산	<ul style="list-style-type: none"> 열역학계산 기반의 상분율을 가정한 물성계산 	<ul style="list-style-type: none"> 열물성, 탄성계수, 열팽창계수, 밀도변화, 점성, 잠열 및 비열 등 계산

Main GUI for Cu alloy

	Wt %
Cu	100.0
Al	0.0
Bi	0.0
Fe	0.0
Cr	0.0
Mg	0.0
Mn	0.0
Nb	0.0
Ni	0.0
Si	0.0
Pb	0.0
Sn	0.0
Zn	0.0
Zr	0.0
P	0.0

Copper Alloy

Calculations Export

Thermodynamic Properties:

Solidification:

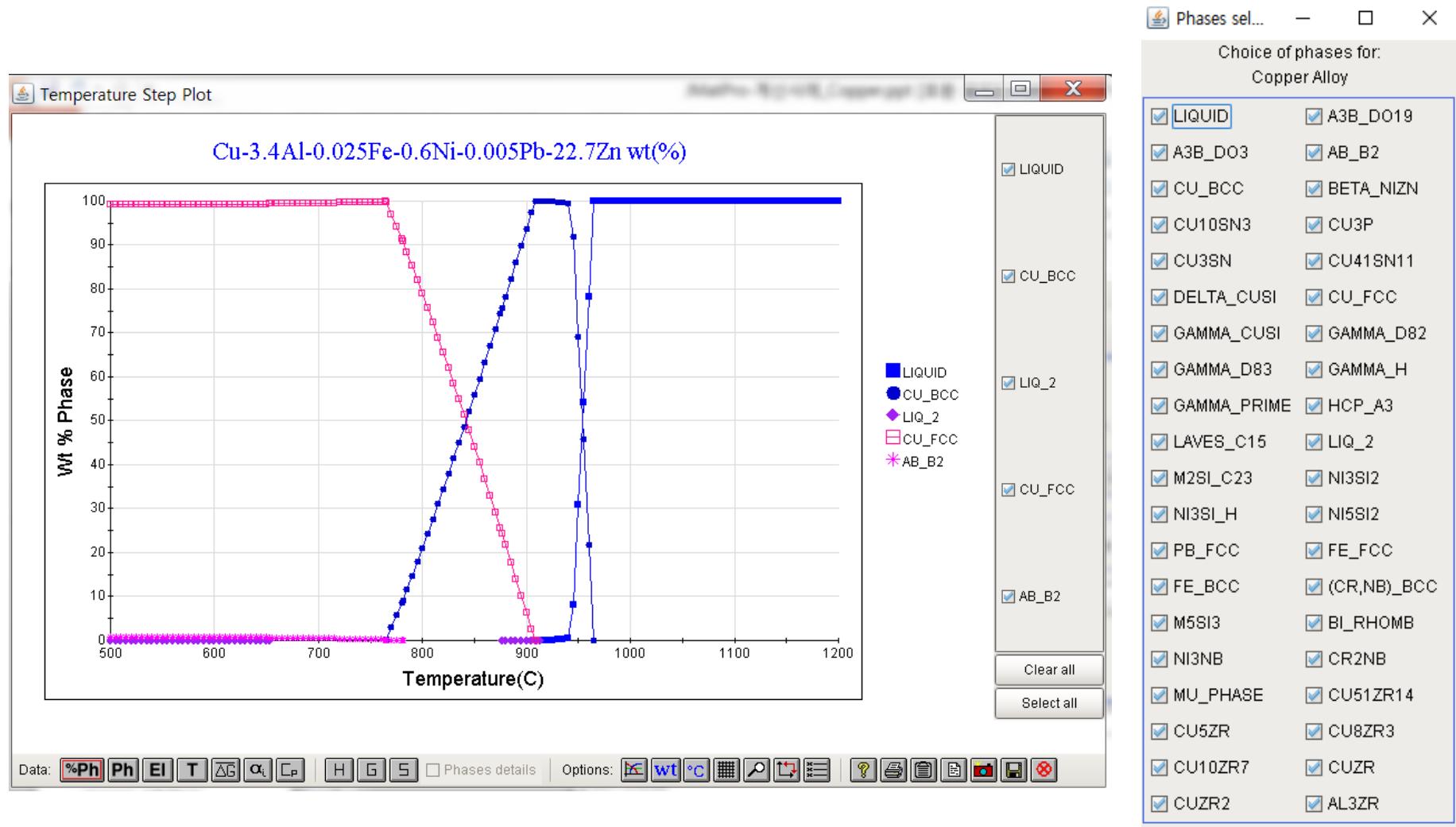
Thermo-Physical Properties:

열역학계산

- Step Temperature : 온도별 안정상 계산
- Step Composition : 조성별 안정상 계산
- Profile : 여러 조성을 동시에 변경하며 열역학 계산
- Isopleth Calculation: 상태도 계산

Temperature Step Calculation

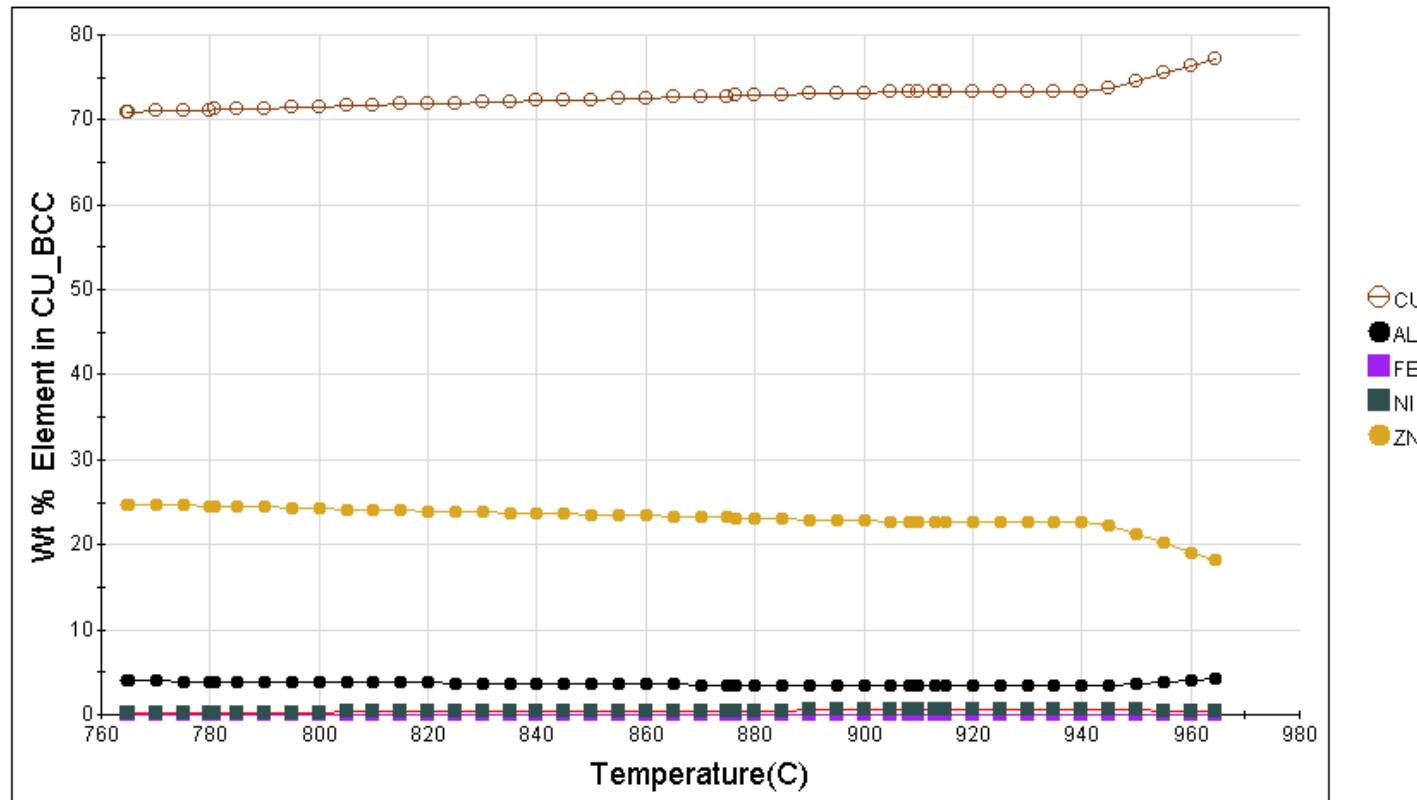
기본 입력사항 및 계산에서
고려하는 상의 목록



Temperature Step Calculation

Cu_BCC 상의 조성변화

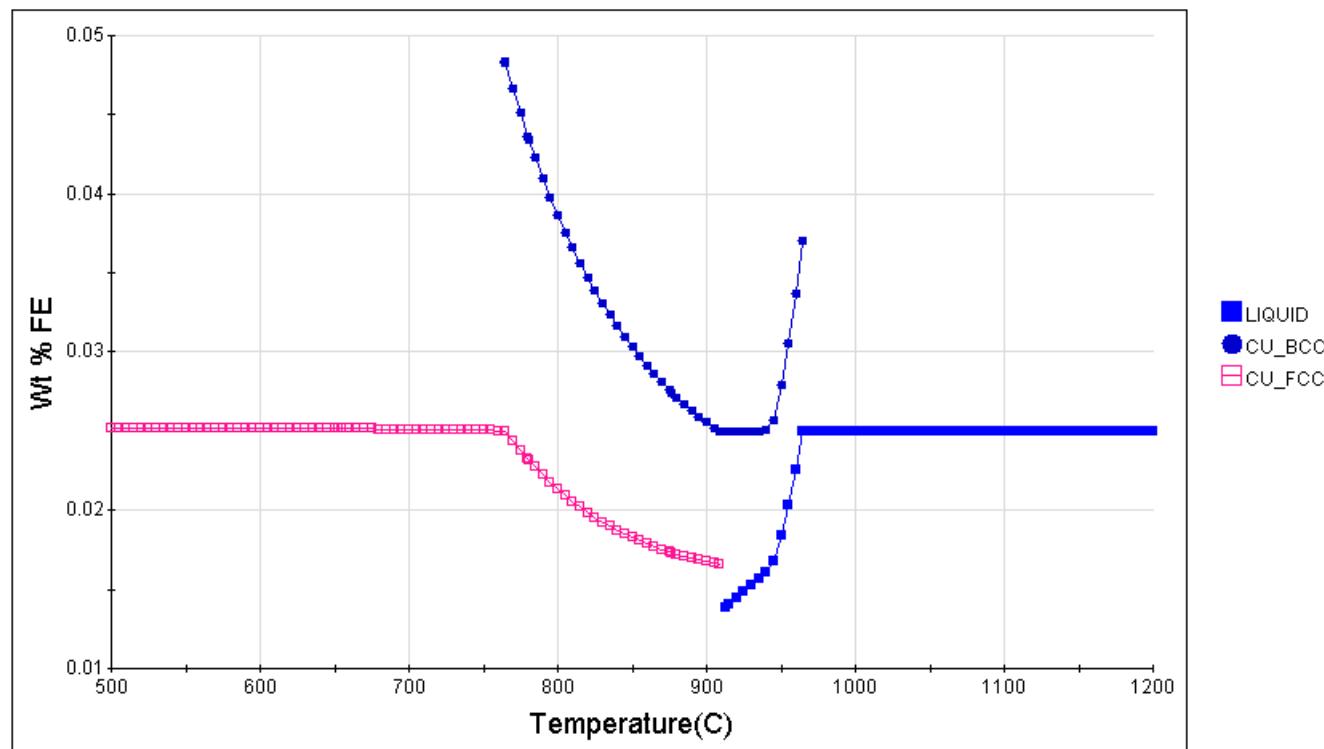
Cu-3.4Al-0.025Fe-0.6Ni-0.005Pb-22.7Zn wt(%)



Temperature Step Calculation

Fe 원소의 각상에서의 분포

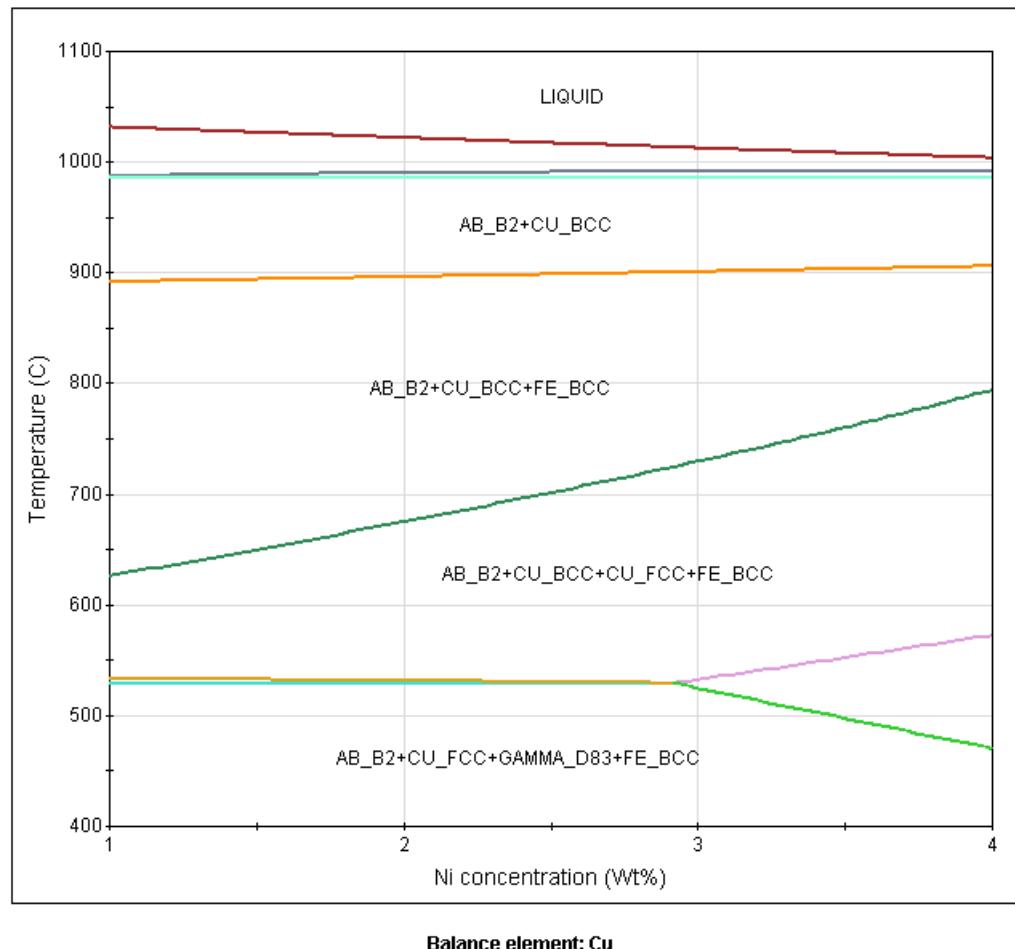
Cu-3.4Al-0.025Fe-0.6Ni-0.005Pb-22.7Zn wt(%)



Isopleth Phase Diagram

2원계 상태도 계산

Isopleth



응고물성 계산

- Fraction Solid: 온도별 응고분율
- Material Properties during Solidification : 밀도, 점도, 열전도 등

Solidification Calculation

응고물성 계산을 위한 입력창

	Wt %
Cu	100.0
Al	0.0
Bi	0.0
Fe	0.0
Cr	0.0
Mg	0.0
Mn	0.0
Nb	0.0
Ni	0.0
Si	0.0
Pb	0.0
Sn	0.0
Zn	0.0
Zr	0.0
P	0.0

Copper Alloy
Solidification calculation

Temperatures (C)

Start: 1200
Step: 5

Solidification cut-off

Fraction liquid (Wt) 0.01

Phases

Take all solid phases into account

Phase Boundaries

Locate phase boundaries

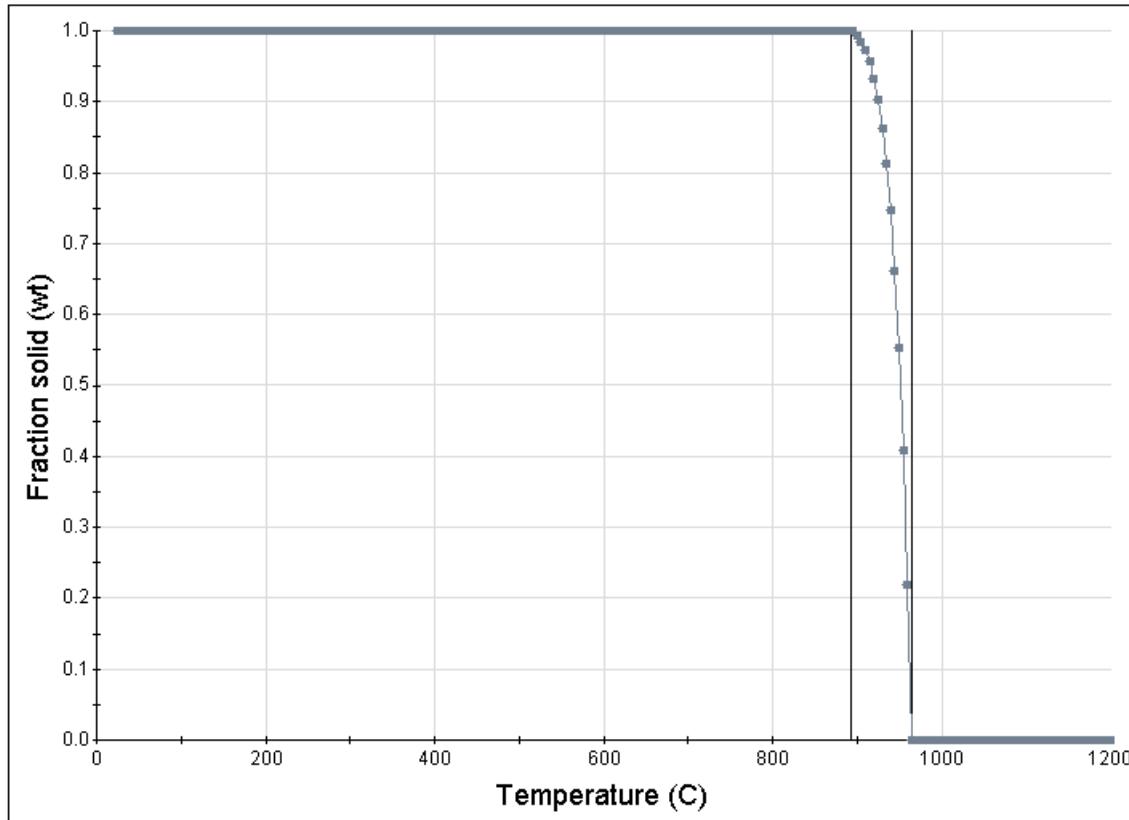
Start calculation **Help**

Reset

Solidification Calculation

온도별 응고분율외 각종 물성
계산

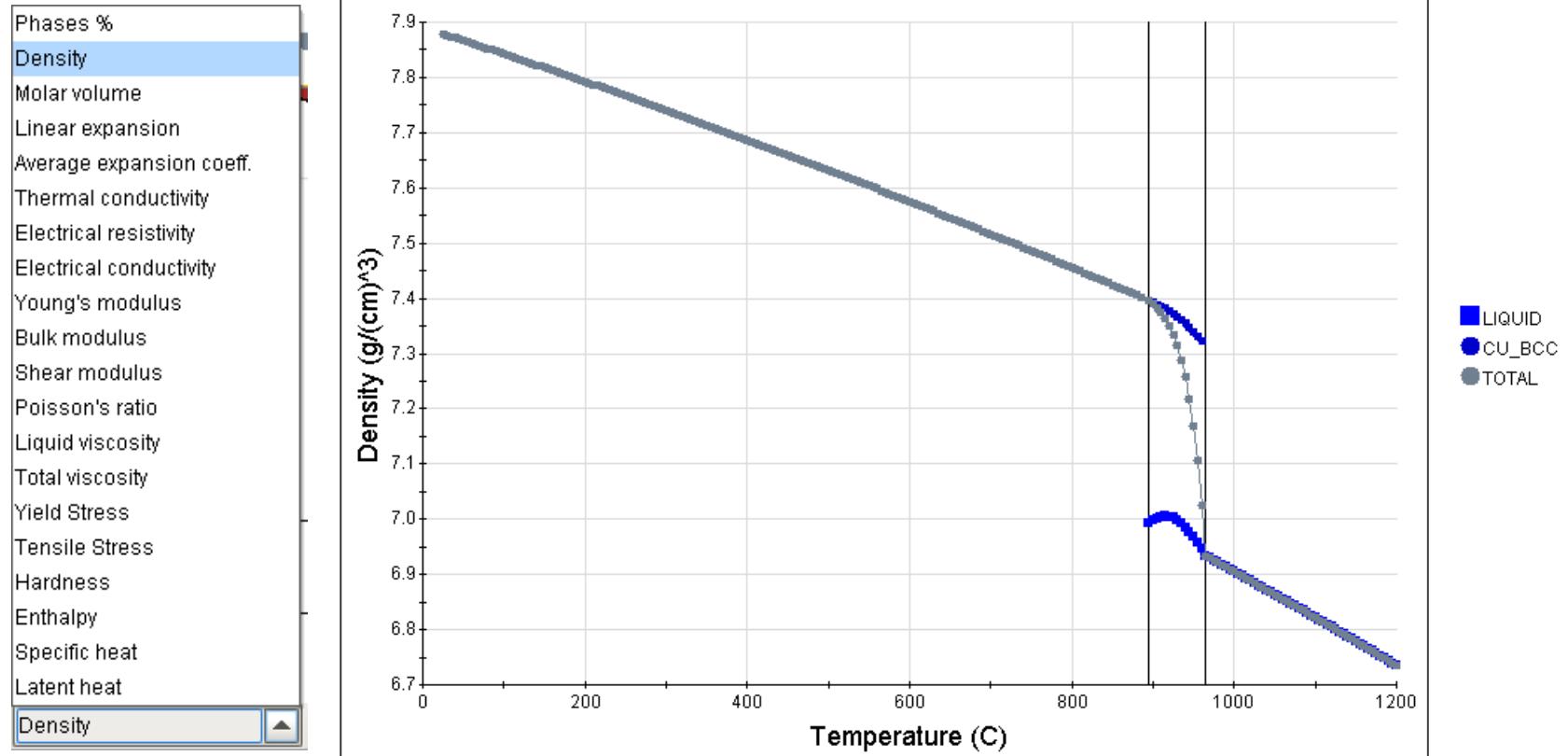
General physical properties



온도별 응고분율

Solidification Calculation

온도별 각상의 밀도변화와



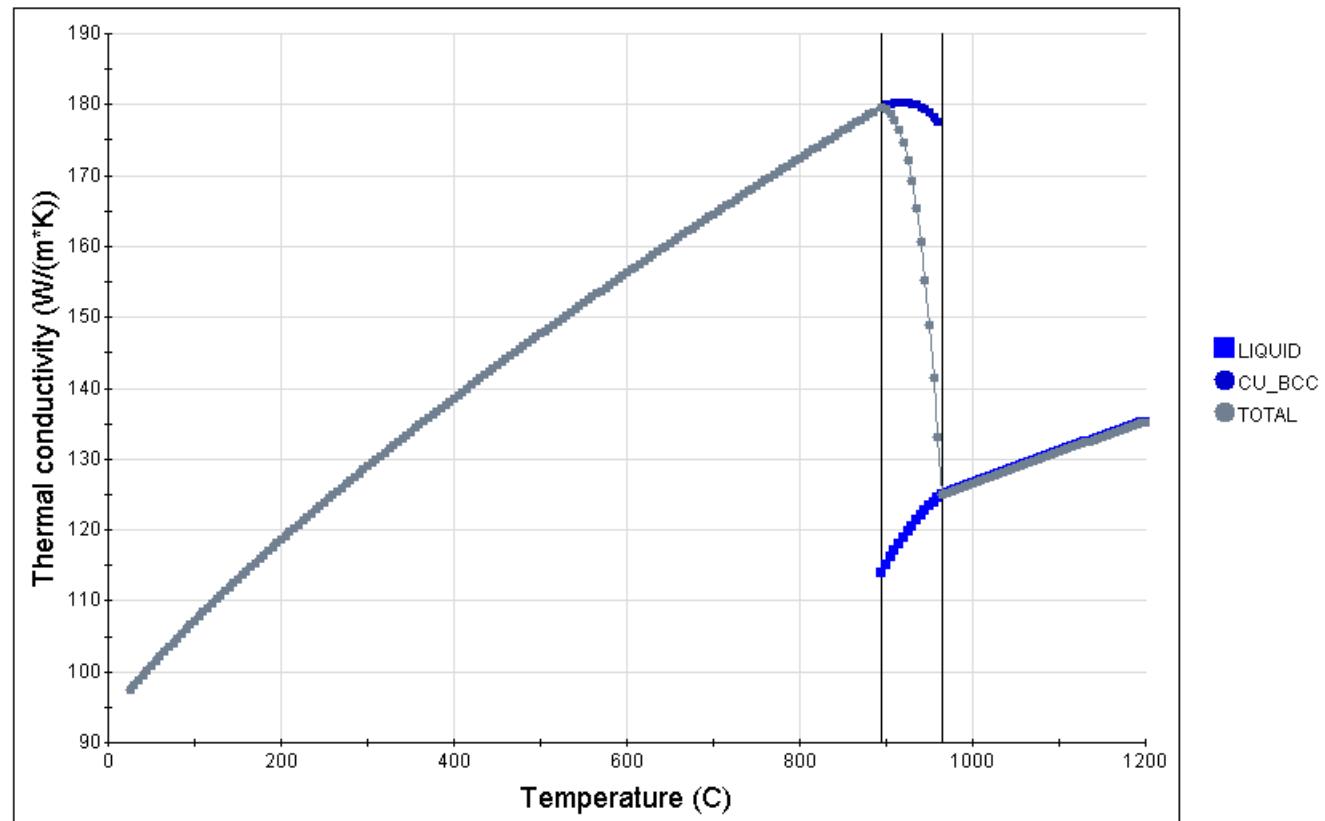
온도별 밀도변화

Solidification Calculation

온도별 각상의 열전도율변화

General physical properties

Fractions solid
Fraction liquid
Density
Molar volume
Volume change
Average expansion coeff.
Thermal conductivity
Electrical resistivity
Electrical conductivity
Young's modulus
Bulk modulus
Shear modulus
Poisson's ratio
Liquid viscosity
Total viscosity
Liquid diffusivity
Total diffusivity
Surface Tension
Enthalpy
Specific heat
Latent heat
Thermal conductivity



온도별 열전도율변화

열물리적 물성 계산

- 밀도, 열전도도, 전기전도도/비저항, 탄성계수, 프와송비, 열팽창계수, 표면장력, 비열 등

Thermo-physical Properties Calculation

열역학 계산에 기반한 상분율을
가정하여 물성계산수행

The screenshot shows the 'Copper Alloy' calculation interface. On the left is a table of element weights (Wt %) for various elements: Cu (100.0), Al (0.0), Bi (0.0), Fe (0.0), Cr (0.0), Mg (0.0), Mn (0.0), Nb (0.0), Ni (0.0), Si (0.0), Pb (0.0), Sn (0.0), Zn (0.0), Zr (0.0), and P (0.0). A 'Reset' button is at the bottom of this table. On the right is a main panel titled 'Copper Alloy' containing sections for 'Thermo-Physical and Physical Properties' and 'Temperatures (C)'. Under 'Temperatures (C)', fields for 'Heat treatment' (600), 'Upper limit' (1200), and 'Step' (10) are shown. Under 'Phases', a checkbox labeled 'Take all phases into account' is checked. At the bottom are 'Start calculation' and 'Help' buttons.

	Wt %
Cu	100.0
Al	0.0
Bi	0.0
Fe	0.0
Cr	0.0
Mg	0.0
Mn	0.0
Nb	0.0
Ni	0.0
Si	0.0
Pb	0.0
Sn	0.0
Zn	0.0
Zr	0.0
P	0.0

Copper Alloy

Thermo-Physical and Physical Properties

Temperatures (C)

Heat treatment:

Upper limit:

Step:

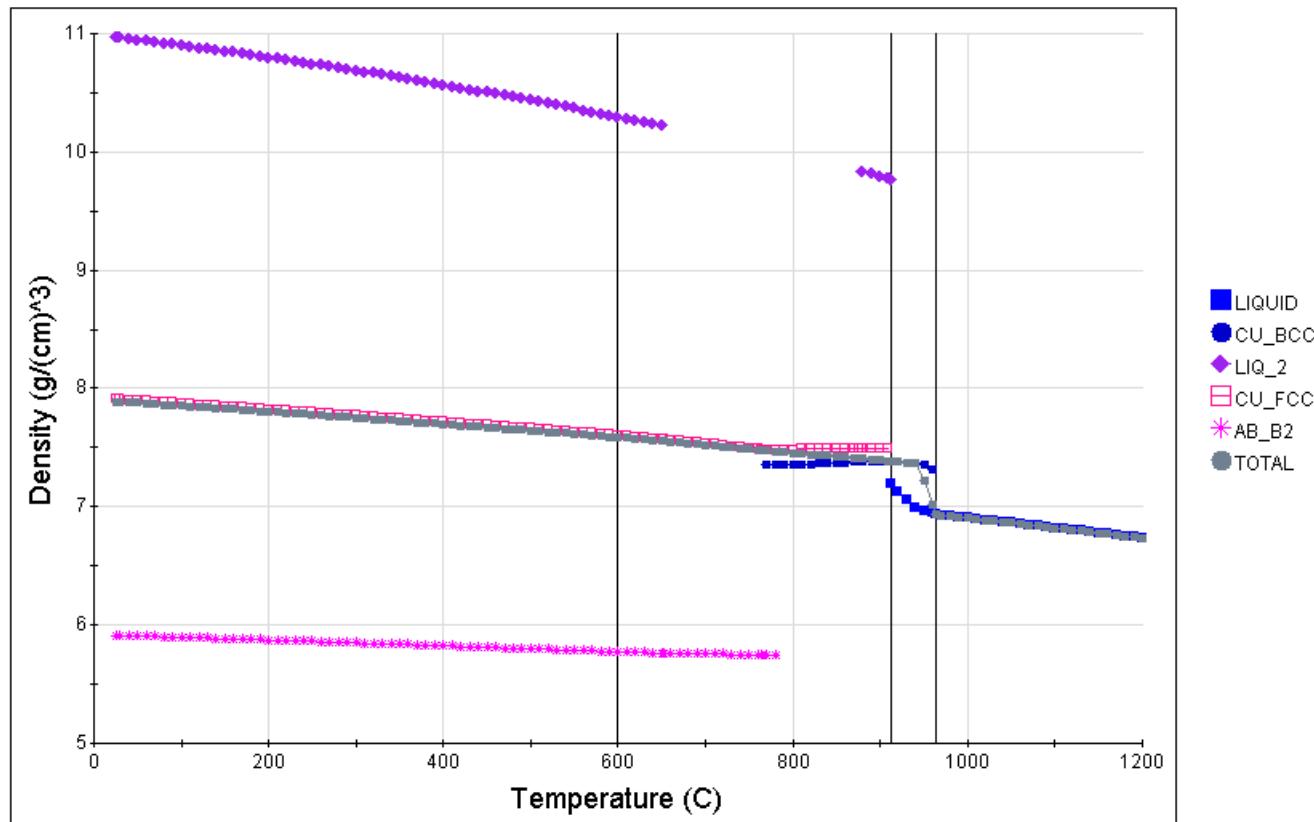
Phases

Take all phases into account

Thermo-physical Properties Calculation

각 상별/각 온도별 물성계산

C69000 - Aluminium Brass Physical properties



ita: Density Phases details

042-628-0789

info@solution-lab.co.kr



FlowVision