DLPP

DANIELI LONG PRODUCTS PROPERTIES PREDICTOR

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DLPP - Danieli Long Products Properties Predictor

Introduction

DLPP

Commissioning
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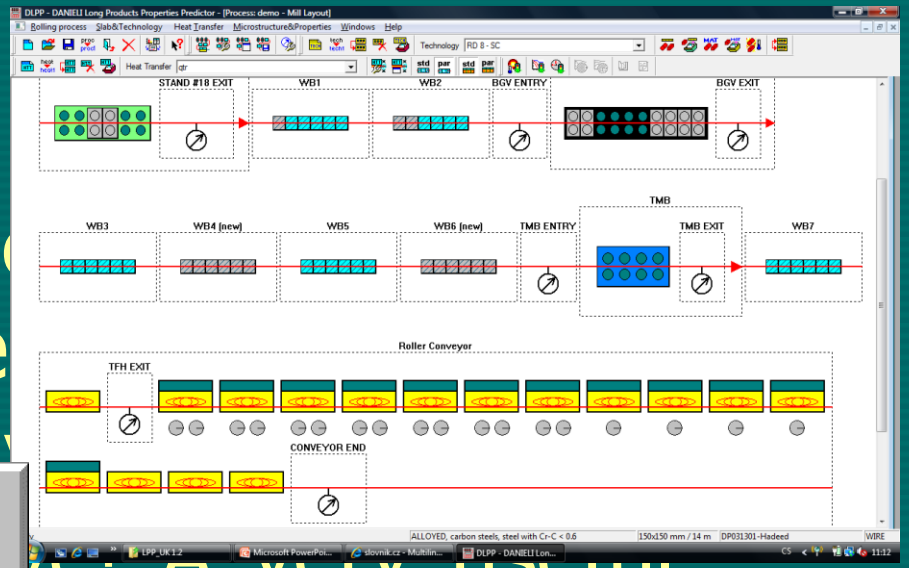
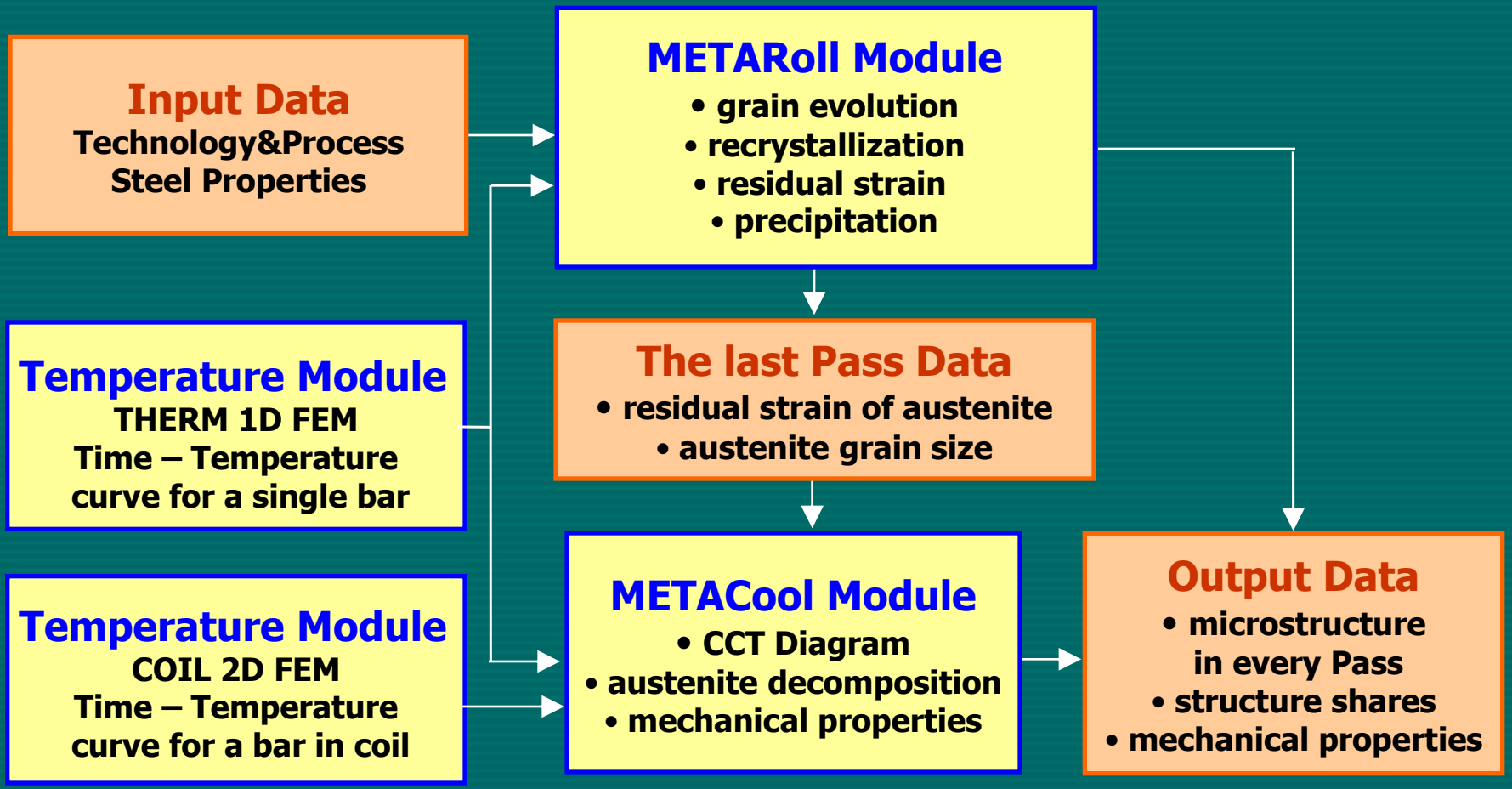


Off-line tool for prediction of microstructure and final mechanical properties of hot rolled bars and wire rods.

DLPP software

Chart of main physically based executive modules



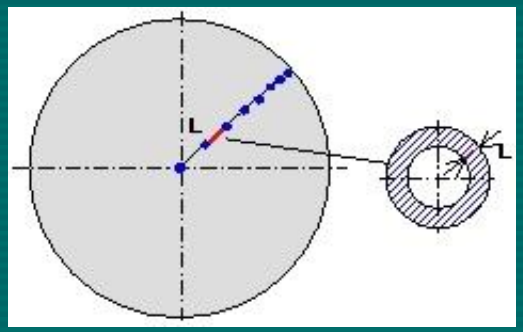
DLPP software

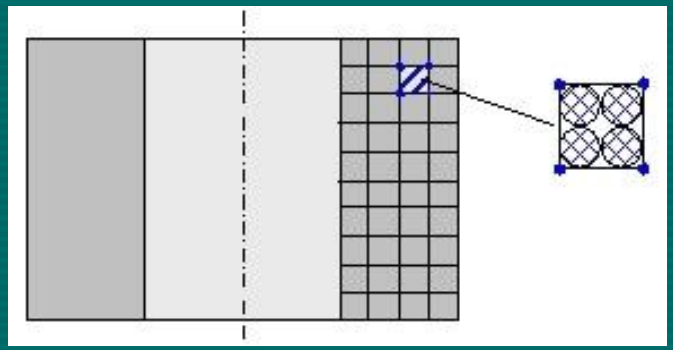
Steel groups and limits of chemical composition

GROUP	C		Mn		Si		Cr		Ni		Mo		V	W	Ti	Nb	B	Al	N
	min	max	min	max	min	max	min	max	min	max	min	max	max	max	max	max	max	max	max
C < 0.06	0.001	0.06	0.05	0.70	0.02	0.30	0	0.10	0	0.10	0	0.10	0.05	-	0.05	0.10	0.004	0.05	0.015
C < 0.20	0.06	0.25	0.20	1.50	0.05	1.50	0	0.40	0	0.25	0	0.10	0.10	-	0.05	0.10	0.004	0.05	0.015
C < 0.50	0.20	0.55	0.20	1.50	0.05	1.50	0	0.40	0	0.25	0	0.10	0.10	-	0.05	0.10	0.004	0.05	0.015
C < 0.95	0.50	1.15	0.20	1.50	0.05	1.50	0	0.40	0	0.25	0	0.10	0.10	-	0.05	-	0.004	0.05	0.015
Mn	0.10	0.50	1.50	2.00	0.05	1.50	0	2.0	0	0.25	0	0.10	0.25	-	-	0.10	0.004	0.05	0.015
Cr C < 0.6	0.15	0.65	0.20	1.20	0.05	0.40	0	1.50	0	0.25	0	0.10	0.40	-	-	-	0.004	0.05	0.015
Cr C > 0.6	0.60	1.15	0.20	1.20	0.05	0.40	0	1.50	0	0.25	0	0.10	0.40	-	-	-	0.004	0.05	0.015
Mo	0.15	0.55	0.40	1.20	0.05	0.40	0	0.40	0	0.25	0	0.40	-	-	-	-	0.004	0.05	0.015
Cr-Mo	0.15	0.65	0.40	1.00	0.05	0.40	0	1.50	0	0.25	0	0.40	-	-	-	-	-	0.05	0.015
Cr-Si	0.45	0.70	0.20	2.00	1.00	2.00	0	1.50	0	0.25	0	0.10	0.10	-	-	-	-	0.05	0.015
Ni-Cr-Mo	0.15	0.65	0.40	1.00	0.05	0.40	0	1.50	0	3.50	0	0.40	-	-	-	-	-	0.05	0.015

DLPP software – Theoretical Background
Finite Element Temperature Models

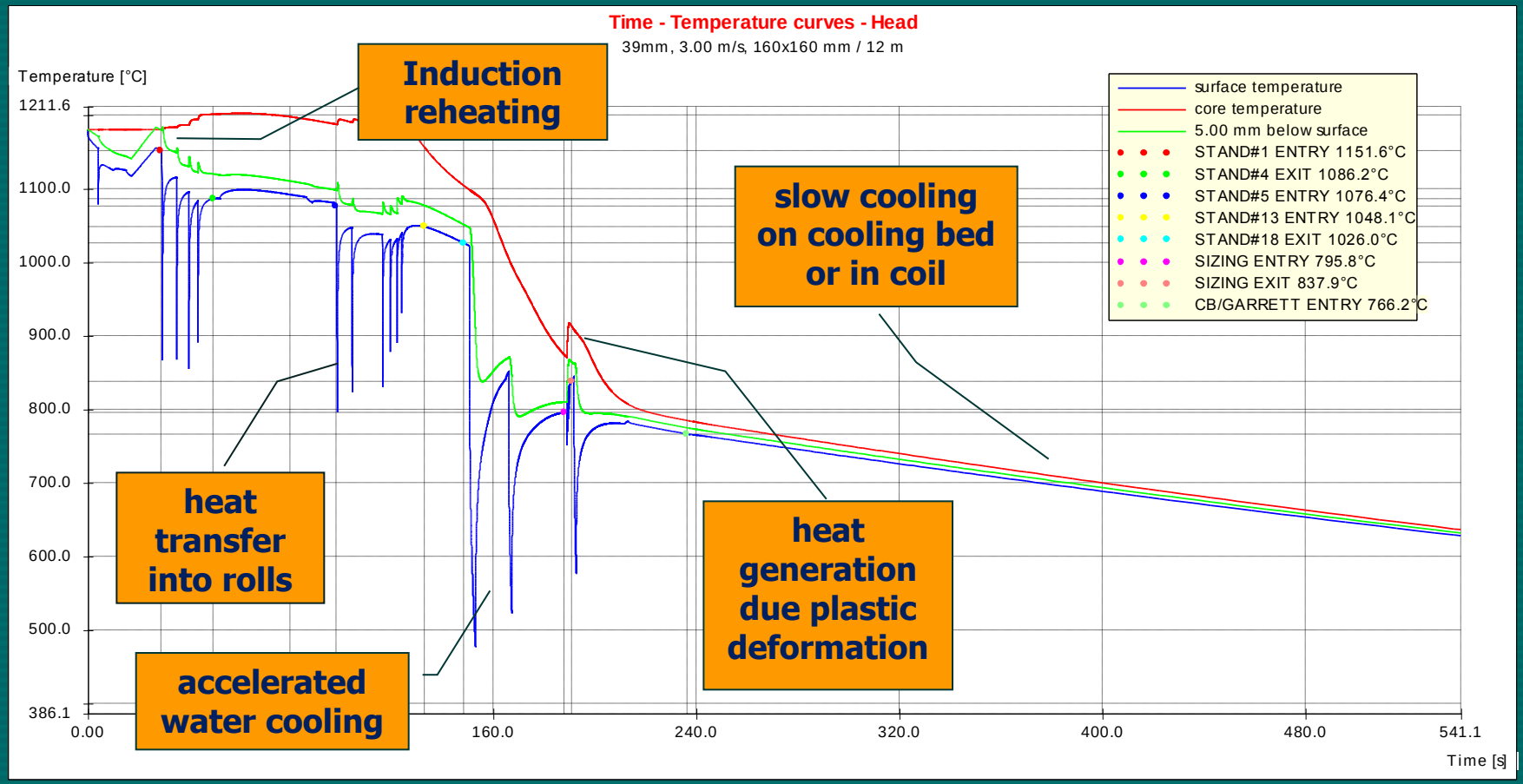
- **Therm 1D** -> nonstationary heat transfer FE analysis for 1D axisymmetric bodies (linear 2-node ring)
- **Coil 2D** -> nonstationary heat transfer FE analysis for 2D plane axisymmetric bodies (linear 4-node quadrangle)
- **Model of thermal properties** -> thermal conductivity, density and specific heat depend on the coil temperature and its tightening
- **Heat transfer** -> time and temperature dependent heat transfer coefficient and ambient temperature





DLPP software – Theoretical Background

Finite Element Temperature Calculations



DLPP software – Theoretical Background

MetaROLL Module – Metallurgy during rolling

Chemical composition

Process parameters in every pass:
- **temperatures**
- **strains**
- **strain rates**

Activation energy of recrystalization Zenner-Hollomon parameter

Increasing of the activation energy in case of precipitation

Recrystallized part Xrex for given temperature, effective strain and time available between neighbouring passes

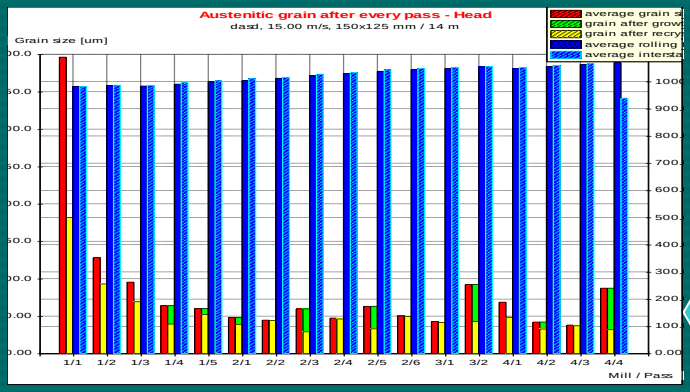
Residual strain

FIrest = FIef *(1 - Xrex)

Size of recrystallized grain of austenite

Growth of recrystallized grain between particular passes

! pure physical approach !



DLPP software

MetaCOOL Module – Metallurgy during cooling - Step 1

CCT Diagram Prediction

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Structure Shares Calculation

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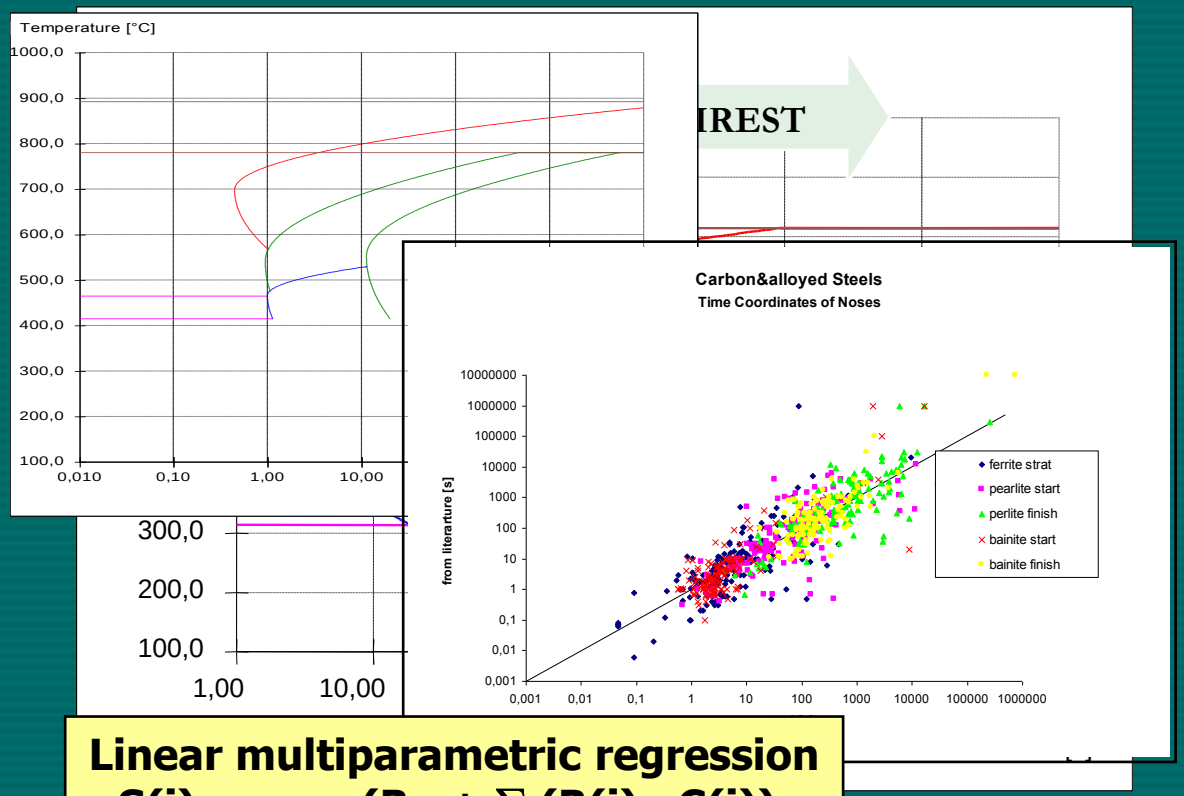
Mechanical Properties Calculation



Linear multiparametric regression

S(i) = exp (Bo + ∑ (B(i) . C(i))

T(i) = Ao + ∑ (A(i) . C(i))

$$Sx = Sox \cdot A_S \cdot \exp((-B_S + C_S \cdot C \ldots /3)) \cdot \exp(F_S \cdot B)$$

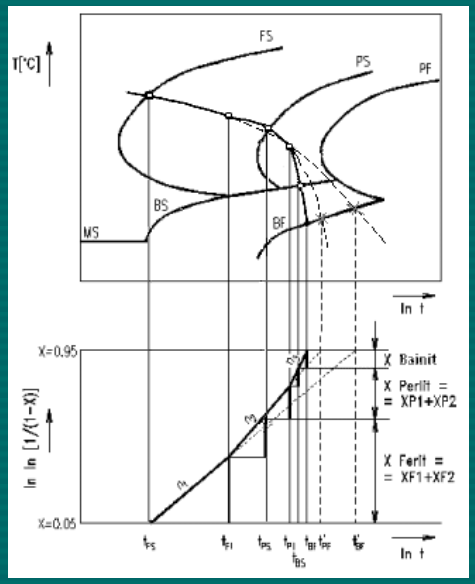
DLPP software – Theoretical Background

MetaCOOL Module – Metallurgy during cooling - Step 2

CCT Diagram Prediction

Structure Shares Calculation

Mechanical Properties Calculation



Avrami equation for pearlite and bainite transformation

$$X_i(t,T) = (1 - \exp(-k \cdot t^n)) \cdot X_\gamma$$

Koistinen-Marburger equation for martensite transformation

$$Xm(T) = (1 - \exp(-b \cdot (T_{Ms} - T)^n)) \cdot X_\gamma$$

DLPP software – Theoretical Background

MetaCOOL Module – Metallurgy during cooling - Step 3

CCT Diagram Prediction

↓

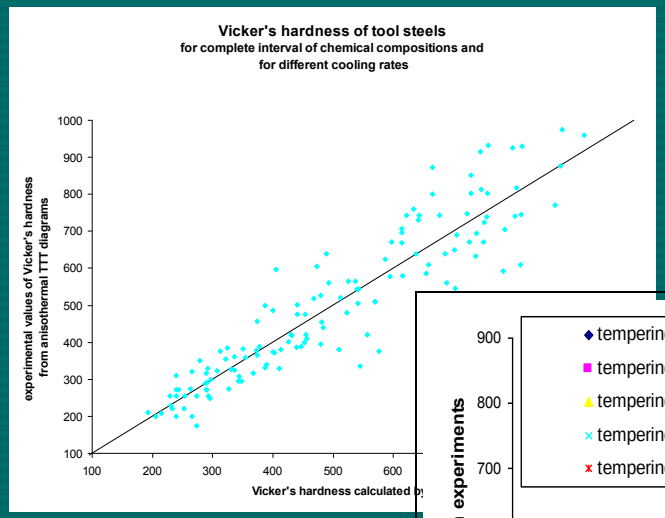
Structure Shares Calculation

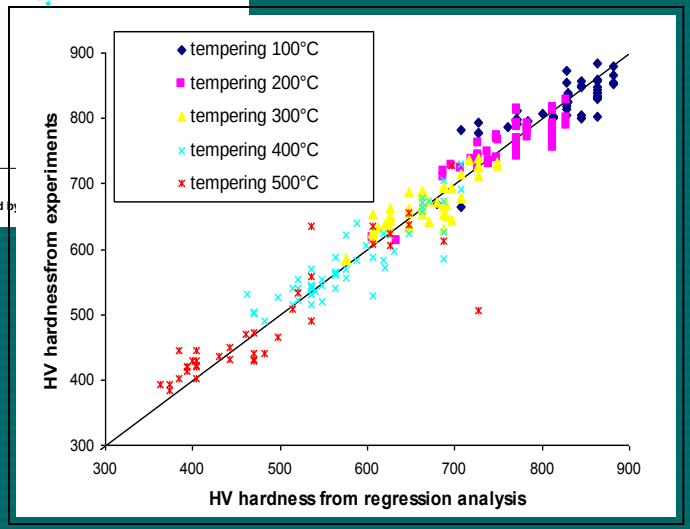
↓

Mechanical Properties Calculation

Linear regression

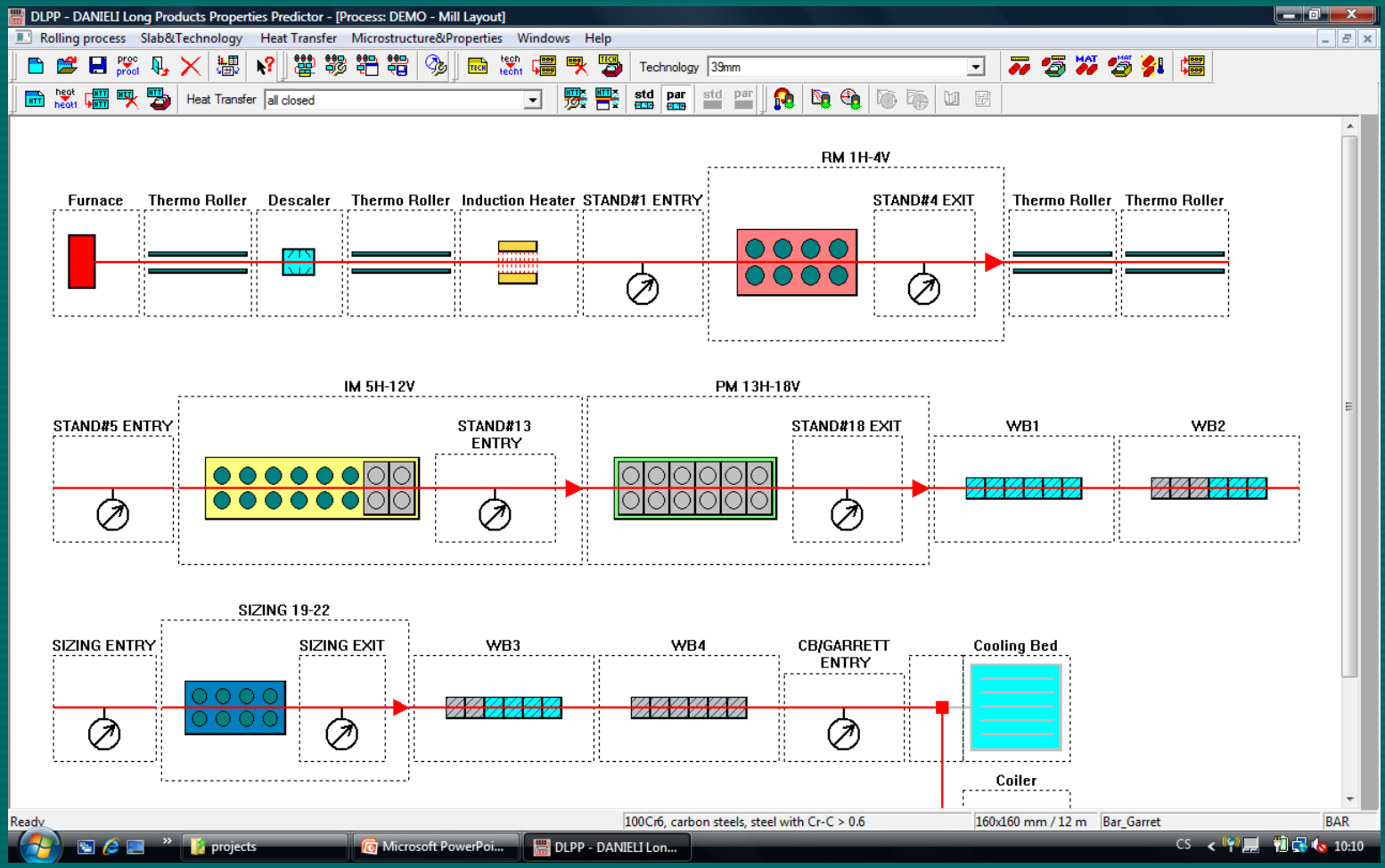
$$HV = C_O + \%Fe * \Sigma (C1_i * c_i) + \%Pe * \Sigma (C2_i * c_i) + \%Ba * \Sigma (C3_i * c_i) + \%Ma * \Sigma (C4_i * c_i)$$





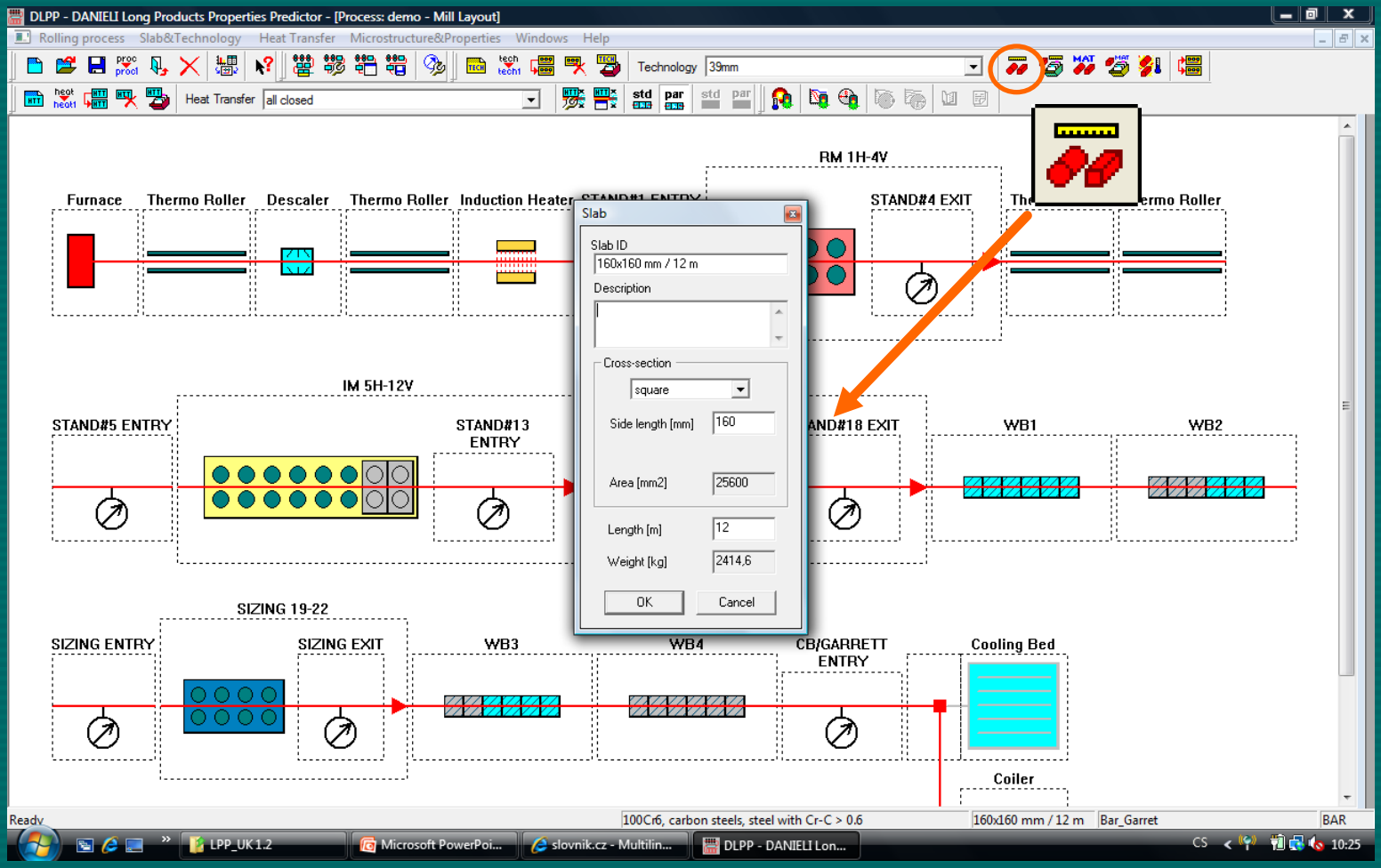
DLPP – Technique of process simulation

New Rolling process -> Import of Layout



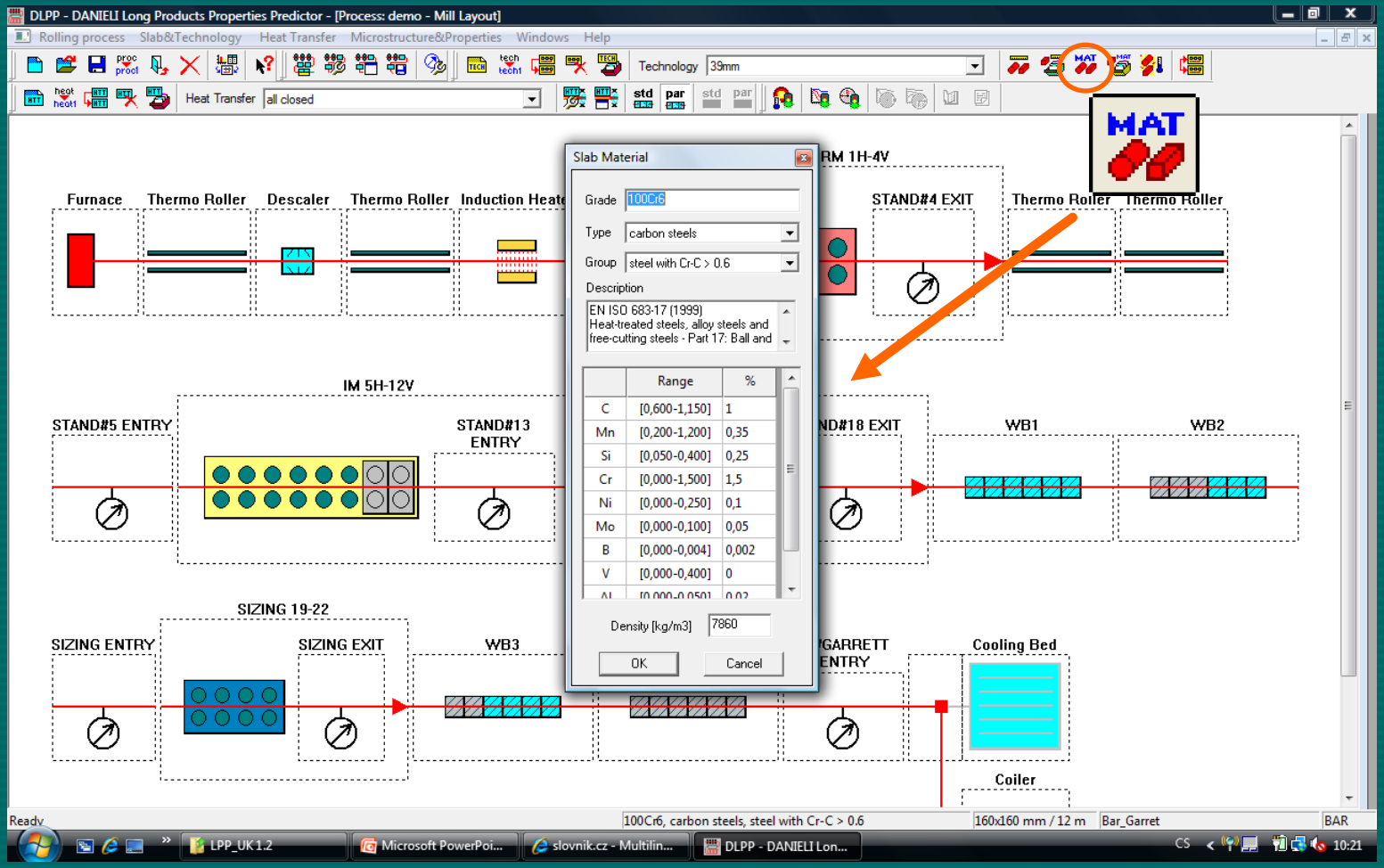
DLPP – Technique of process simulation

Slab specification



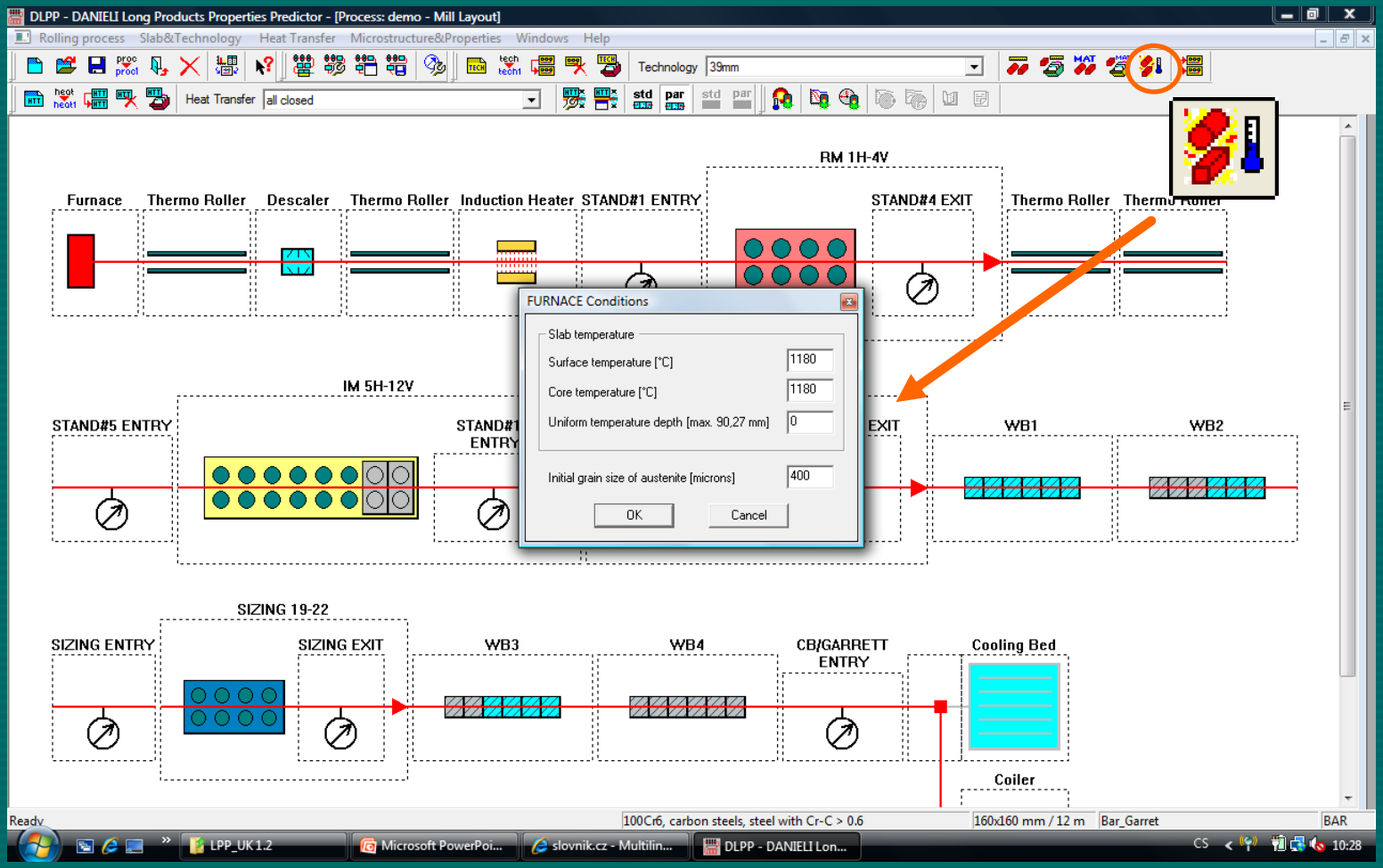
DLPP – Technique of process simulation

Steel specification



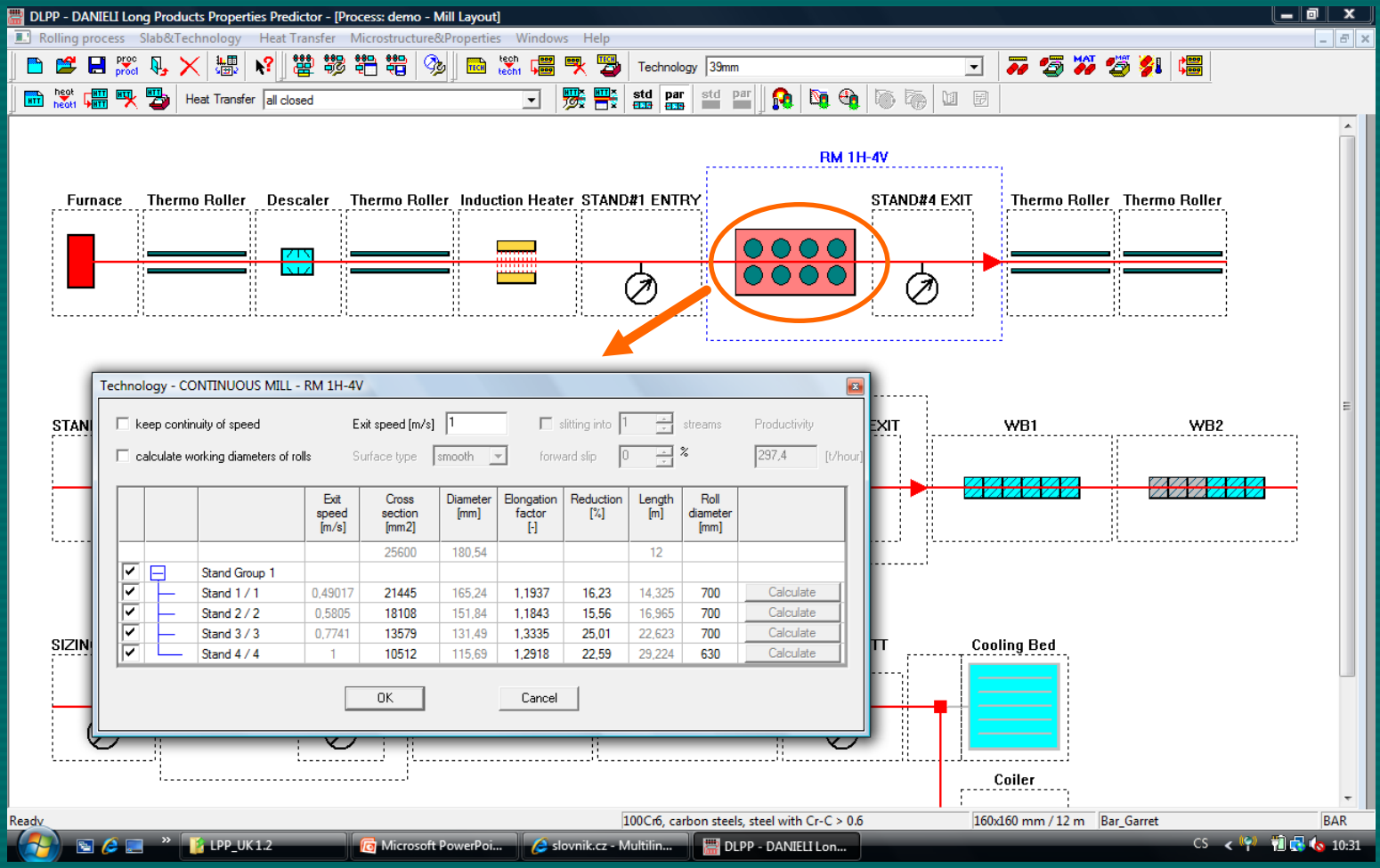
DLPP – Technique of process simulation

Furnace conditions



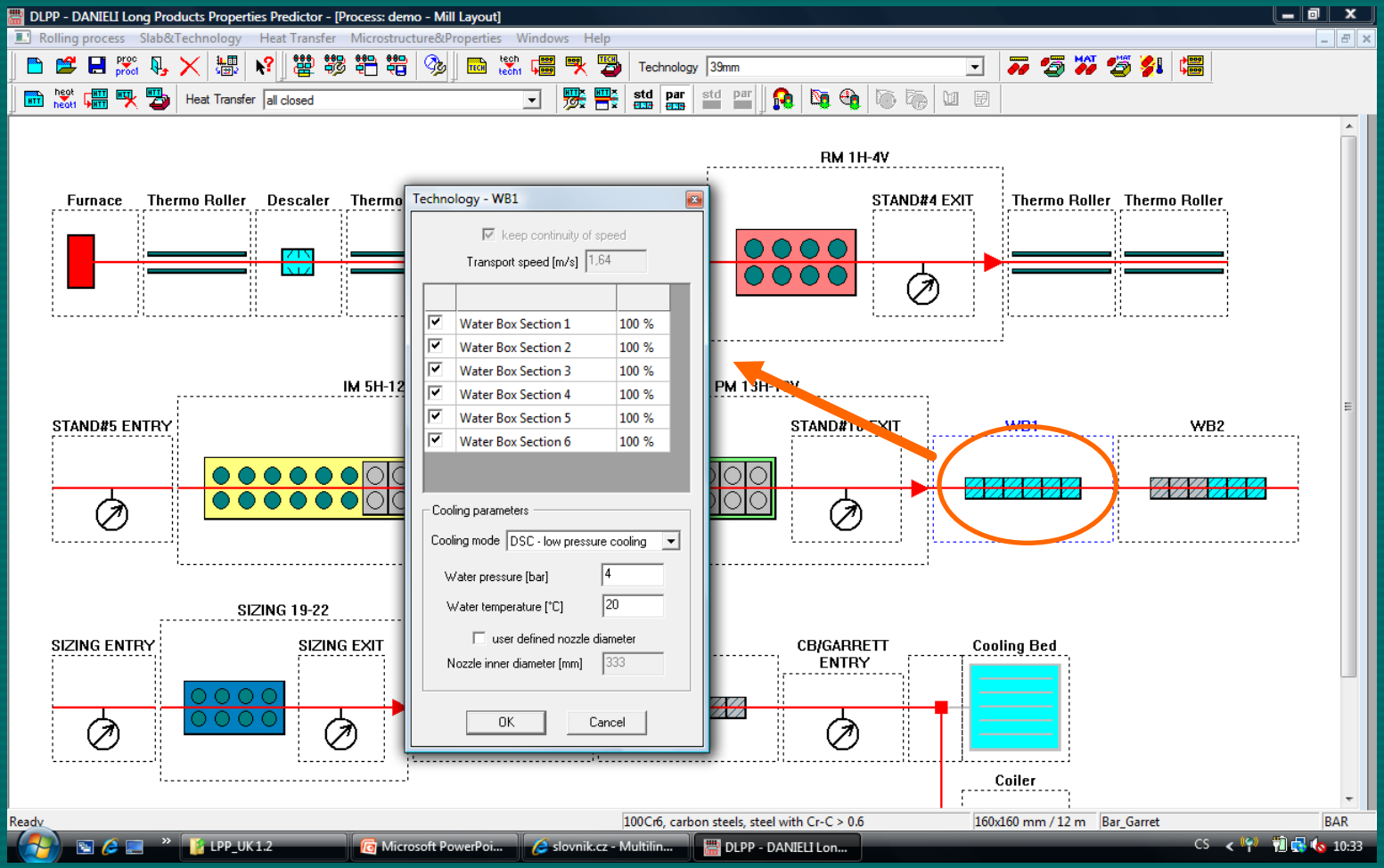
DLPP – Technique of process simulation

Rolling Technology



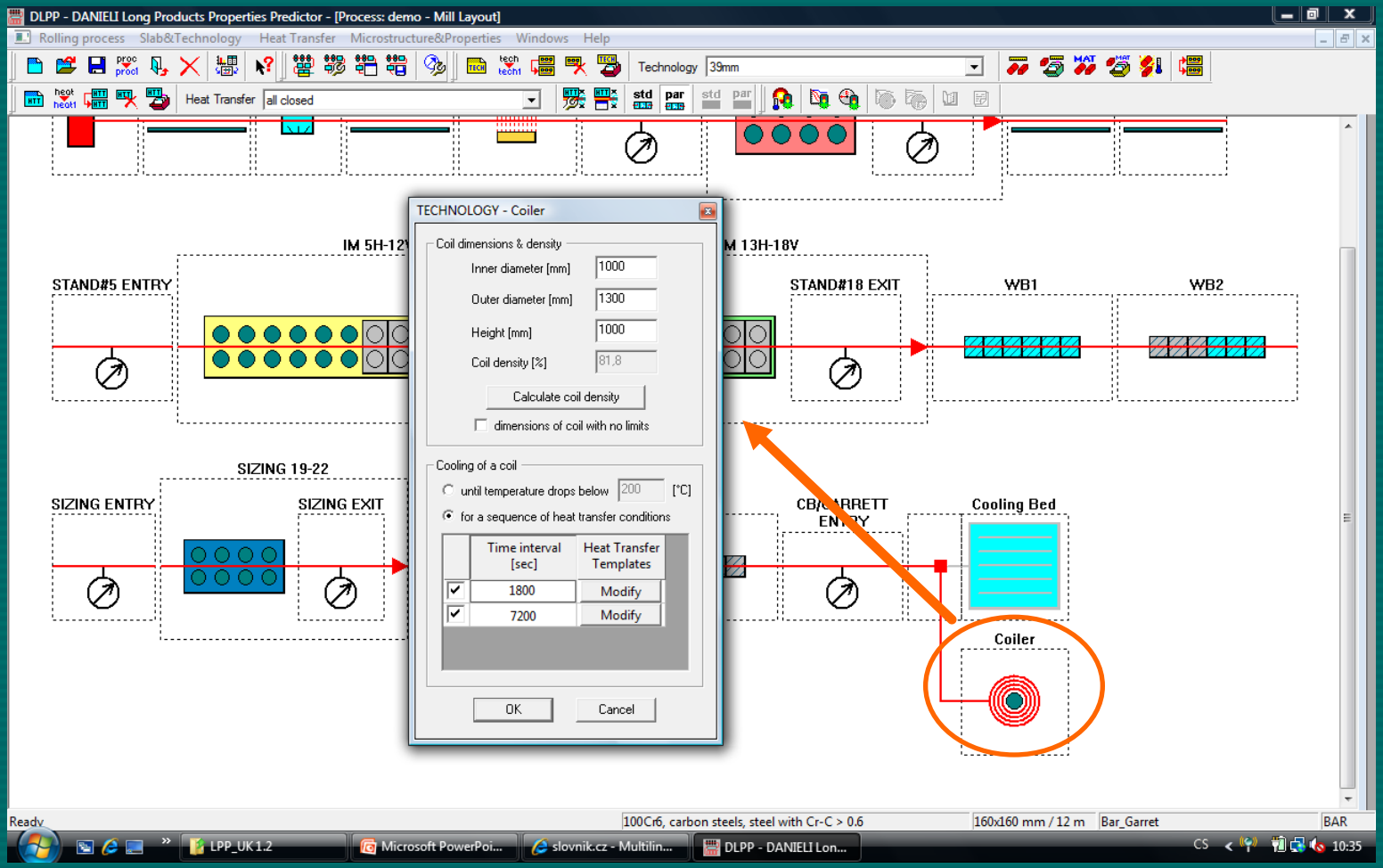
DLPP – Technique of process simulation

Water Box Cooling Technology



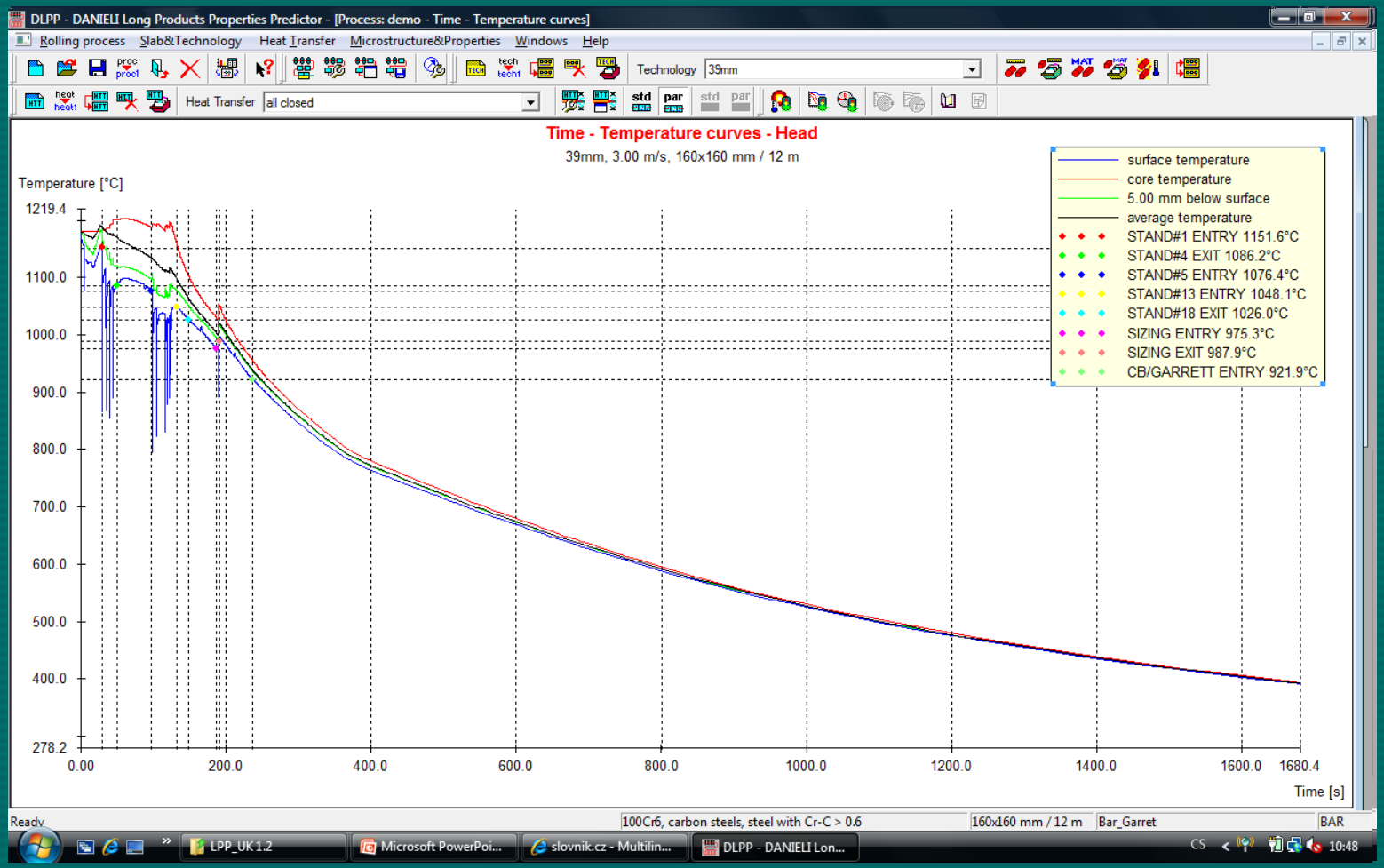
DLPP – Technique of process simulation

Garret Cooling Technology



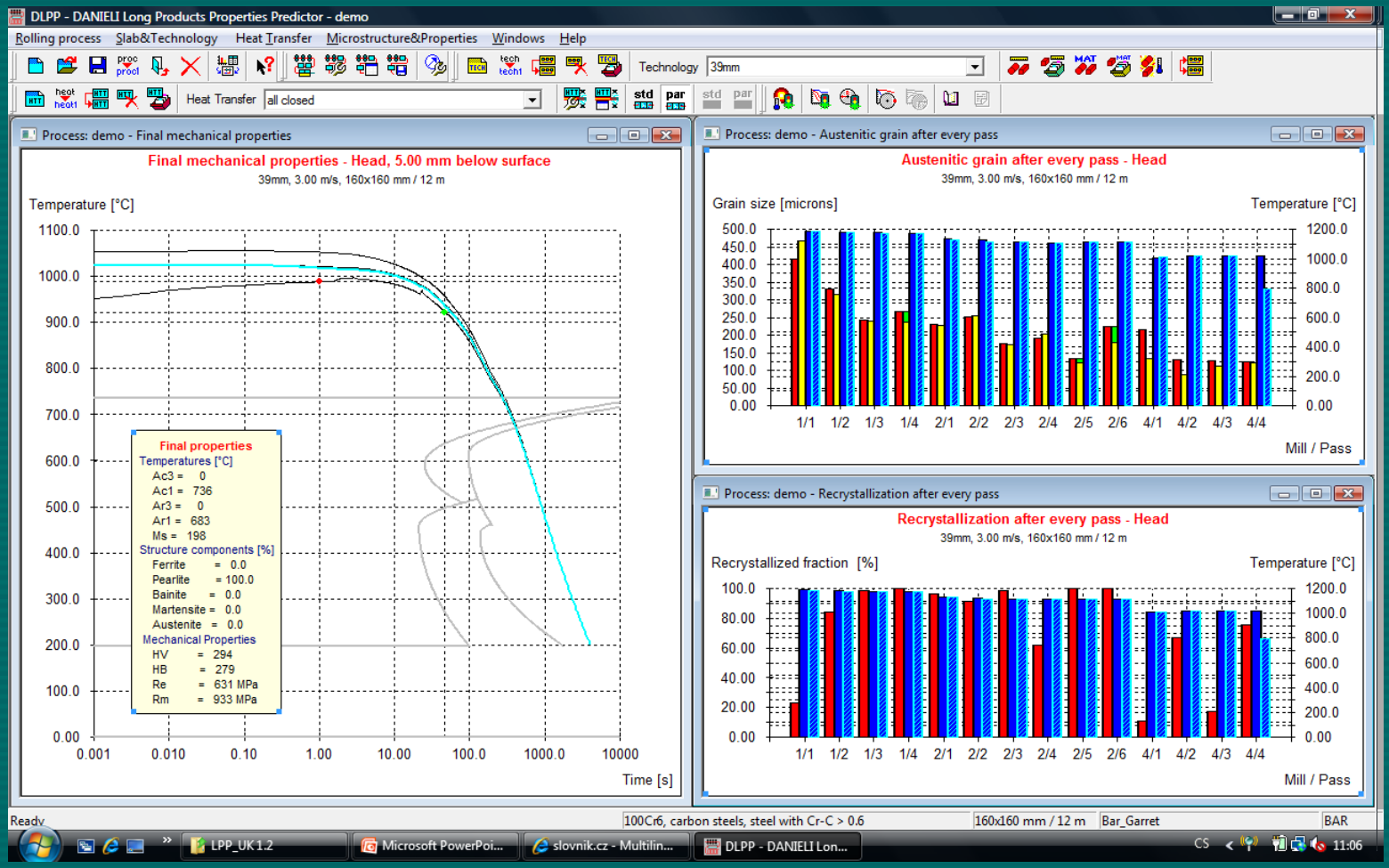
DLPP – Technique of process simulation

Temperature calculations



DLPP – Technique of process simulation

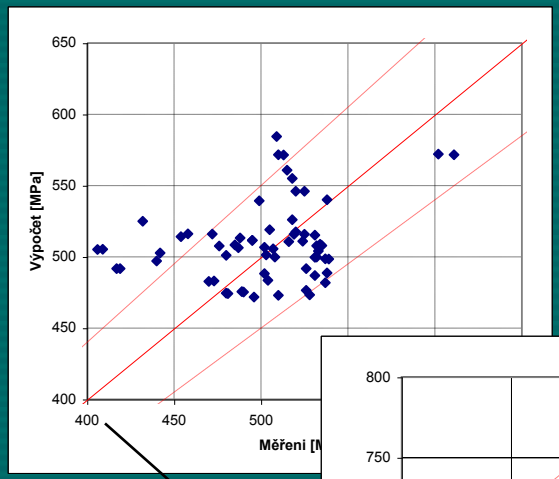
Metallurgical calculations

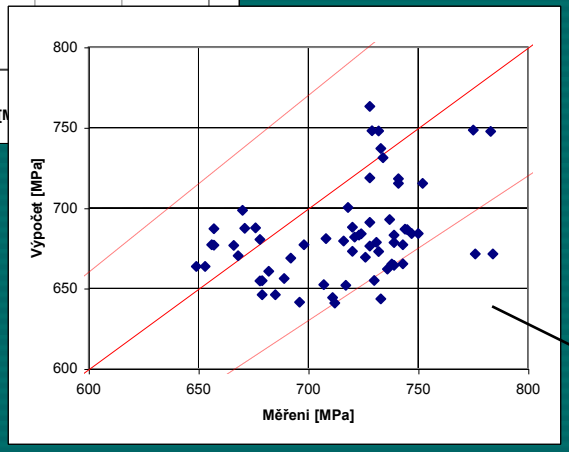


DLPP - Examples

Verification for WIRE ROD rolling

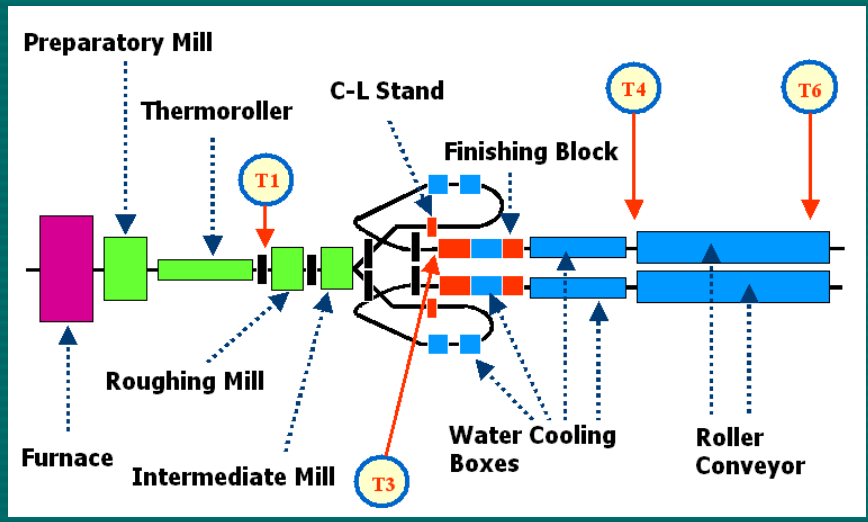
(64 pcs) various diameters	C	Mn	Si	Cr	Ni	Ti	B
	0.403	0.64	0.26	0.06	0.02	0.002	0.0002





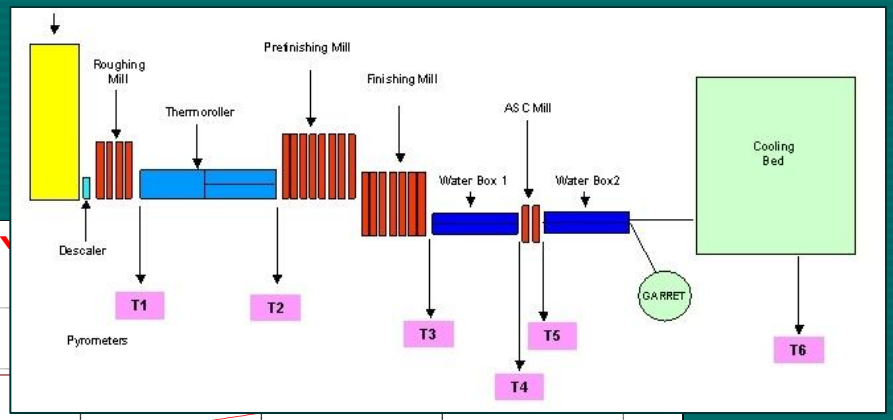
Yield Stress

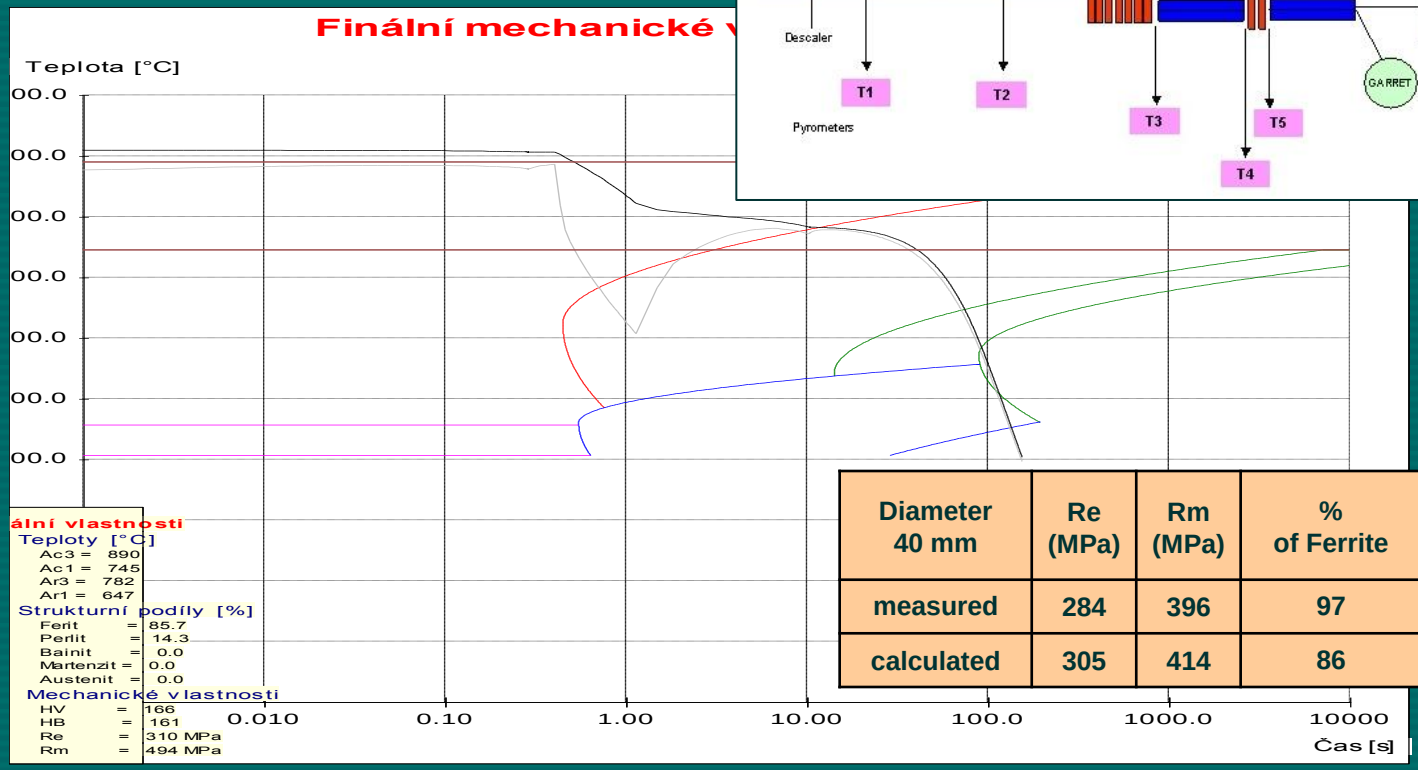
Ultimate Tensile Strength



DLPP - Examples
Verification for BAR rolling

C	Mn	Si	Ti
0.065	0.6	0.2	0.15





Diameter 40 mm	Re (MPa)	Rm (MPa)	% of Ferrite	% of Pearlite
measured	284	396	97	3
calculated	305	414	86	14

DLPP - Examples
QTB Technology - verification

Bar for reinforcement

Diameter: 32 mm

Exit rolling speed: 7.2 m/s

Exit temperature: 995 C

Cooling equipment:

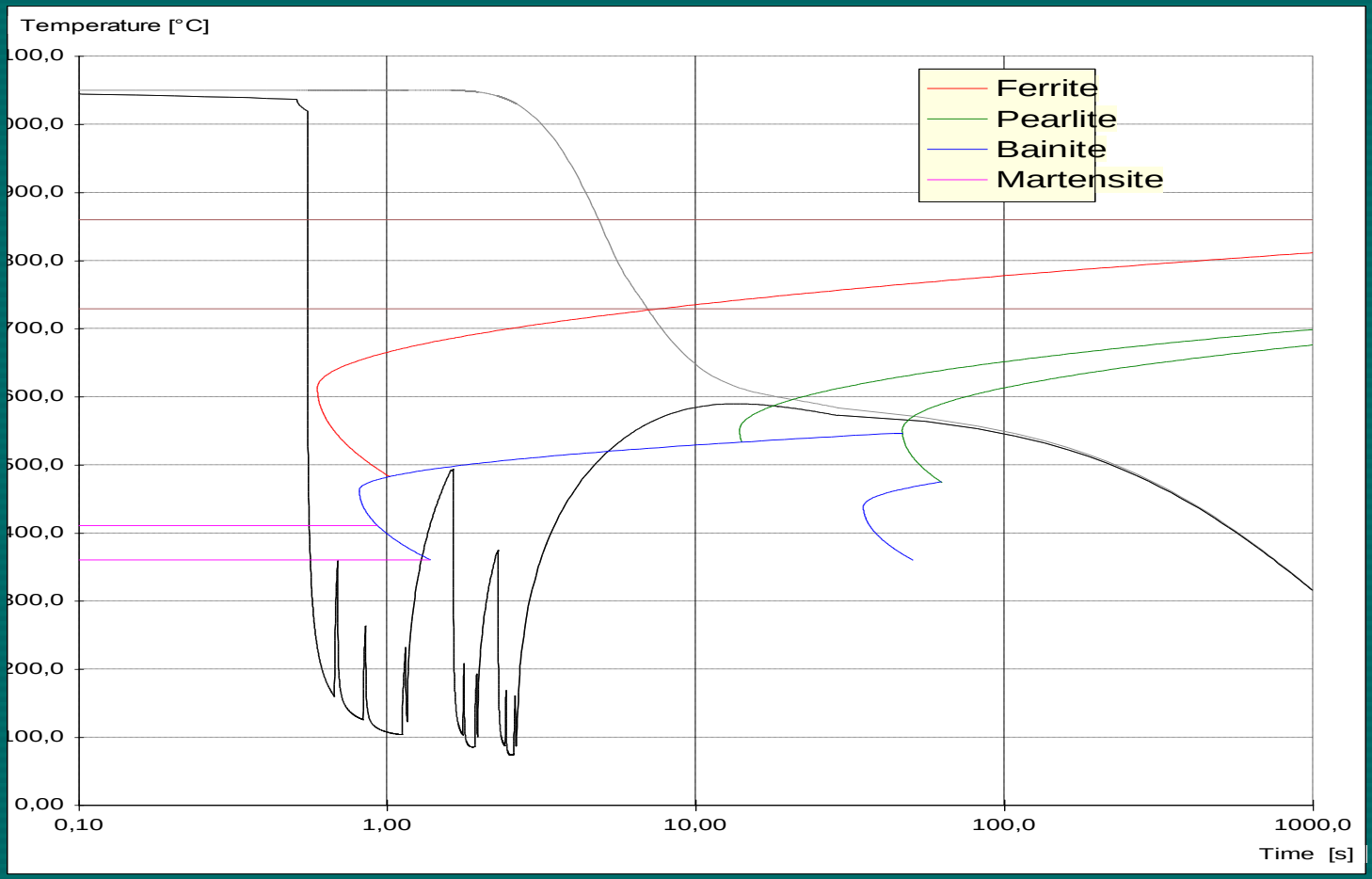
Water tubes + Cooling bed

Chemical composition:

C 0.2, Mn 0.9, Si 0.4, Ti 0.03

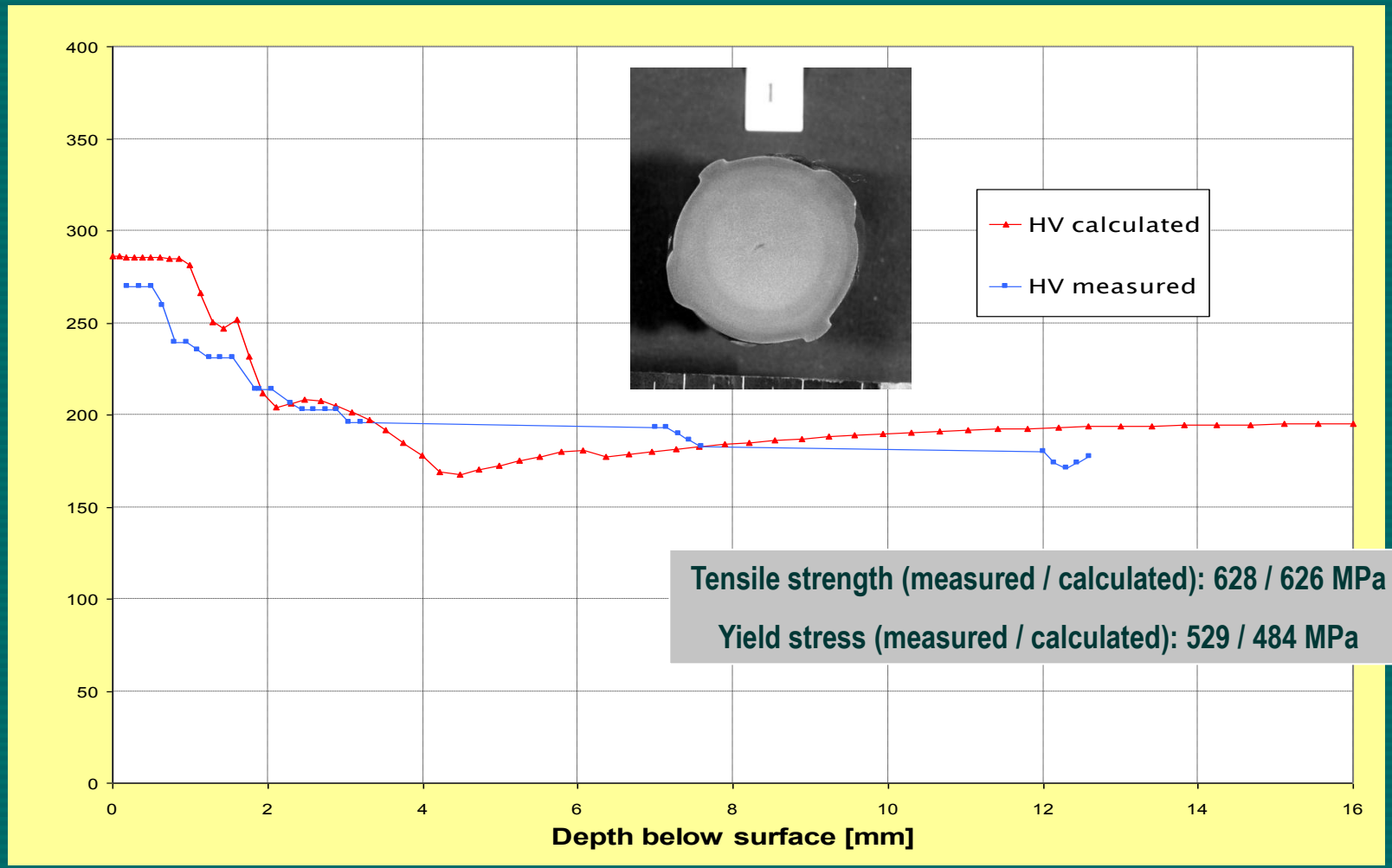
DLPP - Examples

QTB Technology – austenite decomposition



DLPP - Examples

QTB Technology – HV Hardness



DLPP - Danieli Long Products Properties Predictor
Summary

- the DLPP has been developed for off-line computer simulation of metallurgical processes in hot rolled bars or wire rods during rolling and after subsequent cooling!
- based on specified steel chemistry and rolling technology the DLPP predicts microstructure parameters of deformed austenite after rolling, especially grain size, recrystallized fraction and retained strain!
- based on specified steel chemistry, microstructure of deformed austenite and cooling strategy the DLPP predicts secondary structure shares and corresponding mechanical properties of final product!
- the DLPP can be delivered including training and tuning for specific conditions of your plant!

thank for your attention!