Metallurgical, Modeling and Software Engineering Issues in the Further Development of the Steel Mill Level 2 Models

Bingji (Benjamin) Li
John D. Nauman
Metal Pass LLC
www.metalpass.com

Contents

A. Level 2 Model and Performance

1 Level 2 Model Development in Metal Pass

- **Rolling Process Models**
  - Flow stress, Force, …
  - Roll deformation (flattening, deflection, crown, …)
  - Steel deformation (width, draft, shape defects, …)
  - Temperature, Heat transfer, …
  - Material Properties, …
- **Level 2 System (Model, Tracking, Data storage,…)**
- **Level 3 System (Production scheduling, Rolled steel properties prediction, Slab selection)**
- **Examples**
  - Over 100 empirical models, and FEM/FDM models
  - Steel Mill Resources (over 40,000 pages in metalpass.com)
  - 108 mill-related projects (metalpass.com/consulting)

A. Level 2 Model and Performance

2 Error Ranges of Selected Level 2 Models

Error Range	Records Count		
	N. Steel	OSM_old	OSM_new
< 5%	30% (est.)	57%	80%
< 10%	75%	87%	90%
< 15%	80-90%	94%	99%

1) Data here are based on the troubled grades with shape problems in the past
2) OSM data here are before the 2nd improvement (for small strain, hold, etc.)

A. Level 2 Model and Performance

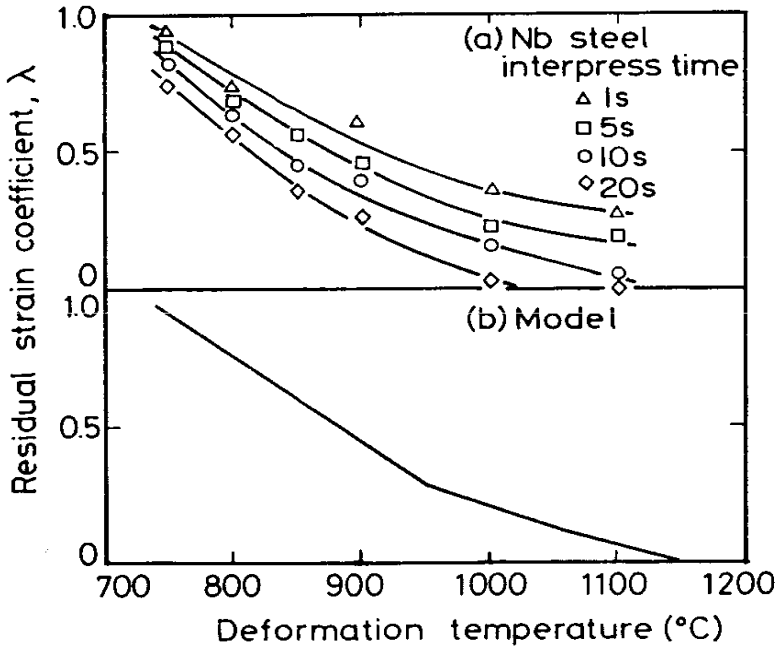
3 Benefits from 10% force error reduction

Item	Value	Annual Total (US$)	Annual Saving (US$)	Assumption
Investment Saving [1)]	15%	20,000,000	3,000,000	Equip. life 40 years
Slab grade saving [2)]	1%	400,000,000	4,000,000	50% of sales price
Energy Saving [3)]	3%	40,000,000	1,200,000	5% of sales price
Yield increase	1%	800,000,000	8,000,000	1% yield increase
Mill test saving for new products [4)]	45%	4,000,000	1,800,000	0.5% of sales price
Total			**18,000,000**	

1) The saving is based on the increase of equipment utilization of 10%.
2) When significant force error occurs, higher grade of steel has to be scheduled for an order to guarantee the rolled steel properties.
3) The increase of energy consumption due to higher grade scheduled.
4) Some plants conduct mill trial-and-errors for scheduling of new products.
5) Data in the table are based on a mill with US$800 million equipment and US$800 million annual sales.

B. Metallurgical Issues

1 Retained strain for the rolling

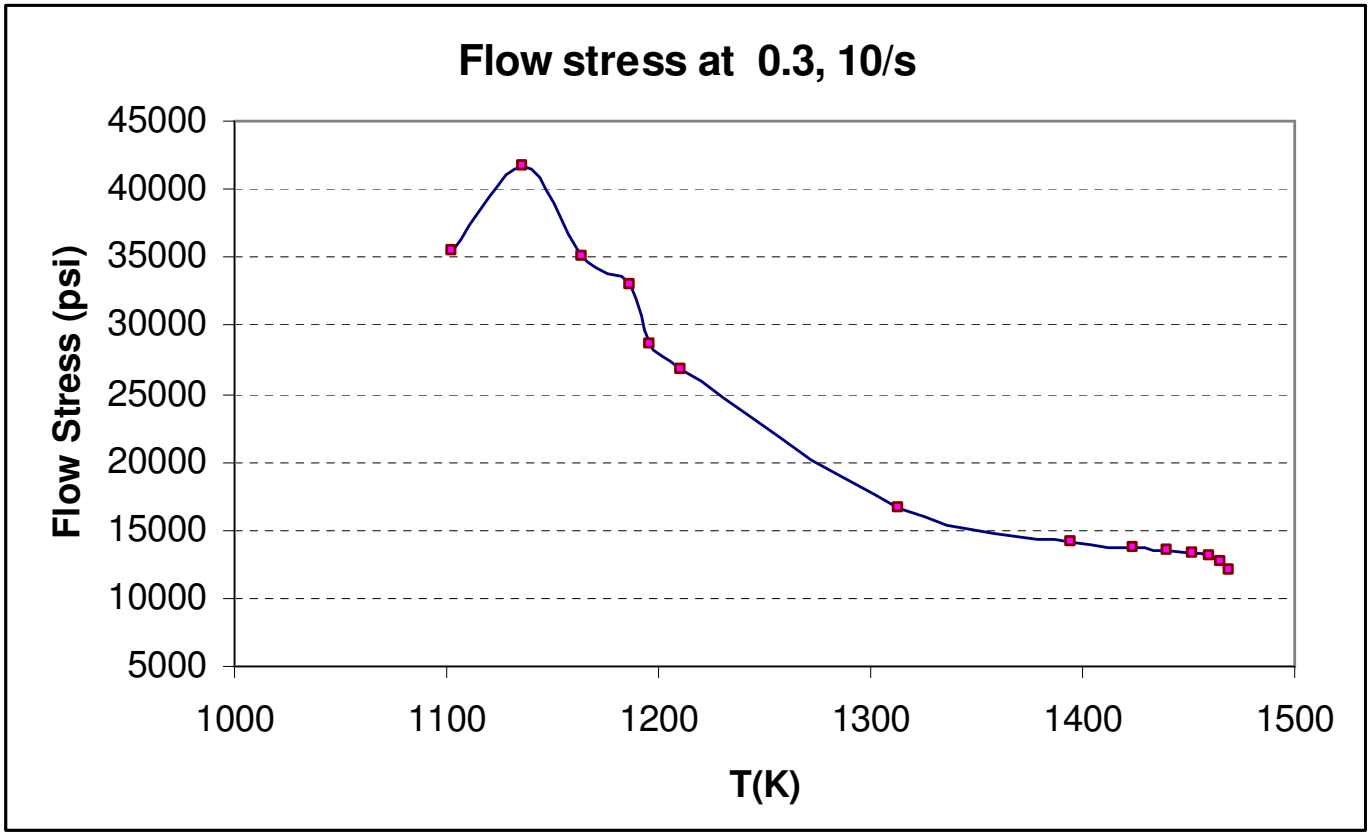


T(˚C)	1000	900	850	800	750
T(˚F)	1830	1650	1560	1470	1380
IT (%)	2	25	35	55	70
BL (%)	0	15	21	33	42

* Nb steel, with inter-pass time:
I. Tamura (IT) 20s
B. Li (BL) 30-40s

B. Metallurgical Issues

2 Possible entry into two-phase region



3 Other Metallurgical Issues

- **Resume Pass after Hold**
  - Steel strength change during hold
  - Most resume passes have 20-40% force error if no correction occurs
- **Grain size vs. Flow stress**
  - Change of grain size affects flow stress
  - Phase change affects temperature

C. Modeling Issues

1 Problem 1: Flow stress equation and learning (old)

$$\sigma = C_1 e^{C_2/T} \cdot \varepsilon^{C_3} \cdot u^{C_4}$$

Fit	Learning Coefficient	Fixed Coefficient
FIT2	C1, C2	C3=0, C4=0
FIT3A	C1, C2, C3	C4=0
FIT3B	C1, C2, C4	C3=0
FIT4	C1, C2, C3, C4	

C. Modeling Issues

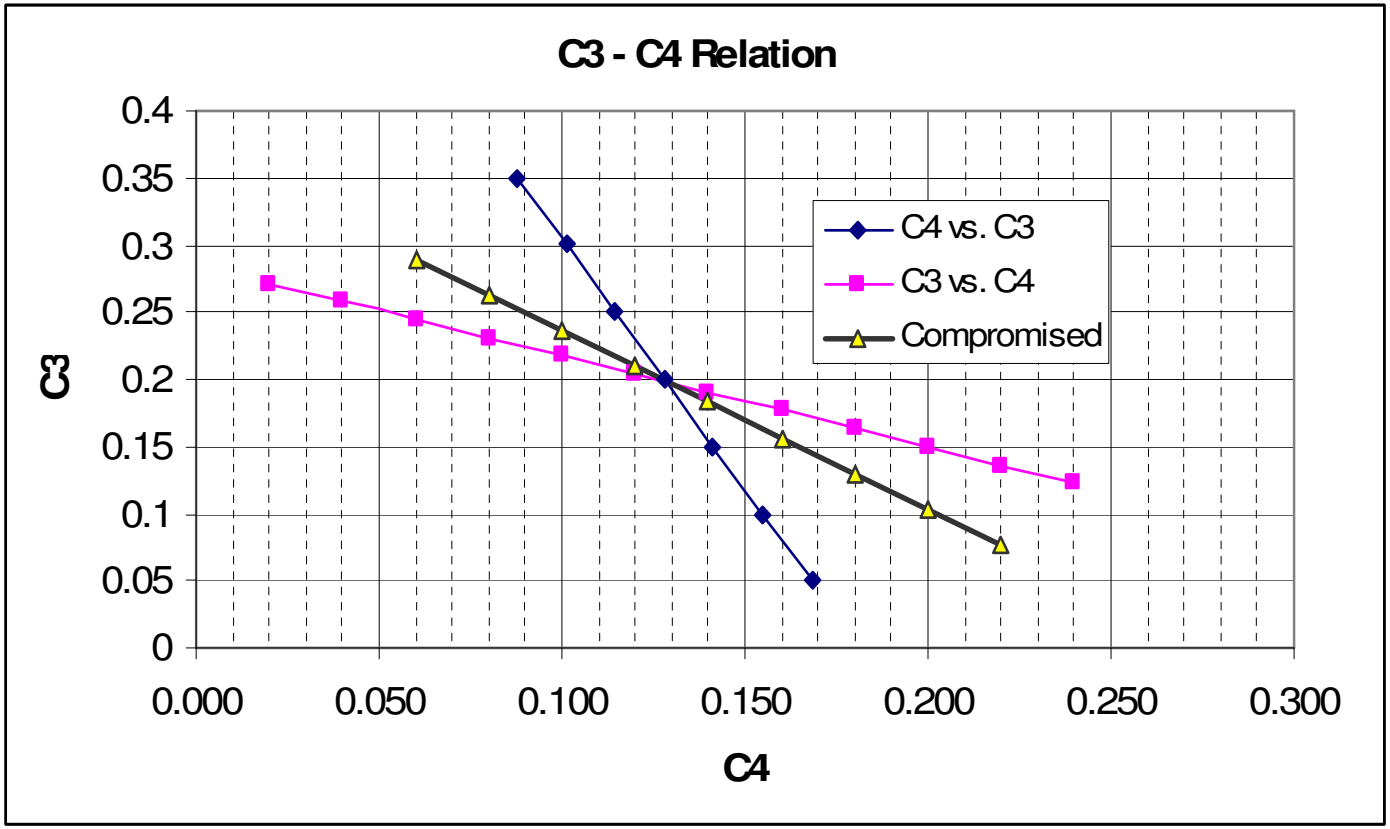
2 Problem 1 solution: using average coefficients instead of 0

$$\sigma = C_1 e^{C_2/T} \cdot \varepsilon^{C_3} \cdot u^{C_4}$$

Fit	Learning Coefficient	Fixed Coefficient
FIT2	C1, C2	C3=C3m, C4=C4m
FIT3A	C1, C2, C3	C4=C3m
FIT3B	C1, C2, C4	C3=C4m
FIT4	C1, C2, C3, C4	

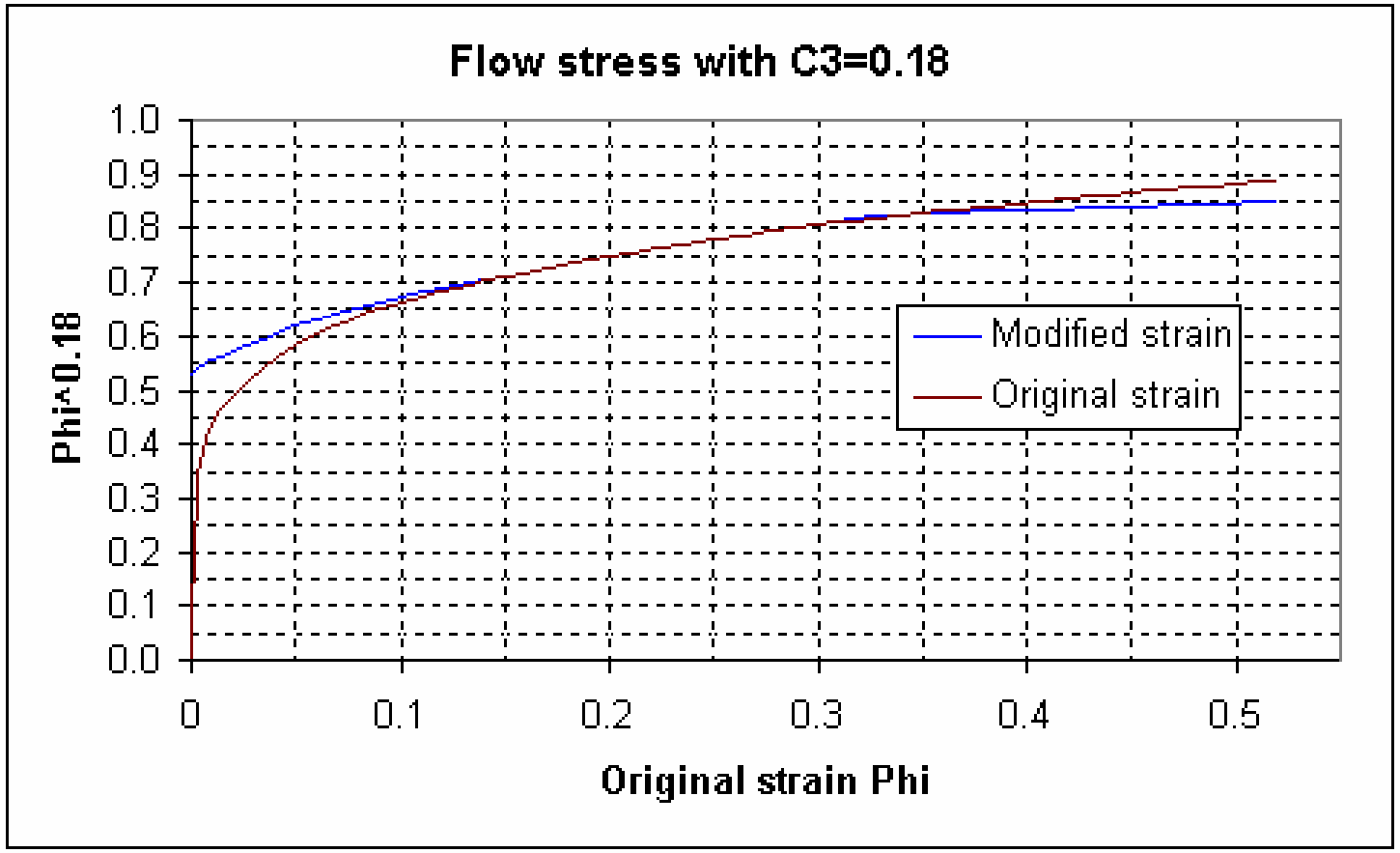
C. Modeling Issues

3 Problem 2: C3-C4 dependence downgrades 4-parameter learning



C. Modeling Issues

4 Problem 3: narrow valid range; not valid for strain below 0.05



C. Modeling Issues

5 Guided two-parameter Learning: Solution for existing Level 2

- Well-designed C3 and C4 as fixed values, using C1 and C2 as learning parameter
- Totally 6000 sets of C1, C2, C3 and C4 for 2000 model grades, one set per temperature per model grade (as in OSM)
  - Solution to Problem 1, 2, 3 integrated into C3 and C4
- Very few changes for source code

D. Software Engineering Issues

1 Development far behind Information Technology industry

- Software: Client-Server (OpenVMS) vs. Service-Oriented Architecture (SOA)
- Hardware: concerns on long-term availability of OpenVMS compatible hardware
- System design and data structure in some Level 2 systems
- System upgrade

D. Software Engineering Issues

2 Current technologies available for Level 2 (examples)

- **Object-oriented design based on interactive relationship of mill models**
  - **Consistence of data structure and class**
- **Web-based Level 2 system and/or remote support**
  - **Example: Mill Diagnosis System (MDS)**
- **SOA to integrate old OpenVMS-based Level 2 systems**

E. Next-Generation Level 2 System

1 From Mechanical System to Metallurgical System

- **Current Level 2: Mechanical System**

- **Next-Generation Level 2: Metallurgical System**
  - **Retained Strain**
  - **Draft distribution: steel properties improvement**
  - **Phase transformation, hold.**

E. Next-Generation Level 2 System

2 Intelligent learning

- **Hybrid solution**
  - **Sufficient empirical models**
  - **Neural network to optimize coefficients in the empirical models**
- **Expert system as guideline**

E. Next-Generation Level 2 System

2 Uninterrupted upgrade

- DLL Level
- Component Level
- Service Level (COM+, SOA, etc.)
- Less or No System Shutdown

Thank You