Significance and Development of a Next-Generation Level 2 Model as a Metallurgical System

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Contents

A. Level 2 Model and Metal Pass

1 Steel Plant Automation System

- **Steel Plant Automation System**
  - Level 1: Basic process automation, in PLC Level
  - Level 2: Production execution system
  - Level 3: Production scheduling and business system
- **Level 2 System**
  - Level 2 Model
  - Process tracking and data communication
  - Data storage
- **Level 2 Model**
  - Parameter prediction and production stage planning
  - Example: roll force prediction and draft scheduling in rolling

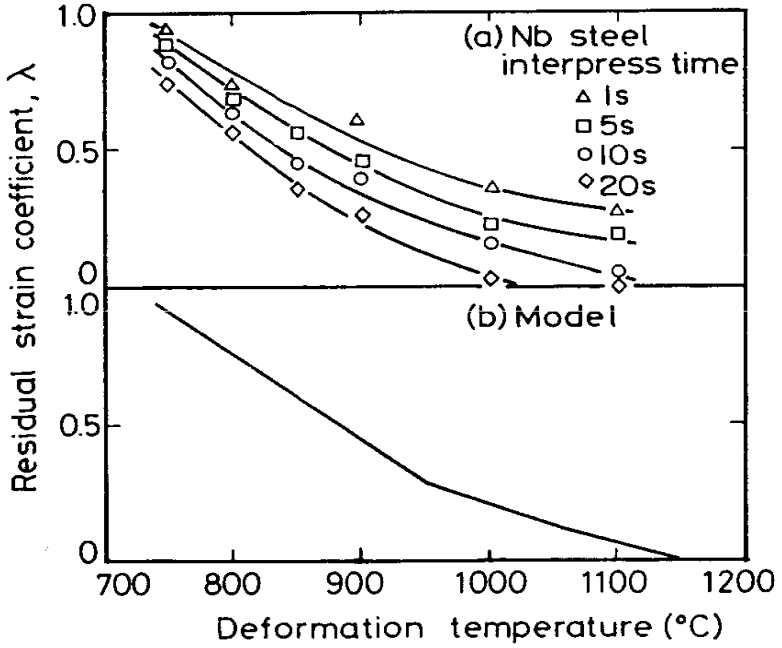
A. Level 2 Model and Metal Pass

2 Development in Metal Pass

- **Focused on Pass Scheduling Models & Software**
  - Consulting & Web-based Services
  - Roll Pass Software, Level 2 / Level 3 Models
- **Level 2 Model for Rolling Process**
  - Force, Temperature, Roll/Metal deformation …
  - Draft schedule
- **Level 3 Model**
  - Rolled steel properties prediction
  - Slab selection
- **Experience**
  - 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)

B. Metallurgical Issues in Level 2

1 Retained Strain during Rolling

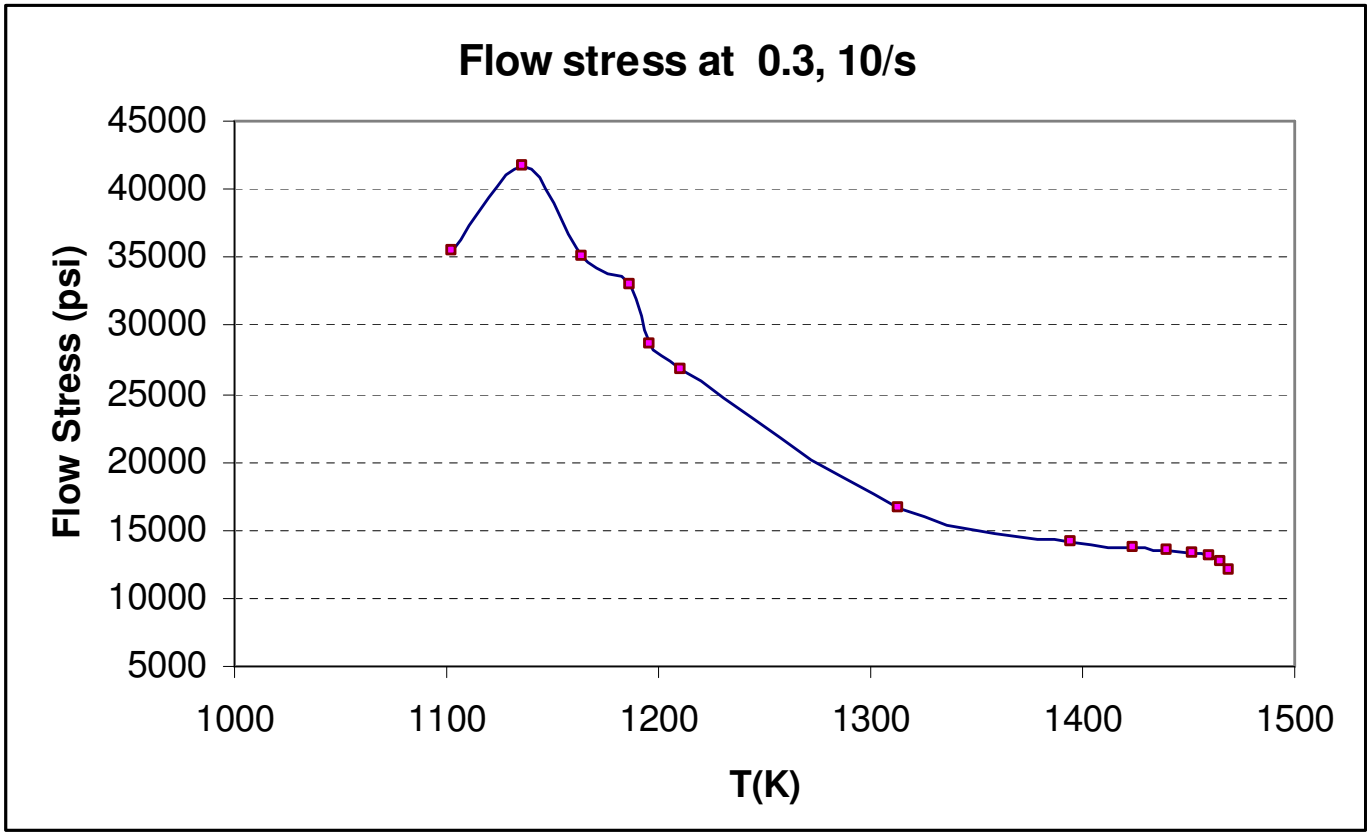


T(˚C)	1000	900	850	800	750
T(˚F)	1830	1650	1560	1470	1380
IT (%)	2	25	35	55	70
BL (%)	0	15	21	33	42

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

B. Metallurgical Issues in Level 2

2 Possible Entry into Two-Phase Region



B. Metallurgical Issues in Level 2

3 Metallurgical Nature of the Flow Stress

- **Flow Stress is a Metallurgical Parameter**

- **Flow Stress vs. Other Metallurgical Parameters**
  - **Smaller grain size leads to larger flow stress**
  - **Phase change affects temperature and Material**
  - **Retained strain increases the value of the strain**

Flow Stress	Metallurgical parameter
- Material - Strain - Strain rate - Temperature	- Phase - Grain size - Retained strain - Temperature

B. Metallurgical Issues in Level 2

4 Other Metallurgical Issues

- **Resume Pass after Hold**
  - Plate 2-piece rolling or 1-piece rolling with hold
  - Steel structure/strength change during hold
  - Most resume passes have 20-40% force error if no correction applies
- **Property Variations**
  - Variations along the length, width and thickness of the rolling stock
  - Grains larger and less flat in plate thickness center than in surface
  - Microstructure across the width (about 100˚C difference in plate)
  - Pattern of variation along the length (over 100˚C difference in plate)

C. Benefits of Metallurgical Level 2

1 Higher Force Prediction Accuracy

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.)

C. Benefits of Metallurgical Level 2

2 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.

D. Next-Generation Level 2 System

1 Features of the Next-Generation Level 2 System

- **Metallurgical + Mechanical/Thermal**
  - From today's mechanical/thermal model to the metallurgical model
  - Full metallurgical models + today's mechanical/thermal models
- **Intelligent Learning with Hybrid Solution**
  - Sufficient empirical models
  - Neural network to optimize coefficients in the empirical models
  - Expert system as guideline
- **Advanced Software Engineering**
  - Uninterrupted upgrade and Object-oriented design
  - SOA to integrate OpenVMS-based systems

D. Next-Generation Level 2 System

2 Rolling Mill Level 2 Model

- **Rolling Process Models**
  - Roll force, temperature, roll and steel deformation, draft distribution, etc.
- **Metallurgical Models**
  - Retained strain, phase, grain size, rolled steel properties, etc.
- **A Hybrid Intelligent Learning System**
  - Neural network + Empirical model + Expert system
- **A Draft-Scheduling Module**
  - Finish shape, microstructure and properties, etc. predicted for every newly generated pass schedule

D. Next-Generation Level 2 System

3 Reheating Furnace Level 2 Model

- FDM Slab Temperature Model
- Furnace Temperature Profile Model
- Slab Thermal Stress Model
- Slab Heating Speed Model
- Micro-Alloy Particles Dissolution Temperature Model
- Residence Time or Walk Speed Optimization Model

D. Next-Generation Level 2 System

4 Controlled Cooling Level 2 Model

- **Phase Transformation Model**
  - Progress of various transformation reactions against time during cooling
- **Grain Size Model for the Start of the Controlled Cooling**
  - Initial grain size and grain structure, etc. of the steel for controlled cooling; may be determined through learning
- **Precipitation Model**
  - Precipitation process for some grades such as HSLA steels that contain small amount of carbide (or nitride) forming elements (e.g. niobium)

Thank You

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