Development of Model-Intensive & Web-based Rolling Mill Applications

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A. Reasons for Development

1 Complicity of Today's Rolling Process

> **Mechanical**
>   - High speed (over 100m/s, or stain rate over 3000/s)
>   - Interstand tension, especially in tied wire block
>
> **Metallurgical**
>   - Low-temperature rolling, incomplete recrystallization, grain growth
>   - Microalloy application, precipitation
>   - Planned delay (e. g. before finish block)
>
> **Thermal**
>   - Controlled water-box cooling, controlled air cooling
>
> **Interaction**
>   - Retained strain & grain change affect force and temperature
>   - Flow stress formula failure in two-phase region

A. Reasons for Development

2 Complicity of Deformation

- ➢ **Spread**
    - ▪ **Material: some have 30-40% higher spread than others**
    - ▪ **Speed: 2-3 times from low to high speed**
    - ▪ **Geometry: roll/stock size, groove, gap, etc.**
    - ▪ **Tension: high influence (unavoidable in wire block)**
    - ▪ **Others: friction, lubrication, cooling, temperature, scale, etc.**
- ➢ **Forward Slip**
    - ▪ **Friction (lubrication, cooling, temperature, scale, etc.)**
    - ▪ **Interstand tension: interactive**
    - ▪ **Others: geometry, material**
- ➢ **Friction**
    - ▪ **Significance: Forward slip, spread, force, …**
    - ▪ **Influence: material, process and geometry, etc.**
- ➢ **Formability**
    - ▪ **Some materials only under small reduction (to avoid crack)**

A. Reasons for Development

3 Needs for High-Quality Model & Software

➢ **High-Quality Model to Describe Complicated Processes**
- **Traditional models**
  - **Not accurate enough for new type of mill (tied stands in high speed)**
  - **Not fit to new rolling practice (low temperature, microalloy application)**

➢ **Software to Handle Complicated Models**
- **Interactive influences**
  - **are currently simplified**
  - **need to be sufficiently considered**
- **Required: Models hard to understand and apply for most engineers**
- **Affordable: High computing speed, to calculate many factors**

➢ **Programmer to Handle Logics Effectively**
- **Many interactive effects**
- **Effective design for software**

A. Reasons for Development

4 Web-based Mill Software

> **Use**
>   - Team from multiple locations (countries, regions)
>   - Maintenance, upgrading; access anywhere, any time, by any one
>
> **Development**
>   - Same way for web- and Windows-based software
>   - Web server available & free
>   - Easier in web: communication, memory and multi-user
>   - More and more web tools available
>
> **Security**
>   - Even for mission critical banking and financial systems
>
> **Software Types**
>   - Particularly suitable for design and development software
>   - Also good for online automation systems such as Level 2
>   - Easier in data communication and memory management

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B. Software Features

1 General Features

Geometry	o Roll, Groove, Gap and Geometry, etc. o Automatic prediction of rolled shape
Procedure	o Shinokura-Li, Hensel-Li, Wusatowski-Li o Modified for new types of mill
Stock material	o AISI 1015, 1025, 1035, 1045, 1055, 1065, 1070, o Stainless 302, 321, 430Ti, 446, Spring 9255, Bearing 52100 o Cu99.97, Al99.5
Roll	o Cast Iron/steel roll, Rough/smooth steel roll, Hard cast roll o Hard metal ground roll, Carbide tungsten roll
Cooling	o Dry, Water, Emulsion
Process parameters	o Speed, Temperature, Interstand tension, Friction (predicted)

B. Software Features

2 Pass Design - AutoForm

➢ **Programs**	▪ **Round-Oval-Round (2 passes)** ▪ **Square-Diamond-Square (2 passes)** ▪ **Billet-Box-Square-Oval-Round (4-passes)** ▪ **Billet-Box-Oval-Round (3-passes)** ▪ **Box-Box (2 passes)**
➢ **Model special**	▪ **Large number of models combined** ▪ **Automatic loops; Both speed and accuracy**
➢ **Features**	▪ **Full automatic pass design** ▪ **Mill operation data as input, no roll pass experience required**
➢ **Internal logics**	▪ **E.g. bite angle; fill ratio; width/height ratio**

B. Software Features

3 Pass Design - FreeForm

➢ **Programs**	▪ **Round-Oval-Round (unlimited passes)** ▪ **Square-Diamond-Square (unlimited passes)**
➢ **Model special**	▪ **Tension correction to spread and forward slip** ▪ **Multiple procedures available for selection** ▪ **Designed/verified based on high-speed wire block (NTM)**
➢ **Features**	▪ **Evaluating existing grooves/schedules to suggest remedial measures** ▪ **Special fit to wire block; verified also with roughing and intermediate mills** ▪ **Creating new passes based on proven old ones** ▪ **Studying tail-end and head-end issues**

B. Software Features

4 Mill Force/Torque

➢ Programs	▪ RD-OV, OV-RD, RD-OV-RD
	▪ SQ-DI, DI-SQ, SQ-DI-SQ
	▪ SQ-OV, BX-BX, General
➢ Model special	▪ Mean flow stress: strain 0.05-1.5, strain rate 0.05-500/s (3000/s), hot forming
	▪ Contact area: models describing real shape of each contact case
	▪ Shape factor and lever arm ratio: experimentally established for each pass sequence

B. Software Features

5 FDM Temperature Profile

➢ **Programs**	▪ **1 program** ▪ **Demo: metalpass.com/cool**
➢ **Model special**	▪ **Finite differential model** ▪ **Heat transfer coefficient models: stock/roll (pressure, speed), stock/air (relative speed), stock/ water (flow rate, pressure, temperature, etc.)** ▪ **Material data models, heat generation models, etc.**
➢ **Features**	▪ **Temperature profile from rolling, interpass cooling, water box cooling, forced air cooling** ▪ **Temperature in the core, surface, middle of the thickness, etc. over time**

B. Software Features

6 Other Programs

|	
➢ **Microstructure**	▪ **Input: material, size, temperature, time, etc.)** ▪ **Output: Recrystallized friction & grain size, etc.** ▪ **Dynamic & static recrystallization, grain growth**
➢ **Pass Manager**	▪ **Needed number of passes or needed entry size** ▪ **Roughing, intermediate, prefinishing & finishing.** ▪ **Mill specific learning**
➢ **Slab Manager**	▪ **Slab inventory - slab-providing** ▪ **Slab size optimization & Slab grade optimization**
➢ **Mill Diagnosis System**	▪ **Weaknesses of Level 2 model** ▪ **Causes and improvement recommendations**

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C. Development & Validation

1 Empirical Models Developed

- **Totally over 100 Models**

- **Metal Flow**
  - **Spread, Forward slip; Tension effects, Material influence, …**

- **Force, Torque, Power**
  - **Flow stress, Contact area, Shape factor, …**

- **Data**
  - **Material data (temperature dependent)**
  - **Boundary data (heat transfer depending on many factors; friction)**

- **Temperature, Heat Transfer**
  - **Heat transfer coefficient models, Thermal property models, …**

- **Microstructure, Finish Properties**
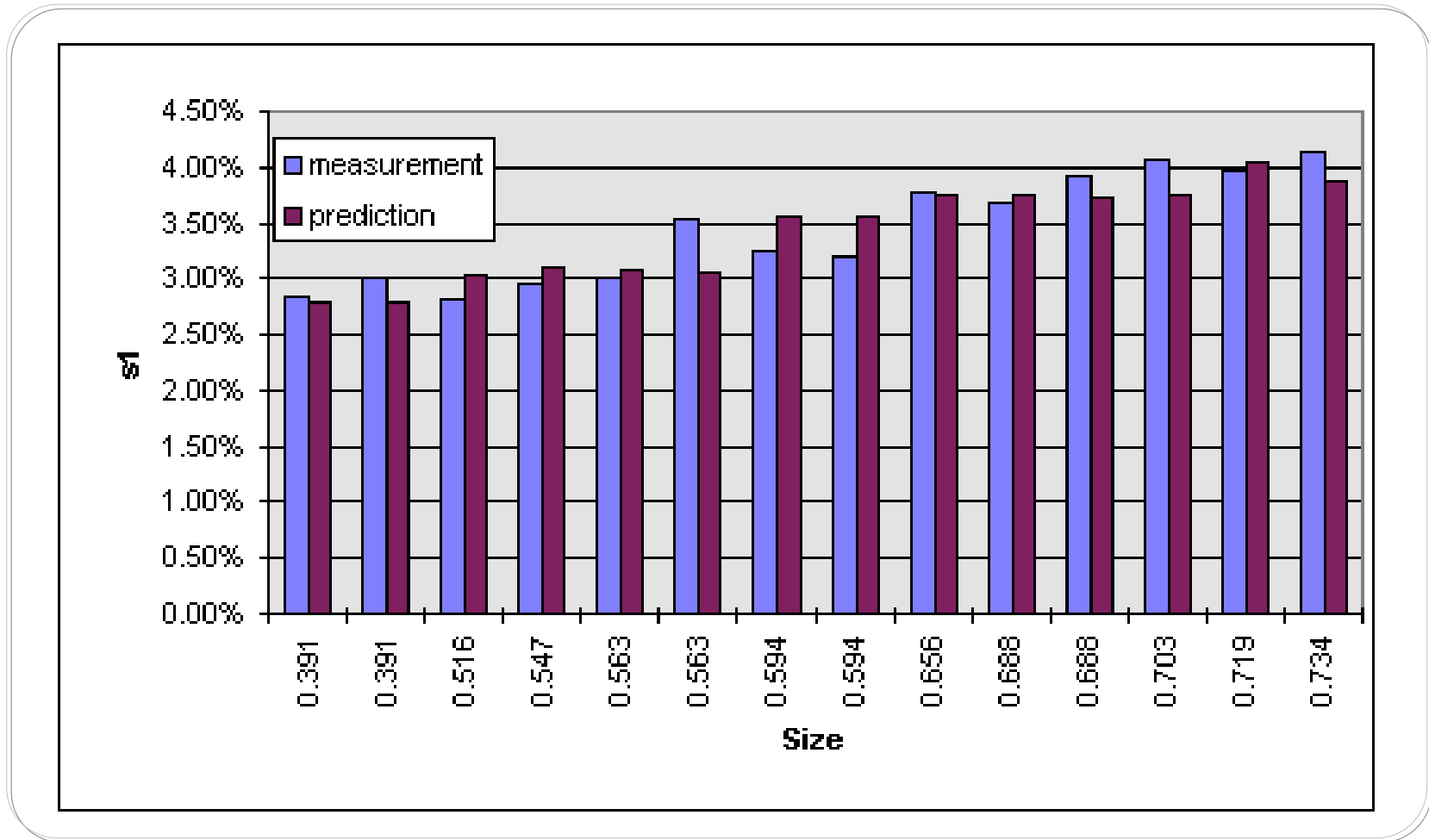 - **Recrystallization, Grain growth, Finish properties, …**

C. Development & Validation
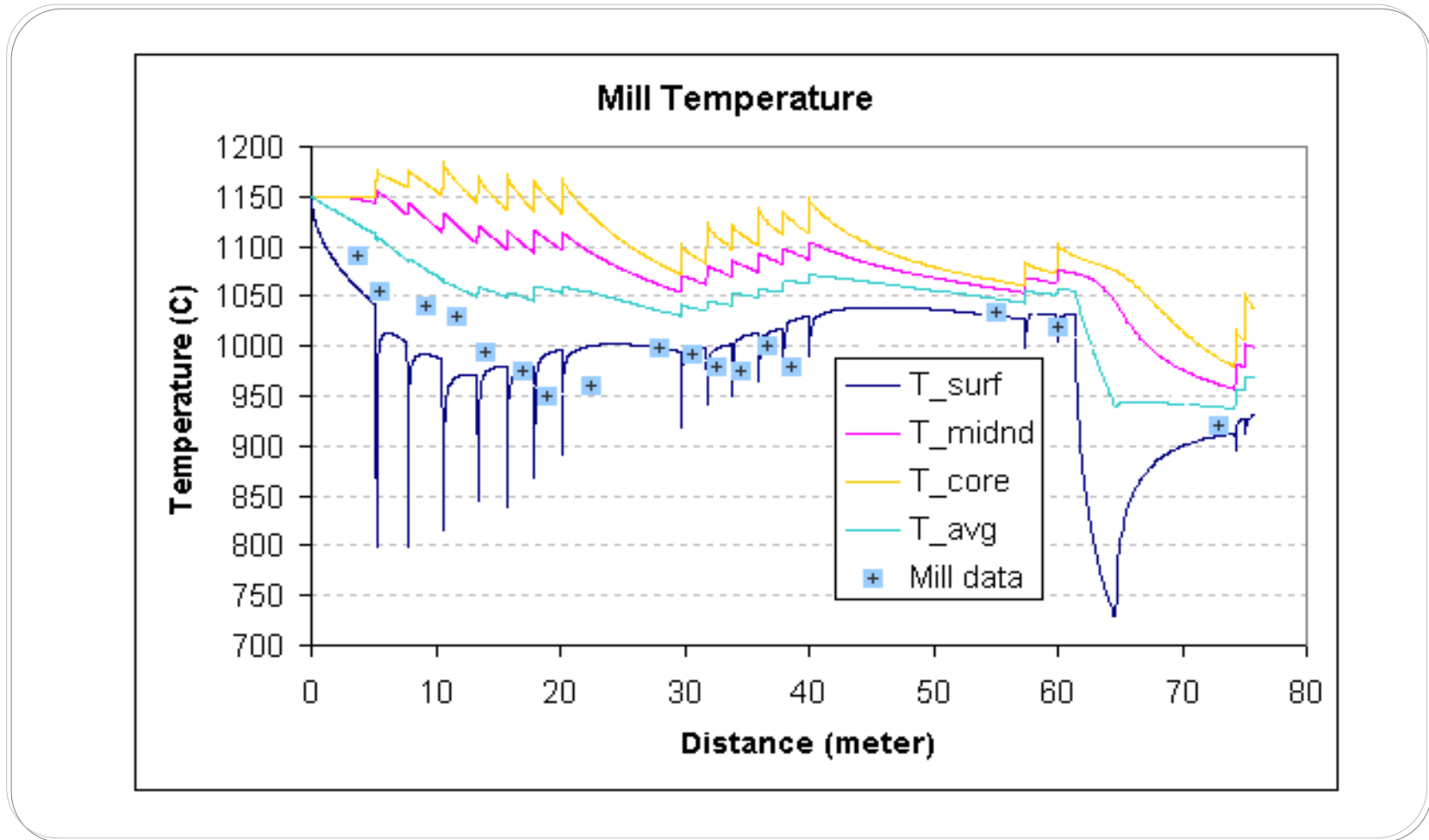
2 Spread Model Validation

Spread in RD-OV pass based on the model of Ks
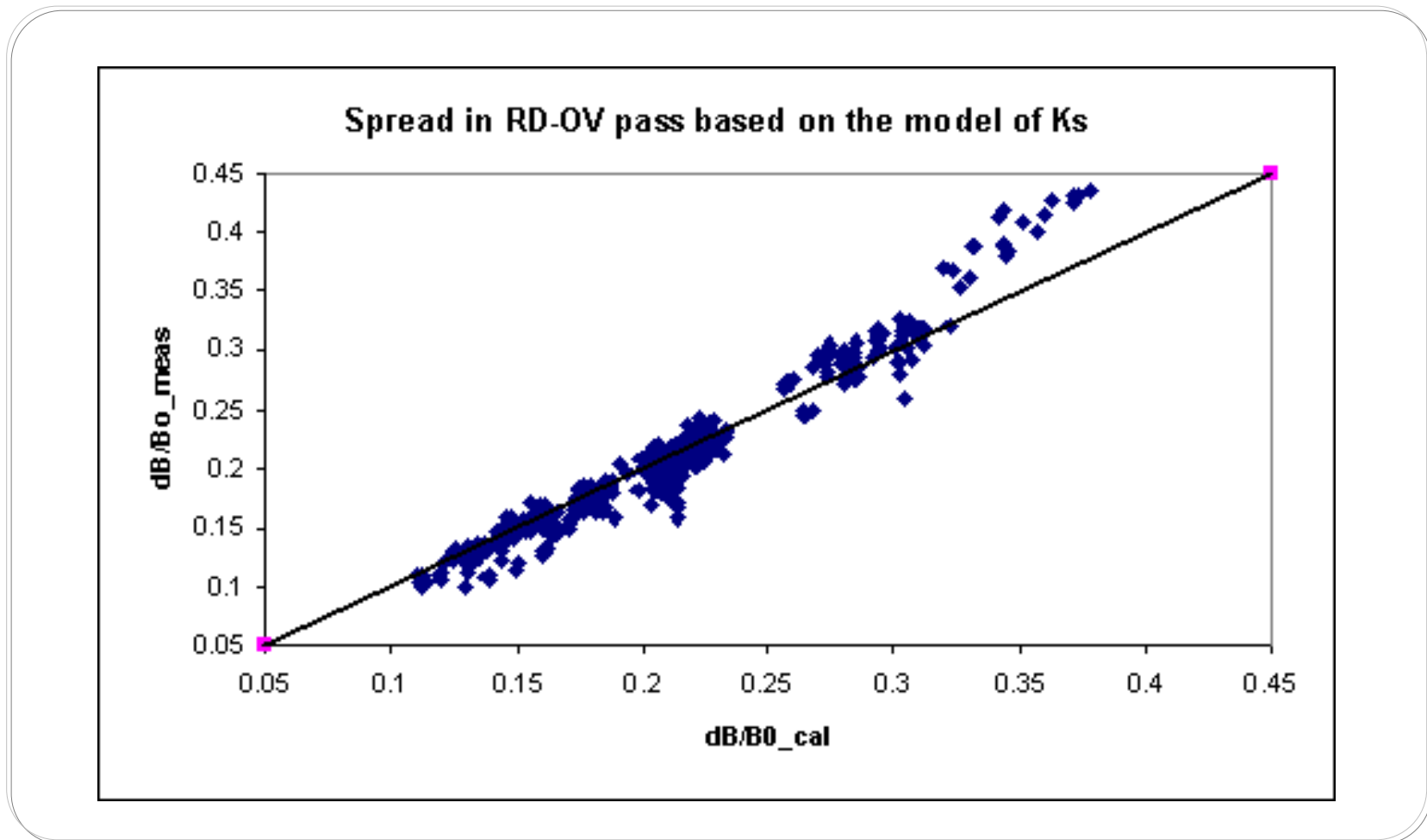
C. Development & Validation

3 Forward Slip Model Validation

C. Development & Validation

4 FDM Model Validation

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D. Summary

1 Summary

➢ **Reasons for Development**
- ▪ **Complicated rolling mill process demands sophisticated models and software**
- ▪ **Good future-potential awaits web-based mill applications**

➢ **Software Features**
- ▪ **Web-based programs available for mill design and development**
- ▪ **Good features: some powerful and others easy to use**

➢ **Development & Validation**
- ▪ **Development based on sophisticated process modeling and data modeling**
- ▪ **Quality verified with highly accurate models and extensive mill-tests**

Thank You

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