Level 2 Model Improvements at Evraz Oregon Steel

Bingji (Benjamin) Li, Ph.D.
www.metalpass.com/bli
Metal Pass LLC
www.metalpass.com

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A. Introduction

1 Level 2 Model & Its Significance

- **Level 2 Model Functions**
  - Prediction for force, torque, temperature, etc.
  - Prediction for roll crown
    - Thermal crown, roll wear, initial roll shape, roll deflection, stand deflection …
  - Creation of draft schedule and stage plan (e.g. hold), etc.
- **Product Quality & Productivity**
  - Equal Deformation Targets
  - Metallurgical Temperature Targets
  - Mill Capacity and Productivity Targets
- **Consequence of Level 2 Force Prediction Error**
  - Wrong initial gap, large AGC movement that triggers shape problems
  - Temperature error (temperature often calculated from force)
  - Roll deflection error, unequal deformation and so bad product shape
  - Insufficiency of controlled rolling
  - Low productivity (e.g. 20% error means only 80% mill utilization)
  - Potential equipment damage

A. Introduction

2 Project Outline

- **Problems**
  - Shape defects: hard and thin products
  - Force error: up to 40%
- **Errors & Issues**
  - Design logical error
  - Limitation for adaptive learning
  - Metallurgical effects
- **First Improvement**
  - Guided Two-Parameter Learning, or FIT2G
    - 6000 sets of well-designed flow stress coefficients
  - Testing, approval for full-scale application
- **Second Improvement**
  - Several new issues identified during testing

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B. First Improvement

1 Logical Error

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

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	

B. First Improvement

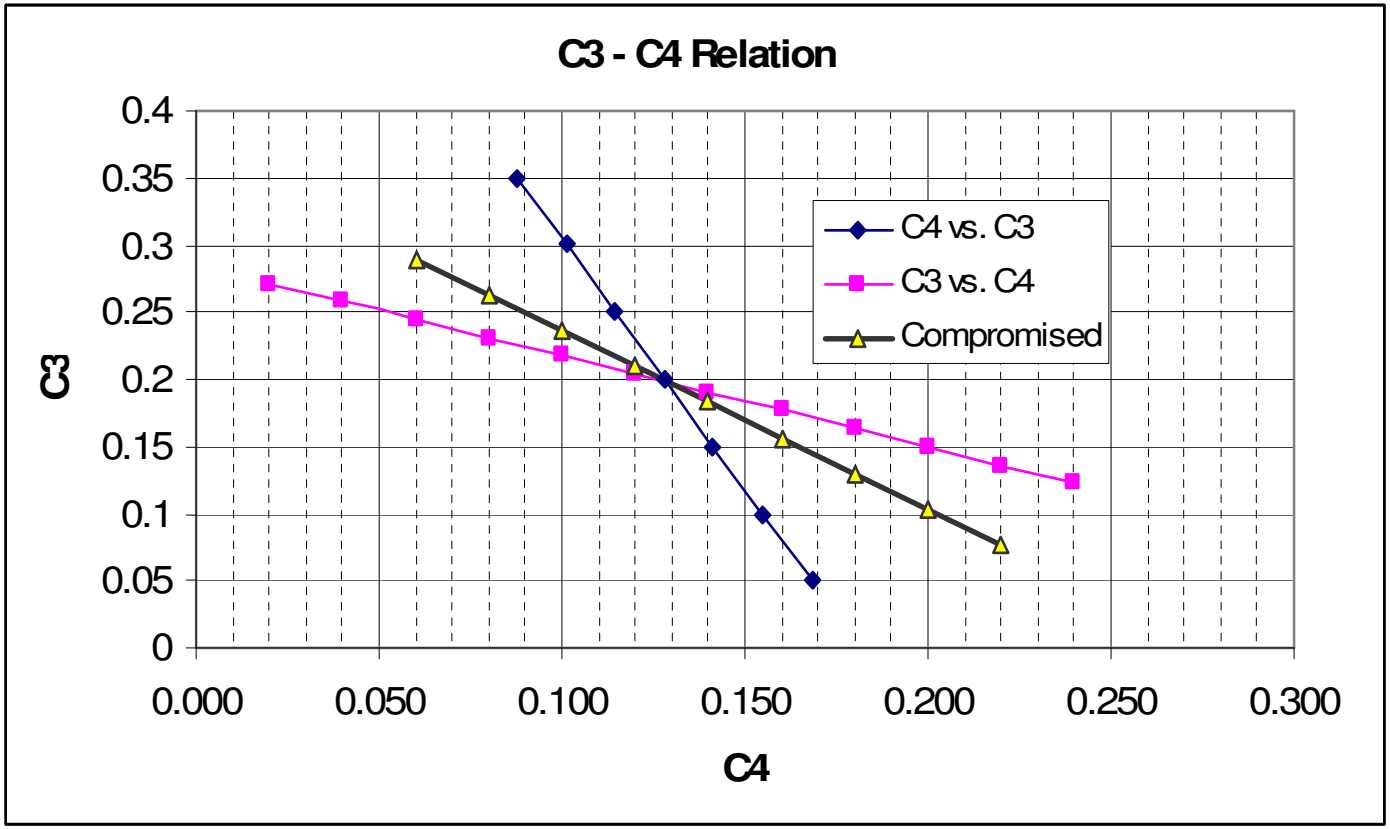
2 Solution to the Logical Error

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

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	

B. First Improvement

3 Weakness of Adaptive Learning: in 4-Parameter Learning FIT4



B. First Improvement

4 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. First Improvement

5 Guided Two-Parameter Learning (FIT2G)

- **Well-designed C_3 and C_4 as Fixed Values, Using C_1 and C_2 as Learning Parameter (FIT2G)**
- **6000 Sets of Flow Stress Coefficients C_1, C_2, C_3 and C_4**
  - **2000 model grades, with three temperature regions each**
  - **C_1 and C_2 as learning parameters; well-tested C_1 and C_2 for first use**
- **Solutions Encapsulated in Flow Stress Coefficients**
  - **Design error and adaptive learning weakness: C_3 and C_4**
  - **Metallurgical effects: retained strain in C_3**
- **Very Few Modifications for Source Code**
  - **Right solution for existing Level 2**

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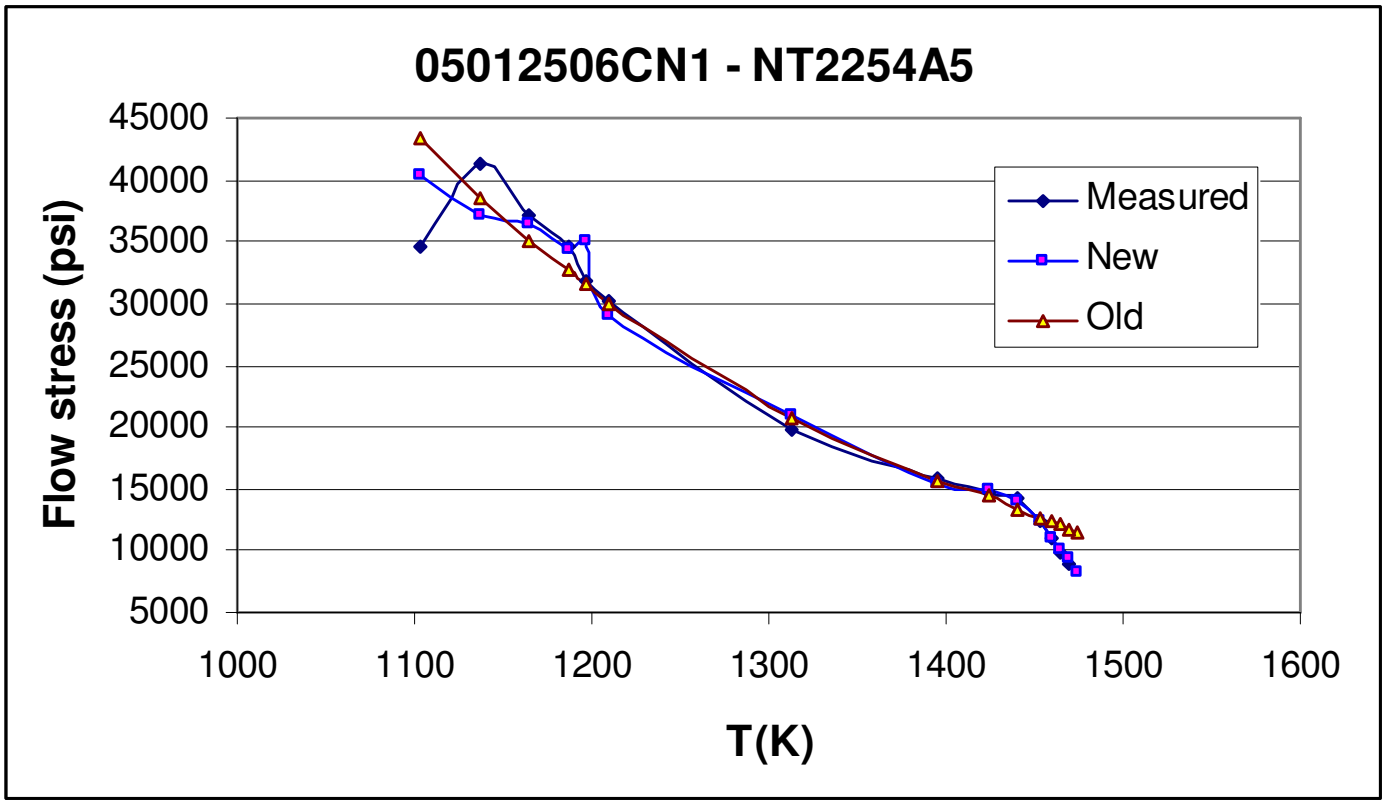
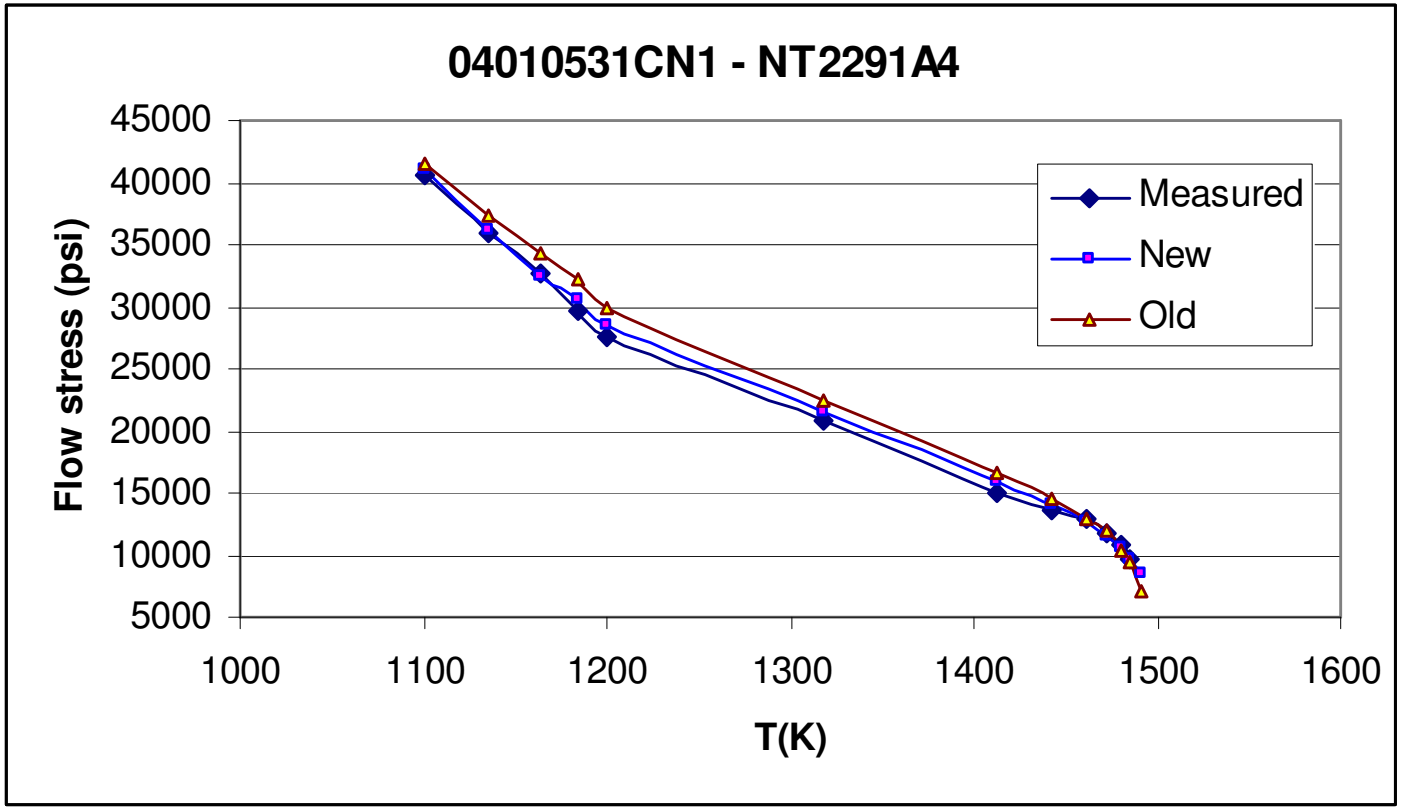
C. Testing Results

1 Hard and Thin Grade (in α/ɣ Region)



C. Testing Results

2 Regular Grade



C. Testing Results

3 Pass Count in Various Error Ranges

Grade, Slab	New Model				Old Model			
	<5%	5%-10%	10%-15%	>15%	<5%	5%-10%	10%-15%	>15%
05012506CN1, NT2245A3	9	2	3	0	8	2	2	2
05012506CN1, NT2254A5	9	2	2	1	5	5	1	3
05010002SN1, NT2386A30	13	1	1	0	10	4	1	0
05010002SN1, NT2385A28	13	1	1	0	10	4	1	0
04010531CN1, NT2291A4	11	1	0	0	7	4	1	0
04010531CN1, NT2291A2	11	1	0	0	7	5	0	0

C. Testing Results

4 Prediction Accuracy

Error Range	Percentage (%) of Passes			
	N. Steel (All Grades)	OSM (Old Model, All Grades)	OSM (Old Model, Troubled Grades)	OSM (New Model, Troubled Grades)
< 5%	30% (est.)	73%	57%	80%
< 10%	75%	91%	87%	90%
< 15%	89-90%	96%	94%	99%

OSM: Evraz Oregon Steel Mills (or EOS)
N. Steel error: Feb. 2007 from N. Steel
OSM New Model: Before the second phase improvement
Average of absolute values of errors is 3.4% (for troubled grades)

C. Testing Results

5 Minimal, Average and Maximum Errors

Grade, Slab	New Model (%)			Old Model (%)		
	Min	Avg (abs)	Max	Min	Avg (abs)	Max
05012506CN1, NT2245A3	-4.00	5.80	14.64	-4.96	7.33	32.4
05012506CN1, NT2254A5	-10.2	4.53	16.96	-6.78	9.02	32.6
05010002SN1, NT2386A30	-10.11	2.60	5.72	-5.84	4.33	12.93
05010002SN1, NT2385A28	-10.73	2.78	7.52	-6.00	4.88	14.78
04010531CN1, NT2291A4	-2.24	2.28	6.92	-2.40	4.91	10.10
04010531CN1, NT2291A2	-1.36	2.36	5.21	-1.46	4.91	8.97
Average	-6.44	3.39	9.50	-4.57	5.90	18.63

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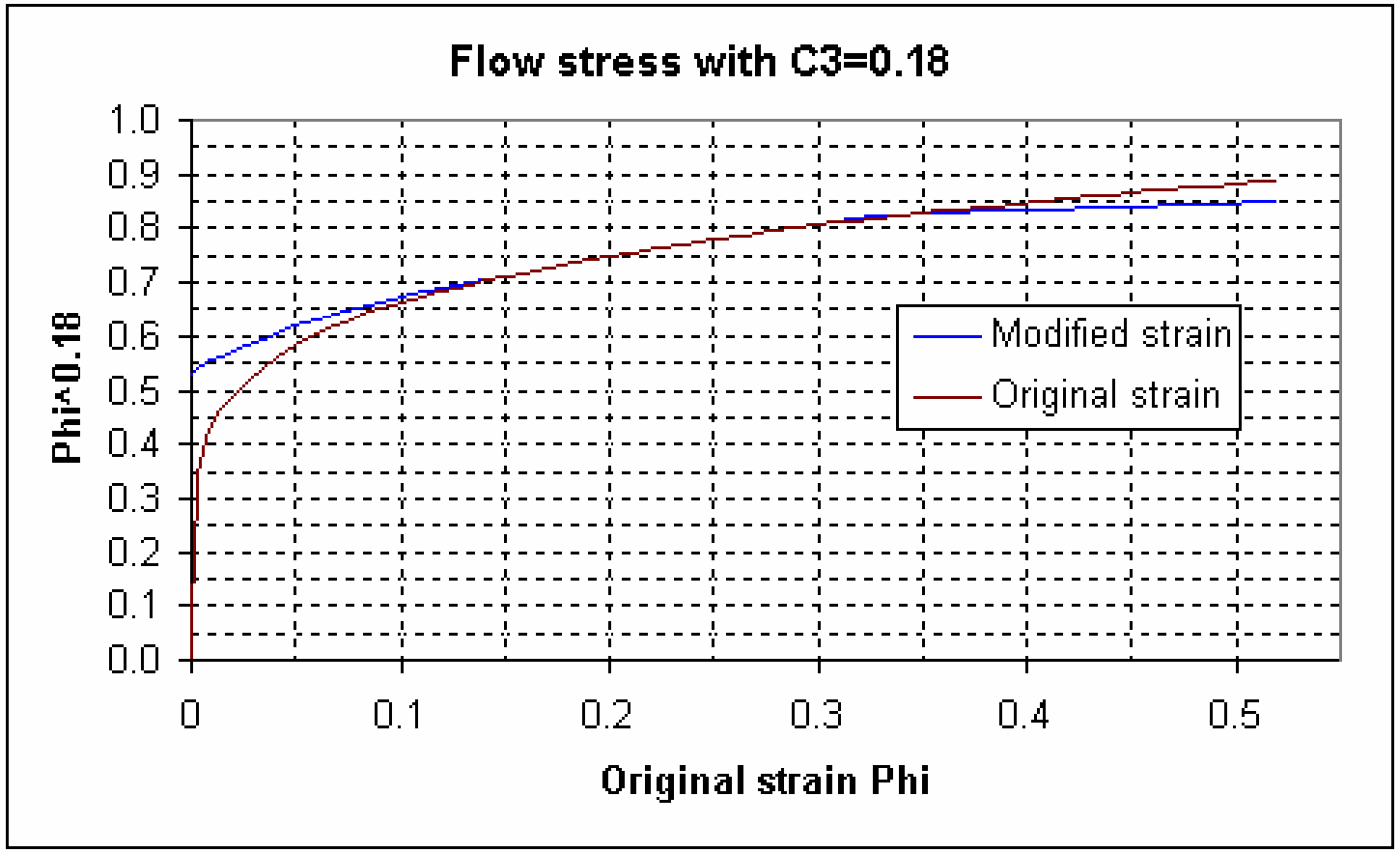
D. Second Improvement

1 Solution Outline

- **Problems**
  - Problems identified during the testing
- **Temperature Range Dividing Points**
  - Temperature ranges to have metallurgical meaning
  - Narrower ranges in finishing passes
- **Flow Stress Formula Valid Range**
- **Resume Pass after Hold**
- **Rolling in Two Phase Region**
  - Solution suggestion

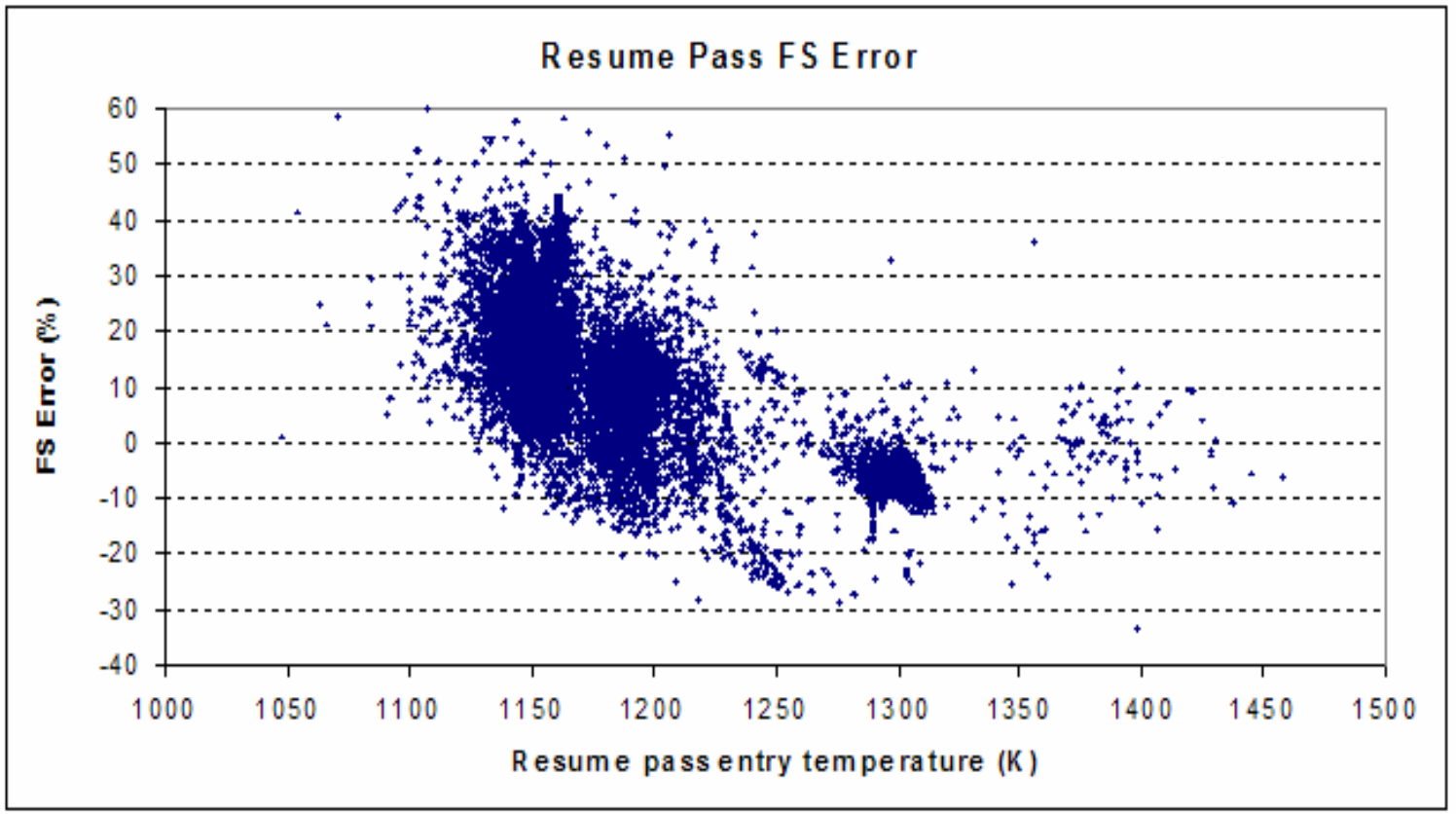
D. Second Improvement

2 Formula Valid Range: Invalid for Draft below 10%



D. Second Improvement

3 Resume Pass Force Error



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E. Summary

1 Summary

- Most Level 2 models in current market have weaknesses such as those related to metallurgical effects and limitation of adaptive learning. Some even have design errors. Solutions to those problems can lead to very high prediction accuracy (for example, force error below 5%).
- Guided Two Parameter Learning (FIT2G) is very effective for improving existing Level 2 systems. It encapsulates solutions to metallurgical issues and to adaptive learning limitations, etc. into thousands sets of flow stress coefficients, and thus requires very few source code modifications.
- Level 2 model accuracy is very critical to product quality and productivity.

Thank You

Bingji (Benjamin) Li
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