

GREAT DESIGNS IN **STEEL**

Risks of Generic Material Card Usage

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Outline

- 1) Introduction
- 2) Inputs in a “Material Card”
- 3) Comparison of “Generic Cards”
- 4) Observations
- 5) Future work

Engineering Quality Solutions – Formed 2002

Engineering, consulting & training in sheet metal forming



Core competence: Product applications assistance to materials & manufacturing companies

Focus – Hands-On: Materials selection/ optimization, tooling buyoff, field formability analyses, stamping failure troubleshooting, manufacturing process improvement, and cost savings / cost avoidance projects.

Focus – Education: Teaching the fundamentals and practical details of material properties, forming technologies, processes, and troubleshooting skills needed to reliably form high quality components

Market: Global, primarily North America, Europe, and Asia

Billur Metal Form

Billur

Founded by Dr. Eren Billur in 2015. Located in Ankara and employs 3 engineers.

Consulting, engineering, training and simulation services around sheet metal forming processes and different sheet metal grades.

Core-competence: Hot stamping of steel and new generation AHSS.

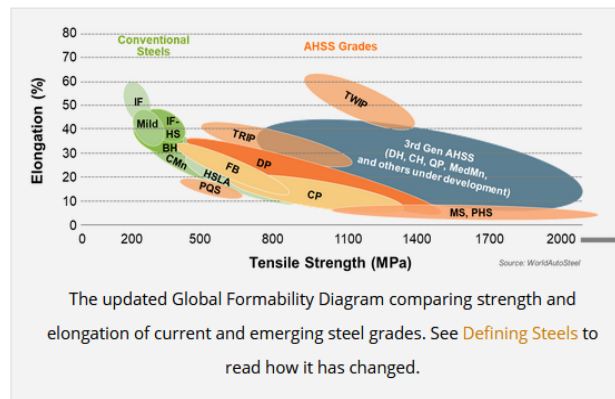
Customers from USA, Germany, Japan and China accounting over 60%.

«Cutting Edge» column in Metalforming Magazine since 2020

Contribution to worldautosteel's AHSS Guidelines.



Welcome to the All New AHSS Application Guidelines!



We are very excited to announce today the launch of a new version of the Advanced High-Strength Steels (AHSS) Application Guidelines, the leading source for technical best practices on AHSS metallurgy, forming and joining. The AHSS Application Guidelines Version 7.0 is now online at ahssinsights.org in this searchable database, allowing users to pinpoint information critical to successful use of these amazingly capable steels. WorldAutoSteel member companies make these Guidelines freely available for use to the world's automotive community.



Thanks are given to [Eren Billur, Ph.D.](#), [Billur MetalForm](#), who contributed this article.



Vision

Making lives better by being the best supplier we can be in the products we make and the services we provide.

Mission

We make people's lives better by:

- Delivering outstanding quality products and services to our customers;
- Providing meaningful opportunity, job satisfaction, and job security for our people;
- Providing superior long-term investment returns to our stake holders; and,
- Being positive contributors to our communities.

19,000 Team Members

10 Countries

56 Locations

OUR PRODUCTS AND CAPABILITIES

STEP ONE

DESIGN AND DEVELOPMENT

- 3D Modeling: Extensive suite of CAD modeling software
- Finite Element Analysis: Static stress, modal, fatigue life prediction, dynamic performance, crash capabilities and multi-body dynamics
- Design for Manufacturing:
 - Forming: Stamping, hydro form simulation, nesting and tooling optimization
 - Assembly: Line simulation, joining and ergonomics
 - Coating: Optimization simulations
 - Shipping: Product density studies, packaging optimization, test simulations

STEP FOUR

VALUE ENGINEERING

- Value Added – Value Engineering:
 - Product and process optimization
- Engineering change Management:
 - Complete product lifecycle management



STEP TWO

PROTOTYPE AND TESTING

- Prototypes:
 - Fit and function prototypes
 - Production emulated soft tooled prototypes
 - Rapid prototyping
- Test Lab:
 - Real phase fatigue
 - Suspension module fatigue
 - Component fatigue
 - Road simulators
 - Stiffness analysis
 - Data acquisition
 - Material testing

STEP THREE

PRODUCTION LAUNCH

- Martinrea Project Management System:
 - Production launch system shaped into six project phases and gate controls which include APQP, TS16949, SCAM and Martinrea and customer requirements
 - Phases: Planning, sourcing, execution, approval, ramp up, closure & reflection

OUR PRODUCTS AND CAPABILITIES

Body-in-White and Chassis



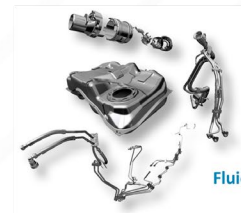
Powertrain



Assembly



Industrial



Fluids



Leading Tier One automotive supplier in lightweight structures and propulsion systems

www.martinrea.com

Simulation at Start of Tooling Development

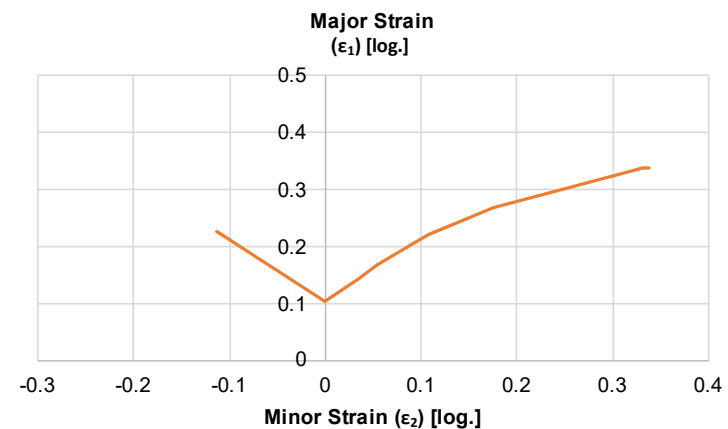
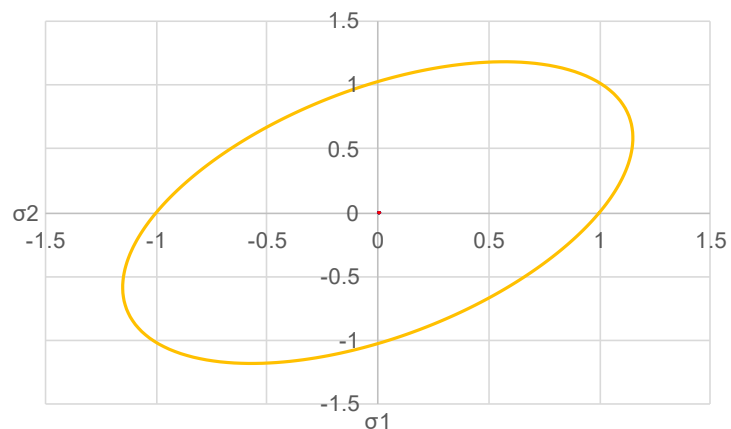
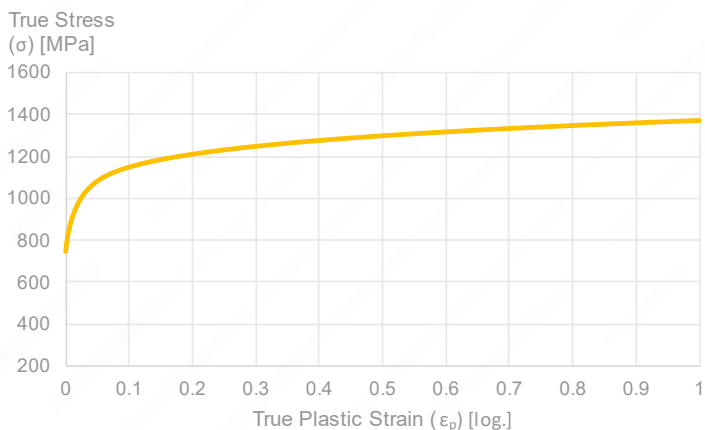
Sim engineer selects material card → randomly based on grade or from targeted supplier


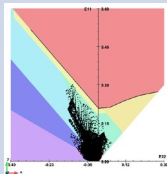
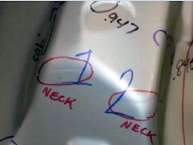


- Major steel companies create material cards for inclusion into the proprietary material card database within the simulation software
- Implications:
 - Stamping feasibility (safe or green zone part)
 - Tonnage predictions (defines the presses where the part can be formed)
 - Local thinning (shows areas at risk for fatigue due to excessive thinning)
 - Blank dimensions and nesting (optimal dimensions change to accommodate metal flow)

Coil-to-coil variability exists

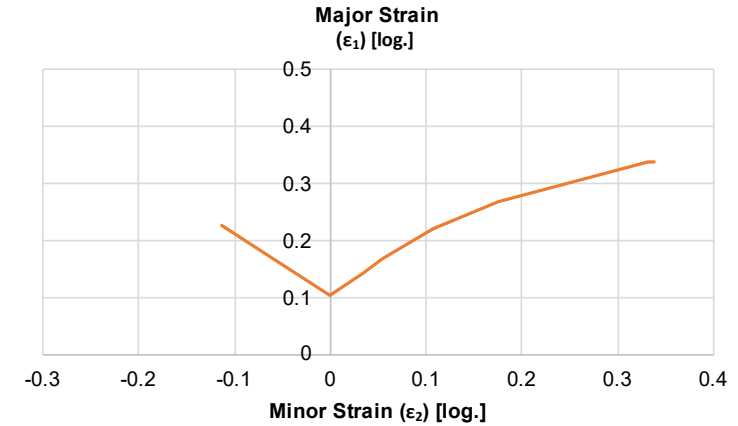
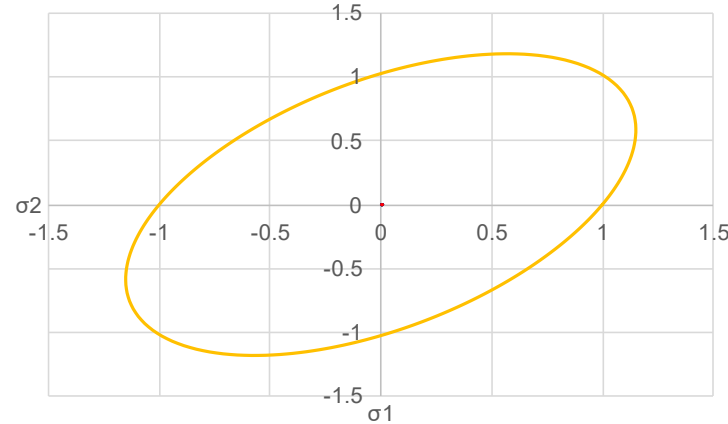
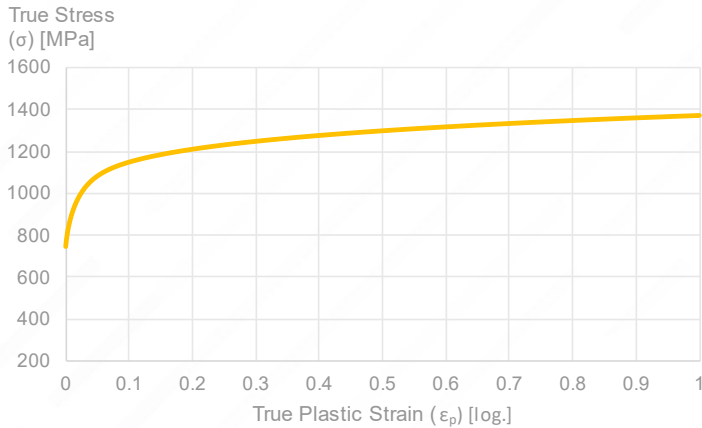
- We assume material card is representative of that supplier's product.
- Magnitude of the difference between the material card and the actual coil properties cannot be estimated without testing the specific chosen coil.
- This report focuses on only the variability in material card properties and assumptions between steel companies for a given steel grade

Inputs in a Material Card



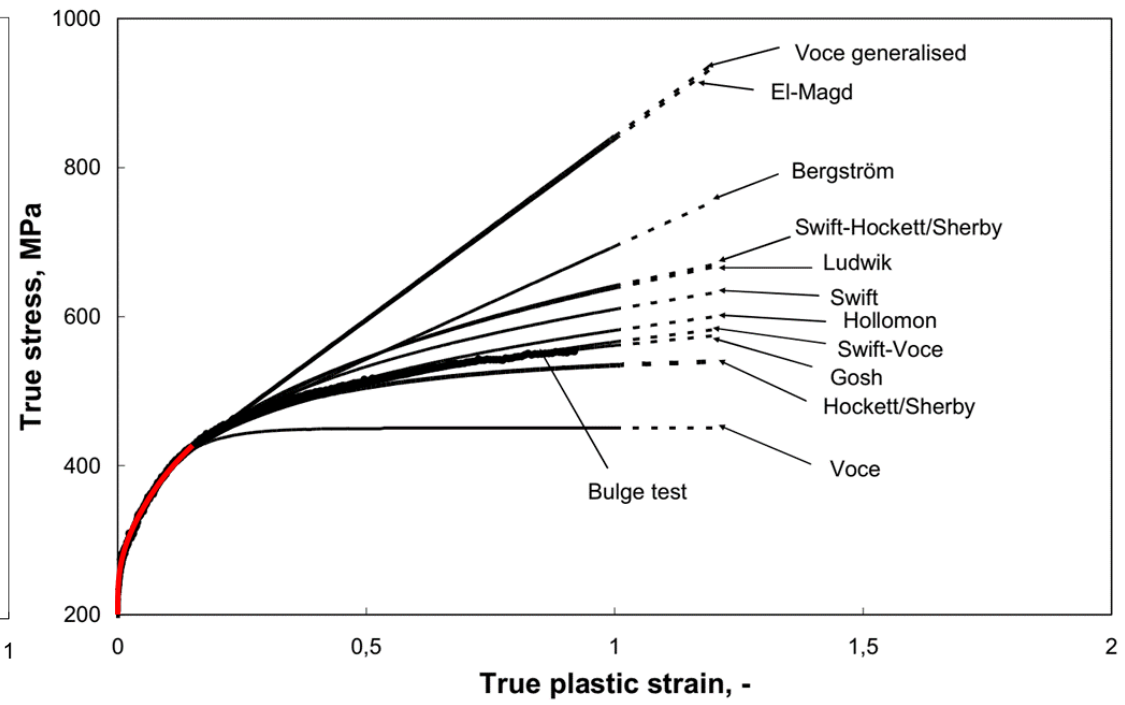
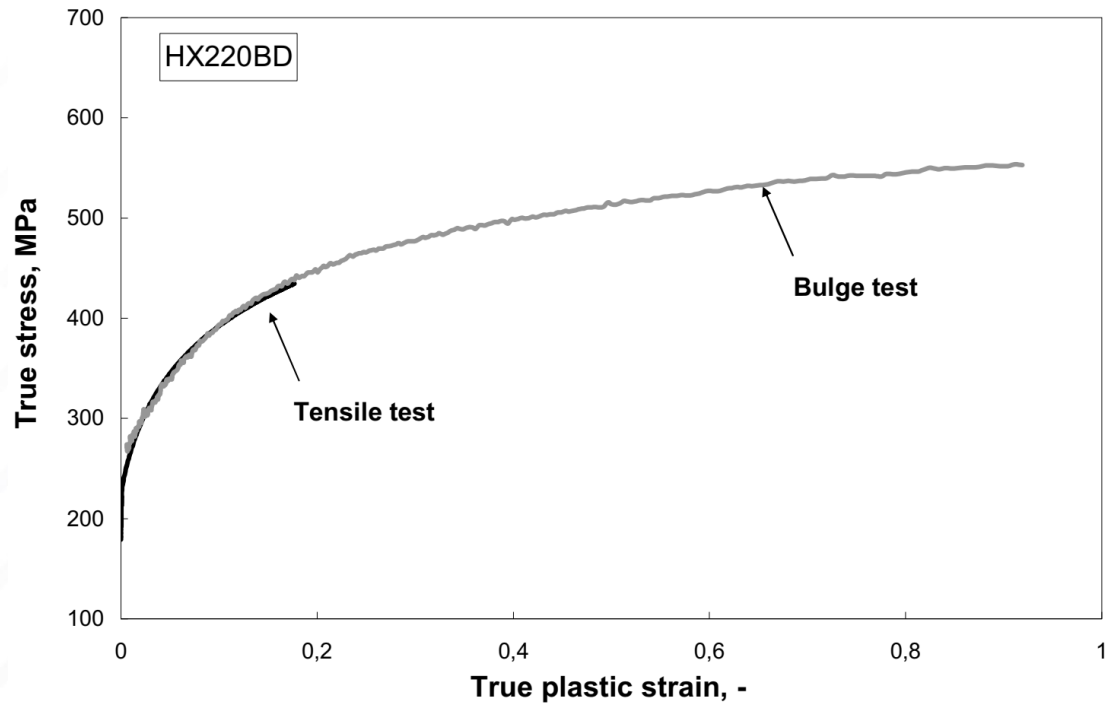
	Hardening Curve	Yield Locus	Forming Limit Curve (FLC)
Importance	Necking initiation 	Strain distribution 	Necking initiation 
	Press Tonnage 		
	Springback 		

Inputs in a Material Card



	Hardening Curve	Yield Locus	Forming Limit Curve (FLC)
Minimum	Tensile test in rolling direction.	Tensile test in at least 3 directions (0, 45, 90° to rolling direction)	Keeler, Cayssials or Abspoel-Scholting equations.
Better	Tensile test with DIC, or Bulge test (not as common)	Requires bulge test to determine biaxial parameters	Nakajima or Marciniak experiments
Note	Extrapolation is a must. Handle with care.	Hill 1948 is not advised if r-values are <1,	Equations have limitations. Nakajima has a shift.

Hardening Law Extrapolation Method



Yield Surface Generation Method

Test	Uniaxial Tensile Test												Biaxial		Shear			Plane Strain			
Value	σ_0	σ_{45}	σ_{90}	r_0	r_{45}	r_{90}	$A_{g,0}$	$A_{g,45}$	$A_{g,90}$	$R_{m,0}$	$R_{m,45}$	$R_{m,90}$	σ_b	r_b	τ_0	τ_{45}	τ_{90}	$\sigma_{ps,0}$	$\sigma_{ps,45}$	$\sigma_{ps,90}$	
Vegter 2017																					
Vegter (Full)																					
BBC 2005 (8)																					
BBC 2005 (7)																					
BBC 2005 (6)																					
Barlat 89																					
Hill 48																					



FLC Generation Method

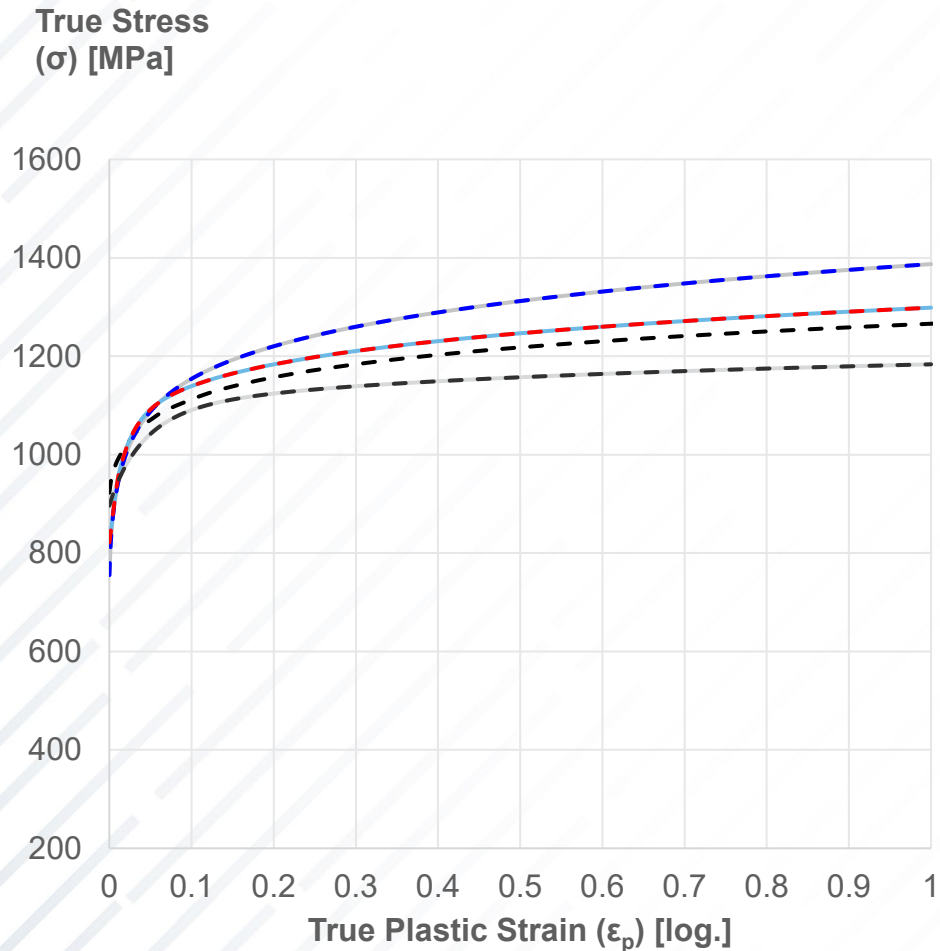
Keeler: Correlation based on n-value and thickness only
Developed using grades available 60 years ago

Arcelor V9 (Cayssials): Correlation based on transverse uniform elongation in tensile test and tensile strength
Developed with grades available in 2005, but still a correlation

Abspoel-Scholting (Tata): Correlation based on total elongation in longitudinal, transverse, and diagonal orientations in ISO II (DIN) tensile test
Developed with grades available in 2012, but still a correlation

Experimental: Multi-days testing, (much) more expensive than tensile testing

Comparison of generic cards – CR780Y980T-CP



4 steel makers were compared.

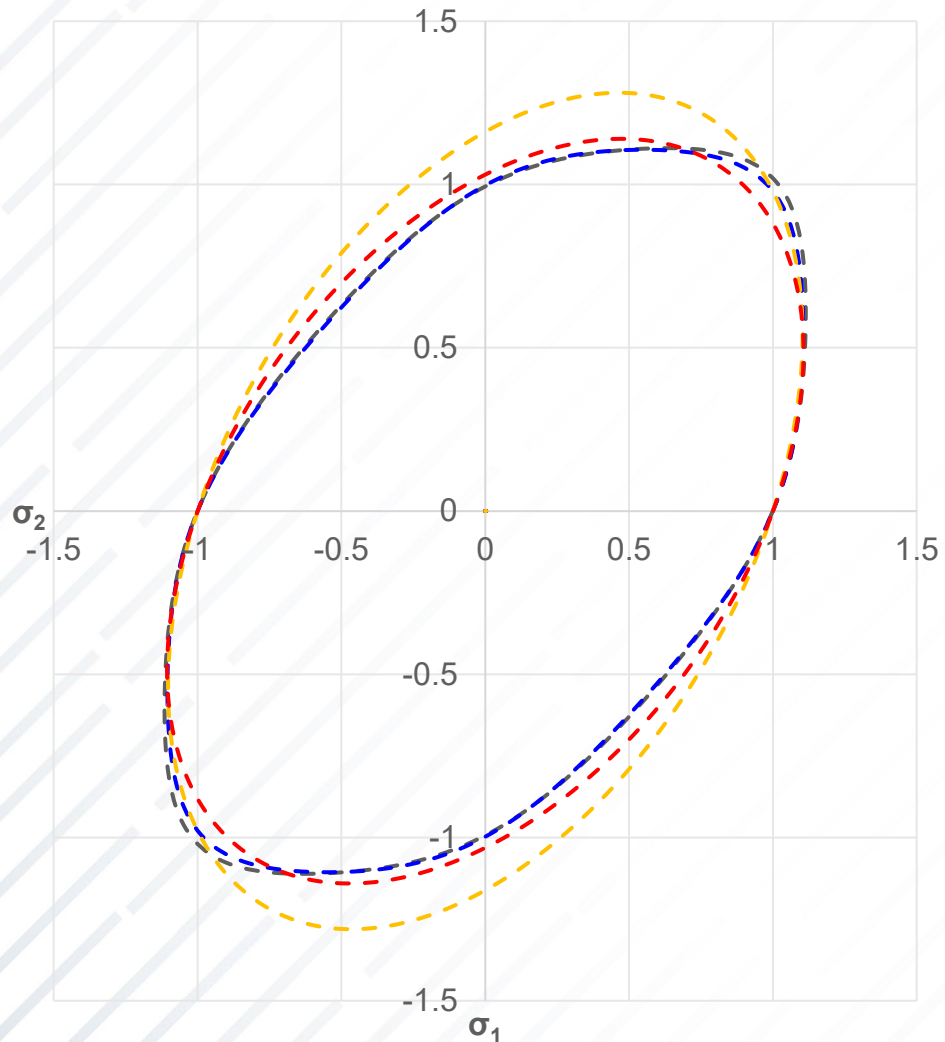
Yield strength varied 12%,
between 820 and 920 MPa.

True stress level at 0.2 plastic strain varied
1125-1225 MPa.

Two steel makers used tables, two used
equations. Tables are preferred for their
better resolution at low strains; however
they hide the extrapolation equation.

All cards were made no later than 2018.

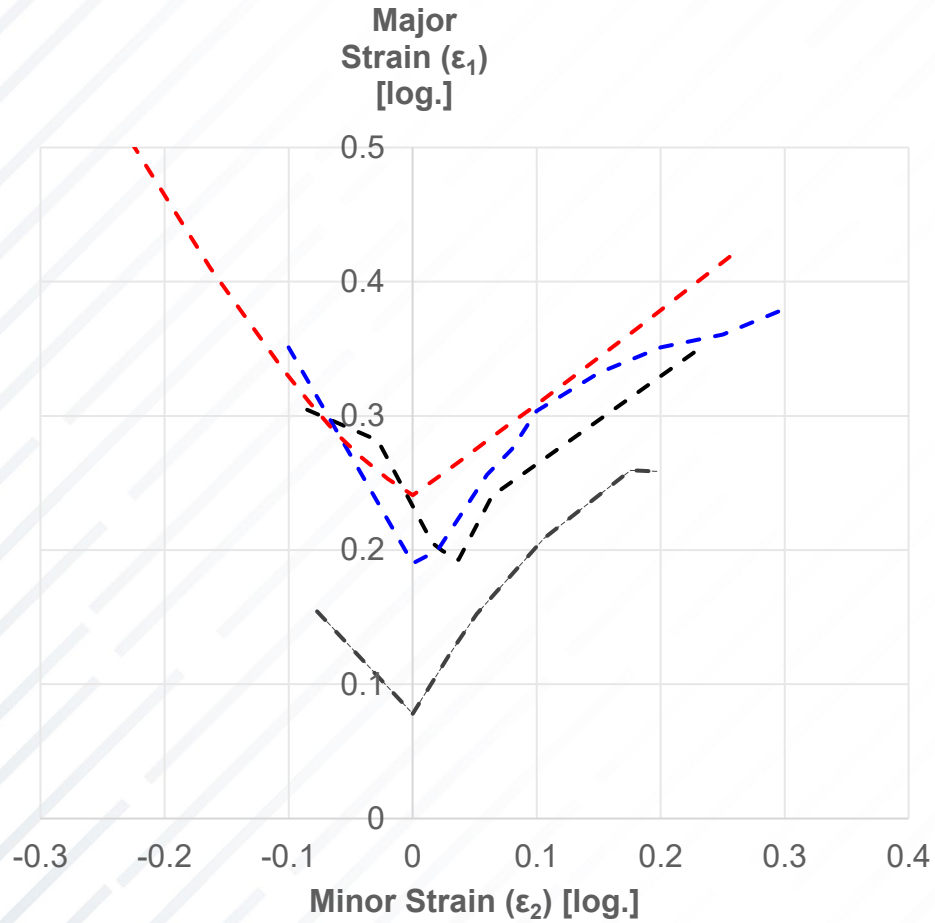
Comparison of generic cards – CR780Y980T-CP



2 cards were written with Hill 1990,
2 were written with BBC 2005.

BBC 2005 cards use 8 parameters, but only
one steel company used experimental biaxial
values. The other one used “From Barlat”.

Comparison of generic cards – CR780Y980T-CP

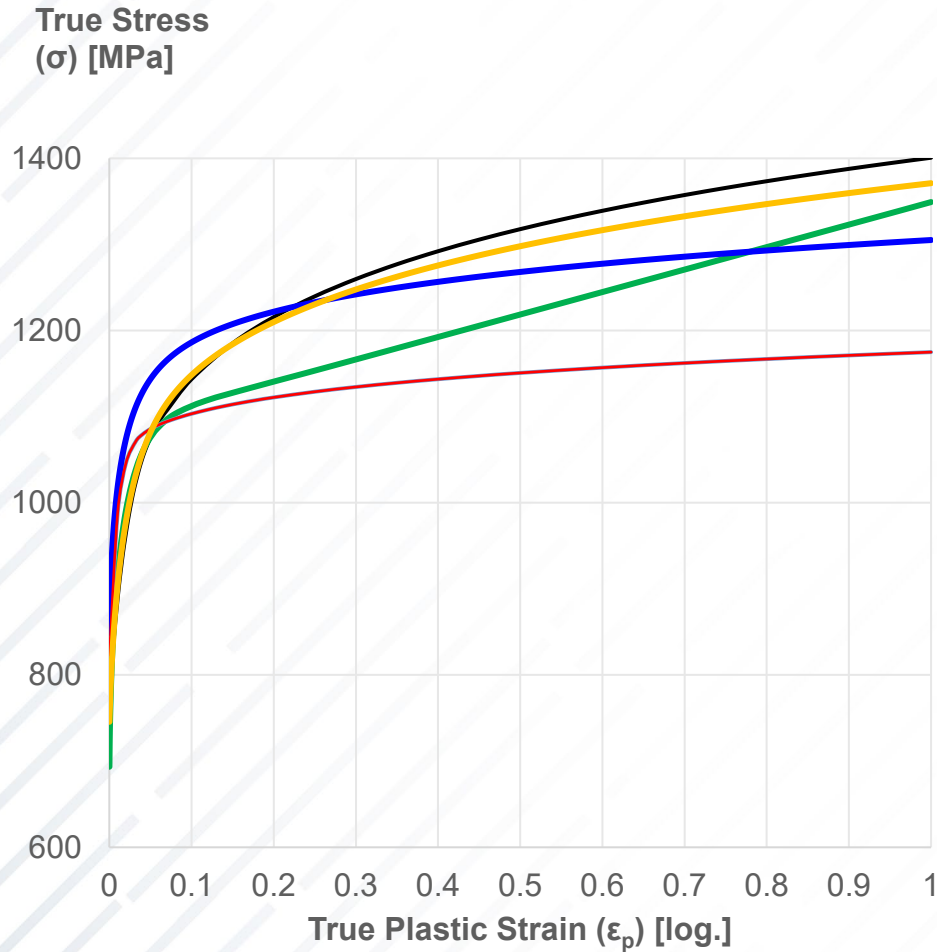


FLC's were shifted to 2 mm thickness for comparison purposes.

One steel maker used Nakajima experiments, shifting the FLC_0 point to 0.03.

At least one steel maker used an equation to predict the FLC. Other two are possibly from Marciniak experiments.

Comparison of generic cards – CR700Y980T-DP



5 steel makers were compared.

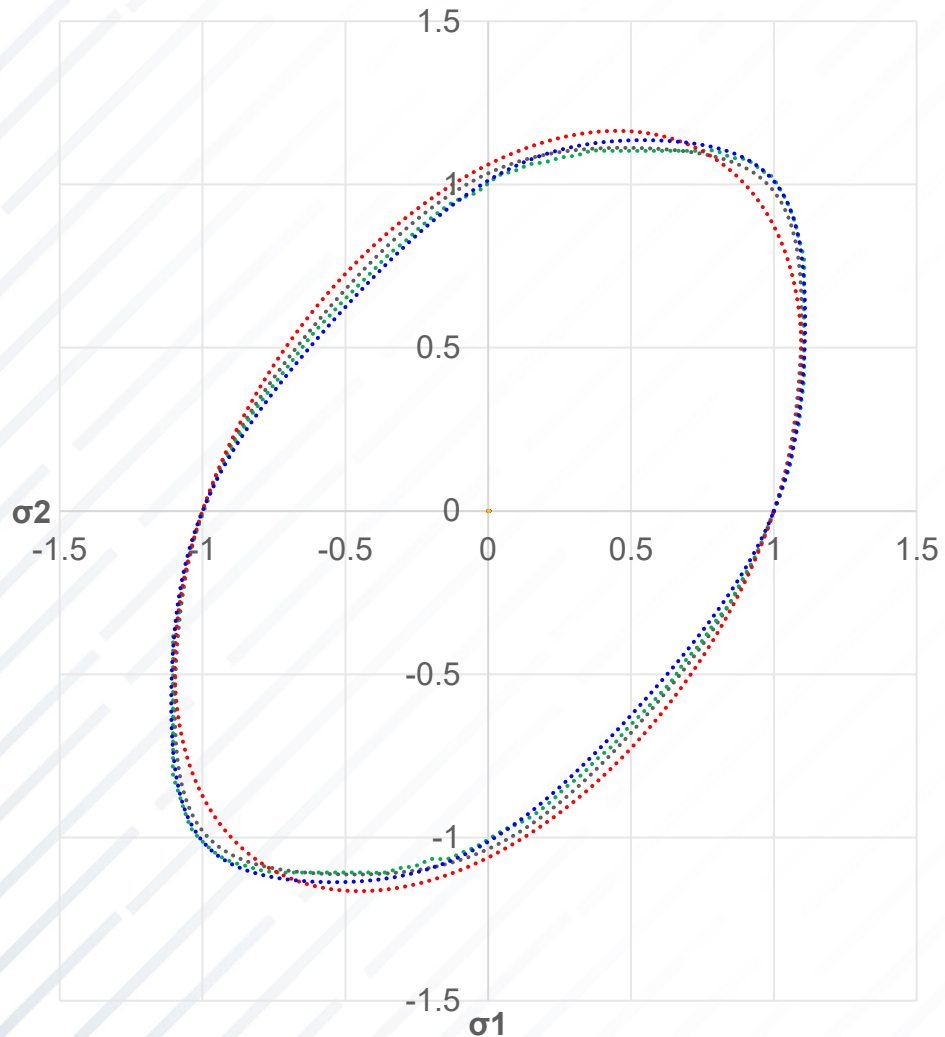
Yield strength varied 22%,
between 693 and 848 MPa.

True stress level at 0.2 plastic strain varied
1122-1215 MPa.

Three steel makers used tables, two used
equations. One steel maker wrote clearly
how they extrapolated. Others had to be
reverse engineered.

All cards were made no later than 2018.

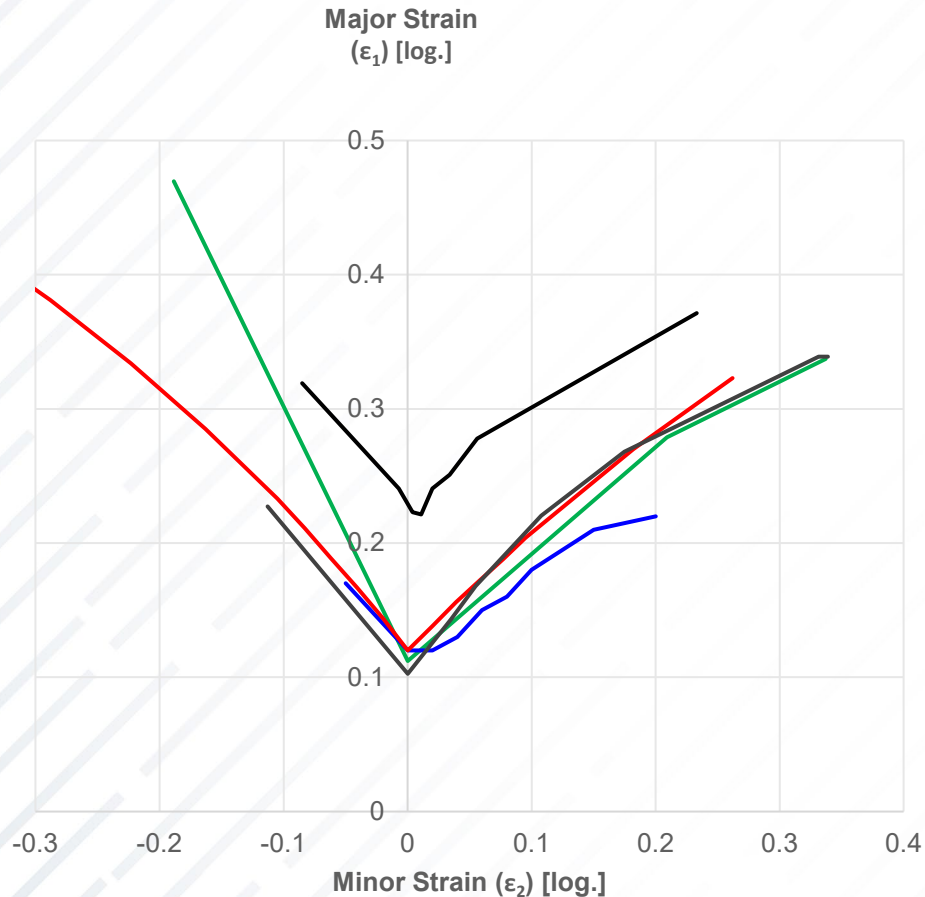
Comparison of generic cards – CR700Y980T-DP



2 cards were written with Hill 1990,
2 were written with BBC 2005,
1 with Vegter Full.

BBC 2005 cards use 8 parameters, but only
one steel company used experimental biaxial
values. The other one used “From Barlat”.

Comparison of generic cards – CR700Y980T-DP



FLC's were shifted to 2 mm thickness for comparison purposes.

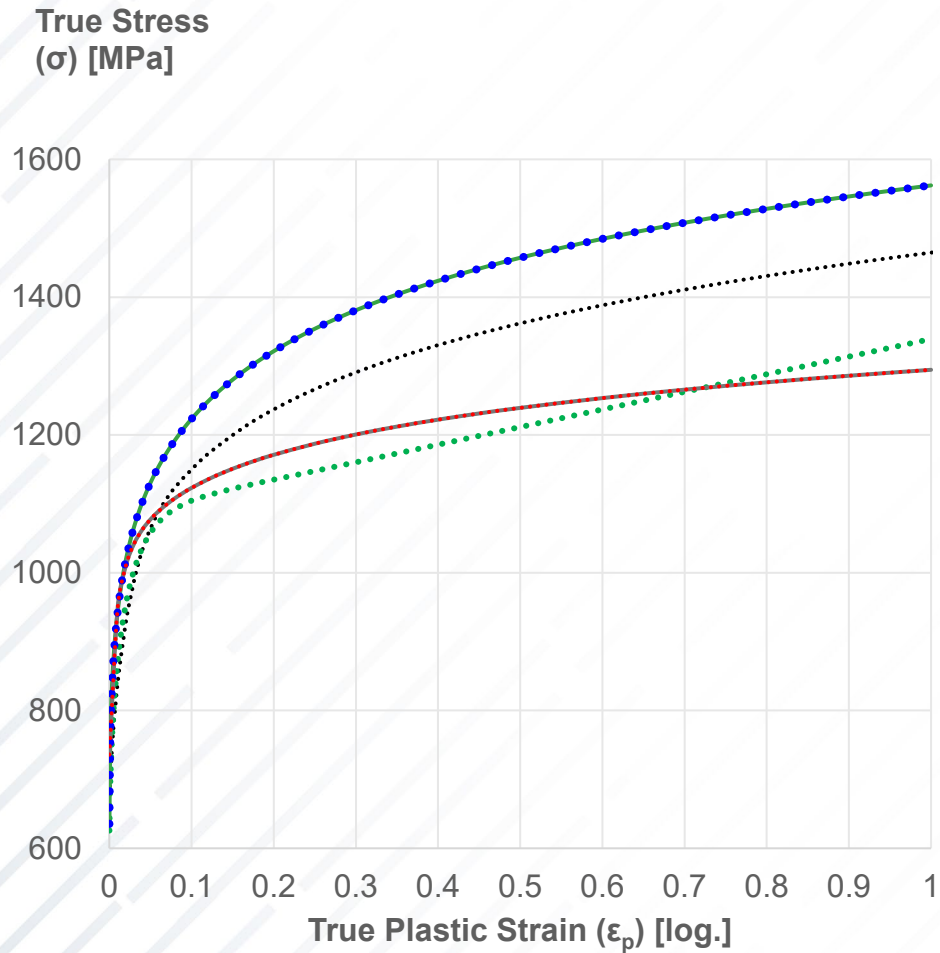
Two steel makers used Nakajima experiments, shifting the FLC_0 point to 0.03.

One steel maker used Abspoel-Scholting method.

Other two are either from equations or Marciniak experiments.

* One steel maker did not select thickness dependent FLC! Thickness information was not found in the card.

Comparison of generic cards – CR590Y980T-DP



4 steel makers were compared.

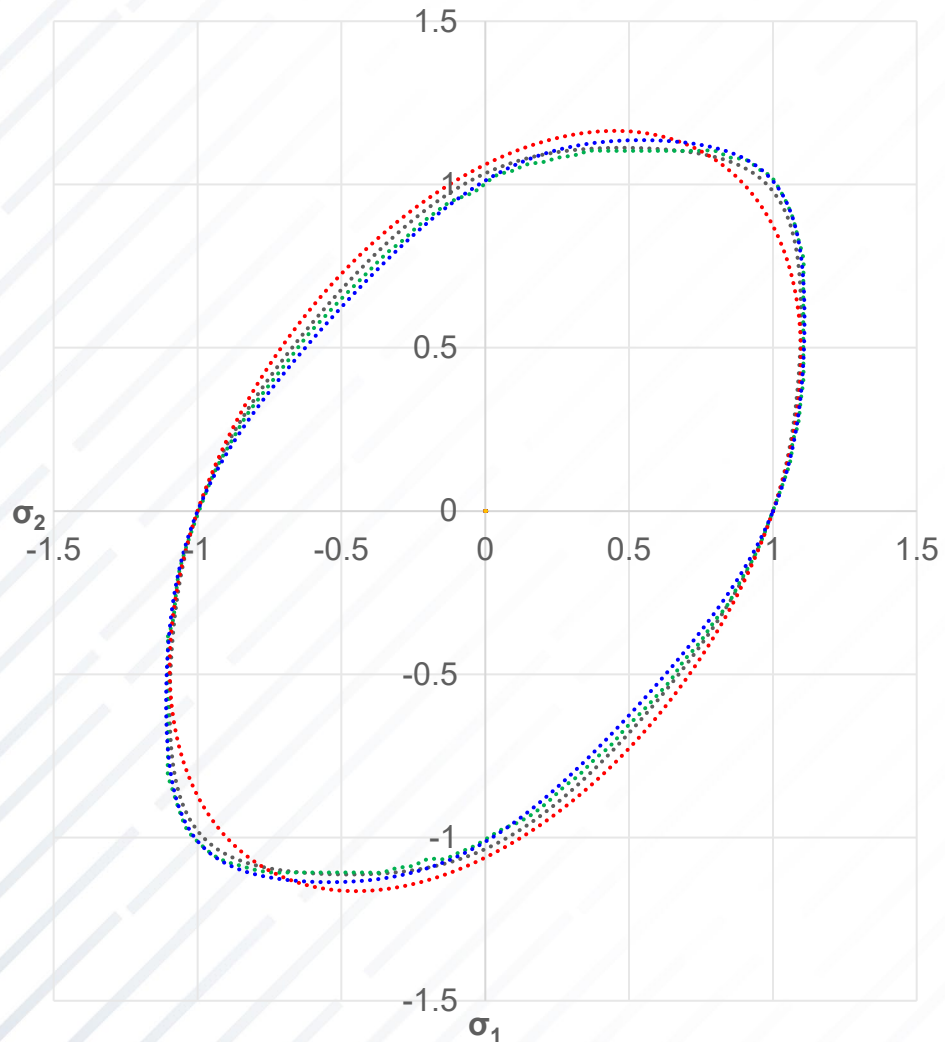
Yield strength varied 18%,
between 625 and 735 MPa.

True stress level at 0.2 plastic strain varied
1135-1321 MPa.

Three steel makers used tables, only one used
equation. One steel maker wrote clearly
how they extrapolated. Others had to be
reverse engineered.

All cards were made no later than 2018.

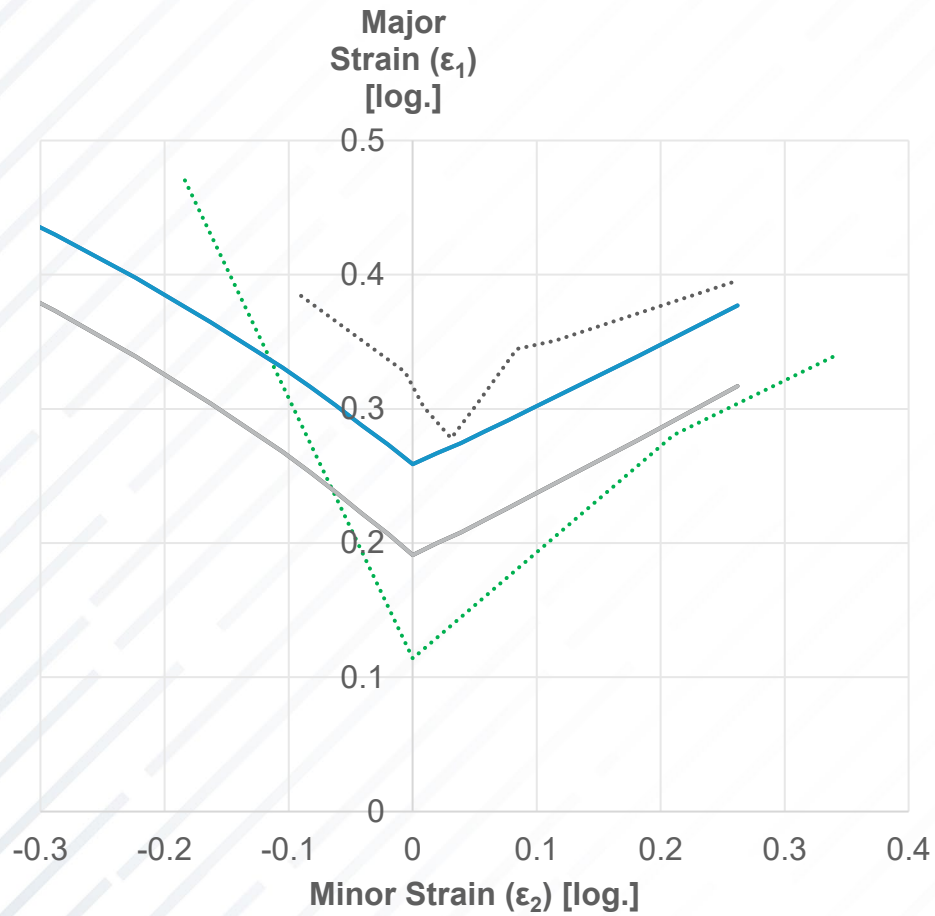
Comparison of generic cards – CR590Y980T-DP



1 card was written with Hill 1990,
2 were written with BBC 2005,
1 with Vegter Full.

BBC 2005 cards use 8 parameters, but only
one steel company used experimental biaxial
values. The other one used “From Barlat”.

Comparison of generic cards – CR590Y980T-DP



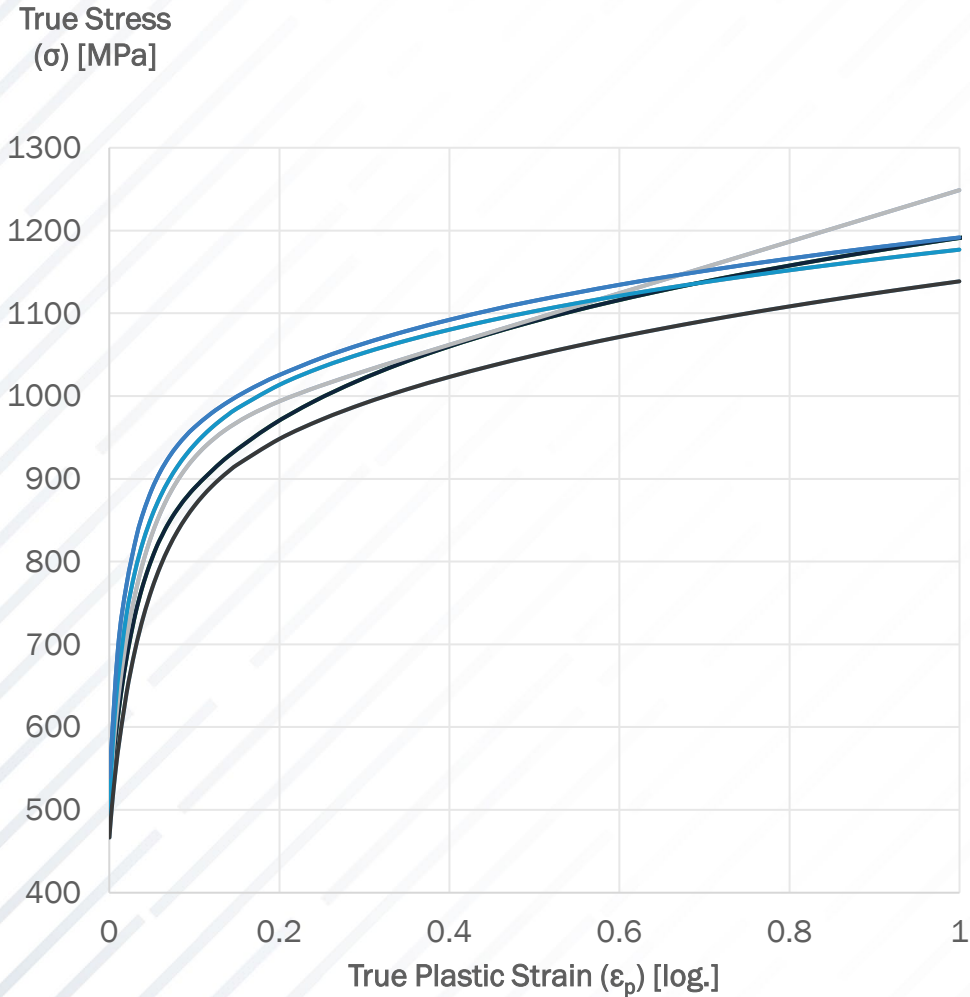
FLC's were shifted to 2 mm thickness for comparison purposes.

One steel maker used Nakajima experiments, shifting the FLC_0 point to 0.03.

One steel maker used Abspoel-Scholting method.

Other two are either from equations or Marciniak experiments.

Comparison of generic cards – CR440Y780T-DP



5 steel makers were compared.

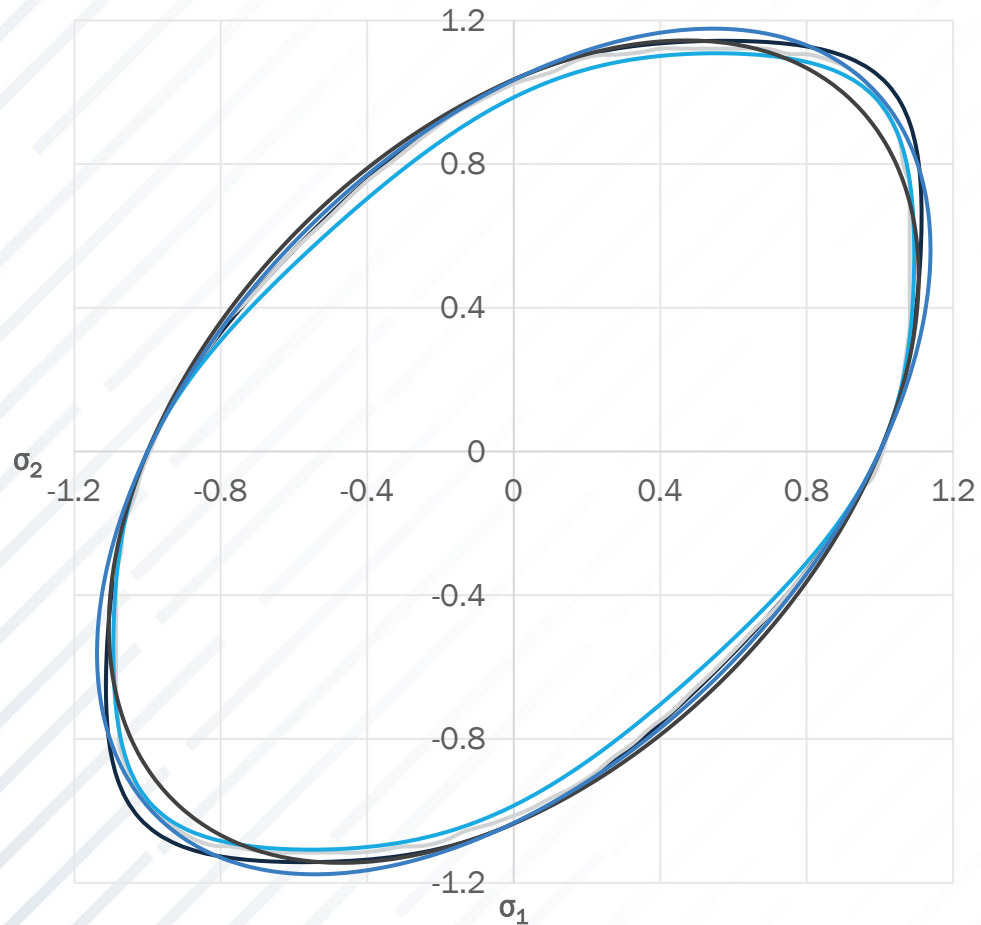
Yield strength varied 16%,
between 466 and 540 MPa.

True stress level at 0.2 plastic strain varied
948-1025 MPa.

Three steel makers used tables, two used
equations. One steel maker wrote clearly
how they extrapolated. Others had to be
reverse engineered.

Four cards were made in 2016, one was made
in 2022

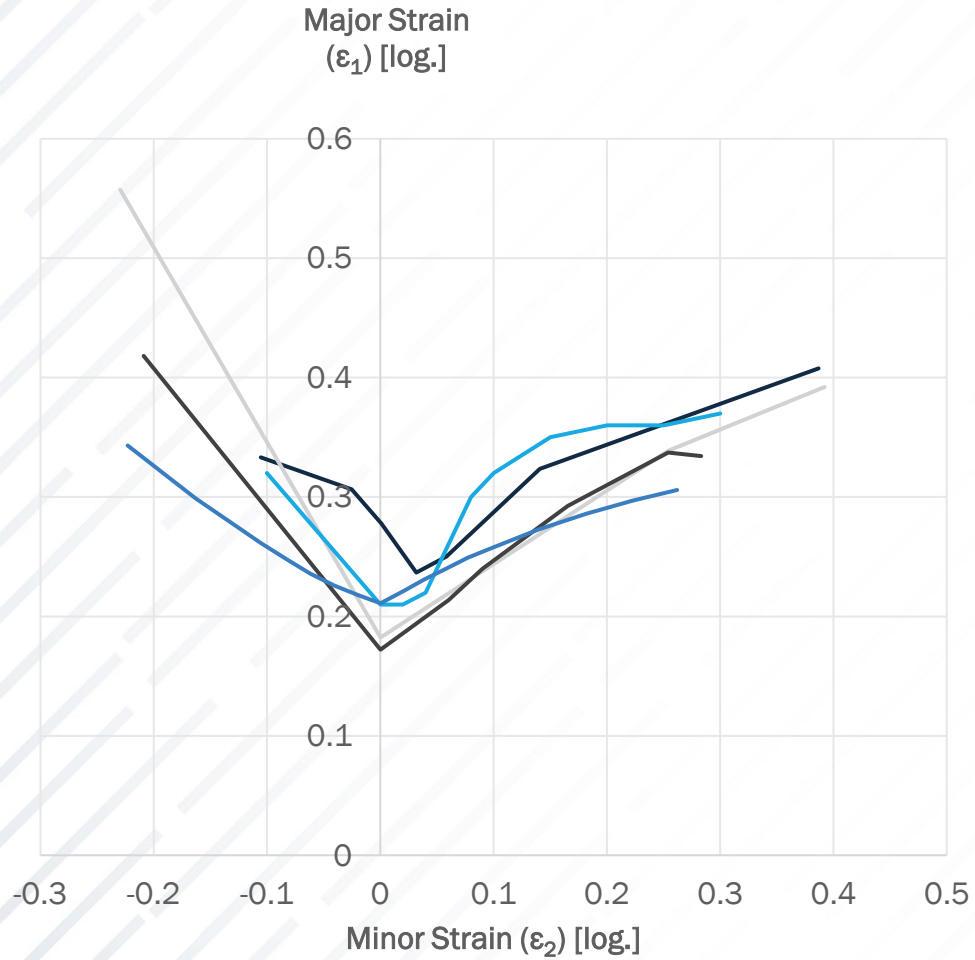
Comparison of generic cards – CR440Y780T-DP



1 card was written with Hill 1990,
2 were written with BBC 2005,
1 with Vegter Full.

BBC 2005 cards use 8 parameters, but only
one steel company used experimental biaxial
values. The other one used “From Barlat”.

Comparison of generic cards – CR440Y780T-DP



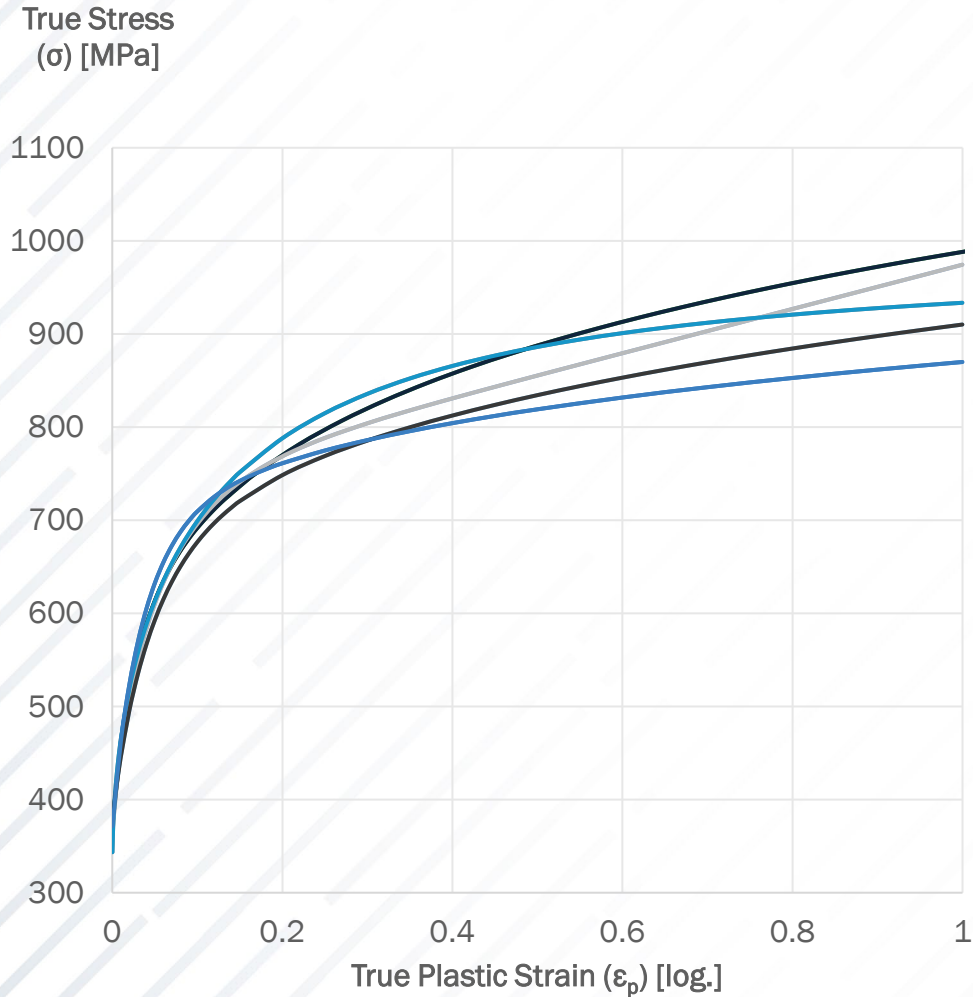
FLC's were shifted to 2 mm thickness for comparison purposes.

Two steel makers used Nakajima experiments, shifting the FLC_0 point to 0.03.

One steel maker used Abspoel-Scholting method.

Other two are either from equations or Marciniak experiments.

Comparison of generic cards – CR330Y590T-DP



5 steel makers were compared.

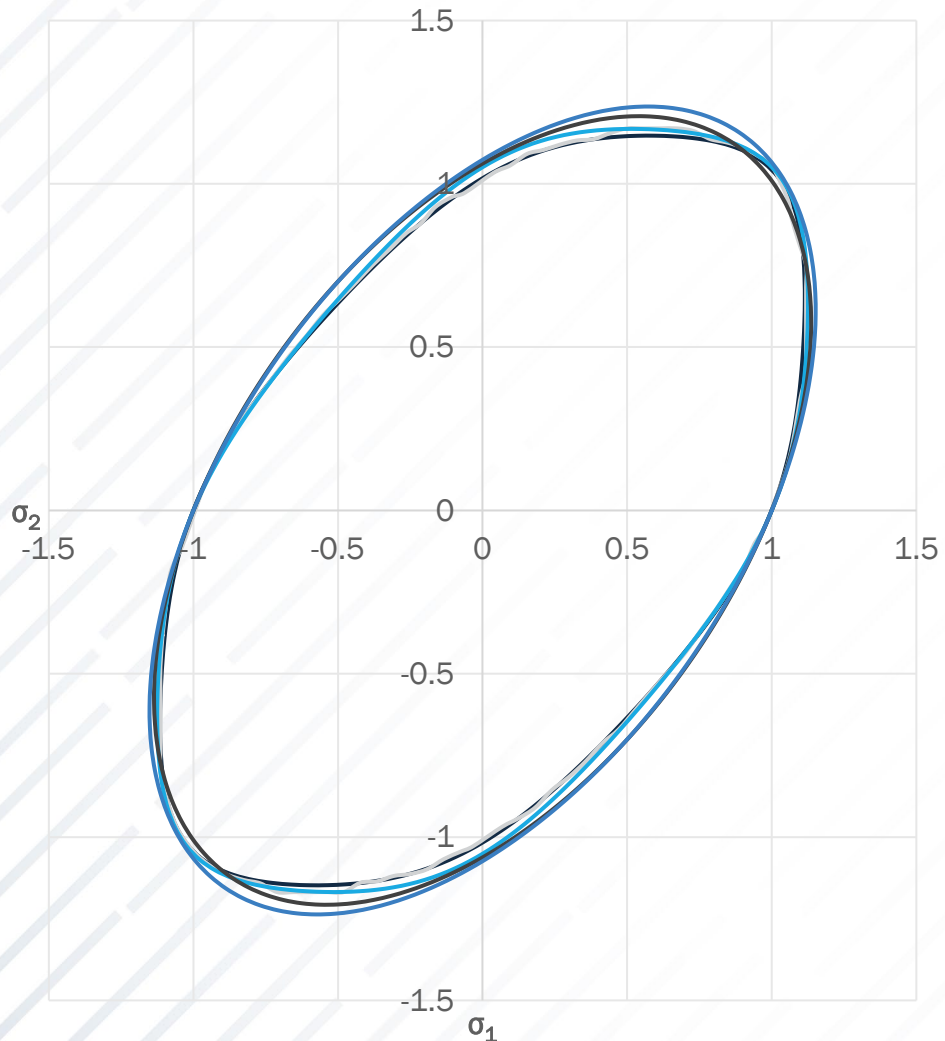
Yield strength varied 10%,
between 343 and 377 MPa.

True stress level at 0.2 plastic strain varied
748-788 MPa.

Three steel makers used tables, two used
equations. One steel maker wrote clearly
how they extrapolated. Others had to be
reverse engineered.

Four cards were made in 2016, one was made
in 2022

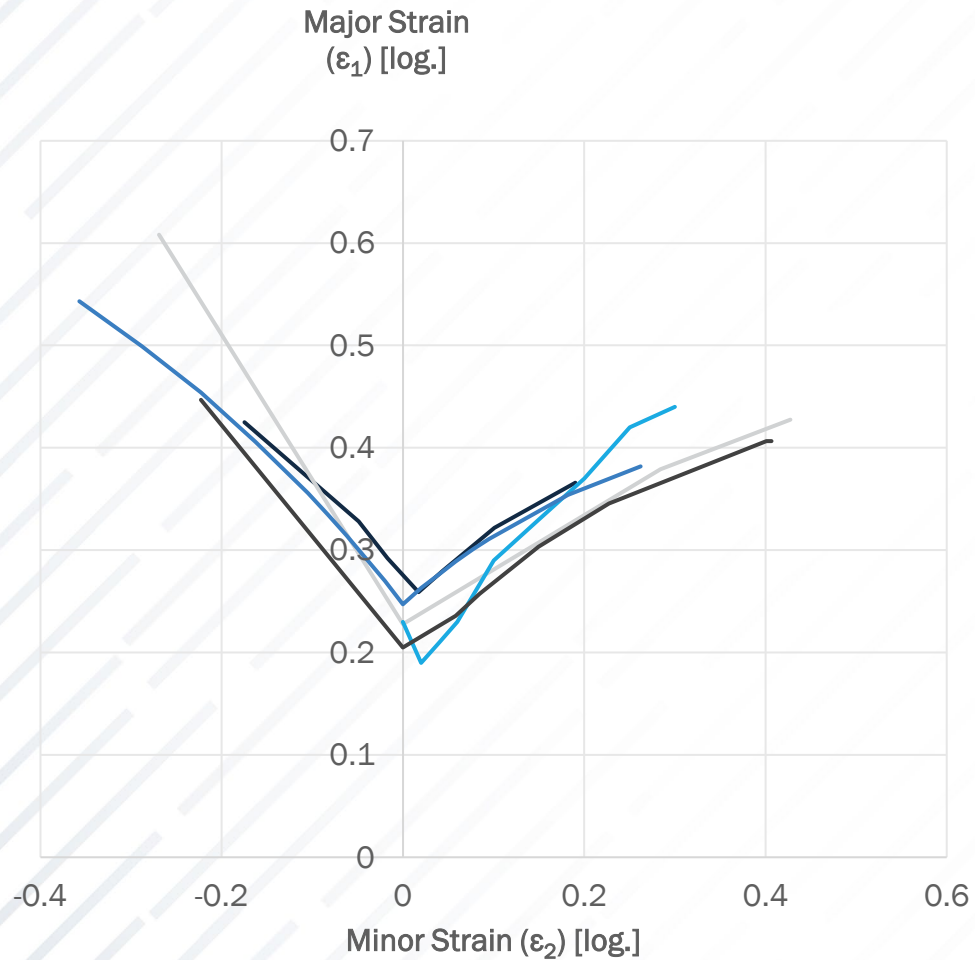
Comparison of generic cards – CR330Y590T-DP



1 card was written with Hill 1990,
2 were written with BBC 2005,
1 with Vegter Full.

BBC 2005 cards use 8 parameters, but only
one steel company used experimental biaxial
values. The other one used “From Barlat”.

Comparison of generic cards – CR330Y590T-DP



FLC's were shifted to 2 mm thickness for comparison purposes.

Two steel makers used Nakajima experiments, shifting the FLC_0 point to 0.03.

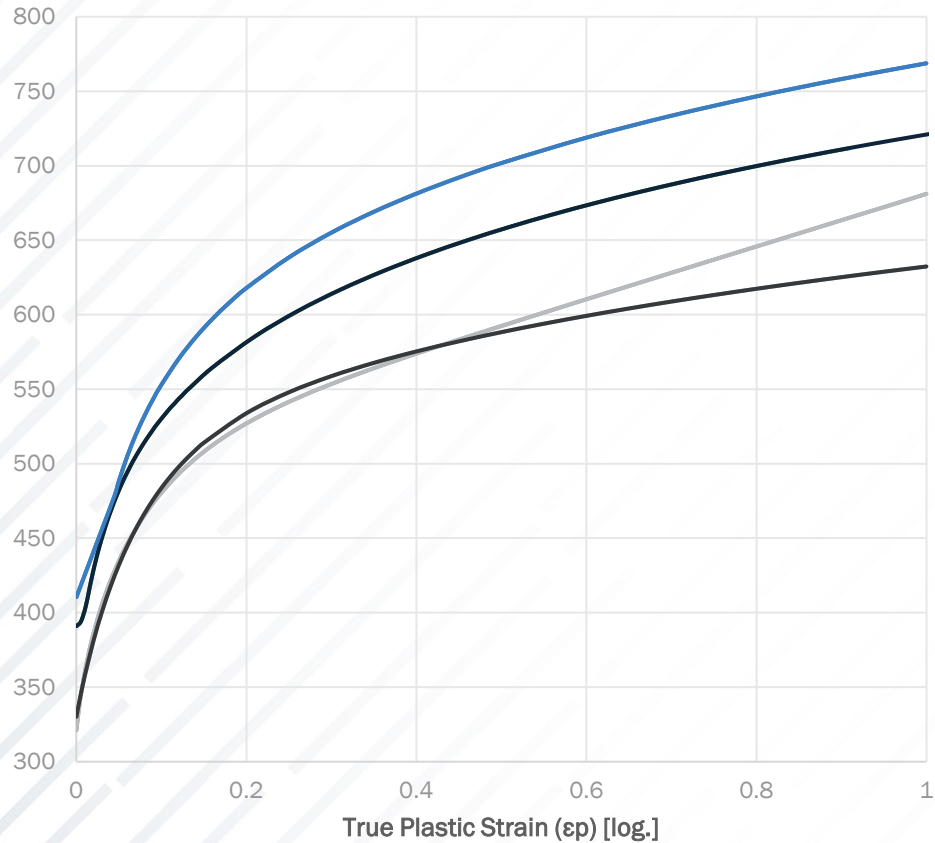
One steel maker used Abspoel-Scholting method.

Other two are either from equations or Marciniak experiments.

One steel maker had an experimental (Nakajima) FLC, only on the positive minor strain side.

Comparison of generic cards – CR340LA

True Stress (σ)
[MPa]



4 steel makers were compared.

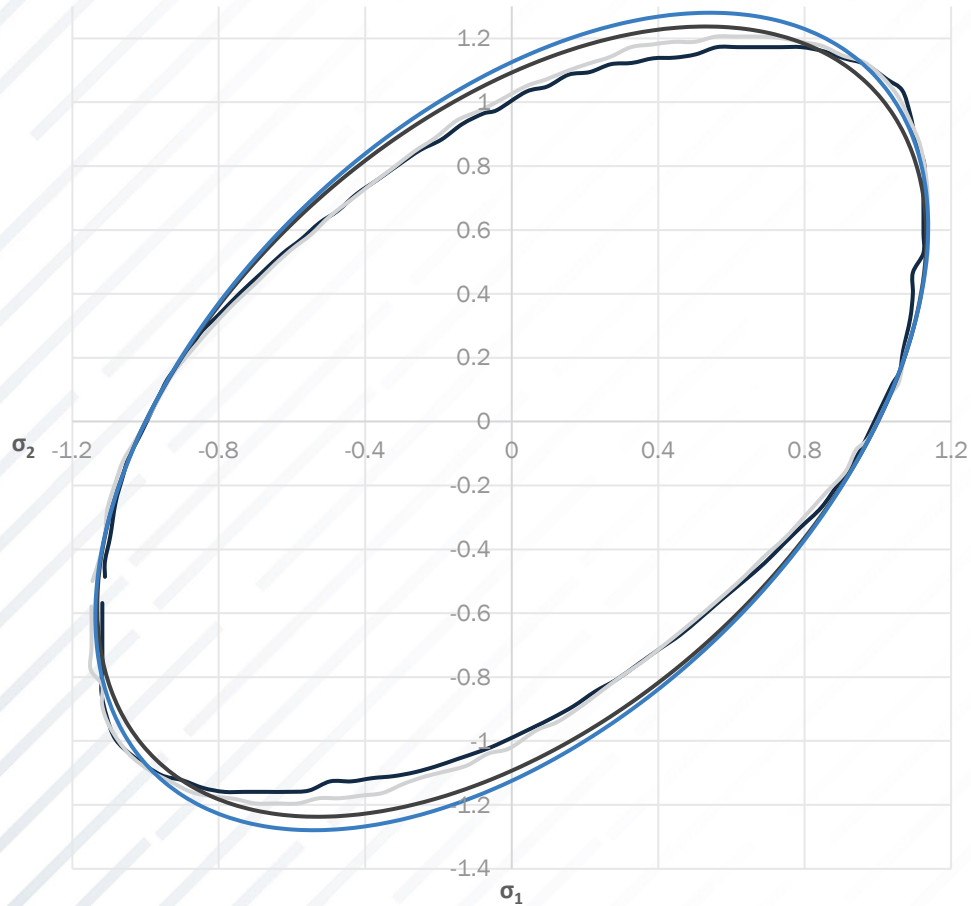
Yield strength varied 24%,
between 330 and 410 MPa.

True stress level at 0.2 plastic strain varied
527-618 MPa.

Three steel makers used tables, one used
equations. One steel maker wrote clearly
how they extrapolated. Others had to be
reverse engineered.

Three cards were made before 2018, one was
made in 2022

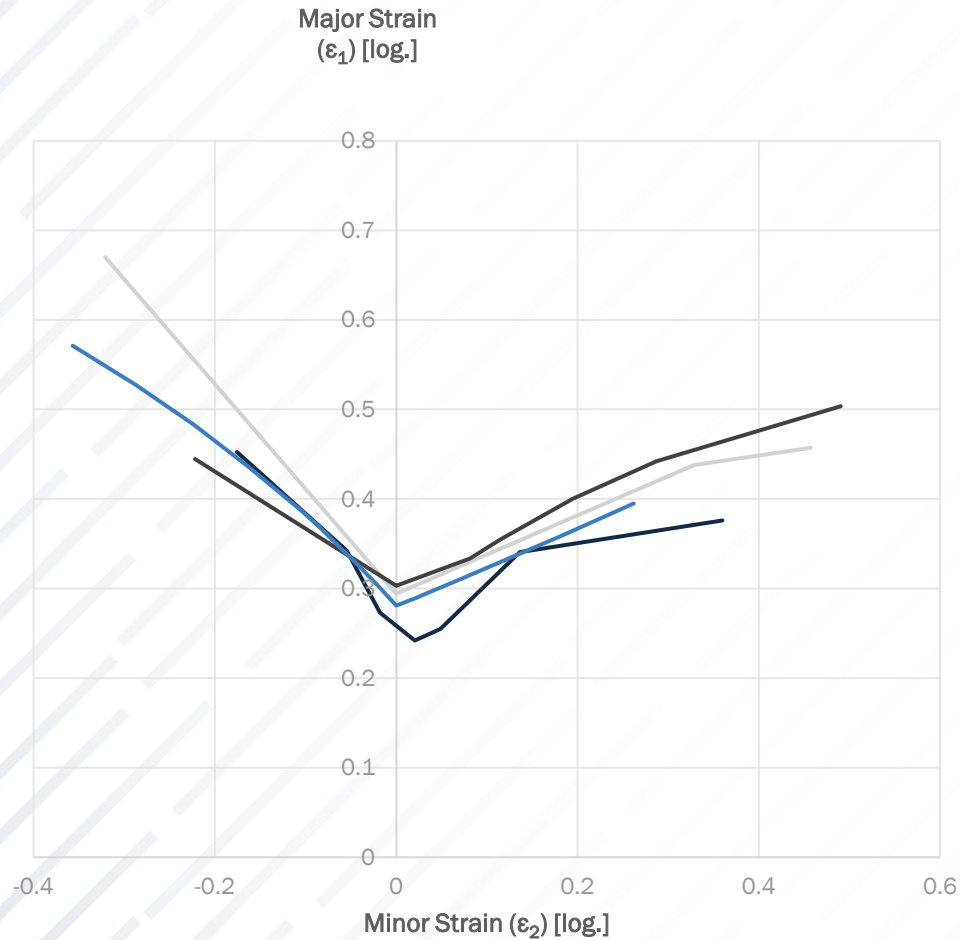
Comparison of generic cards – CR340LA



2 cards was written with Hill 1990,
1 was written with BBC 2005,
1 with Vegter Full.

BBC 2005 card uses 8 parameters, and has
experimental biaxial values.

Comparison of generic cards – CR340LA



FLC's were shifted to 2 mm thickness for comparison purposes.

One steel maker used Nakajima experiments, shifting the FLC_0 point to 0.03.

One steel maker used Abspoel-Scholting method.

Other two are either from equations or Marciniak experiments.

Observations: Variation comes from chosen card

Three 980 grades: 780/980-CP (4 suppliers), 700/980-DP (5), 590/980-DP (4)

- Yield strength varies between 12% (780/980-CP) to 22% (700/980-DP), representing a range of 100 MPa to 155 MPa
- True stress at 0.20 true plastic strain varies between 8% (700/980-DP) to 16% 590/980-DP, representing a range of 93 MPa to 186 MPa

780DP (5 suppliers), 590DP (5 suppliers) and 340LA (4 suppliers)

- Same trends and same magnitude of variability (340LA: 24% in YS, 17% in $\sigma(\epsilon_p=0.2)$)

No standard method exists that defines how material cards should be created

Some cards were developed using assumptions inappropriate for the particular grade

Most cards developed between 2016 and 2018 (one 2022 card for 780DP, 590DP, 340LA)

**Stamping tonnage, metal flow, and springback approximation
will be affected based on the chosen material card**

Future Work

- 1) Using same set of experimental tooling and simulation set-up, evaluate multiple cards to determine differences in predicting:
 - a) Thinning distribution
 - b) Draw-in
 - c) Press tonnage

- 2) Investigate methods for simpler, faster material card generation

For more information

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