GREAT DESIGNS IN STEEL™

GDIS Technical Webinar Series:

Next Generation CAE & Automotive Steel Developments Driven by Big DATA & A.I.

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President and Technical Manager

Material Insights

September 9, 2025

Towards Next Generation CAE & Automotive Steel Developments Driven by Big DATA & A.I.

GDIS Technical Webinar Series … Hosted by AISI

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09th September 2025

Thank you!

Acknowledgements

Material Insights

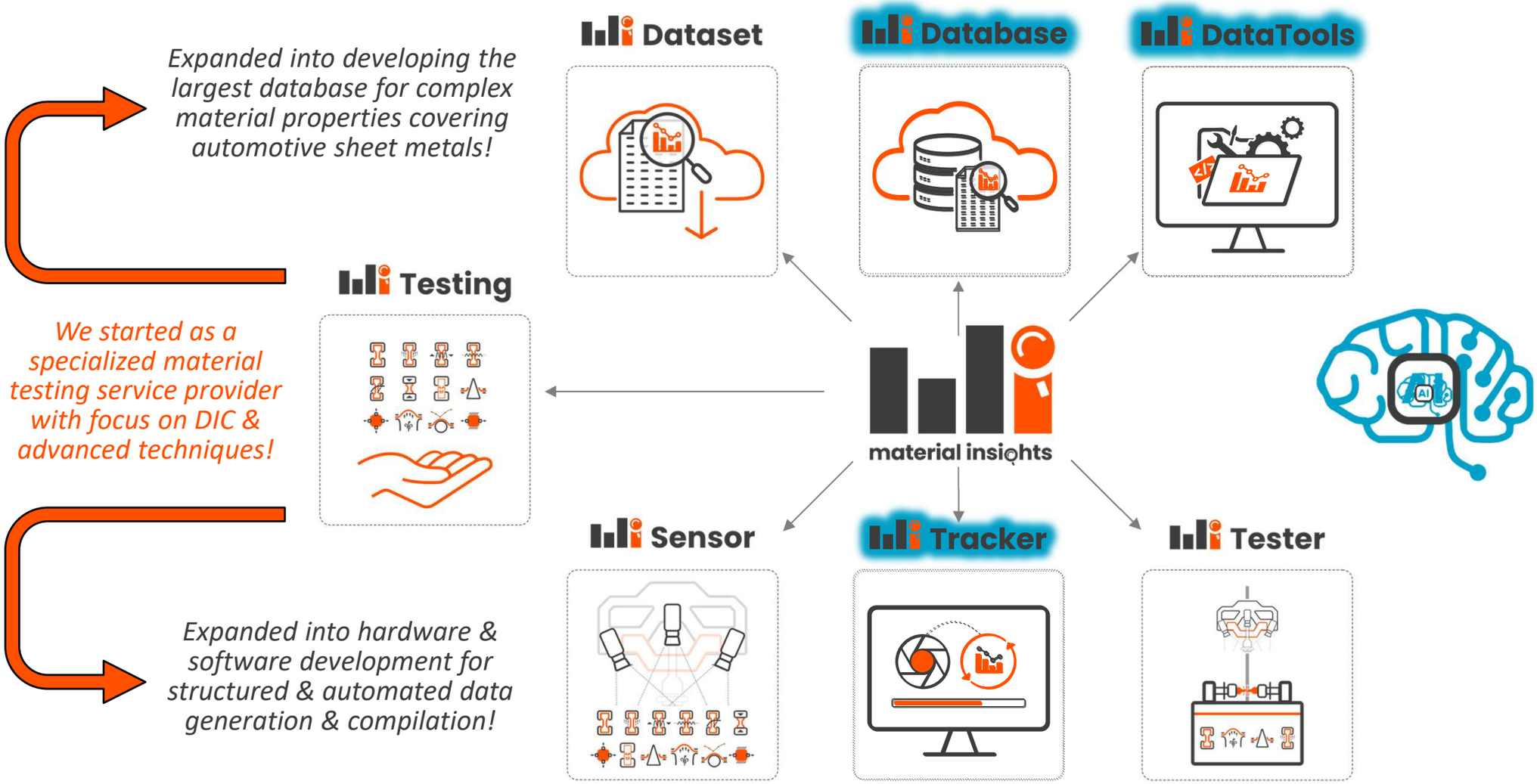
Who We Are … In One Slide!

*We are a "**Data-Centered Company**" that offers several products all cohesively integrated to provide access to high quality "material data" for … advanced characterization, streamlined qualification, efficient CAE, & optimized R&D.*

Expanded into developing the largest database for complex material properties covering automotive sheet metals!

We started as a specialized material testing service provider with focus on DIC & advanced techniques!

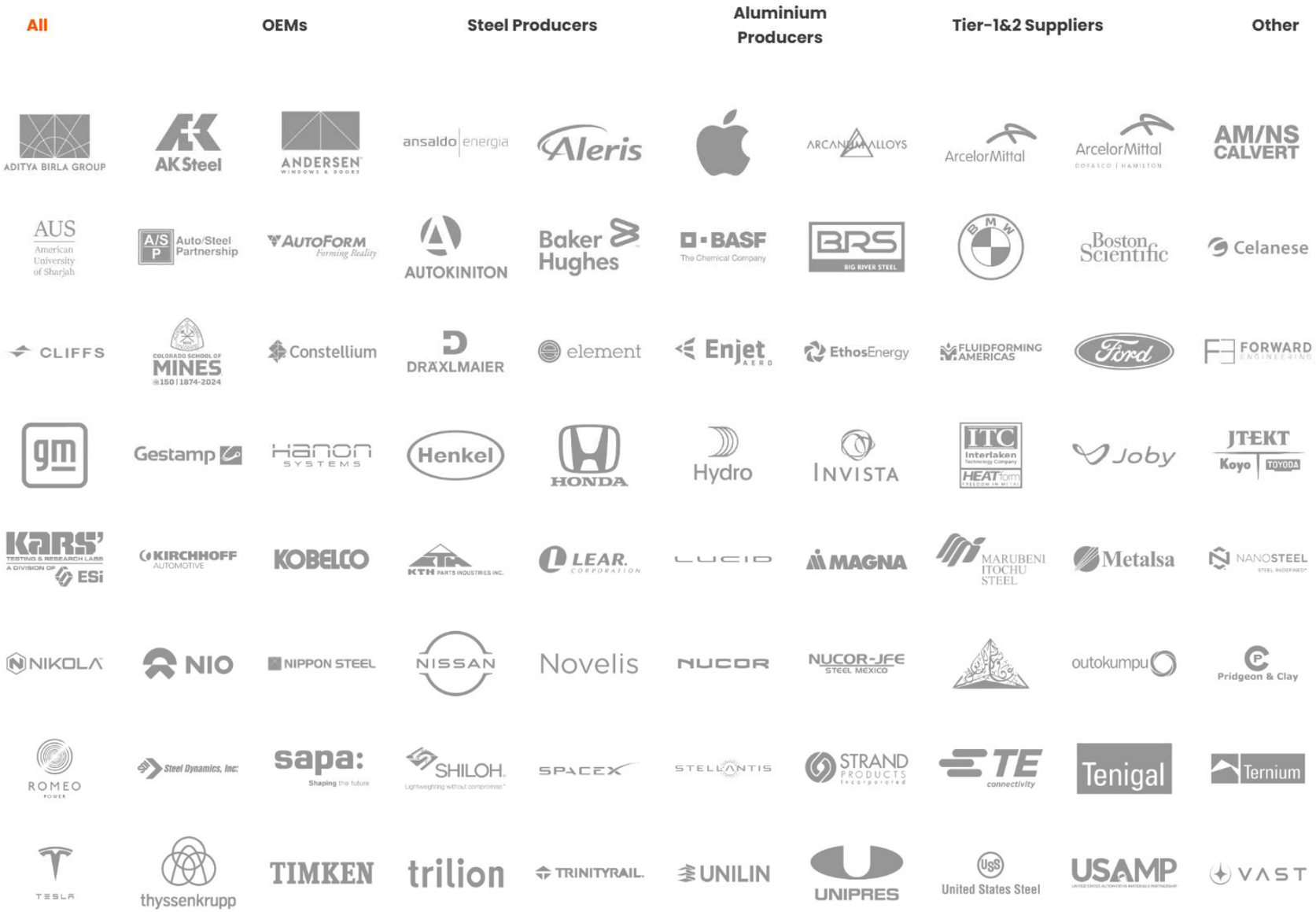
Expanded into hardware & software development for structured & automated data generation & compilation!



Material Insights
Our Clients

Strong "Automotive" focus …

This provides us with valuable feedback about the current issues and future needs of the industry …



Introduction

Technical Motivations (Extractions Based on the Needs of Clients)

Motivations

Material Data Needs & Challenges

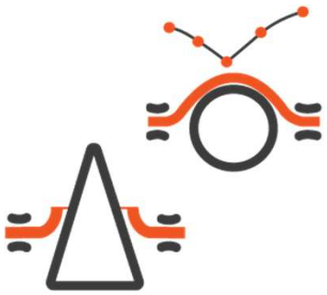
Material Testing … High Cost & Technical Complexity!

- *Regardless of the objective (qualification, spec. check, material selection, R&D), this is the general sentiment!*
- *Typical hierarchy of technical complexity and cost of testing …*

Simple Hardening

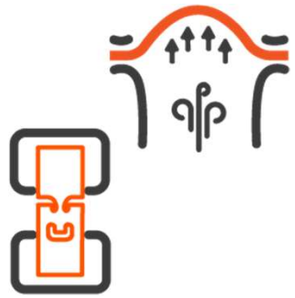
&

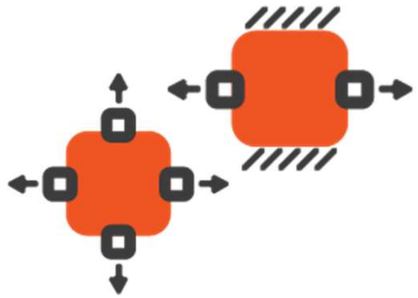
Anisotropy



Formability (Global, Local, Edge)

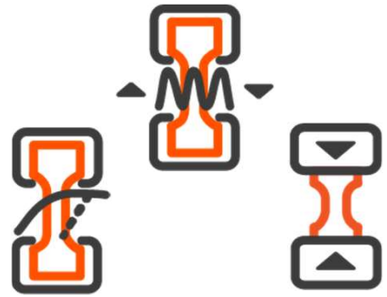
Complex Hardening & Anisotropy





Fracture & Strain Path Dependence

Springback & Kinematic Hardening



Strain Rate Sensitivity

Every lab should have

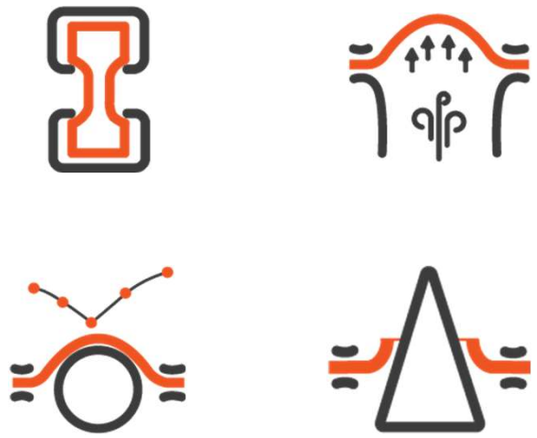
Some labs have
(not easily accessible)

Very technically demanding (rare)
(OEMs are pushing to suppliers)

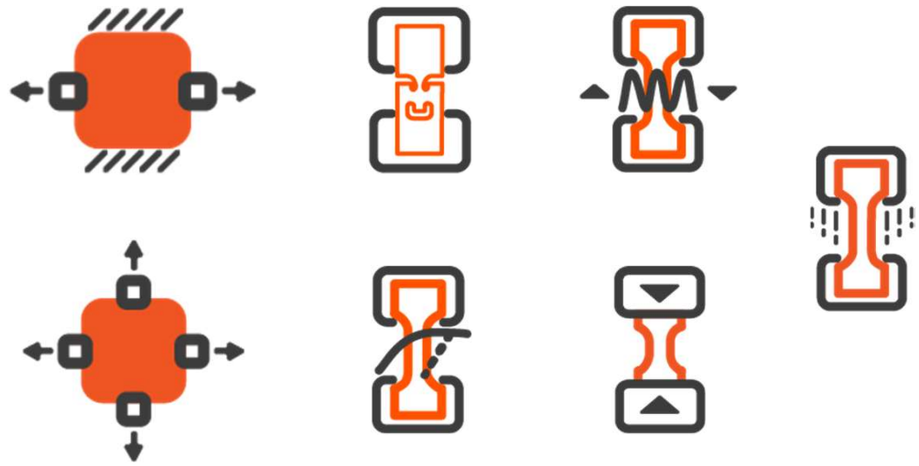
Motivations
Material Data Needs & Challenges

Material Testing … High Cost & Technical Complexity!

- *Regardless of the objective (qualification, spec. check, material selection, R&D), this is the general sentiment!*
- *Typical hierarchy of technical complexity and cost of testing …*



Standard Tests



Non-Standard Tests

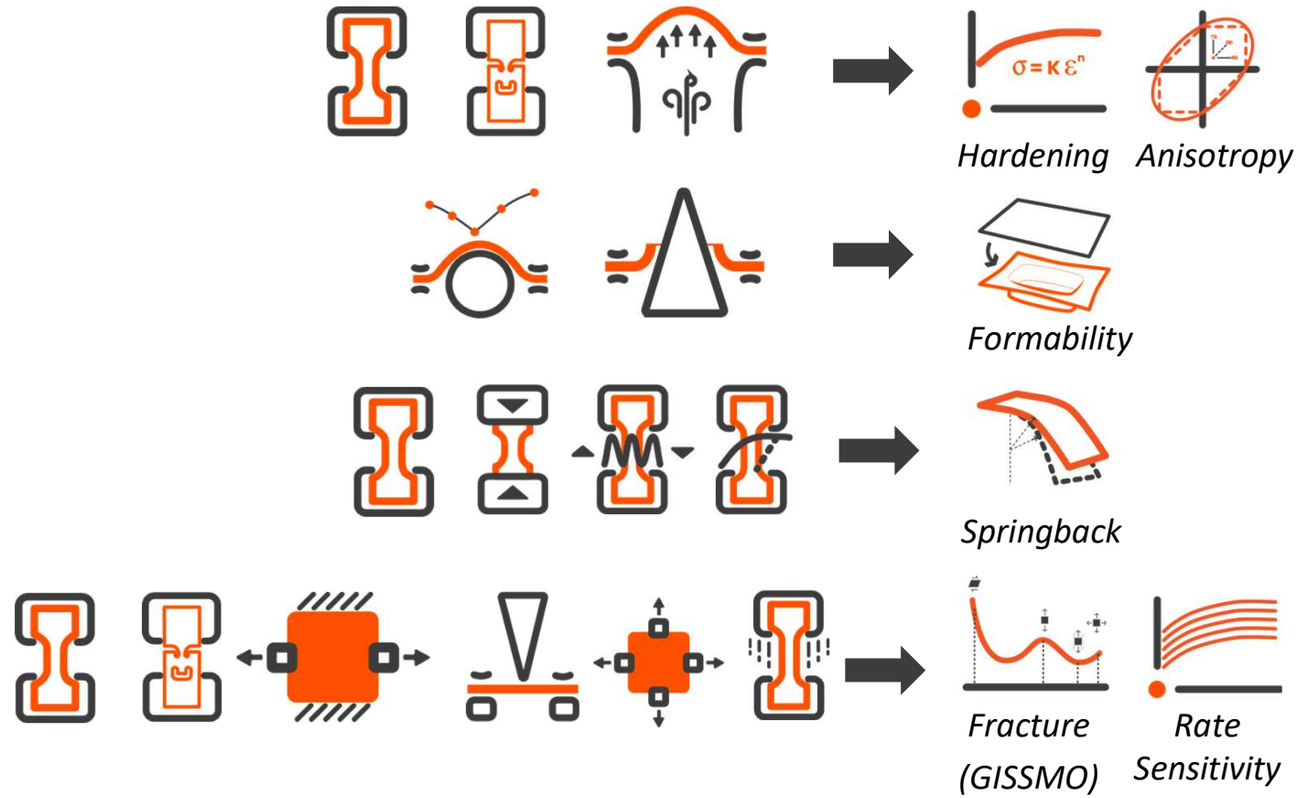
- ***Extraction: All organizations would like to do LESS material testing to save cost & time!***
- ***Extraction: Everyone wants to run a few simple tests and get a comprehensive evaluation of material response!***

Motivations

Material Data Needs & Challenges

Facilitating CAE Work … Extracting Parameters for FEA Material Cards!

- *After material testing, someone must take the data and extract FEA parameters to enable running CAE simulations!*
- *This is an expensive and time-consuming step!*
- *Most steel mills (and some suppliers) are not equipped to do this step… OEMs are pushing more of this to suppliers!*



- ***Extraction: All would like to "accelerate" the extraction of model parameters & generating Material Cards for CAE work!***
- ***Extraction: Would be nice to develop preliminary "Material Cards" for "exploratory CAE work" using simple "Data Inputs"!***

Motivations
Material Data Needs & Challenges

Material Qualification & Evaluation … and Development of New Steel Grades!

- *Steel mill provides samples … OEM or external lab performs testing to verify material meets specs or extract key outputs!*
- *This could be a long process …*
- *Sometimes materials pass tension testing but do not pass formability or fracture testing!*
- *This is critical for steel mills developing new grade offerings!*
- *This is even more critical for the development of **next-generation steel grades** (long cycles, limited lab heats)!*

- ***Extraction: Would be nice to have "consistent" data sets for different grades from different steel mills for comparison!***
- ***Extraction: Would be nice to have "reliable tools" for "preliminary" checks before significant investments!***
- ***Extraction: Is it possible to have intelligent tools that can "accelerate" material development efforts?***

Motivations
Material Data Needs & Challenges

Selected Scenarios …

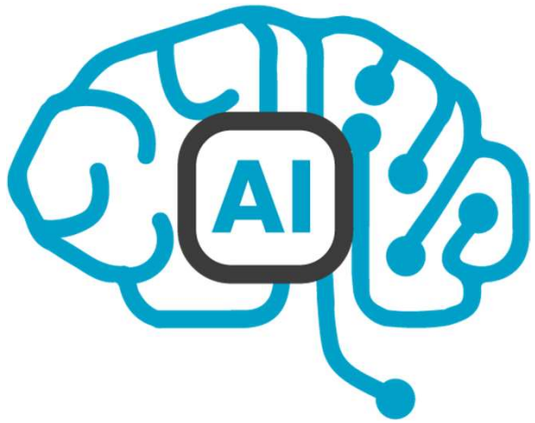
- *an OEM … would like to check how the MS#### steel grade received from X steel mill compares to DATA of the same grade but from many other diverse sources!*
- *an OEM … needs DATA for proper material selection … a selection that is not merely based on "uniaxial tension strength/ductility" but rather based on complex loading cases!*
- *a CAE Engineer … is exploring how replacing a DP### with 03rd Gen. Steel Grade ### would affect the crash response of a B-pillar!*
- *a Development Engineer … is exploring how replacing an HSLA part with a TRIP#### steel could affect springback simulations & die design and simply needs the right DATA to run a "proper" virtual study!*
- *a Metallurgist … is developing a TBF### grade and needs comprehensive DATA for multiple loading paths and test types for an equivalent grade to reference and compare to!*
- *a Metallurgist … is developing an AHSS## and needs accurate comprehensive DATA for many other Steel grades to overlay on top of and compare to!*
- *a Material Engineer at a Steel Mill … whose material is not passing OEM specs and needs DATA for an equivalent grade to identify where the issues with his/her production material are!*
- *a Graduate Student or a Researcher … needs detailed experimental DATA for different steel grades (no particular preference) in order to simply calibrate theoretical material models he/she is developing!*
- *And more …*

This Presentation
Overview

- *Interactions with different automotive OEMs, suppliers & steel producers motivated us to go into two non-conventional directions regarding the topic of “Material Data”:*

Database

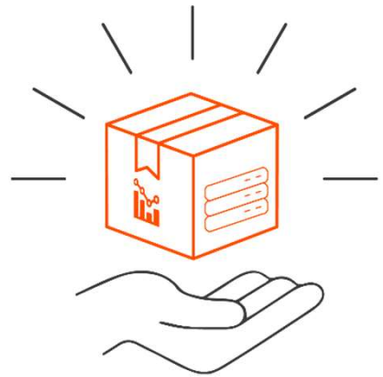
Big Data!



Artificial Intelligence

- *In this presentation, we provide you an overview of our efforts in these two directions and we show some results that highlight the new possibilities enabled with these approaches & tools!*

Database



Towards Solutions …

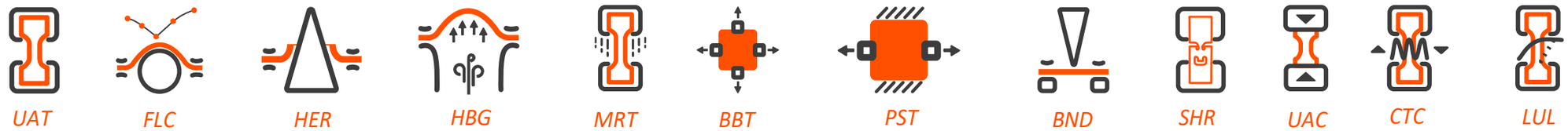
Big Data!

Big Data

Developing a Comprehensive Database of Automotive Steels

General Targets …

- *Cover all test types (loading conditions) per material or steel grade!*



- *Use optical tracking and digital image correlation (DIC) in each test type and maximize testing output!*

- *Cover parameters for all prominent FEA model & *Material Cards!*

- *Cover all automotive steel grades!*

  Mild Steels, High Speed Steels, 01st Gen. Advanced High Strength Steels & 03rd Gen. Advanced High Strength Steels

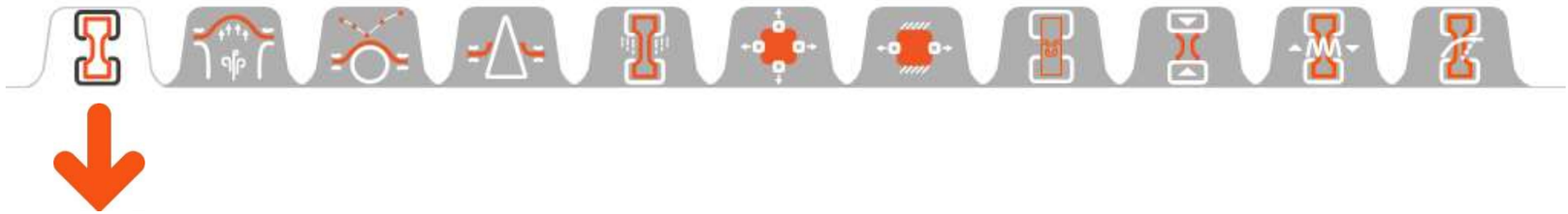
- *Cover multiple variations or flavors (thickness, coating, mill type & producer) of each automotive steel grade!*

- ***In a Nutshell: Generate the largest & most comprehensive R&D-level database for automotive steel grades!***

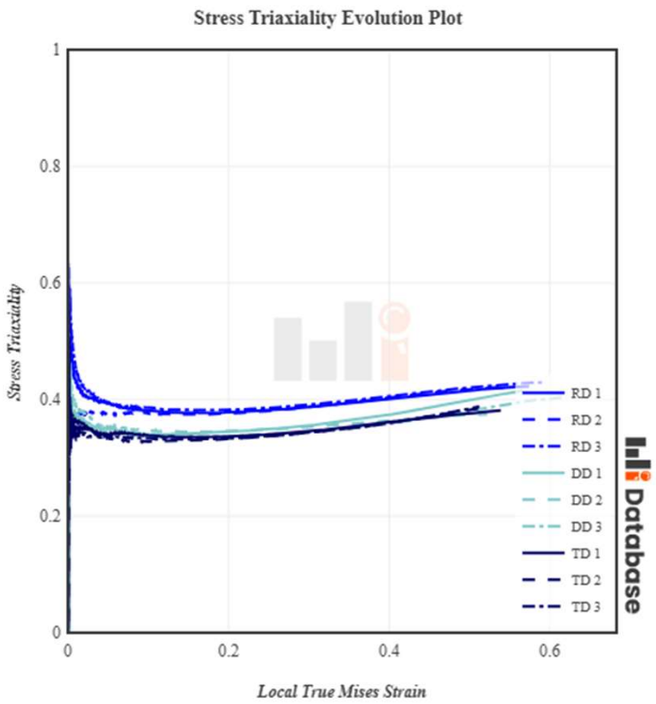
Big Data

Developing a Comprehensive Database of Automotive Steels

Example ... *Data Content*



Detailed Datasets (Curves)



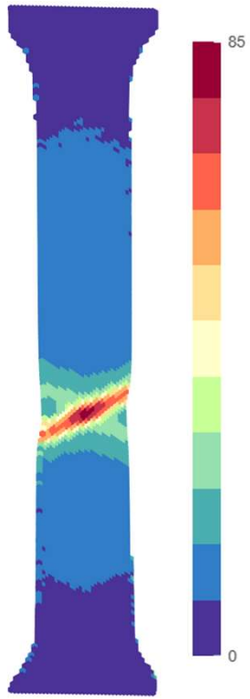
Extractions (Tabulated Data)

Fracture Strains (Local Strains Around Fracture Point)

COLUMNS Export

[2mm]			[1mm]			[0.5mm]		
Maj.	ε Min.	ε Eff.	ε Maj.	ε Min.	ε Eff.	ε Maj.	ε Min.	ε Eff.
540	-0.219	0.543	0.597	-0.218	0.605	0.594	-0.207	0.603
512	-0.199	0.516	0.571	-0.206	0.579	0.574	-0.194	0.583
550	-0.209	0.555	0.609	-0.214	0.618	0.607	-0.219	0.615
534	**-0.209**	**0.538**	**0.593**	**-0.213**	**0.601**	**0.591**	**-0.207**	**0.600**
020	**0.010**	**0.020**	**0.019**	**0.006**	**0.020**	**0.017**	**0.012**	**0.016**
533	-0.222	0.536	0.578	-0.213	0.585	0.577	-0.206	0.584
495	-0.235	0.496	0.551	-0.242	0.553	0.568	-0.244	0.569
599	-0.258	0.601	0.650	-0.250	0.656	0.642	-0.235	0.649
543	**-0.238**	**0.544**	**0.593**	**-0.235**	**0.598**	**0.595**	**-0.228**	**0.601**
052	**0.018**	**0.053**	**0.051**	**0.019**	**0.053**	**0.040**	**0.020**	**0.042**
515	-0.237	0.515	0.560	-0.256	0.561	0.552	-0.248	0.553
491	-0.223	0.491	0.523	-0.234	0.524	0.533	-0.238	0.534
497	-0.226	0.497	0.536	-0.229	0.538	0.530	-0.227	0.532
501	**-0.229**	**0.501**	**0.540**	**-0.239**	**0.541**	**0.538**	**-0.238**	**0.540**
012	**0.007**	**0.012**	**0.019**	**0.014**	**0.018**	**0.012**	**0.011**	**0.011**

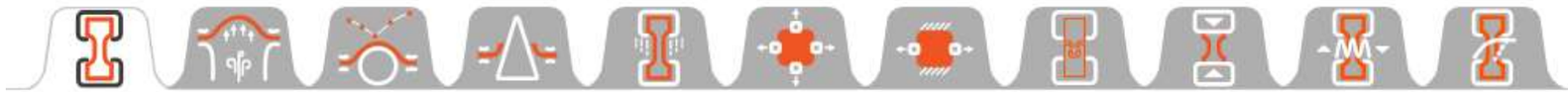
Digitized Surface Strain Maps



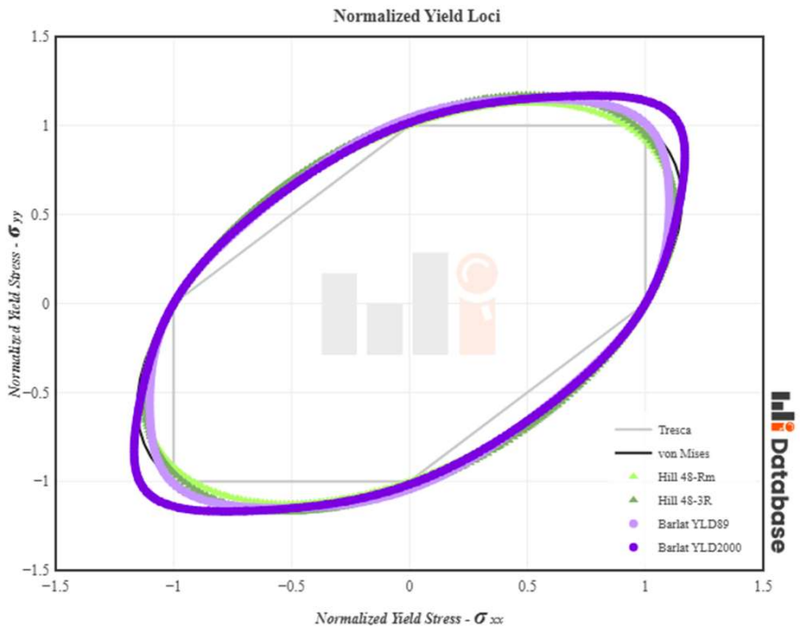
Big Data

Developing a Comprehensive Database of Automotive Steels

Example … *CAE Parameters*



FEA Outputs
(for Direct Feed into CAE Tools)



Hill 48-3R Model Parameters

COLUMNS Export

F	G	H	N
0.481	0.563	0.437	1.420

Anisotropy

Rate Sensitivity

Barlat YLD89 Model Parameters

COLUMNS Export

a	c	h	p
1.089	0.911	0.958	0.945

Forming

Fracture

Barlat YLD2000 Model Parameters

COLUMNS Export

α1	α2	α3	α4	α5	α6	α7	α8
0.898	1.004	0.869	0.965	0.977	0.758	0.952	1.112

Springback

Big Data

Developing a Comprehensive Database of Automotive Steels

Example … *DP980*

Big Data

Developing a Comprehensive Database of Automotive Steels

Example … *Steel Grades & Their Flavors!*

material insights

- Testing
- Sensor
- Tracker
- Database
- Resources
- Lab

Database

Access Off-The-Shelf R&D-Level Material DATA!

Overview

Tools

- mi Data-Maps
- mi Data-Visualizer
- mi Data-Comparator

Materials

- Automotive Steels
- Aluminium Alloys
- Titanium Alloys
- Magnesium Alloys
- Stainless Steels*

Requests

Automotive Steels

- Conventional Steels
- High Strength Steels
- 01st Gen. Adv. High Strength Steels (Mixed-Phases)
- 01st Gen. Adv. High Strength Steels (Martinsite-Dominant)
- 02nd Gen. Adv. High Strength Steels
- 03rd Gen. Adv. High Strength Steels

01st Gen. Adv. High Strength Steels (Mixed-Phases)

- Ferritic-Bainitic (FB) Steels
- Dual Phase (DP) Steels
- Complex Phase (CP) Steels
- Multi-Phase (MP) Steels
- Transformation-Induced Plasticity (TRIP) Steels

Dual Phase (DP) Steels

Cold Rolled

- (Free Sample)
- DP490
- DP590
- DP780
- DP980
- DP980-LY
- DP1180
- DP1270
- DP1470

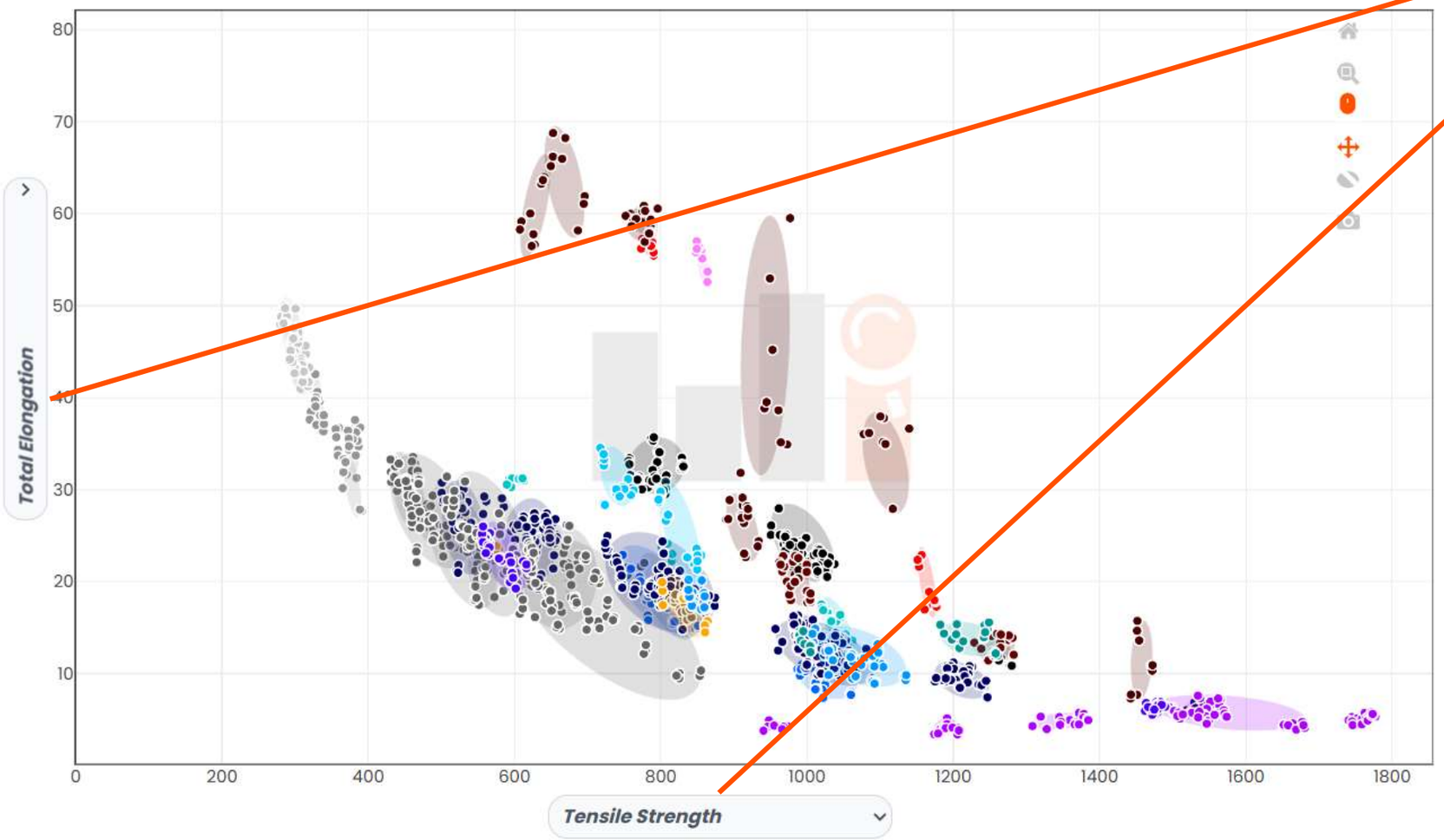
Hot Rolled

- DP580-HR
- DP780-HR

Big Data

Facilitating Next Generation CAE & Steel Developments

Big data allows us to move from simple "Banana Charts" to rich "Data Maps" …



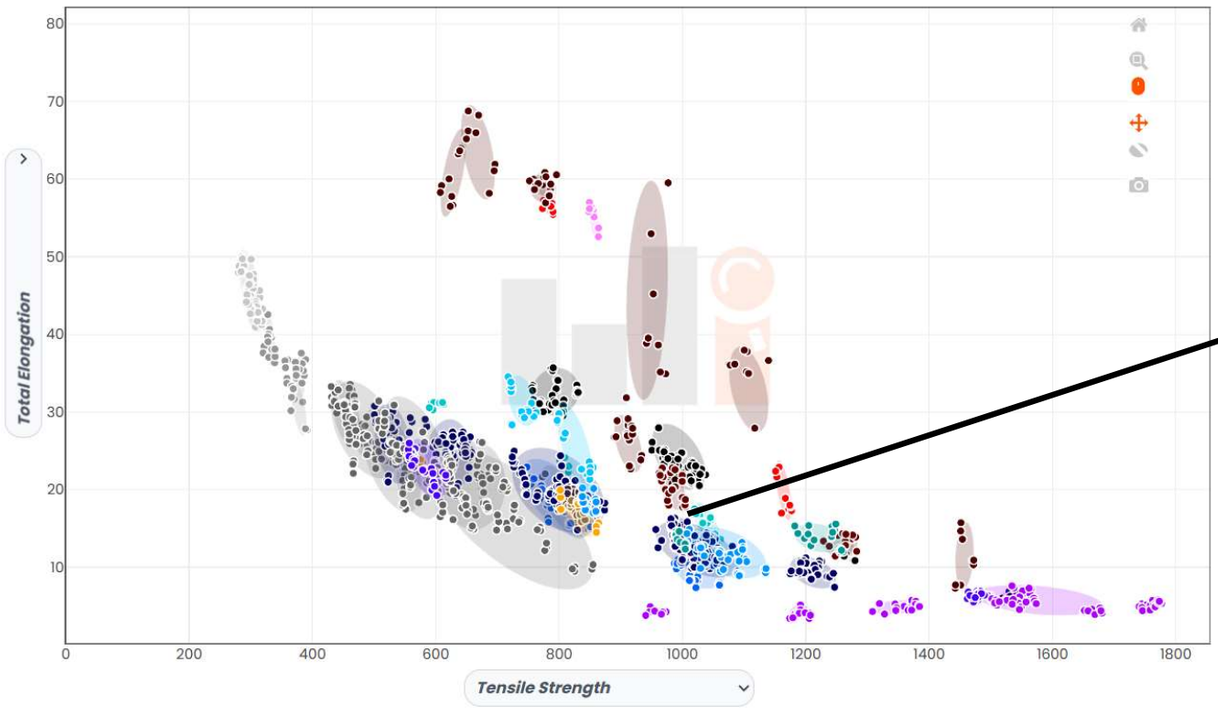
Yield Strength
Tensile Strength
Uniform Elongation
Total Elongation
n-Value
R-Value
Tensile Total Toughness
Tensile Fracture Strain
Uniform/Total Ductility
Post Uniform/Total Ductility
Post Uniform/Uniform Ductility
Fracture/Uniform Ductility
Fracture/Total Ductility

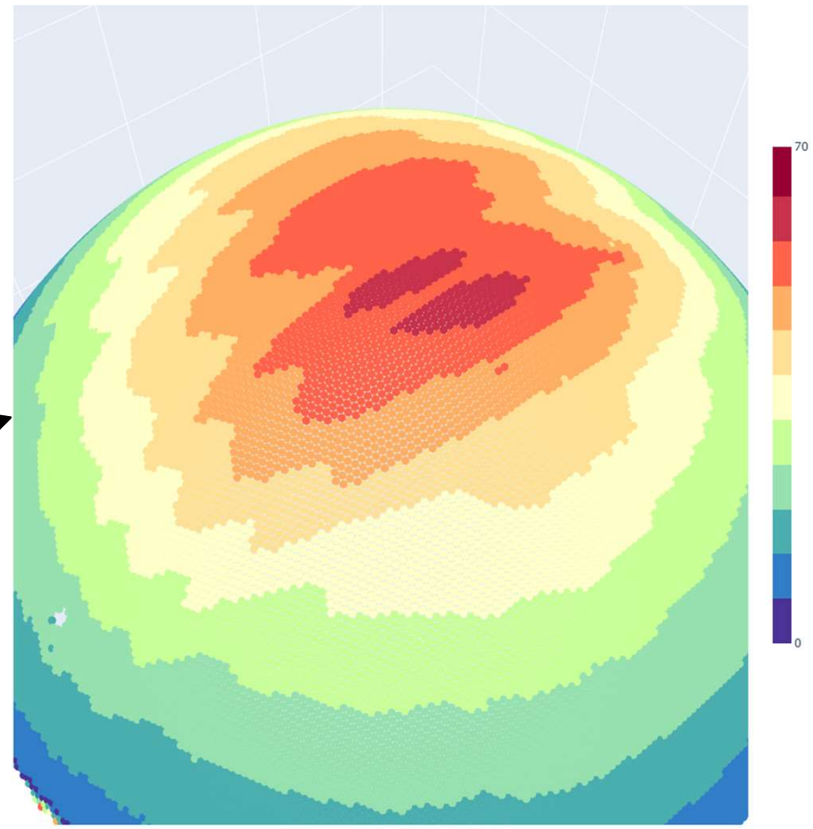
HER Value – 0min Hold
HER Value – 240min Hold
FLC0 – Section Method
FLC0 – LBF Method
Compressive Yield Strength
UAC/UAT Yield Strength
Shear Yield Strength
SHR/UAT Yield Strength
Biaxial Yield Strength
BBT/UAT Yield Strength
Shear Fracture Strain
PST Fracture Strain
Biaxial Fracture Strain
Biaxial Total Toughness

Big Data

Facilitating Next Generation CAE & Steel Developments

Big data allows us to move from rich "Data Maps" to detailed "Datasets" …





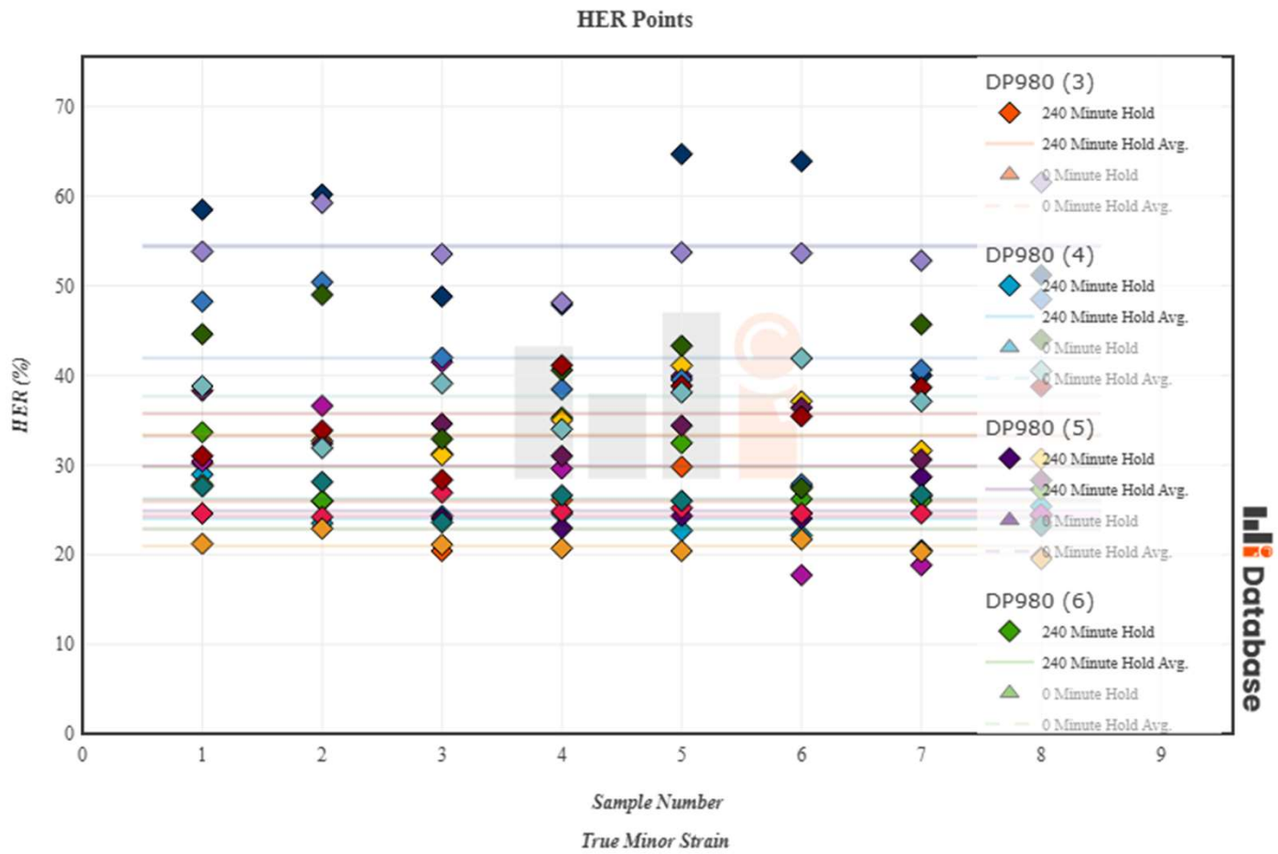
Big Data

Facilitating Next Generation Steel Developments

Qualification, evaluation and development of steel grades becomes faster & more effective!

- *Rich comparisons … accessing data for similar steel grades by various mills!*
- *Proper comparisons … consideration of all loading cases beyond classic "Uniaxial Tension"!*
- *Reducing evaluation cycles!*
- *Filtering based on thickness, coating & mill type!*
- *Mini-mills vs integrated mills!*
- *Green steels!*

980MPa Steels!



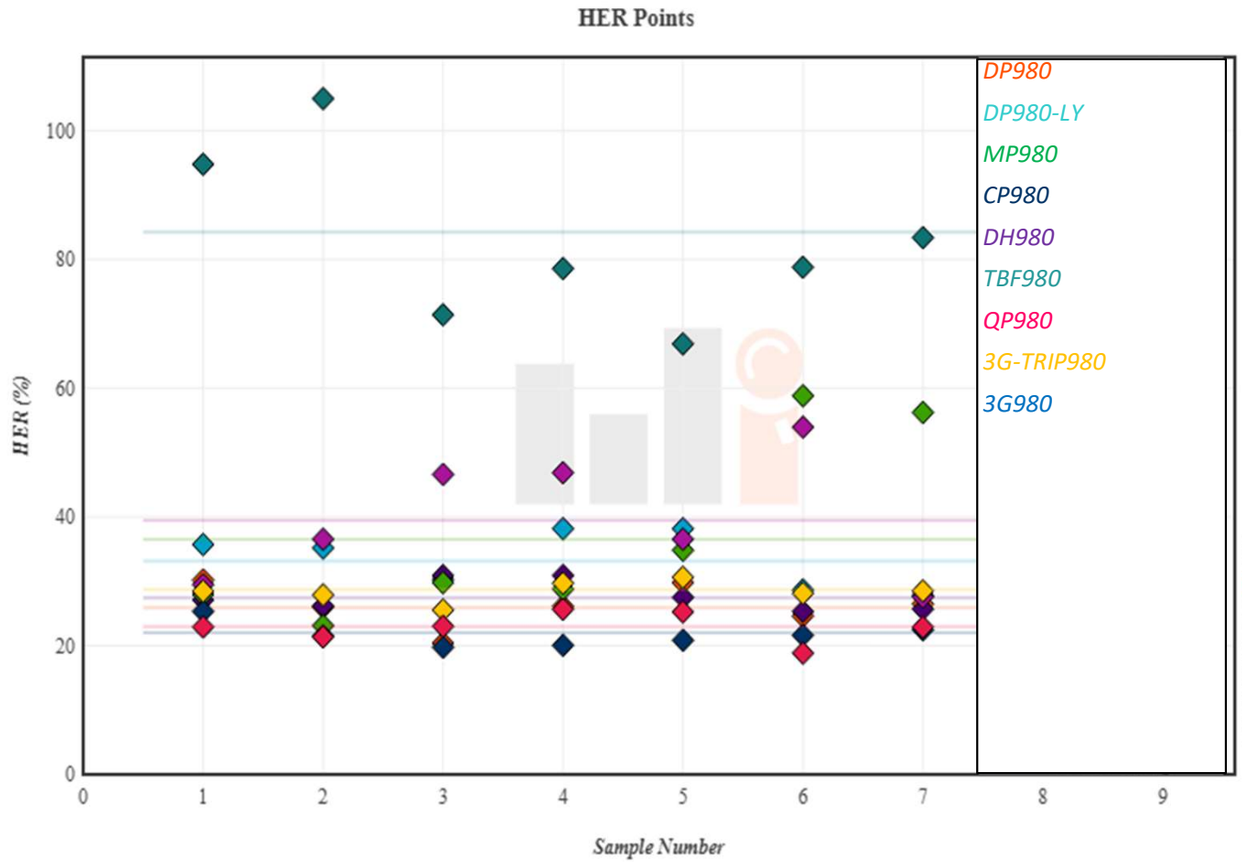
Big Data

Facilitating Next Generation Steel Deployment & CAE Efforts

Considering replacement steel grades for CAE work becomes faster & more efficient!

- *Rich comparisons and proper screening of materials … accessing data for wide ranging steel grades!*
- *Proper comparisons & material selection … consideration of all loading cases!*

Courtesy of Volvo



Big Data

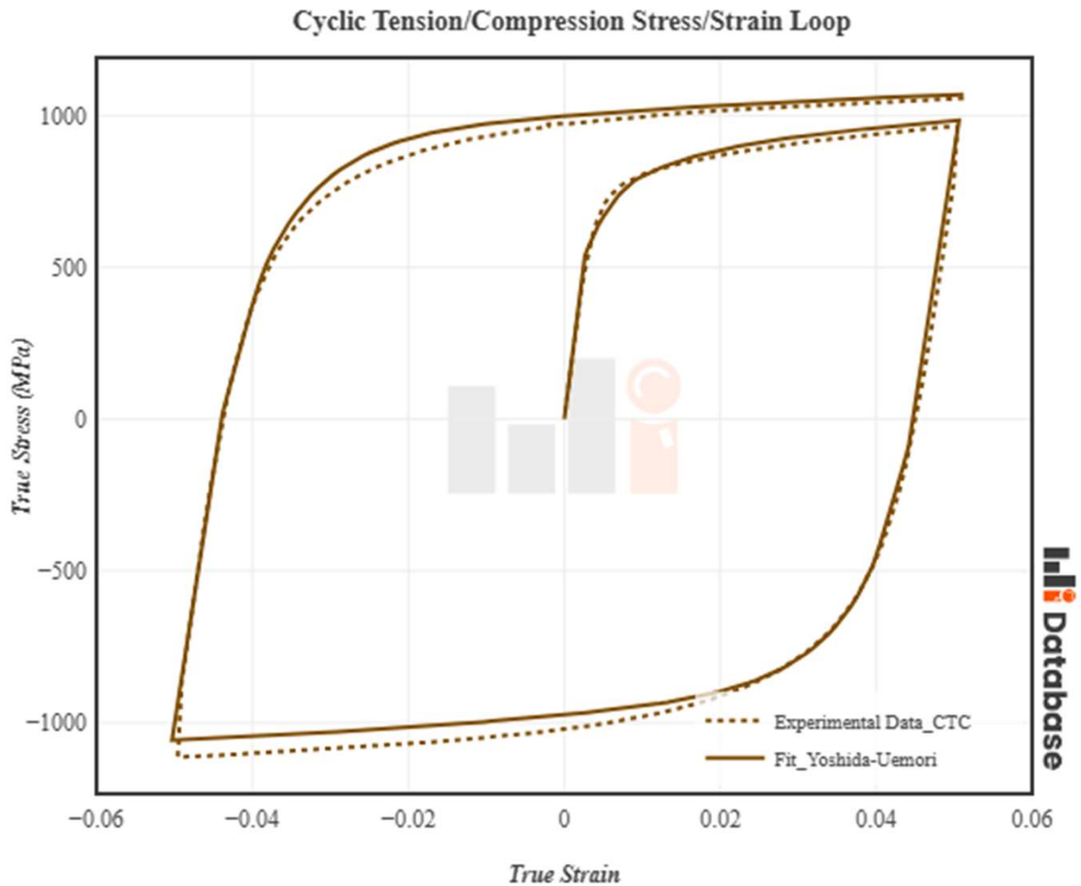
Facilitating Next Generation Steel Deployment & CAE Efforts

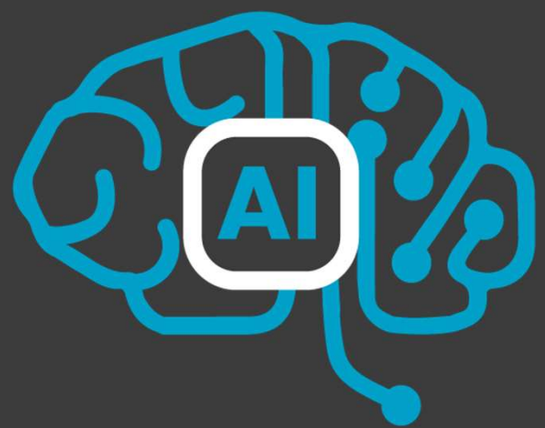
Considering replacement steel grades for CAE work becomes faster & more efficient!

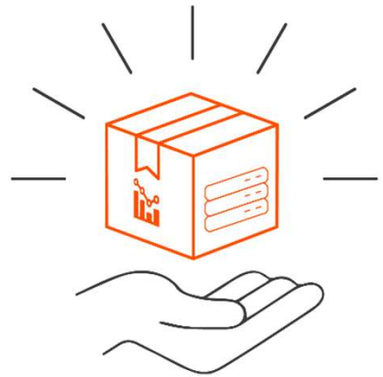
- *Rich comparisons and proper screening of materials … accessing data for wide ranging steel grades!*
- *Proper comparisons & material selection … consideration of all loading cases!*
- *Consideration of relevant CAE data (forming, crash, etc.)*
- *Reducing cost (characterization/modeling)*
- *Reducing design & development cycles!*
- *Targeted (faster & smarter) CAE efforts!*
- ***Refined Material Specifications by OEMs!***

Courtesy of Volvo

Select 3G-TRIP980 Steel for instance … run preliminary FE simulations!







Towards Solutions …

Artificial Intelligence!

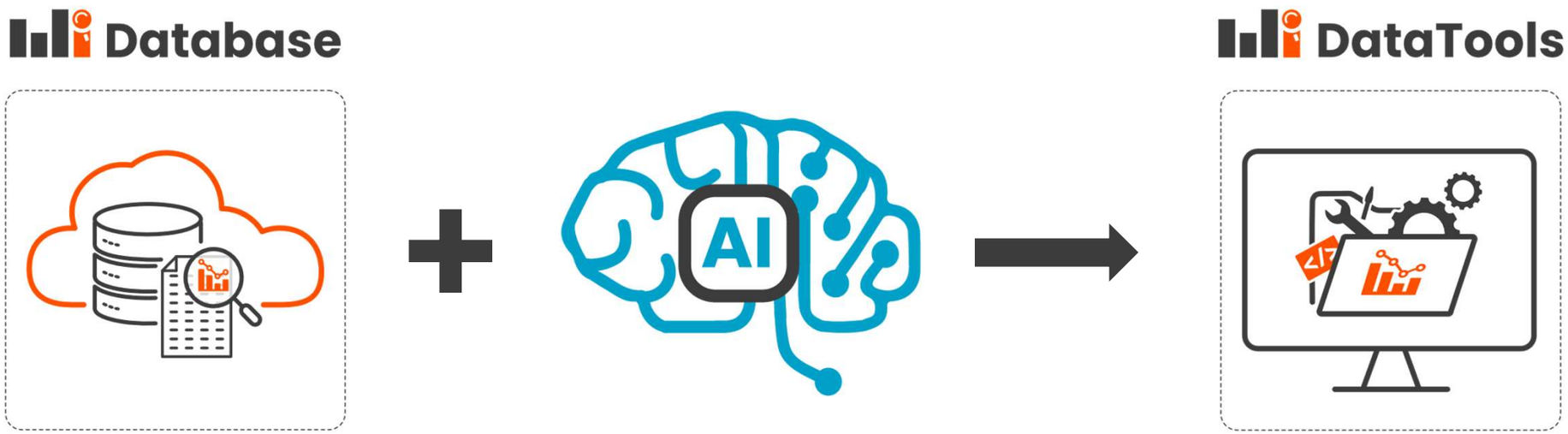
Artificial Intelligence

Developing Smart Tools to Facilitate Next Gen. Automotive Steels & CAE Efforts

General Objective & Approach …

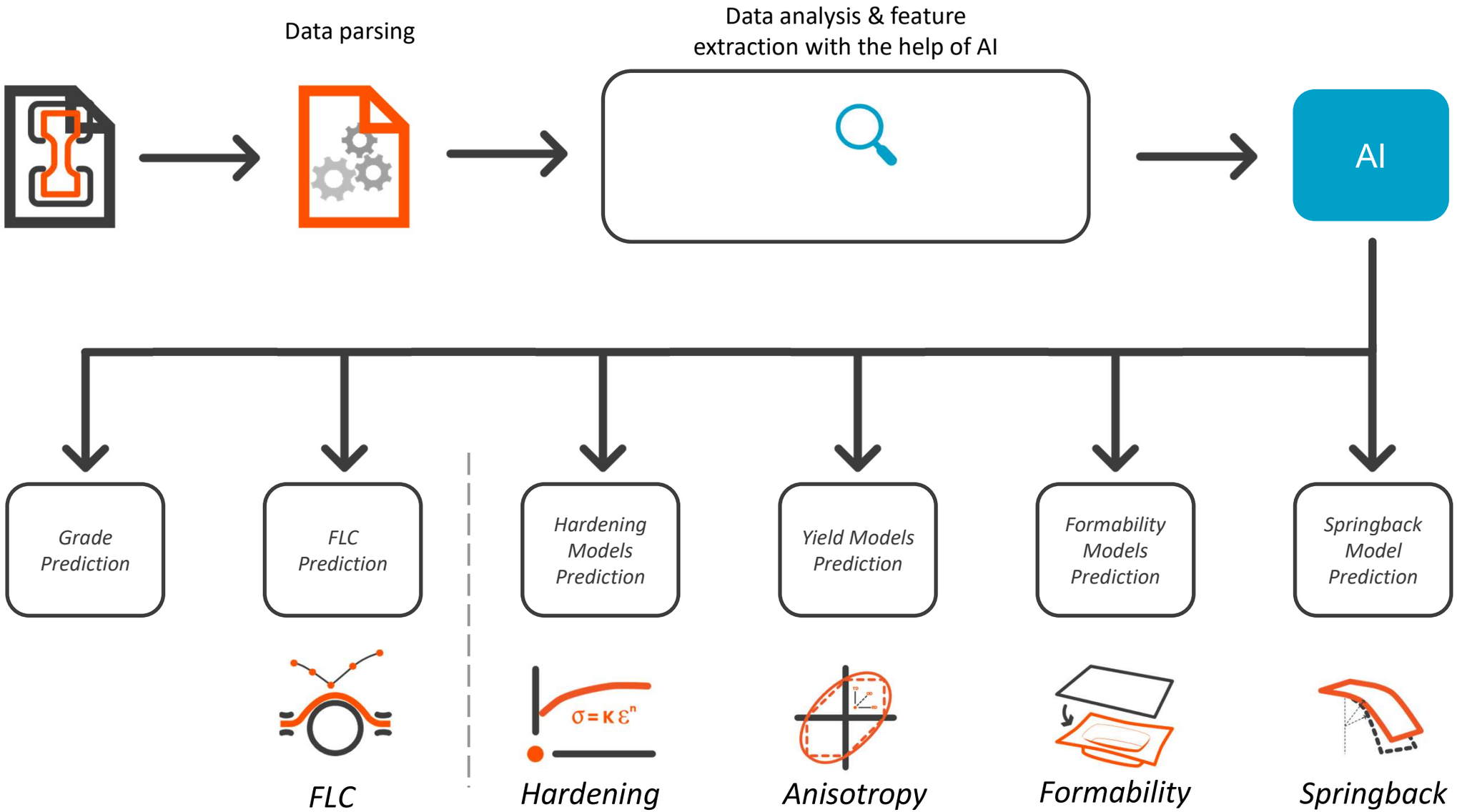
Take all the big data produced and utilize it to develop state-of-the-art artificial intelligence tools to accelerate/boost/ transform how we develop and deploy automotive steels!

- *Can we predict complex material behavior by simply inputting basic material properties or fundamental curves (UAT)?*
- *Can we generate FEA *Material Cards by simply inputting basic material properties or fundamental curves (UAT)?*
- *Can we use big data and A.I. tools to extract complex hidden microstructure-macro relationships (future objective)!*



Artificial Intelligence Tools

Overview _ General Interaction Architecture



Artificial Intelligence Tools

Inputs

	Material 1	Material 2
	Sample_2.csv	Sample_1.csv
Yield Strength (MPa)	384.83	771.27
Tensile Strength (MPa)	678.87	1058.54
Uniform Elongation (%)	14.27	6.42
Total Elongation (%)	21.20	10.69
n-Value	0.183	0.085
r-Value	Type Here	Type Here
Thickness (mm)	Type Here	Type Here
Mill Type	Unknown	Unknown

Input any .csv file that contains axial strains, engineering stresses and transverse strains*

**r-value will be automatically calculated if transverse strain is provided.*

**Thickness is provided manually.*

**Mill Type is optional to enhance certain results.*

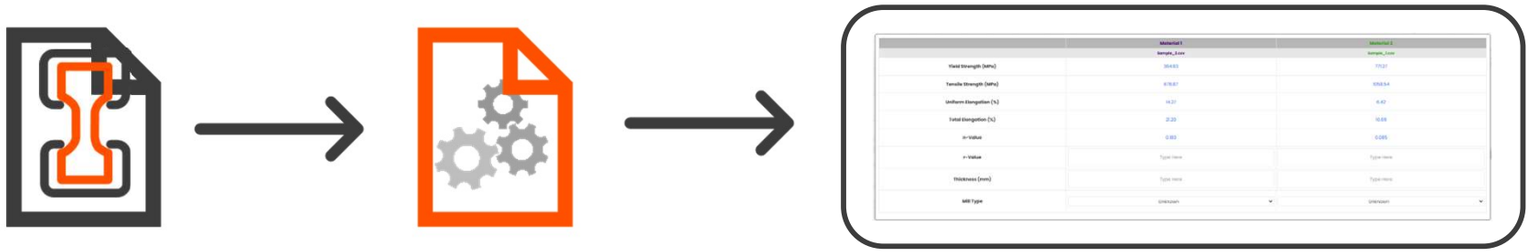
*****No need to load data … you can simply enter mechanical proprieties!***

Artificial Intelligence Tools

General Interaction Map

Data parsing

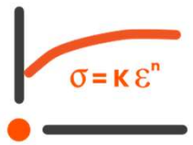
Data analysis & feature extraction with the help of AI



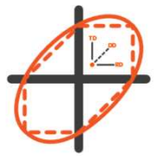
AI

- *Grade Prediction*
- *FLC Prediction*
- *Hardening Models Prediction*
- *Yield Models Prediction*
- *Formability Models Prediction*
- *Springback Model Prediction*

FLC



Hardening



Anisotropy

Formability

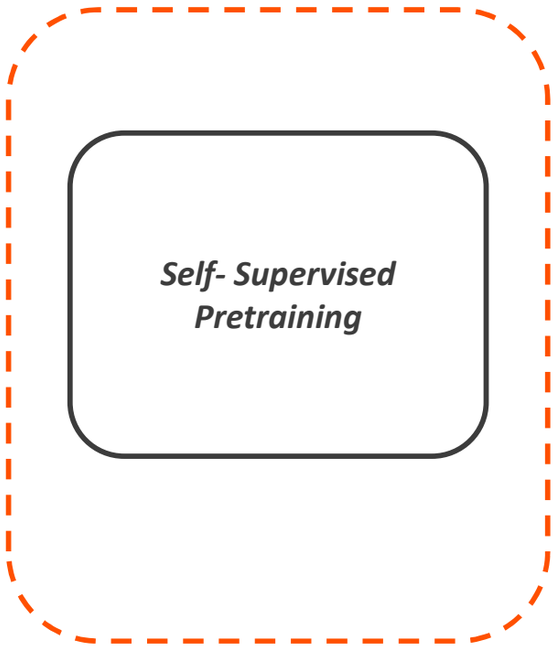
Springback

Artificial Intelligence Tools

A.I. Model Architecture

mi-Transformer

Phase 1



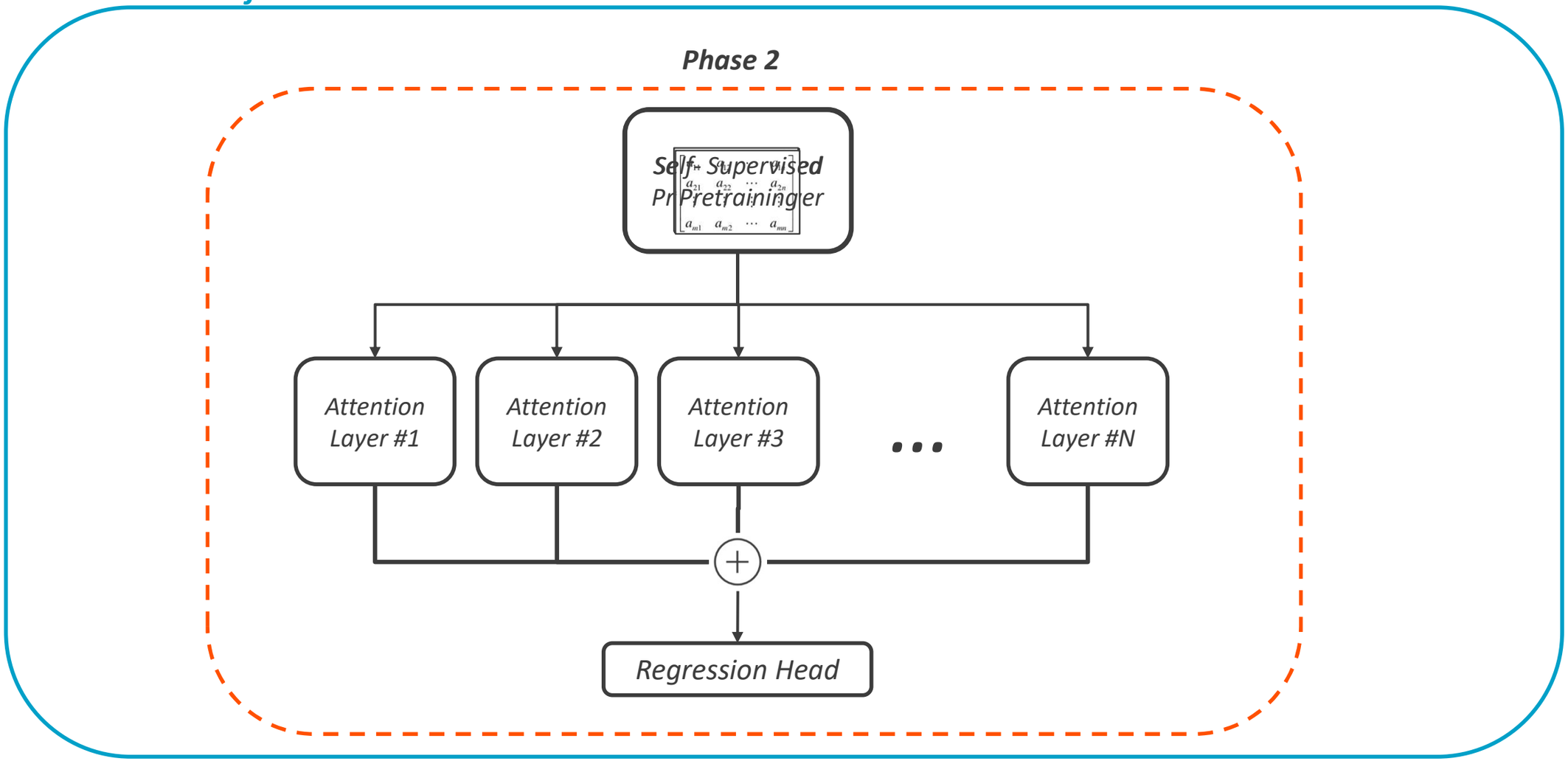
- *Pretraining step to build relations between the input material properties.*
- *Attention mechanisms used to detect complex non-linear patterns represented as relational matrix describes the input features (same as technologies used in LLMs but instead of words and sentences it is properties and materials behavior now).*
- *The output of this phase for each input sample is:*

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

Artificial Intelligence Tools

A.I. Model Architecture

mi-Transformer

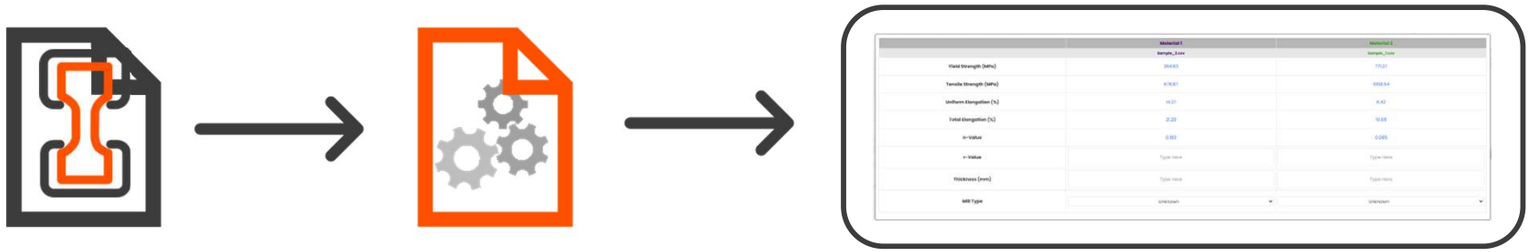


Artificial Intelligence Tools

General Interaction Map

Data parsing

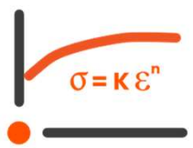
Data analysis & feature extraction with the help of AI



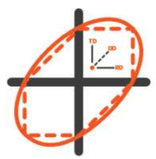
AI

- Grade Prediction
- FLC Prediction
- Hardening Models Prediction
- Yield Models Prediction
- Formability Models Prediction
- Springback Model Prediction

FLC



Hardening



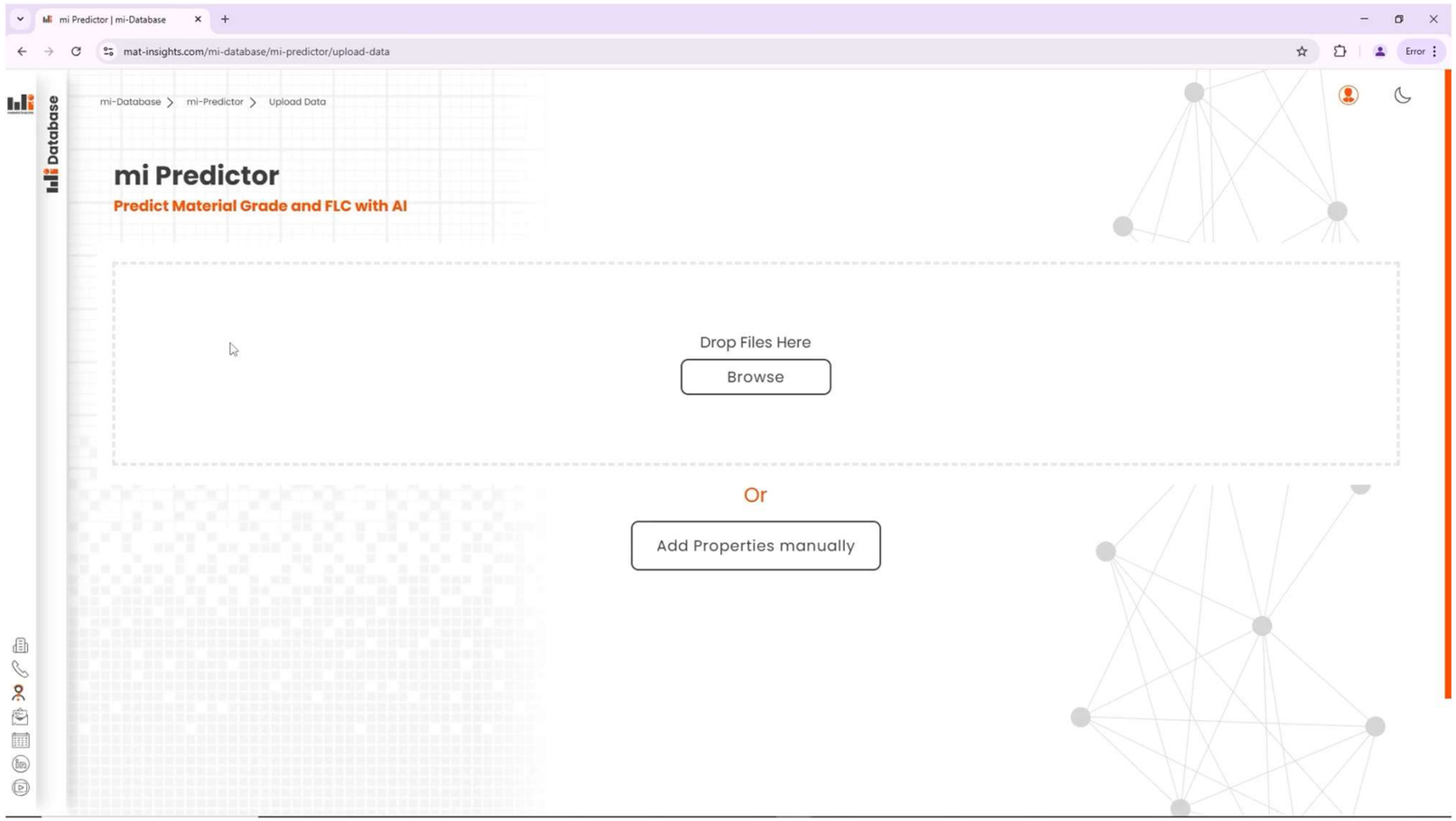
Anisotropy

Formability

Springback

Artificial Intelligence Tools

Grade Prediction



Artificial Intelligence Tools

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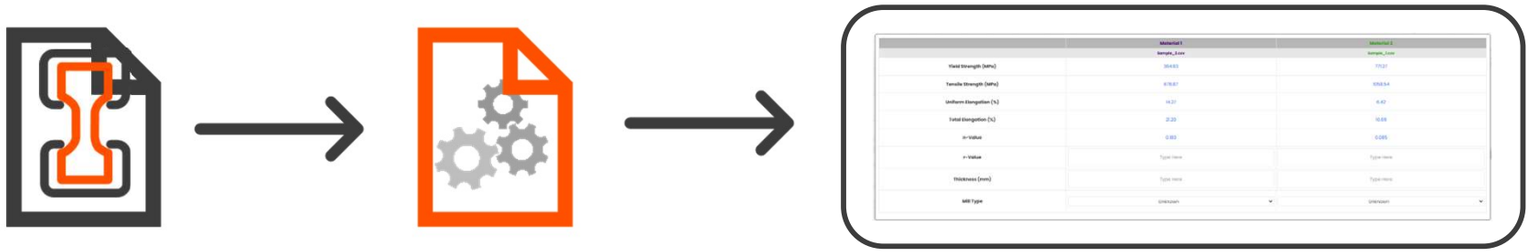

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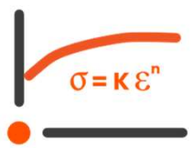
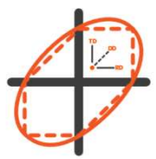


Hardening



Anisotropy

Formability

Springback

Artificial Intelligence Tools

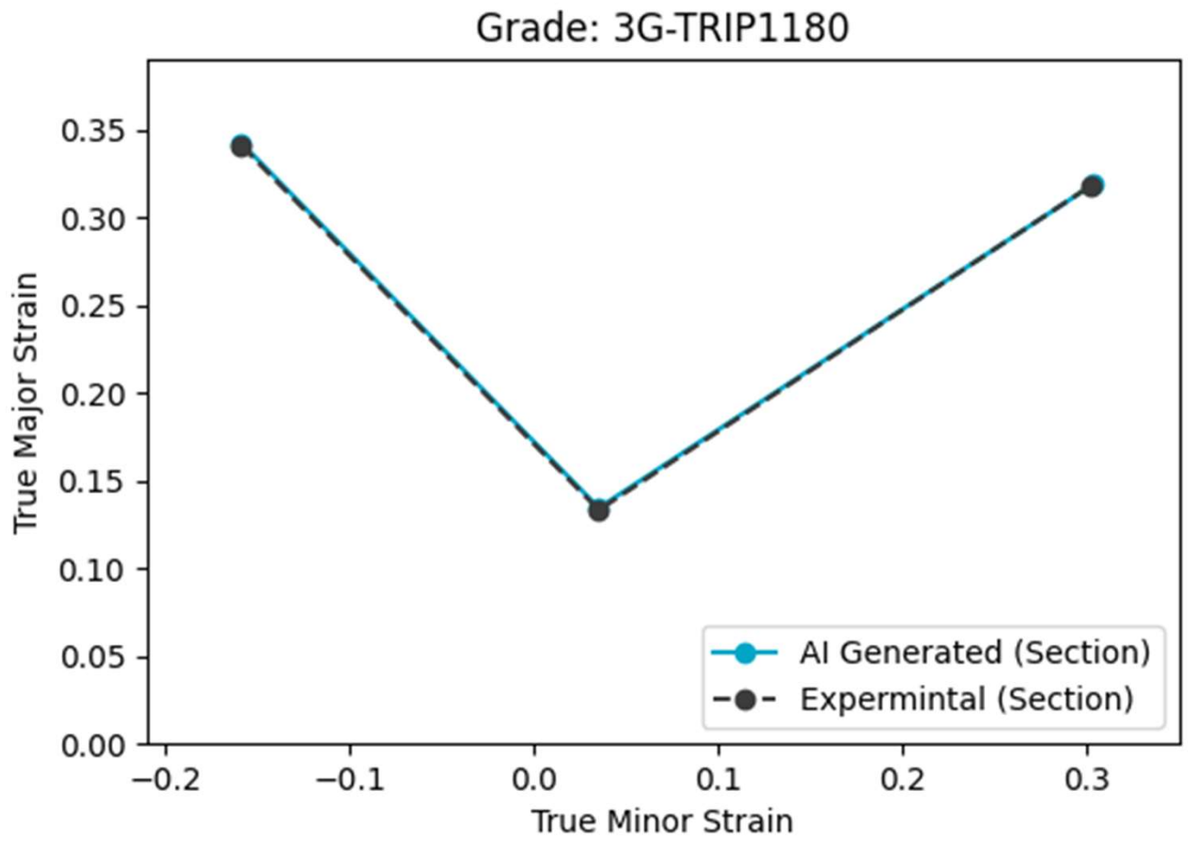
Predicting FLCs & Formability Mat. Cards

Selected examples for a variety of steel grades …

Input: UAT Curve(s)

Output: FLC and Formability Material Card

Note here that the A.I. tool is generating FLCs for direct input into your FEA solver (equivalent of experimental data per the section method in ISO 12004)!



Artificial Intelligence Tools

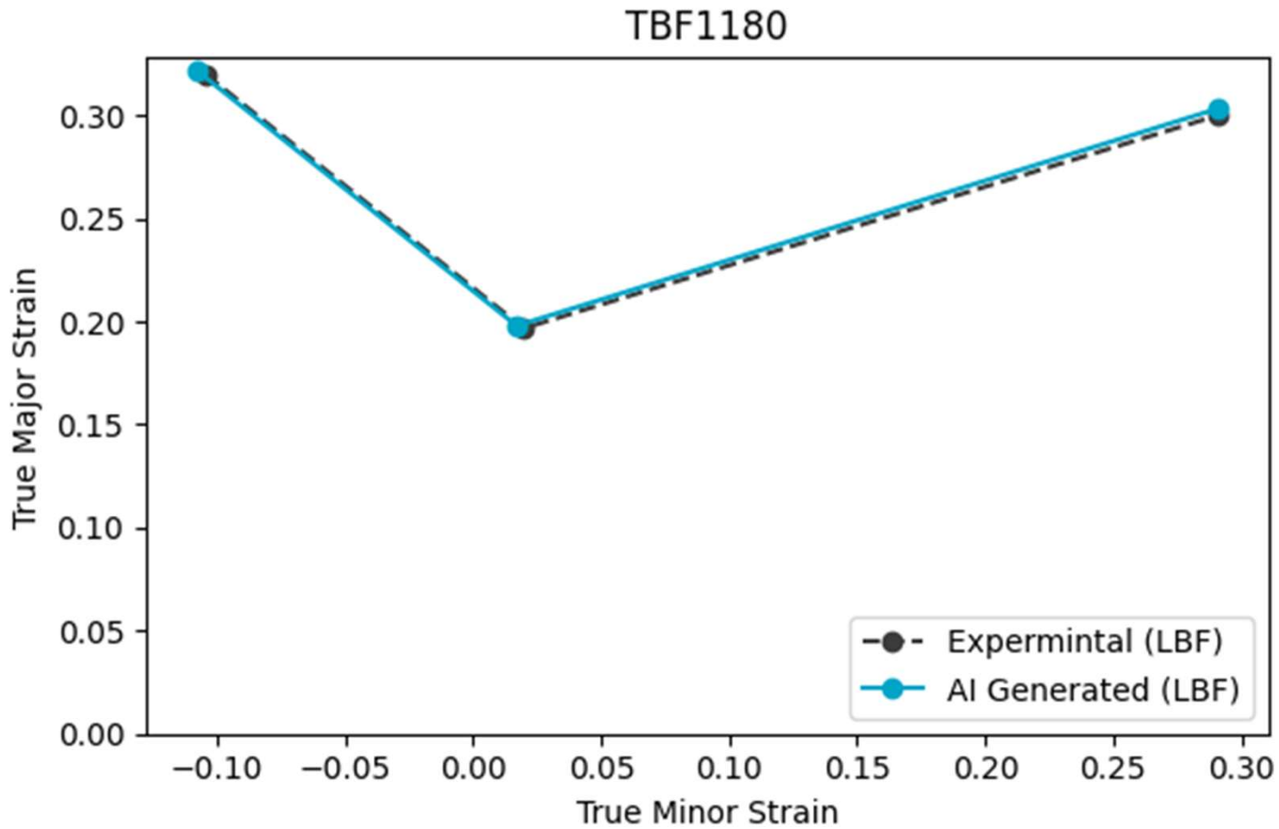
Predicting FLCs & Formability Mat. Cards

Selected examples for a variety of steel grades …

Input: UAT Curve(s)

Output: FLC and Formability Material Card

What if I am interested in experimental data but NOT based on the section method! What if I am interested in "Time Dependent" algorithms (preferred by European OEMs)?



Artificial Intelligence Tools

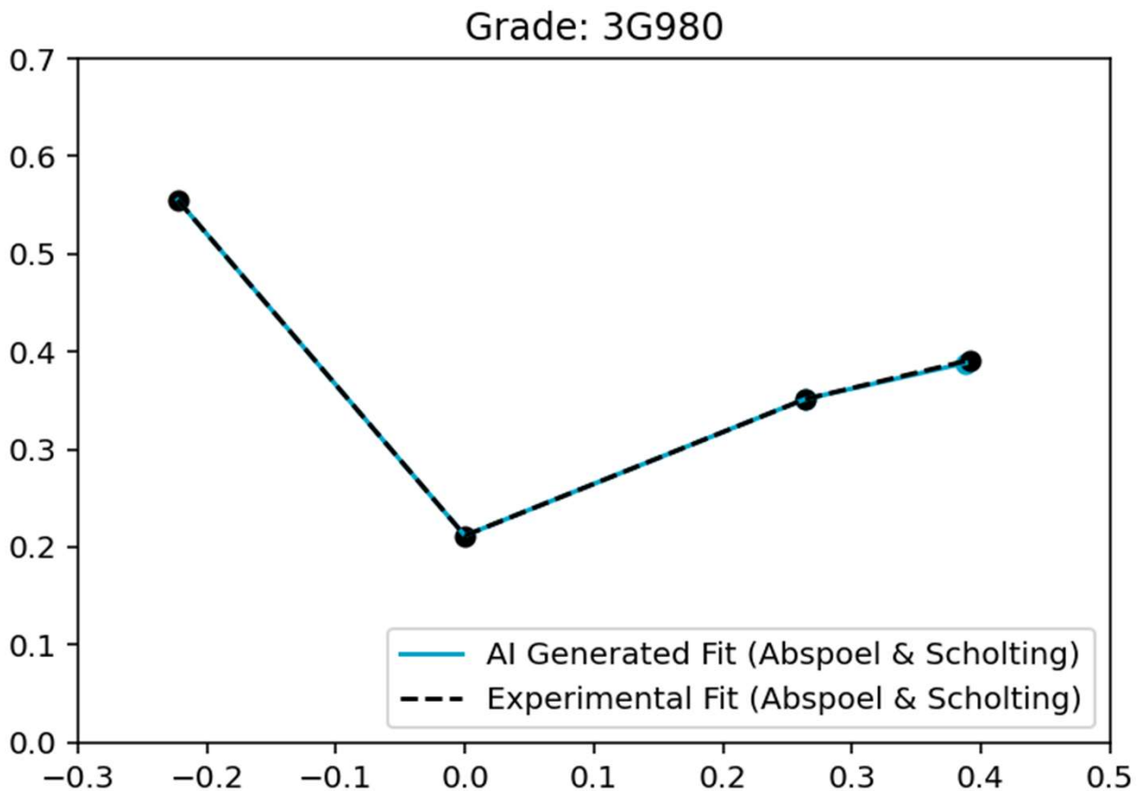
Predicting FLCs & Formability Mat. Cards

Selected examples for a variety of steel grades …

Input: UAT Curve(s)

Output: FLC and Formability Material Card

What if I use a particular FE solver ("AutoForm" for instance) and I am used to feeding a fitted FLC per a particular empirical model … Abspoel & Scholting for instance!!!



Artificial Intelligence Tools

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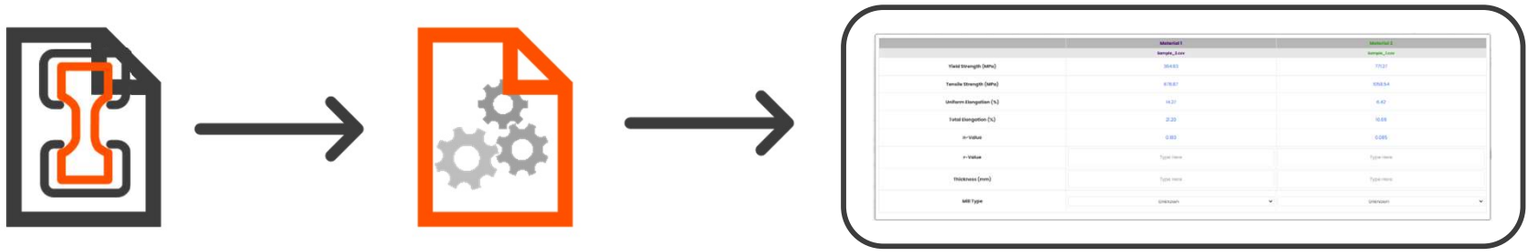


AI

Grade Prediction

FLC Prediction

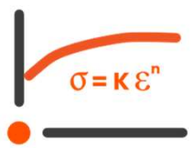
Hardening Models Prediction

Yield Models Prediction

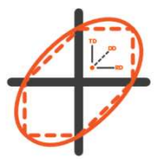
Formability Models Prediction

Springback Model Prediction

FLC



Hardening



Anisotropy

Formability

Springback

Artificial Intelligence Tools

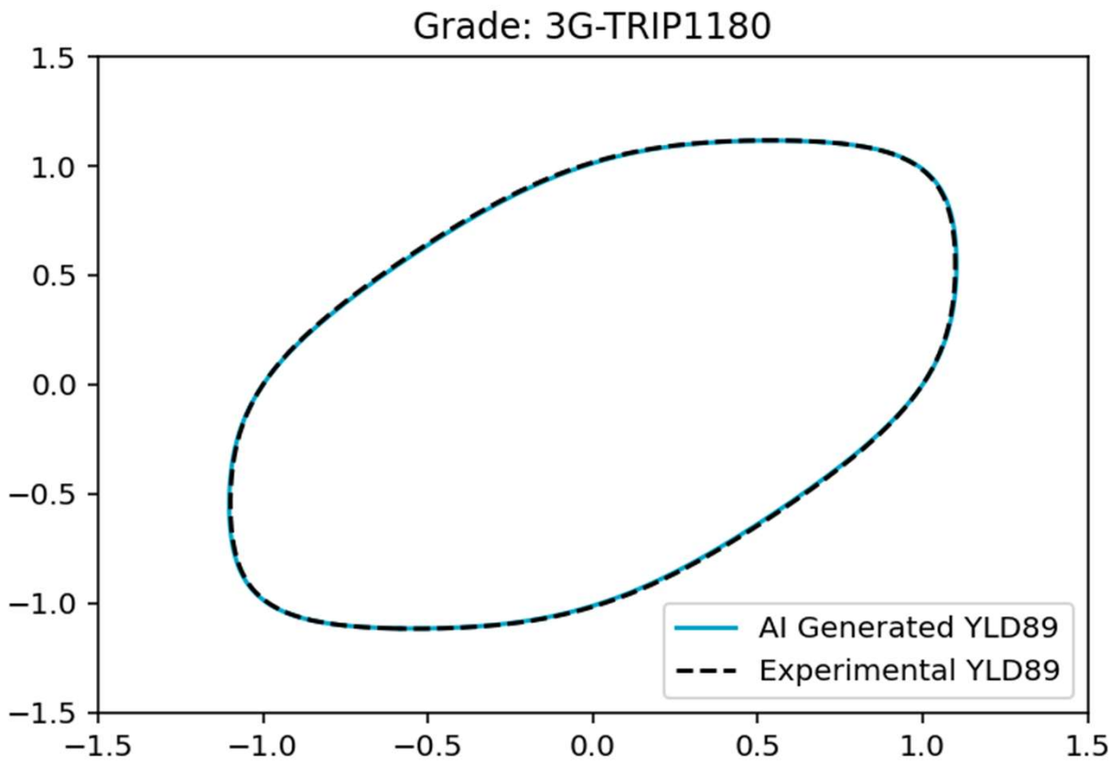
Predicting Hardening & Anisotropic Yield Function Material Cards

Selected examples for a variety of steel grades …

Input: UAT Curve(s)

Output: Hardening & Anisotropic Material Cards with Fits

Note here that the A.I. tool is generating parameters for hardening and anisotropic yield functions for direct input into your FEA solver…



Artificial Intelligence Tools

Predicting Hardening & Anisotropic Yield Function Material Cards

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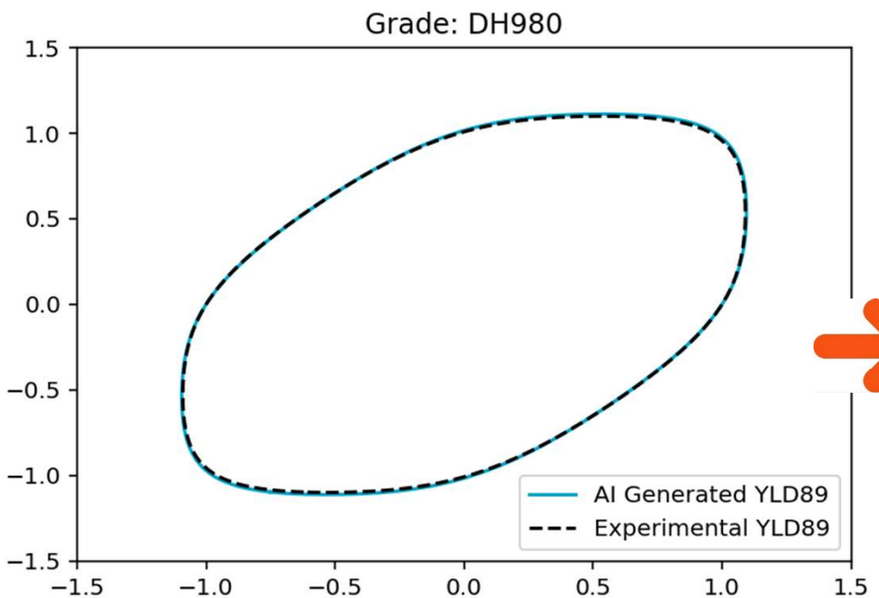


Barlat YLD89 Model Parameters

COLUMNS EXPORT

a	c	h	p
1.089	0.911	0.958	0.945

Artificial Intelligence Tools

Predicting Hardening & Anisotropic Yield Function Material Cards

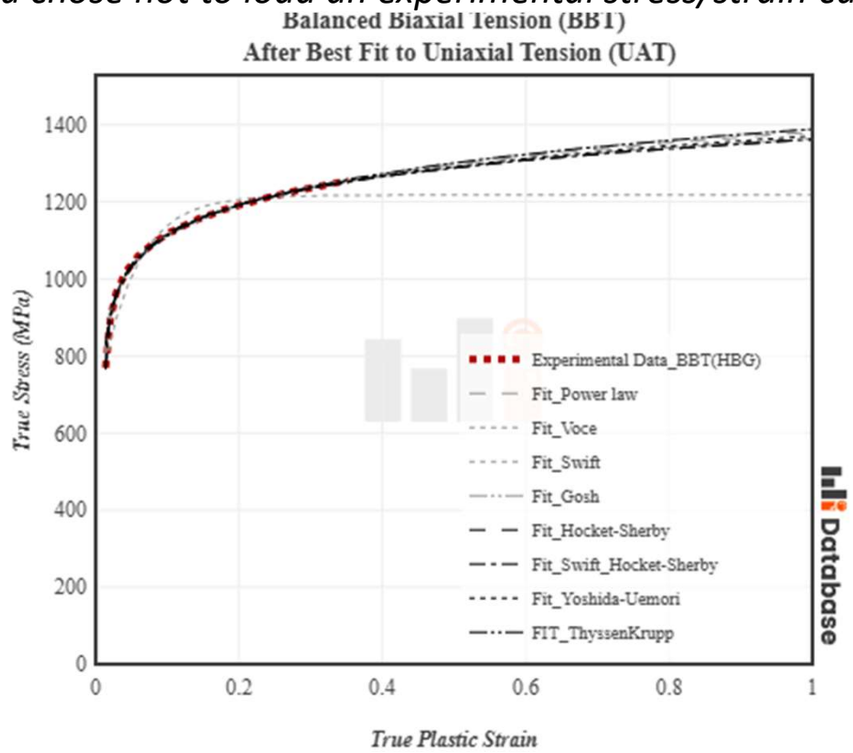
Selected examples for a variety of steel grades …

Input: UAT Curve(s)

Output: Hardening & Anisotropic Material Cards with Fits

Note here that the A.I. tool is generating parameters for hardening and anisotropic yield functions for direct input into your FEA solver…

If you chose not to load an experimental stress/strain curve



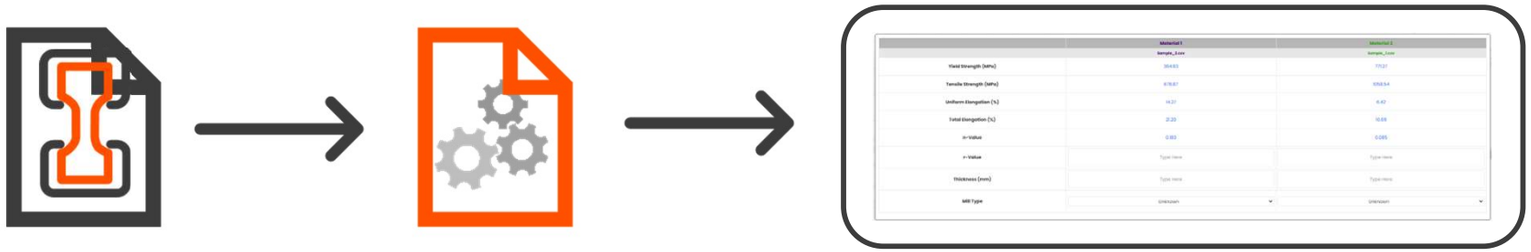
	Hocket-Sherby $\sigma = a - be^{-c\varepsilon^n}$				
Loading Path & Orientation	α	b	C	n	r²
UAT-RD	1280.0	10000.0	4.911	0.085	1.000
UAT-DD	1224.8	10000.0	5.478	0.096	1.000
UAT-TD	1230.7	10000.0	5.734	0.104	1.000
SHR-RD	9287.8	10000.0	0.228	0.055	0.994
SHR-DD	5744.9	10000.0	0.813	0.024	0.996
SHR-TD	3526.9	10000.0	1.518	0.025	0.997
BBT(HBG)	8426.4	10000.0	0.348	0.043	0.999

Artificial Intelligence Tools

General Interaction Map

Data parsing

Data analysis & feature extraction with the help of AI



AI

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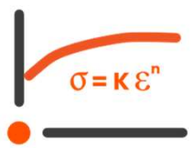
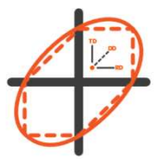
FLC



Hardening



Anisotropy

Formability

Springback

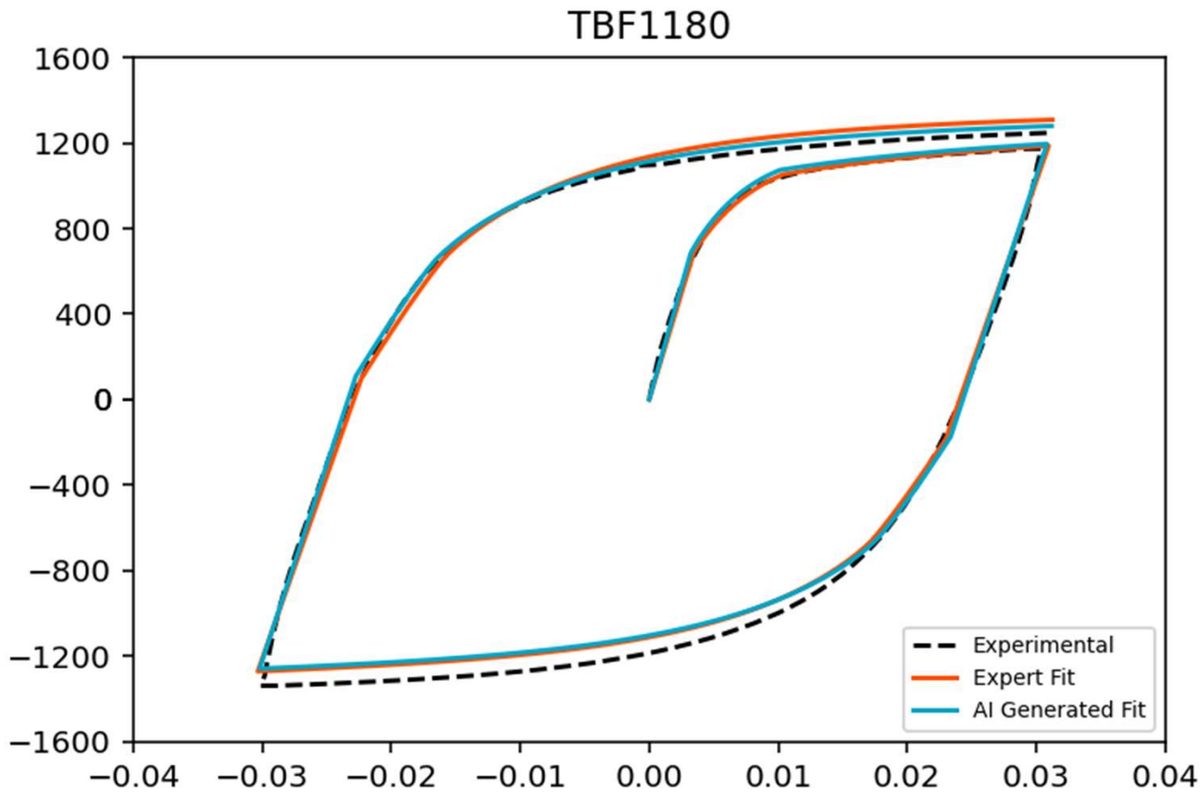
Artificial Intelligence Tools

Predicting Cyclic Loading & Springback Material Cards (Y-U Model)

Selected examples for a variety of steel grades …

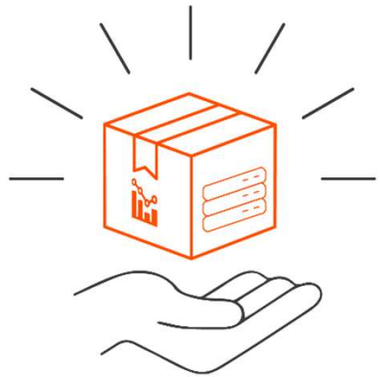
Input: UAT

Output: CTC curves & Springback Material Card (Yoshida-Uemori Model)



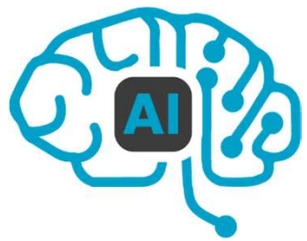
Summary

What does A.I. Enable and What More to Expect?



Towards Solutions …

Artificial Intelligence!

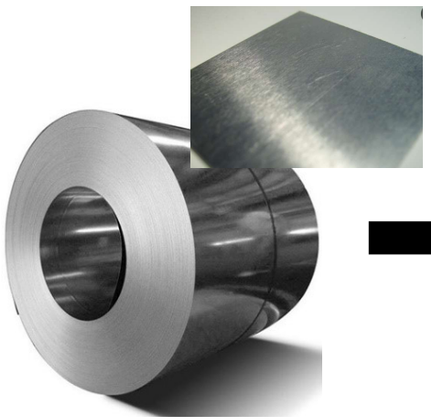


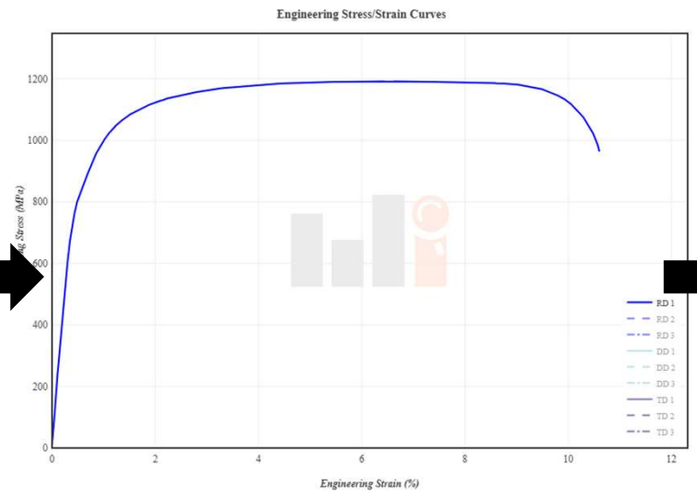
Artificial Intelligence

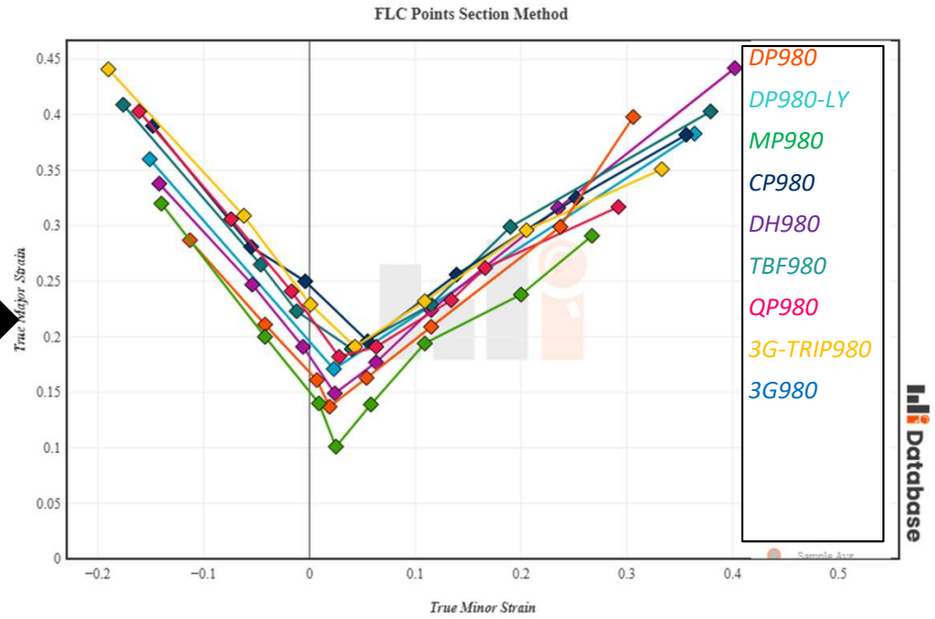
Facilitating Next Generation Steel Developments

Qualification, evaluation and development of steel grades will be faster, smarter & more efficient!

Whether it is development or production Steel! → *Run basic UAT tests then feed to A.I. model(s)* → *Predict complex behavior, check, compare, refine, adjust,…*







Grand Objectives:

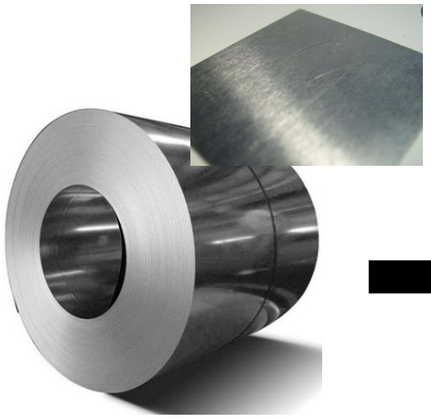
- *Save time & cost!*
- *Shortcuts to complex characterization!*
- *Faster feedback to further refinement & development*
- *Accelerated development cycles!*

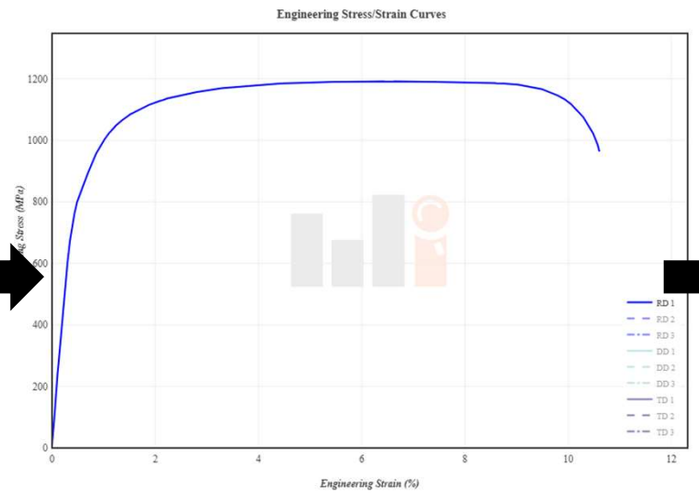
Artificial Intelligence

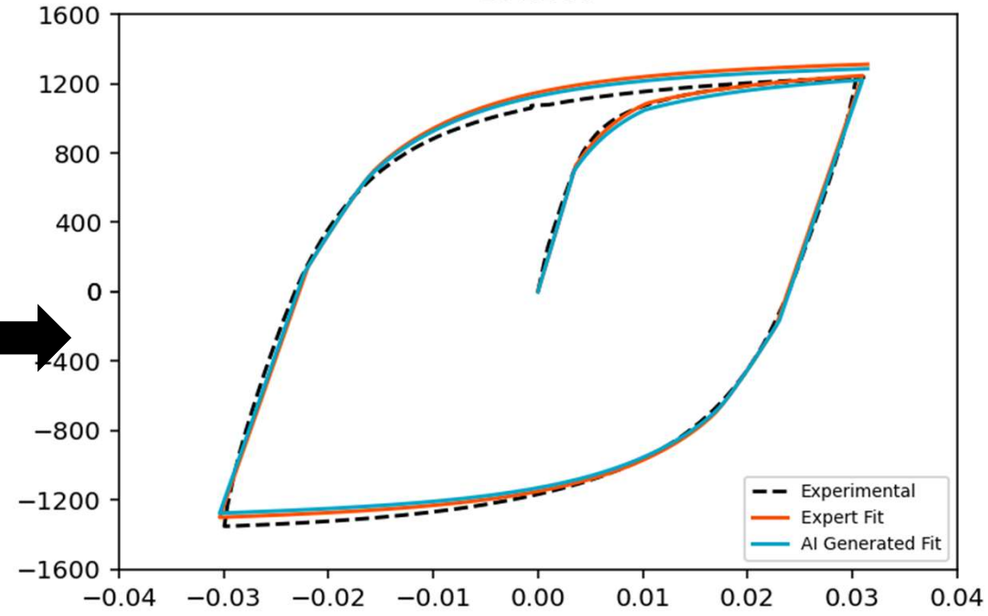
Facilitating Next Generation Steel Deployment & CAE Efforts

CAE work (structure optimization & lightweighting efforts with advanced steels) will be faster, smarter & more efficient!

Whether you are considering a development or production Steel! → *Run or ask for basic UAT tests then feed to A.I. model(s)* → *Predict complex behavior, check, compare & run preliminary FE simulations !*







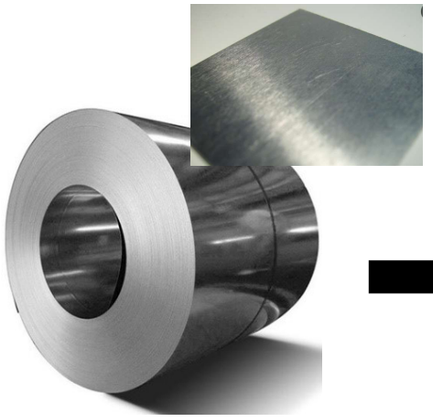
For lightweighting & structure optimization …

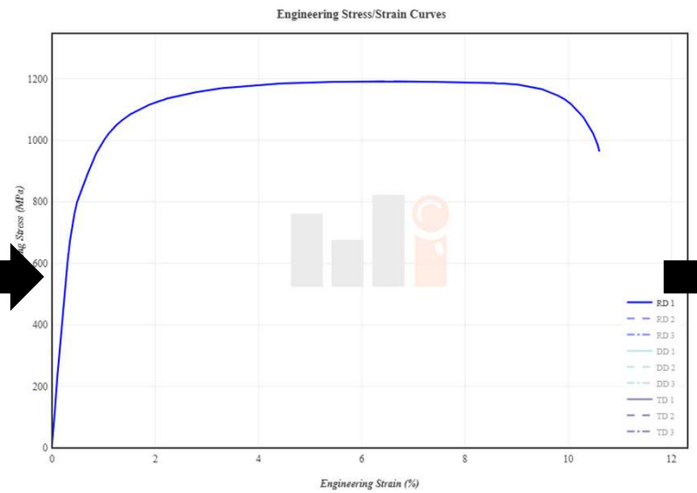
Artificial Intelligence

Facilitating Next Generation Steel Deployment & CAE Efforts

CAE work (structure optimization & lightweighting efforts with advanced steels) will be faster, smarter & more efficient!

Whether you are considering a development or production Steel! → *Run or ask for basic UAT tests then feed to A.I. model(s)* → *Predict complex behavior, check, compare & run preliminary FE simulations !*





*mi-MatCard_AutoForm_DP1180(6).txt - Notepad

File Edit Format View Help

```
# Anistropic Yield Function [FE2]
# Model: Barlat (1989)
Parameters
        m 6
        a 1.115
        c 0.885
        h 0.977
        p 1.010



# FLC for  1.5 mm [FE4]
FailureCurve
          0     -0.1421 0.3375
          1     -0.0539 0.2467
          2     -0.0058 0.1913
          3     0.0244 0.1487
          4     0.0632 0.1771
          5     0.1152 0.2237
          6     0.2354 0.3165
          7     0.4019 0.442

# Springback [FE6]
Model: Yoshida-Uemori
Parameters
        Y 665.6
        B 943.7
        C1 529.0
        C2 294.0
        b 19.9
        m 18.8
        Rsat 249.4
        h 0.28
        r 0
```

For lightweighting & structure optimization …

Grand Objectives:

- *Save time & cost!*
- *Shortcuts on multiple levels*
- *Faster feedback to development efforts*
- *Accelerated smart development cycles!*

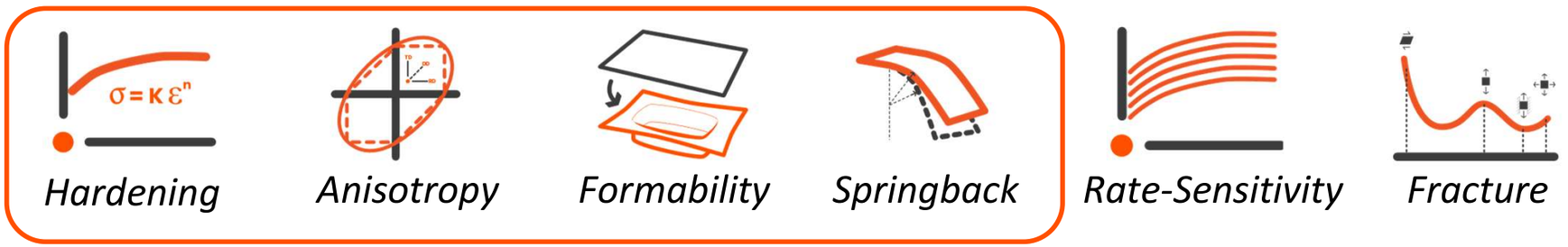
Final Wrap-up
& Remarks

Summary

Wrap-up & Final Remarks

- *Presented a short story about one of our most important recent projects on "big data and artificial intelligence" … this is the result of 2-3 years of development!*
- *Provided highlights on the largest R&D database for automotive steels, and a mature set of A.I. tools designed to support and transform how we approach the topic of "material data" for steel development & deployment*
- *We believe that big data and A.I. are transforming and will further transform how we develop and deploy automotive steels*, how we run FE simulations, how we perform CAE work … how we develop and deploy next-generation automotive structures!*
- *This will have long reaching effects on vehicle structure design and its optimization!*
- *Current status: able to facilitate forming & springback simulations based on minimal input!*
- *Future work: expanding to crash simulations (rate sensitivity and fracture models) …*

CAE Categories →



material insights

Thank you!

Reach out to us with any questions …
FADI Abu-Farha, PhD (FADI@mat-insights.com)
Technical Team (Support@mat-insights.com)

Q & A:

Please use the Q & A feature to ask your questions

For More Information:

Dr. FADI Abu-Farha

President and Technical Manager

Material Insights

Fadi@mat-insights.com

Moderator:

Dr. Hesham Ezzat

Senior Technical Consultant,
Automotive Program

American Iron and Steel Institute

hezzat@steel.org

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