



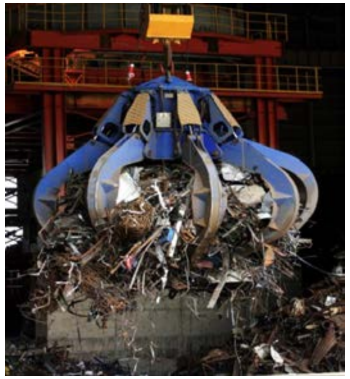

GROWTH IN AUTOMOTIVE APPLICATIONS AND ASSOCIATED MANUFACTURING AND MANUFACTURING TOOLING CHALLENGES

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Auto/Steel Partnership

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www.a-sp.org

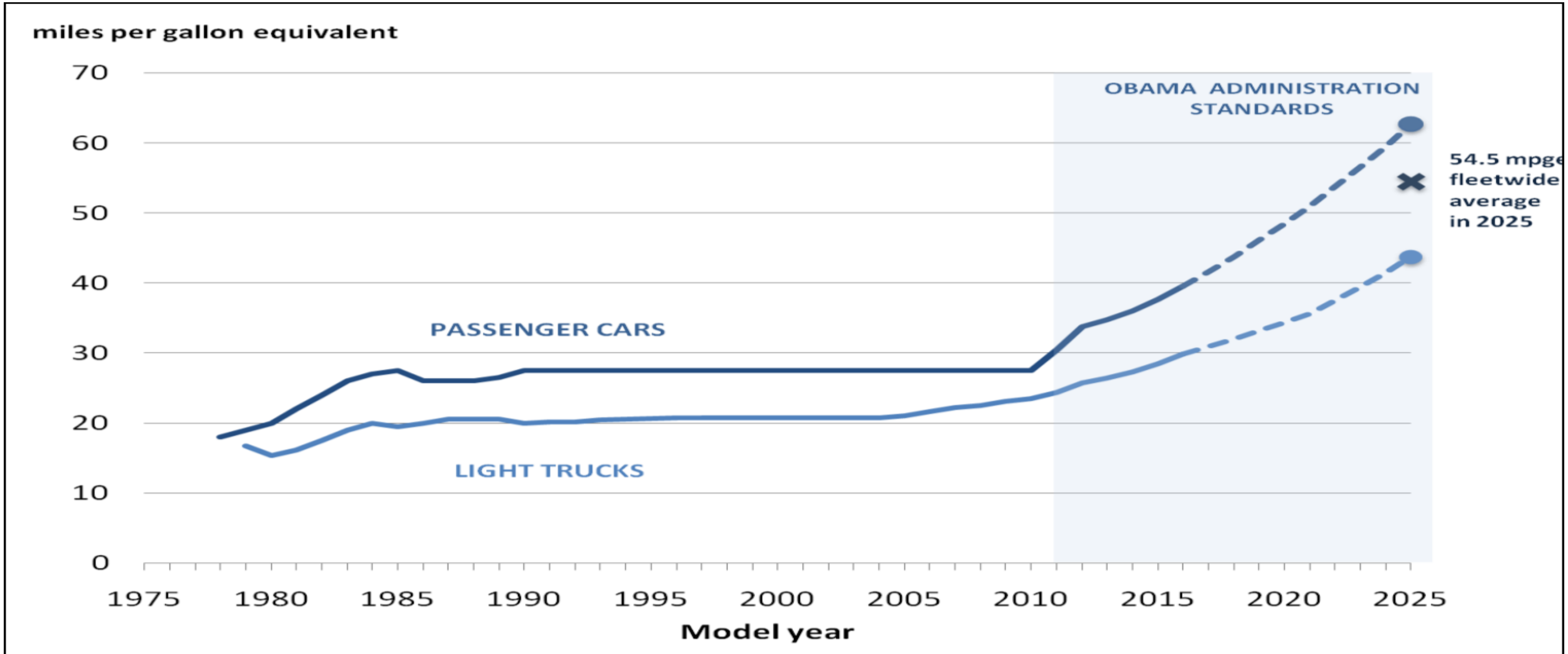
Introduction

- Currently the Executive Director of the Auto/Steel Partnership
- Over 38 years in automotive steel industry
- 17+ years with General Motors – Global Lead; innovation, body and chassis structures
- Prior experience in project execution, management, coordination and technical leadership
- Education: Bachelor of Science – Mechanical and Production Automotive from Bolton Technical College

Agenda

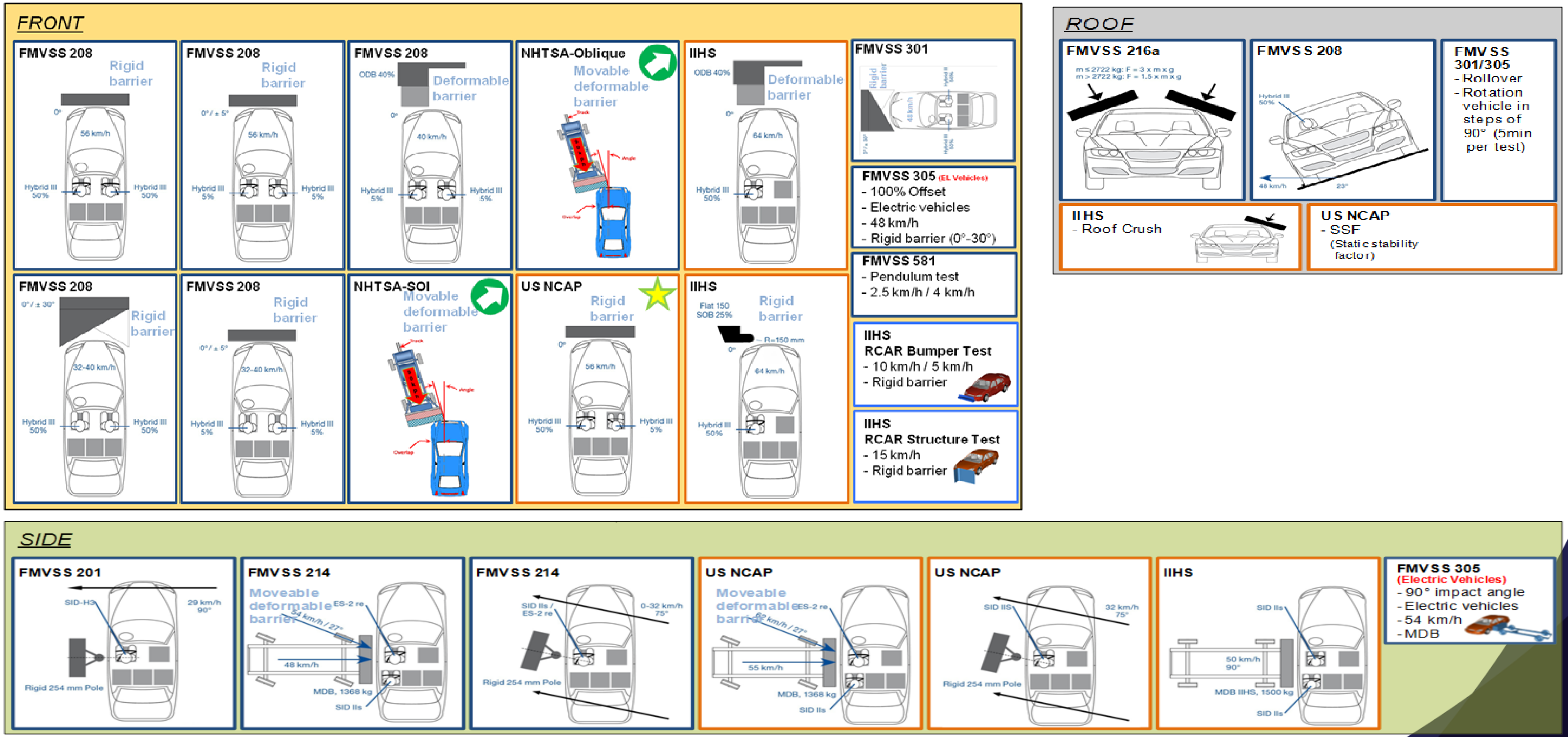
- Drivers for growth of Advanced High-Strength Steel (AHSS)
- AHSS defined
- Impact on Progressive Die Tooling
- AHSS Hole Punch Force and Edge Cracking Study
- Conclusion

Fuel Economy Regulations History

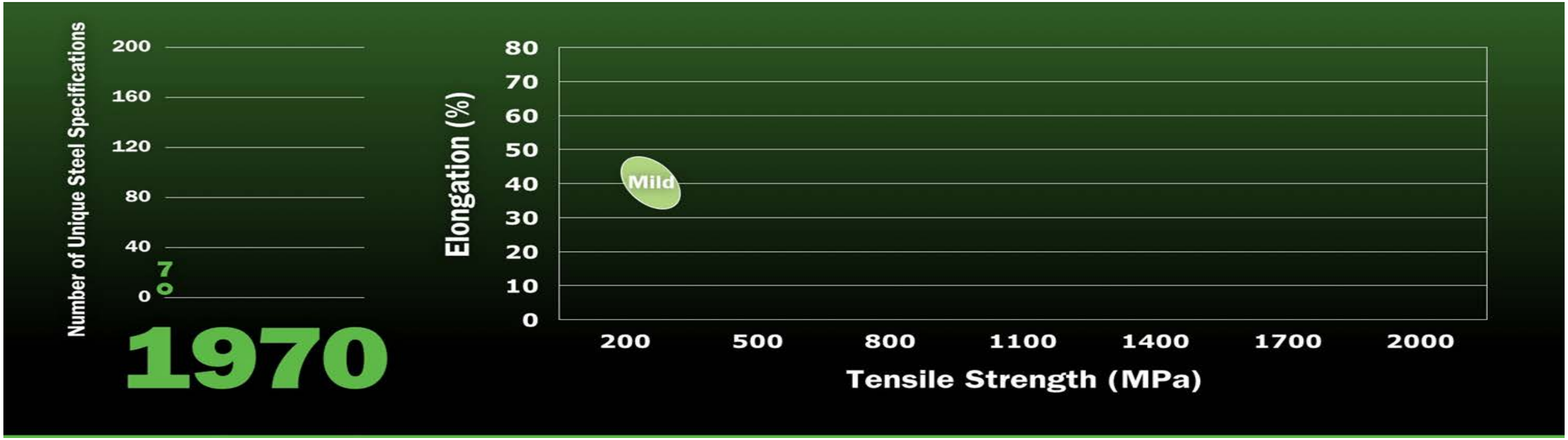


MY1978-2011 figures are NHTSA Corporate Average Fuel Economy (CAFE) standards in miles per gallon. Standards for MY2012-2025 are EPA greenhouse gas emission standards in miles per gallon equivalent, incorporating air conditioning improvements. Dashed lines denote that standards for MY2017-2025 reflect percentage increases in Notice of Intent.

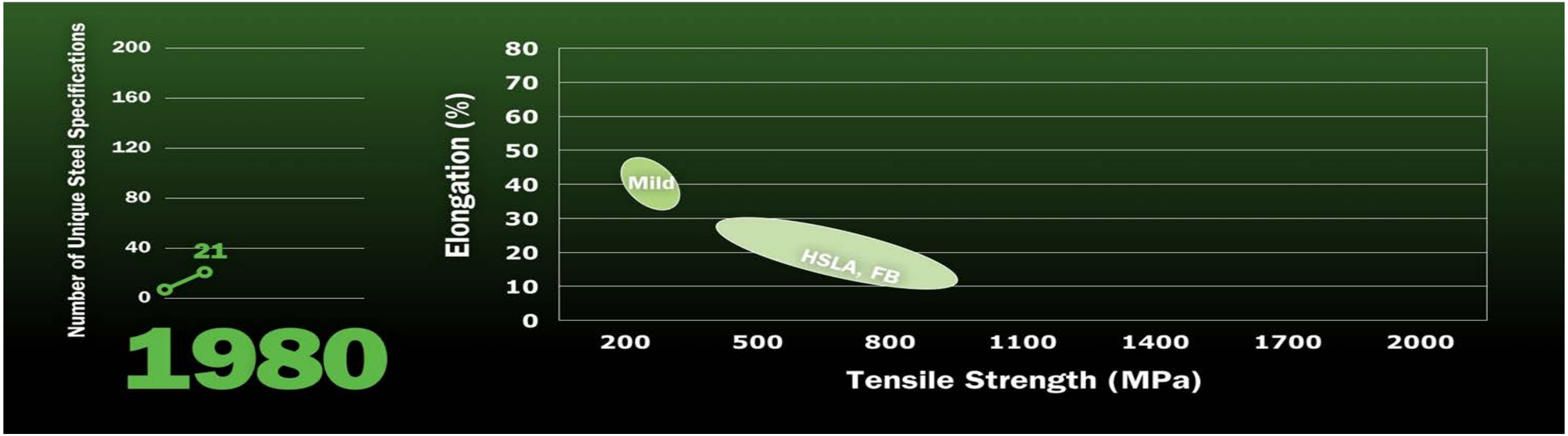
Overview – U.S. Crash Regulations



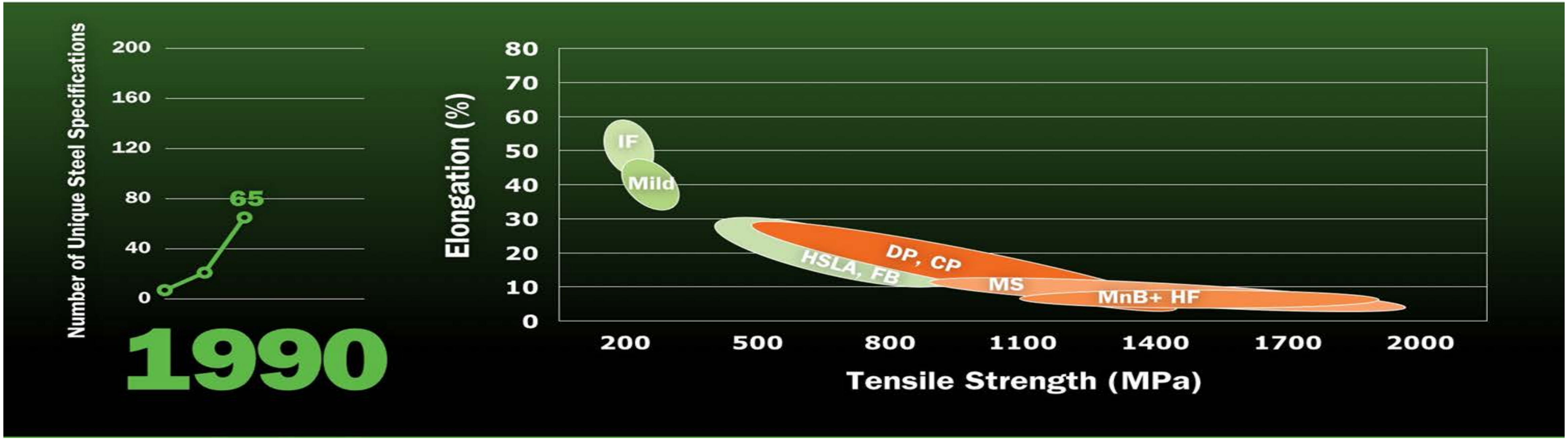
Automotive Steel Grade Innovation



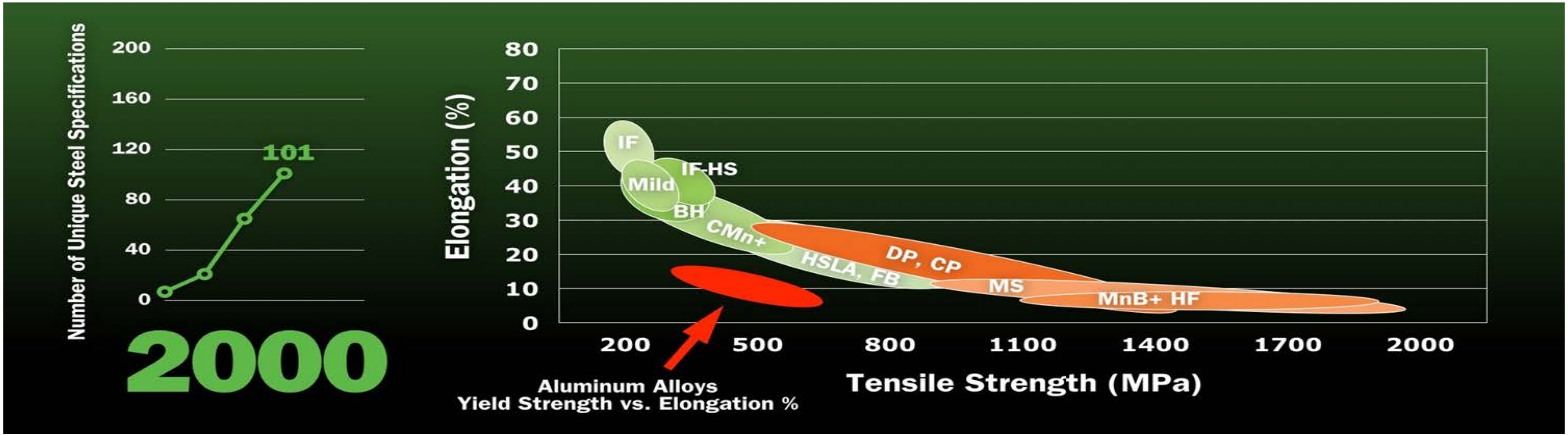
Automotive Steel Grade Innovation



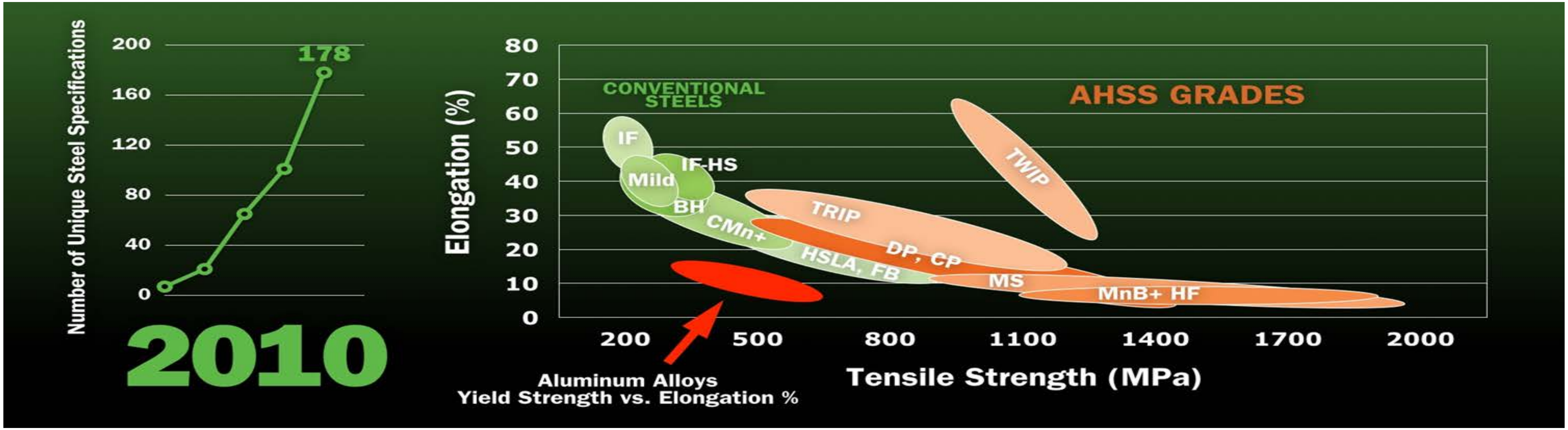
Automotive Steel Grade Innovation



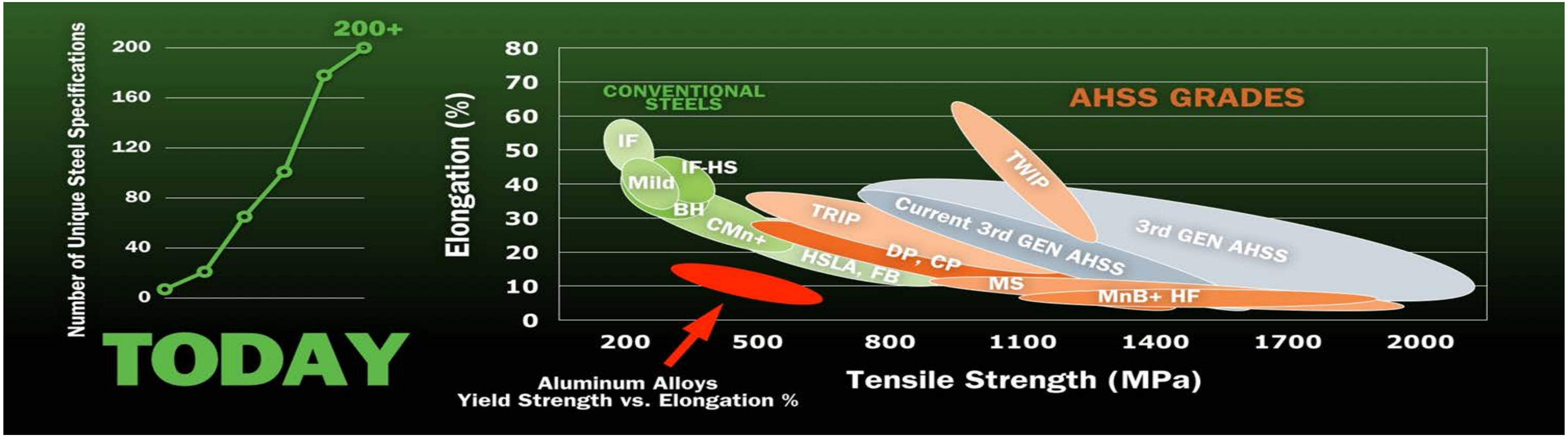
Automotive Steel Grade Innovation



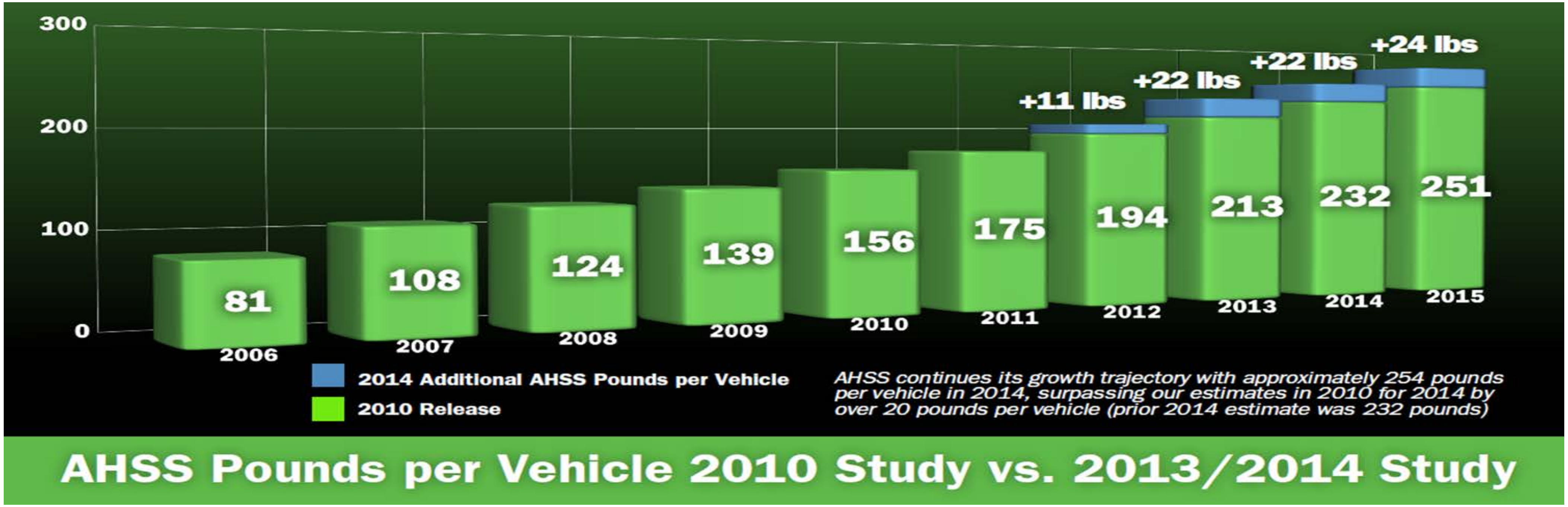
Automotive Steel Grade Innovation



Automotive Steel Grade Innovation



AHSS Growth Exceeds Forecast



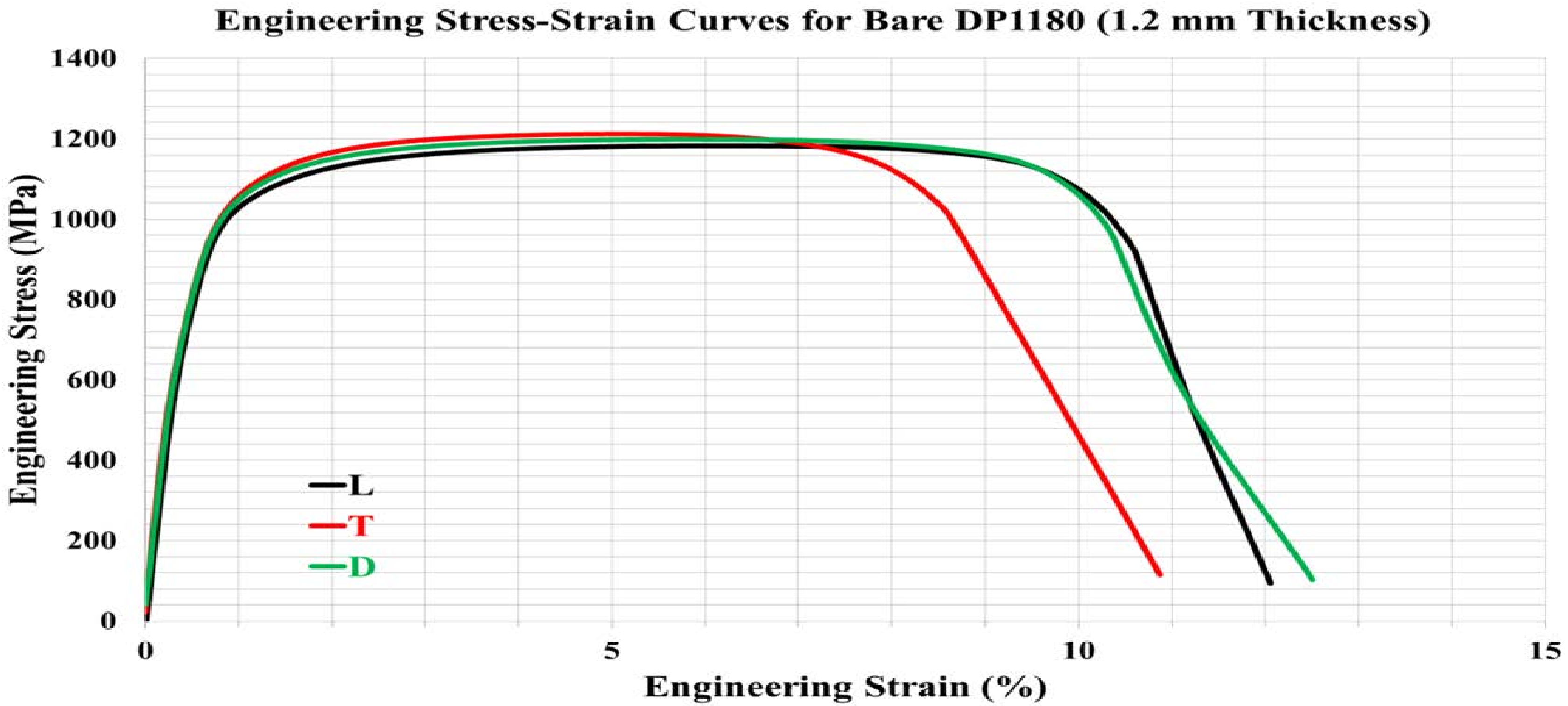
Auto/Steel Partnership (A/SP)

- Collaborative organization
- Founded in 1987
- Members include:

Evaluation of Progressive Die Wear Properties of Bare DP1180

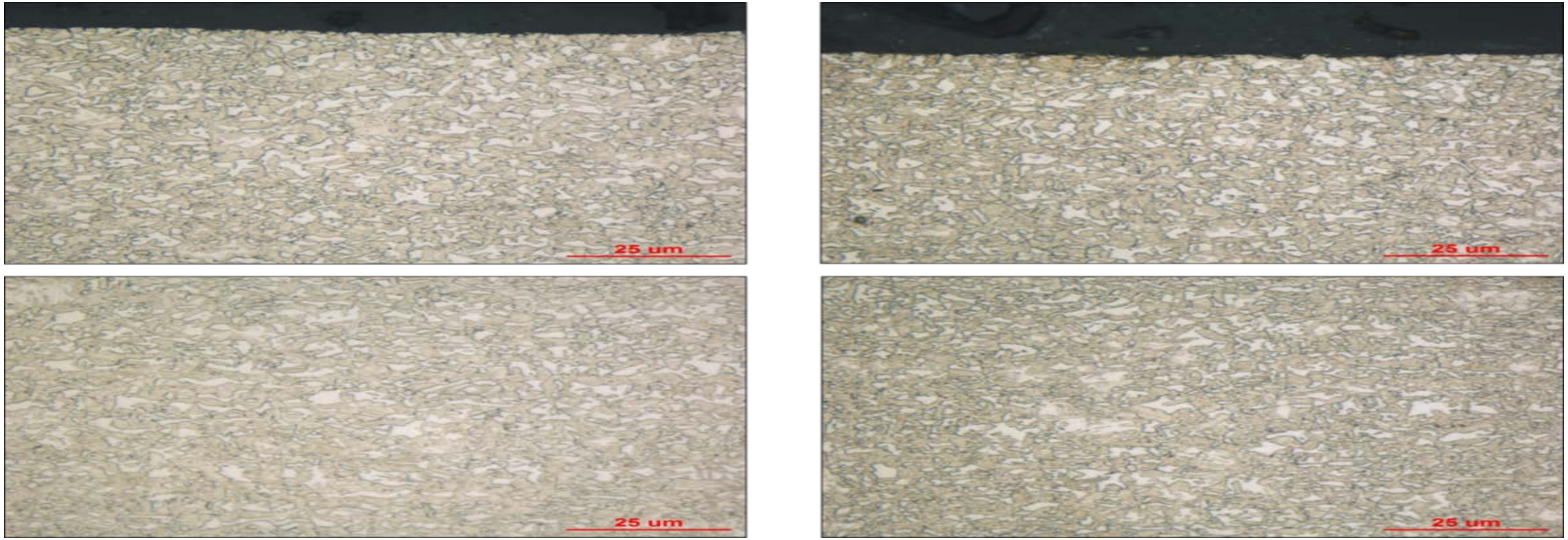
- Study die wear durability of various tooling materials and coatings for flanging operations on bare DP1180 steel
- Update OEM tooling standards based on the test results

Experimental Material – Bare DP1180



Sample Orientation	Specimen Gauge (mm)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Total Elongation (%)	Uniform Elongation (%)	Yield Point Elongation (%)
L	1.23	919	1182	10.6	5.6	0.0
T	1.24	926	1212	8.8	5.1	0.0
D	1.22	909	1198	10.4	5.4	0.0

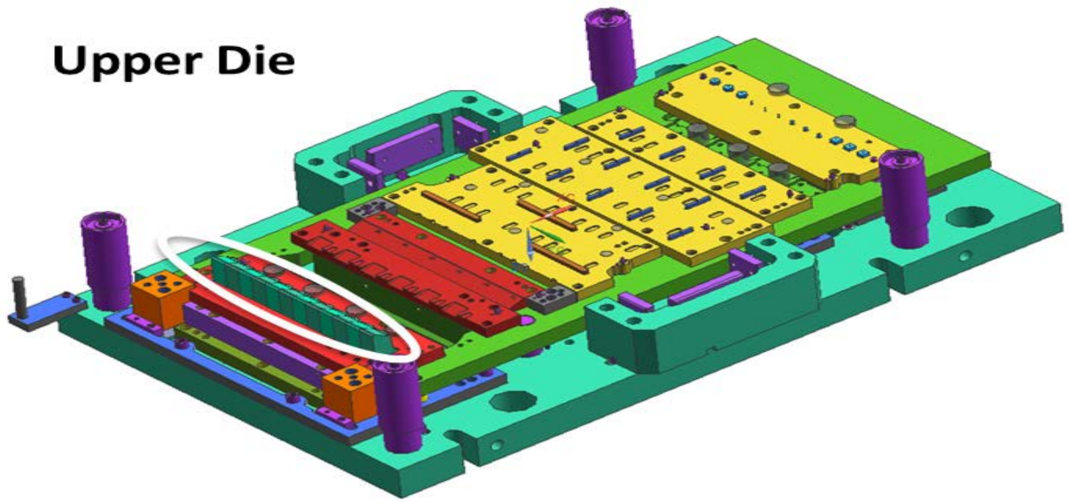
Microstructure – Bare DP1180

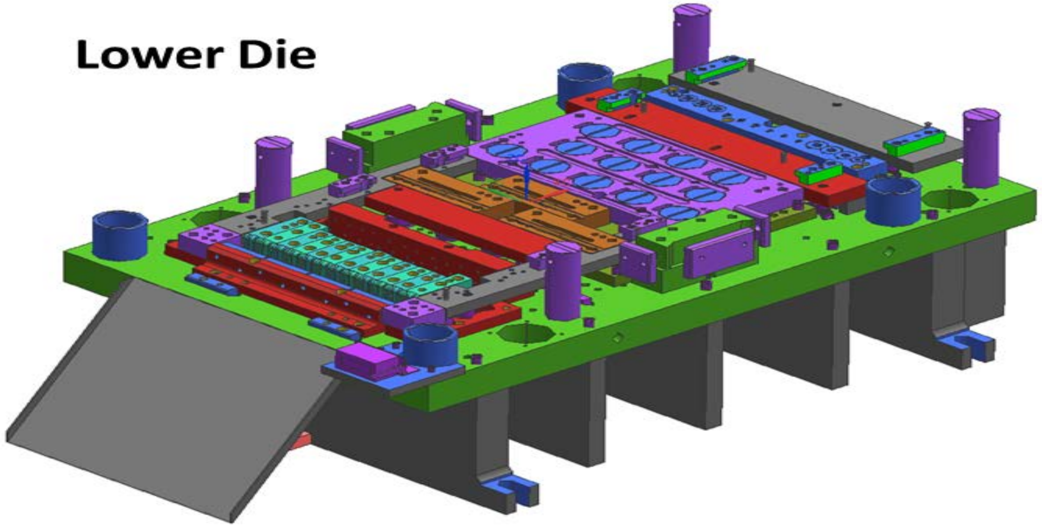


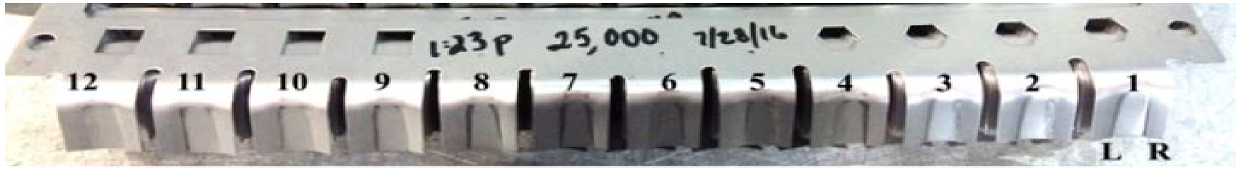
The volume fraction of martensite was calculated using Image Pro Plus software.

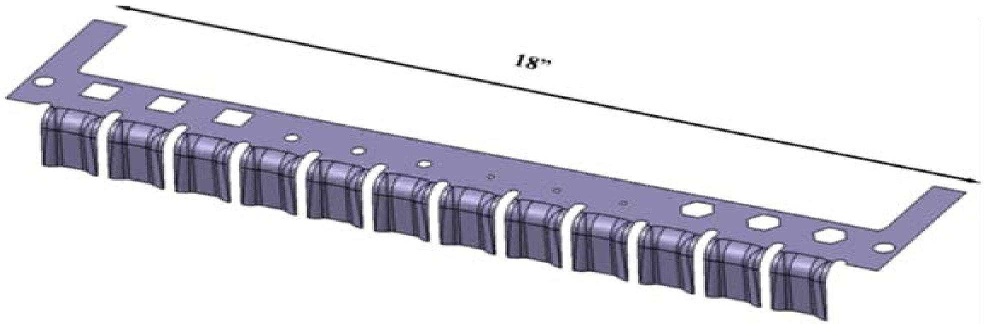
The volume fraction of martensite was found to be approximately 70.2% in the longitudinal section, and 71.1% in the transverse section.

Progressive Die Setup

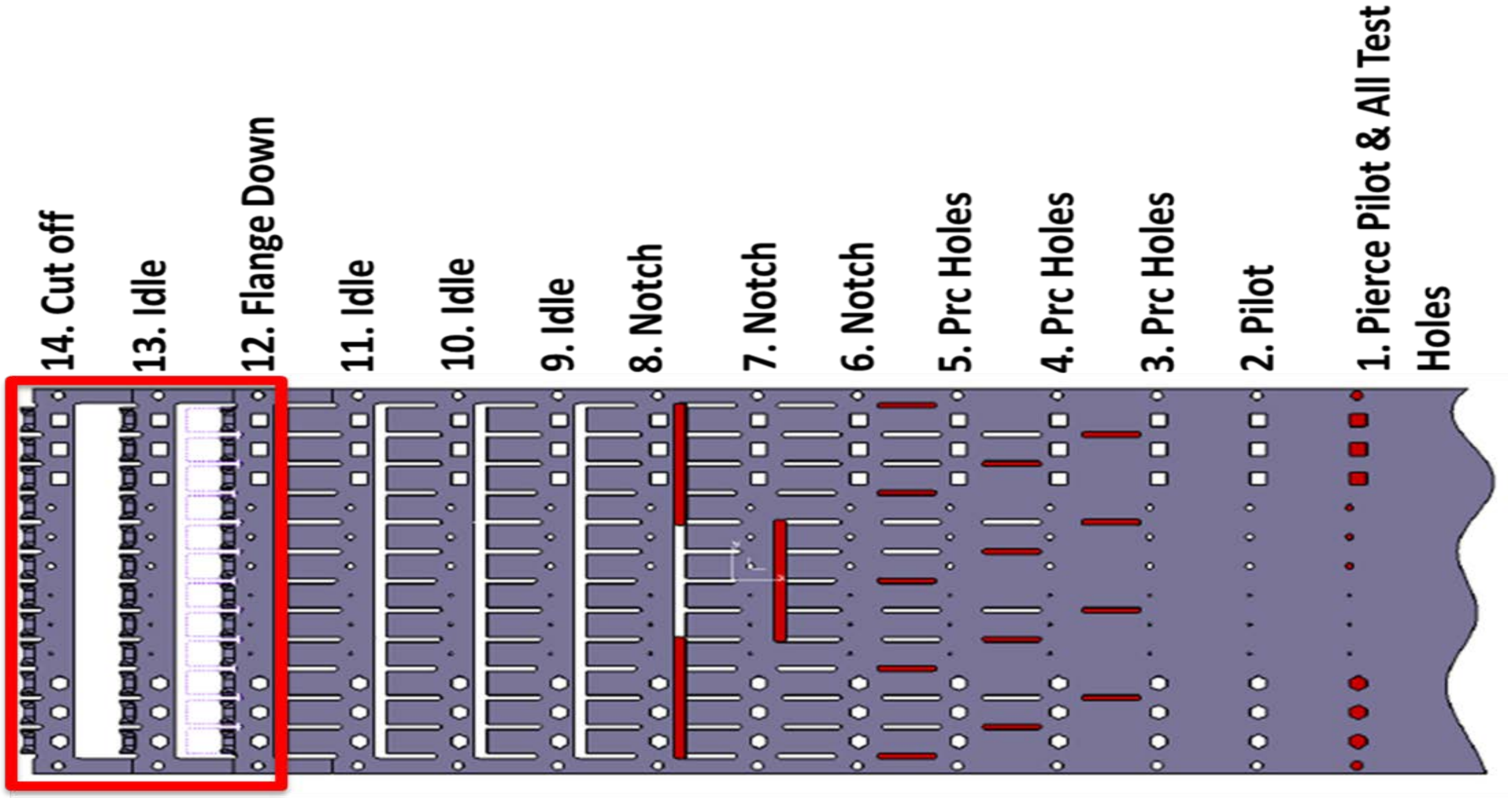








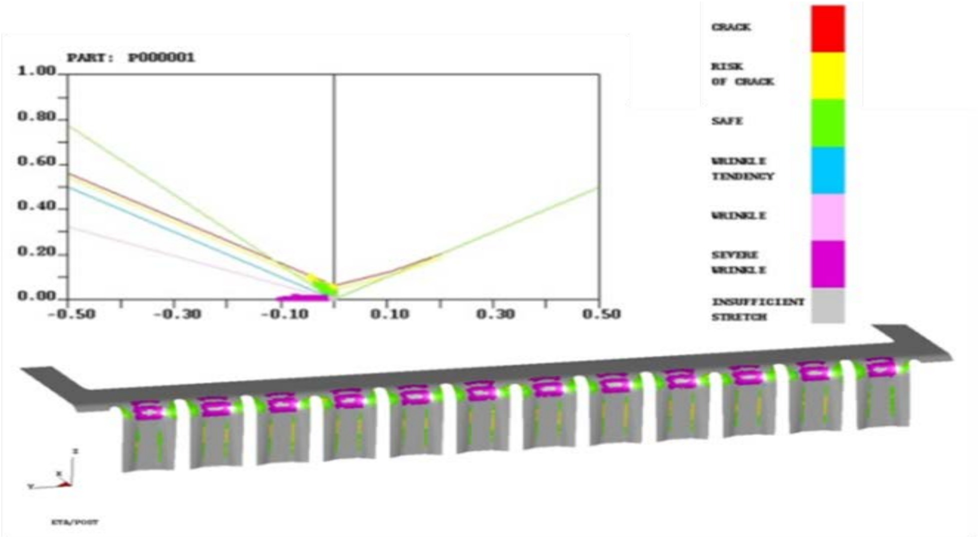
Progressive Die Setup



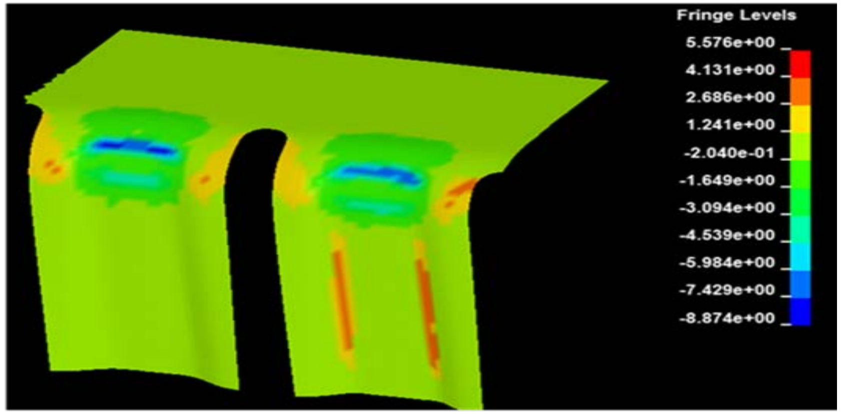
Die Wear Experiment in Production Environment

- Over 100k hits; 33 die inserts; Combination of 10 die materials and 9 coatings; 42 ton testing materials
- Preserve one panel every 500 hits

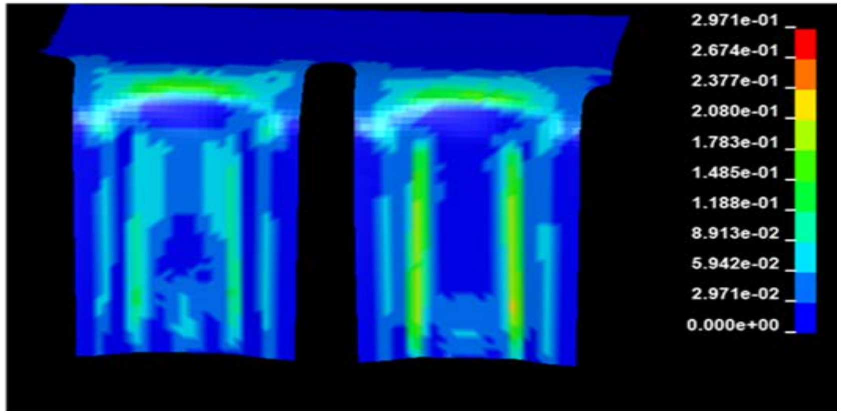
Forming Simulation for Progressive Die Wear Experiment



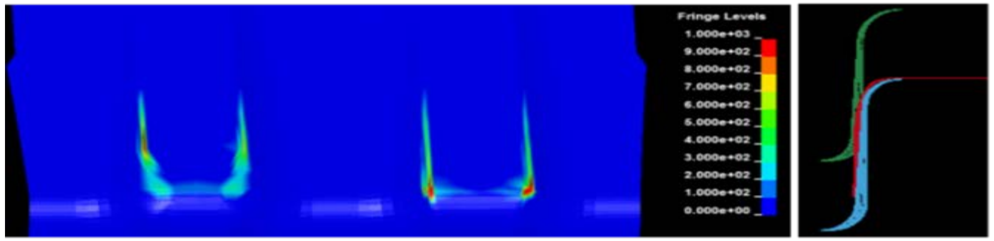
Thinning Strain Comparison



Effective Strain Comparison



Sliding Energy Density Comparison



2015/2016 Progressive Die Wear Experiment Stamping

2015 Progressive Die Wear Experiment Matrix

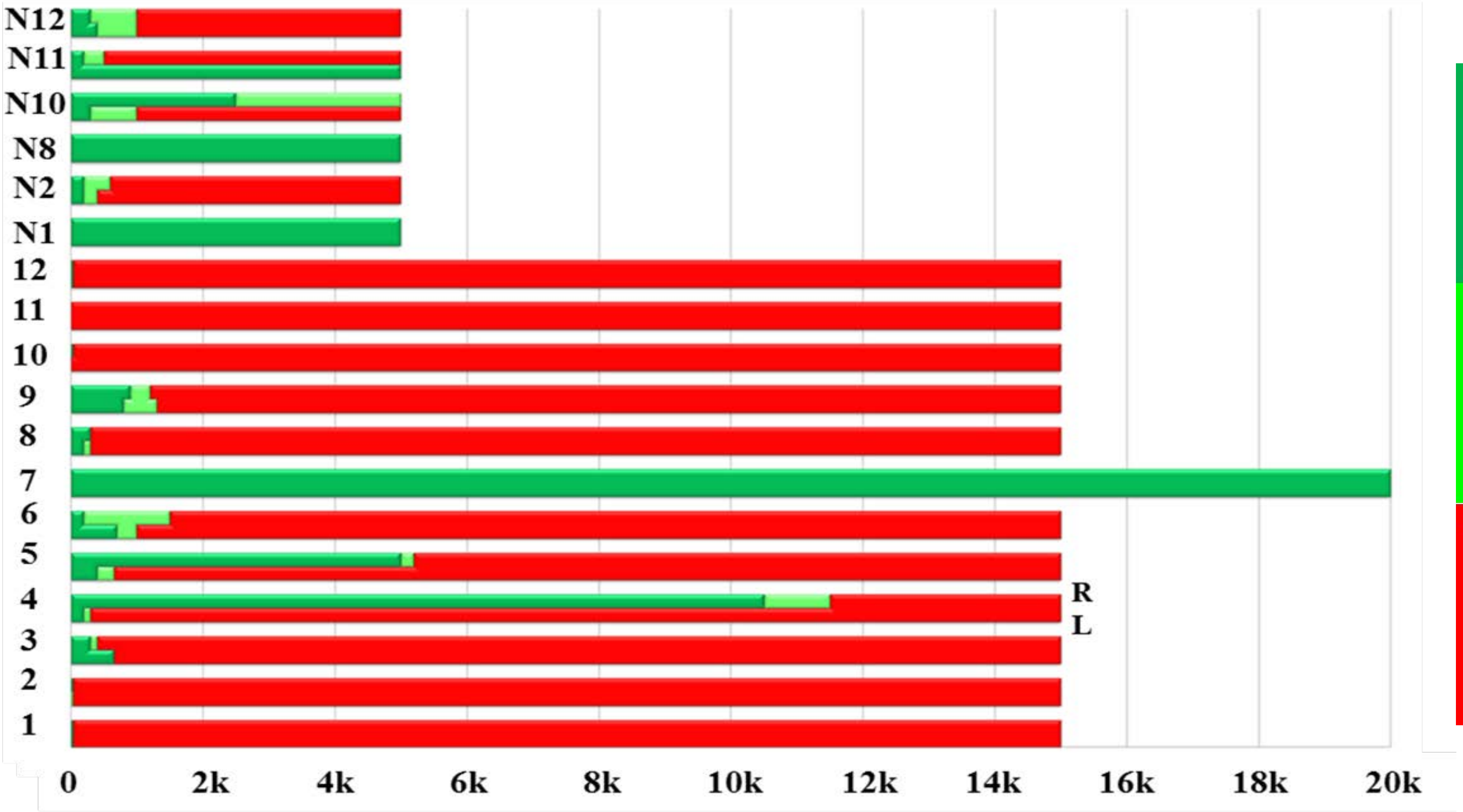
	12	11	10	9	8	7	6	5	4	3	2	1
Die Mater.	CC1	S0050A	S0050A	S2333	TD2	TD2	DC53	TD2	TD2	T44	CC1	D6510
Coating	HVOF MPD	Cr Plate over Ion Nitride	Cr Plate	**PVD Duplex CrN**	Concept	Cool Sheet	**PVD Duplex CrN**	**PVD Duplex CrN**	**PVD Duplex CrN**	**PVD Duplex CrN**	**PVD Duplex CrN**	**PVD Duplex CrN**
Hardness (Rc)	54-58	38-43	54-58	40-45	55-60	55-57	55-60	55-57	55-58	44-46	38-42	54-58

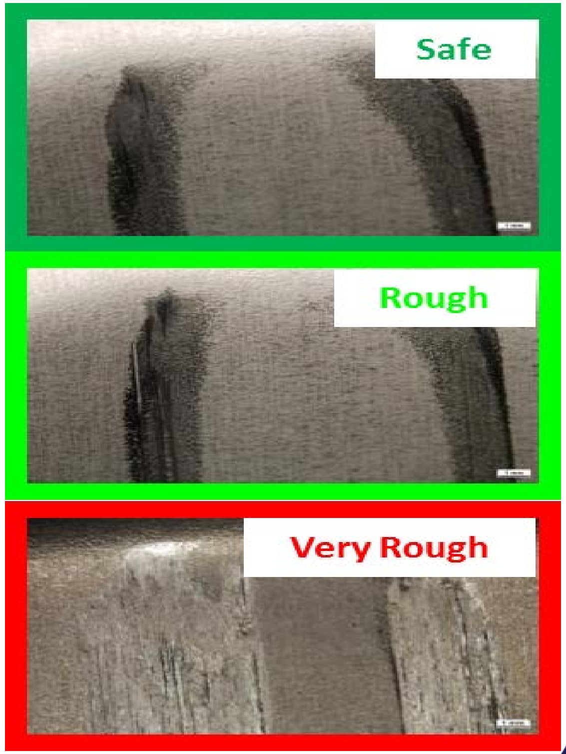
	12	11	10	9	8	7	6	5	4	3	2	1
Die Mater.	D2 (NEW)	D2 (NEW)	D2 (NEW)		TD2 (NEW)						D2 (NEW)	D2 (NEW)
Coating	**PVD Duplex CrN**	**PVD Duplex CrN**	**PVD Duplex CrN**		Concept + Most						**PVD Duplex CrN**	**PVD Duplex CrN**
Hardness (Rc)	58-60	58-60	58-60		58-60						58-60	58-60

No. 1, 2, 8, 10, 11, and 12 were replaced by new inserts after 15,000 hits

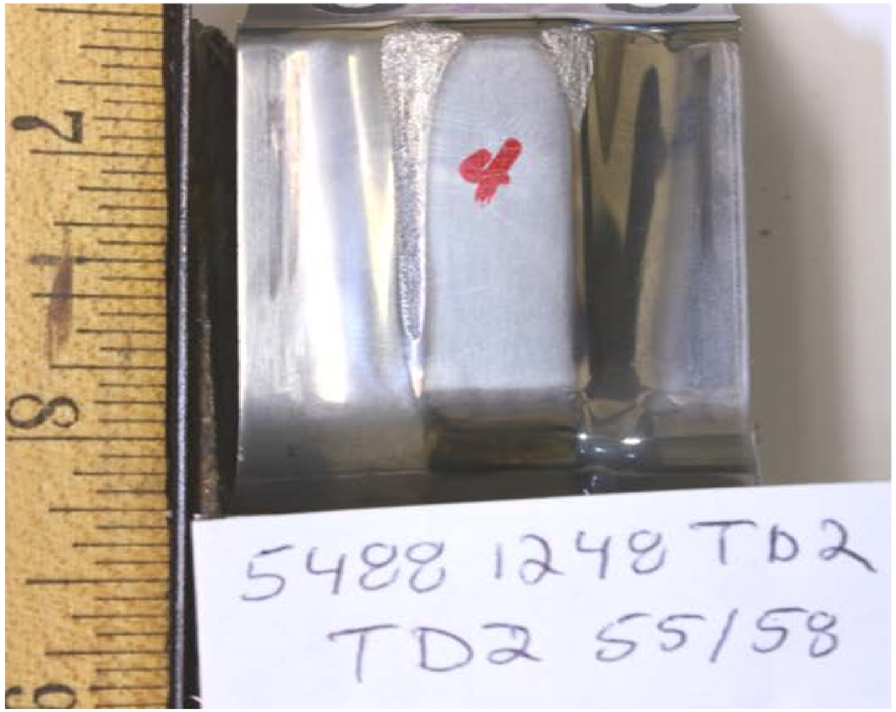
The combinations of 8 die materials and 7 coatings were evaluated up to 20k hits

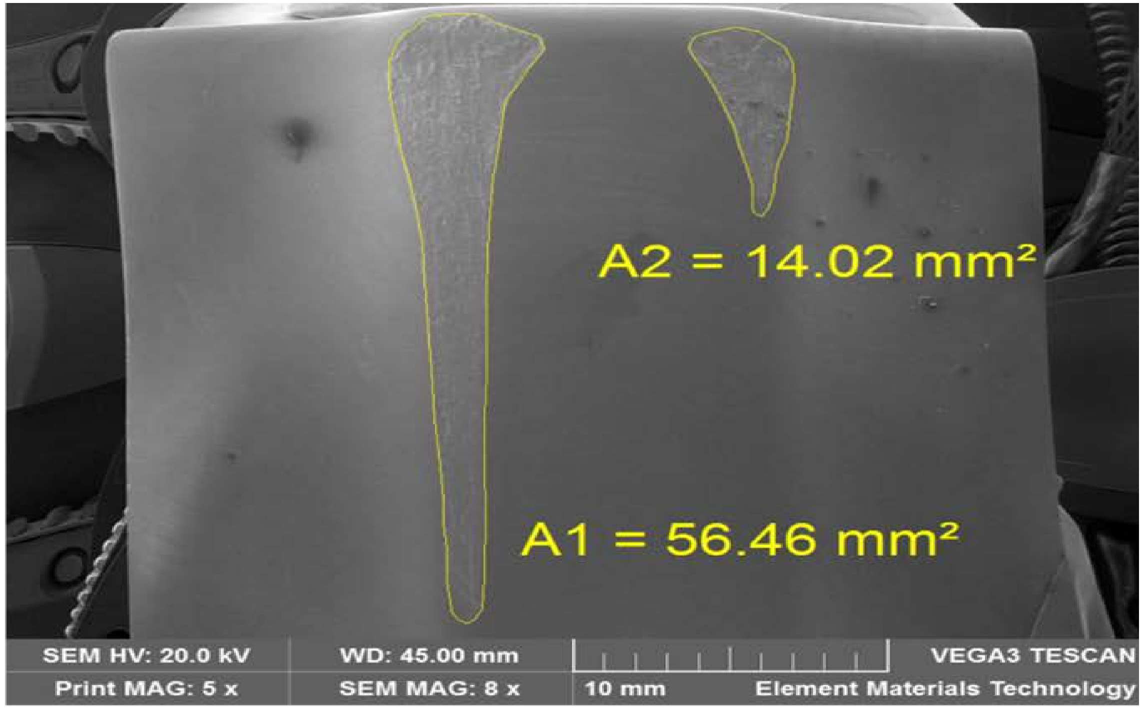
2015 Progressive Die Wear Experiment Results





2015 Progressive Die Wear Experiment Results





Die Wear Ranking for 2015 Project

Die ID	Die Material	Hardness (Rc)	Coating	SEM Worn Area (mm^2)	Visual ranking	Hits to "RR" Both Die Marks are Rough
6	DC53	55-60	PVD Duplex CrN	46	6	1400
3	T44	41-47	PVD Duplex CrN	62	4	700
4	TD2	55-58	PVD Duplex CrN	70	2	5000
9	S2333	40-45	PVD Duplex CrN	71	1 (least wear)	1200
8	TD2	55-60	Concept	87	7	300
5	TD2	55-57	PVD Duplex CrN	91	5	5000
11	S0050A	38-42	Cr Plate over Ion Nitride	103	3	35
10	S0050A	54-58	Cr Plate	109	8	35
1	D6510	54-58	PVD Duplex CrN	247	11 (most wear)	35
2	CC1	38-42	PVD Duplex CrN	286	10	35
12	CC1	54-58	HVOF MPD	3893	9	35

2016 Progressive Die Wear Experiment Matrix

	12	11	10	9	8	7	6	5	4	3	2	1
Die Mater.	SLD-i	TD2	DC53	Cast Caldie	TD2	TD2-old	TD2	SLD-i	Toolox 44	Cast Caldie	S2333	S2333
Coating	Concept + most	Duplex Variantic	Concept + most	Concept + most	Duplex CrN + most	Cool sheet	Concept + most	Cool sheet	Cool sheet	Cool sheet	Cool sheet	Cool sheet
Hardness (Rc)	58-62	55-58	62-64	58-62	55-58	55-57	55-58	58-62	-	58-62	50-54	40-45

No. 8 was replaced by No. 14 after 4,000 hits

No. 3 was replaced by No. 13;

No. 5 was replaced by No. 15;

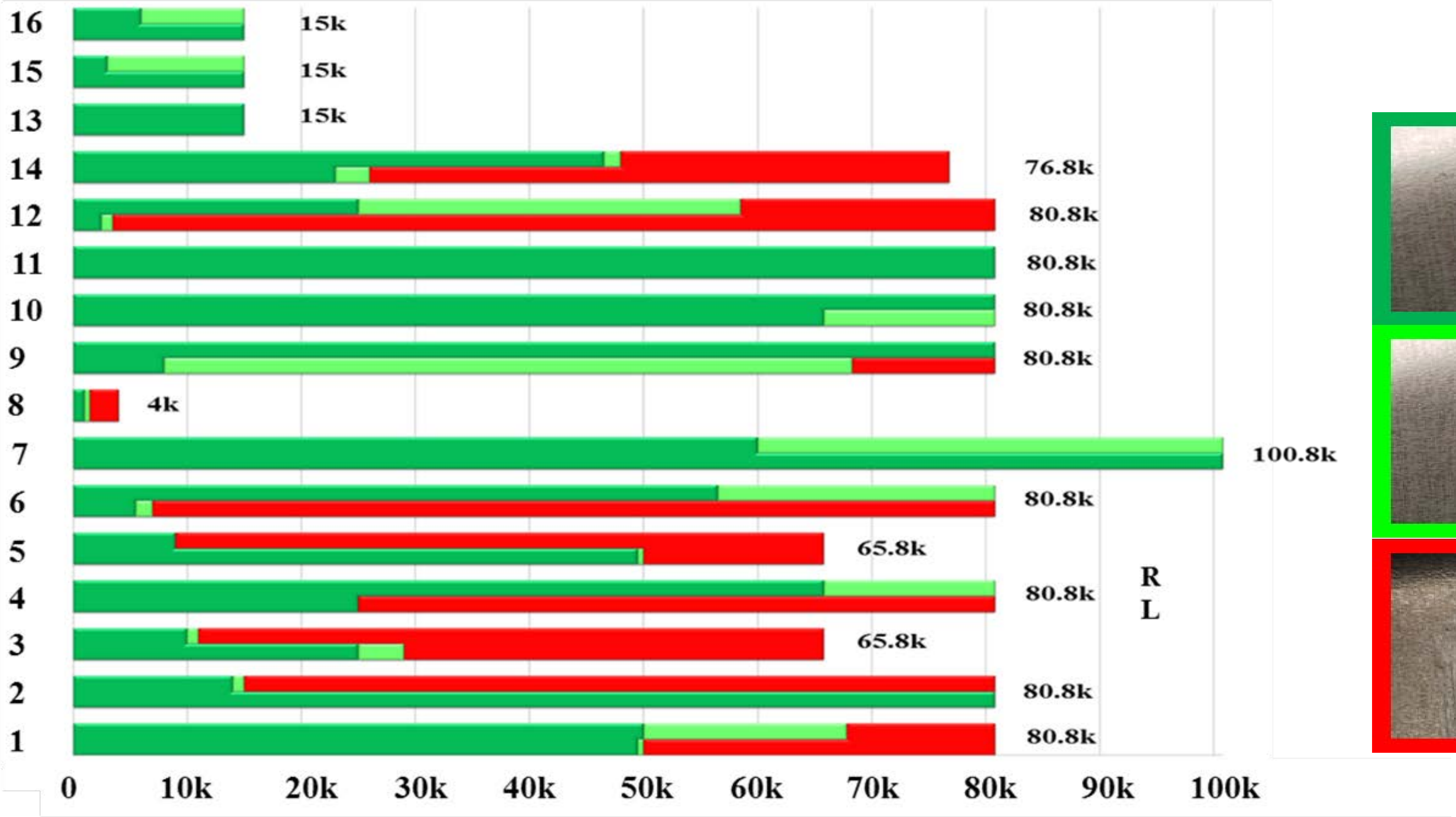
No. 14 was replaced by No. 16;

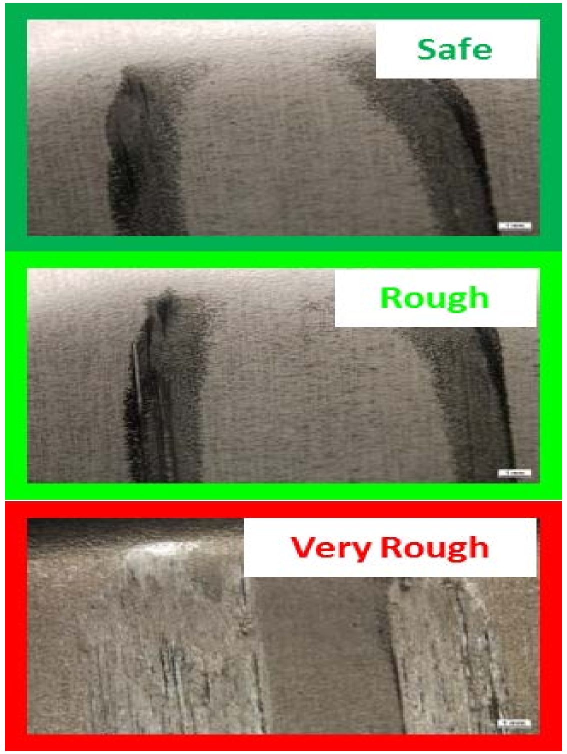
After 70,000 hits

14 and 16	15	13
TD2	S2333	TD2
Concept + Most	Concept + Most	Concept (Only)
58-62, N.A.	40-45	55-58

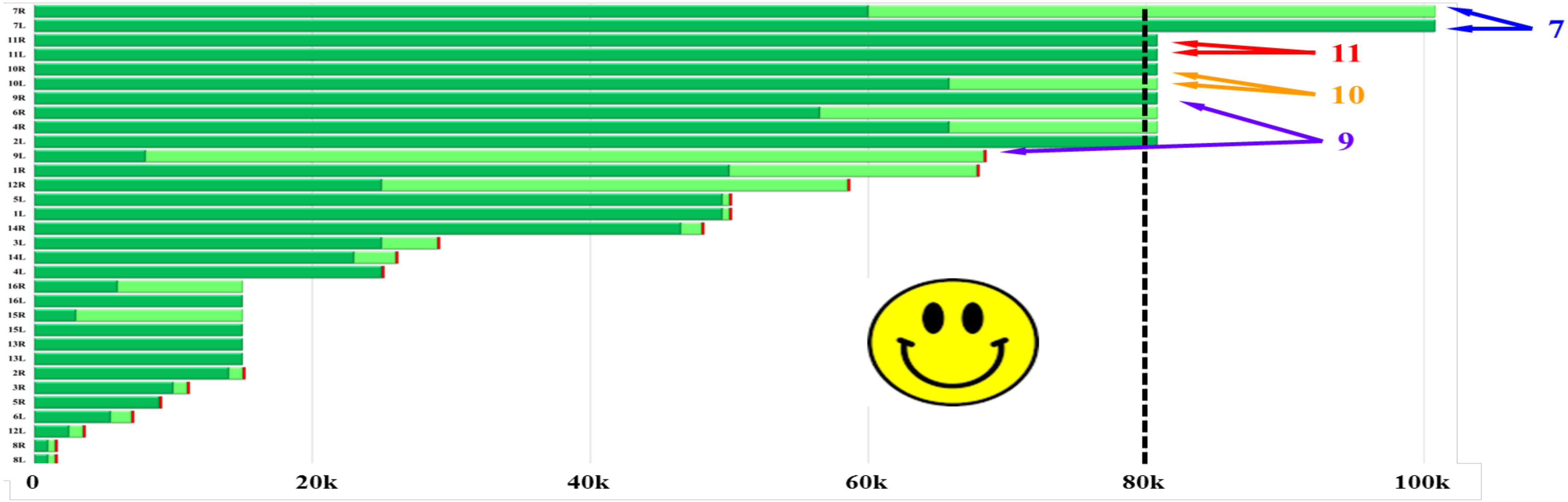
The combinations of 6 die materials and 6 coatings were evaluated up to 80k hits

2016 Progressive Die Wear Experiment Results





Die Wear Ranking for 2016 Project



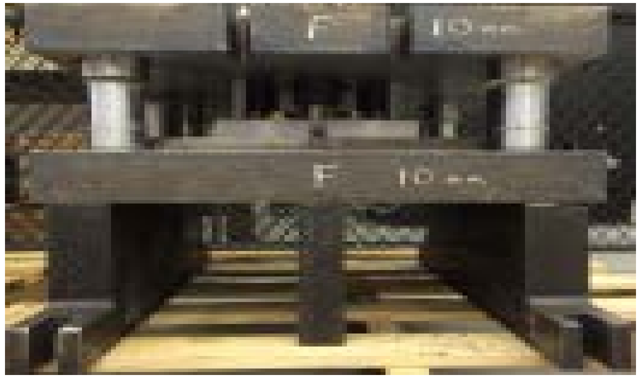
Conclusions – Progressive Die Wear Properties on Bare DP1180

- The die wear was evaluated by various combinations of die materials and coatings in 2015 and 2016, up to 100,800 hits for bare DP1180 steel
- The inserts #7 (TD2, Cool Sheet), 9 (Cast Caldie, Concept+Most), 10 (DC53, Concept+Most), and 11 (TD2, Duplex+Variantic) are the potential candidates for stamping 1180 grades steel in mass production

AHSS Hole Punch Force and Edge Cracking

Goals:

- Understand the impact of punch size, shape, clearance tolerances and surface roughness on the punch force and edge cutting quality
- After samples are collected, edge stretchability and failure criteria will be investigated for FEA relating to cut quality



10mm Hole

30mm Hole

60mm Hole

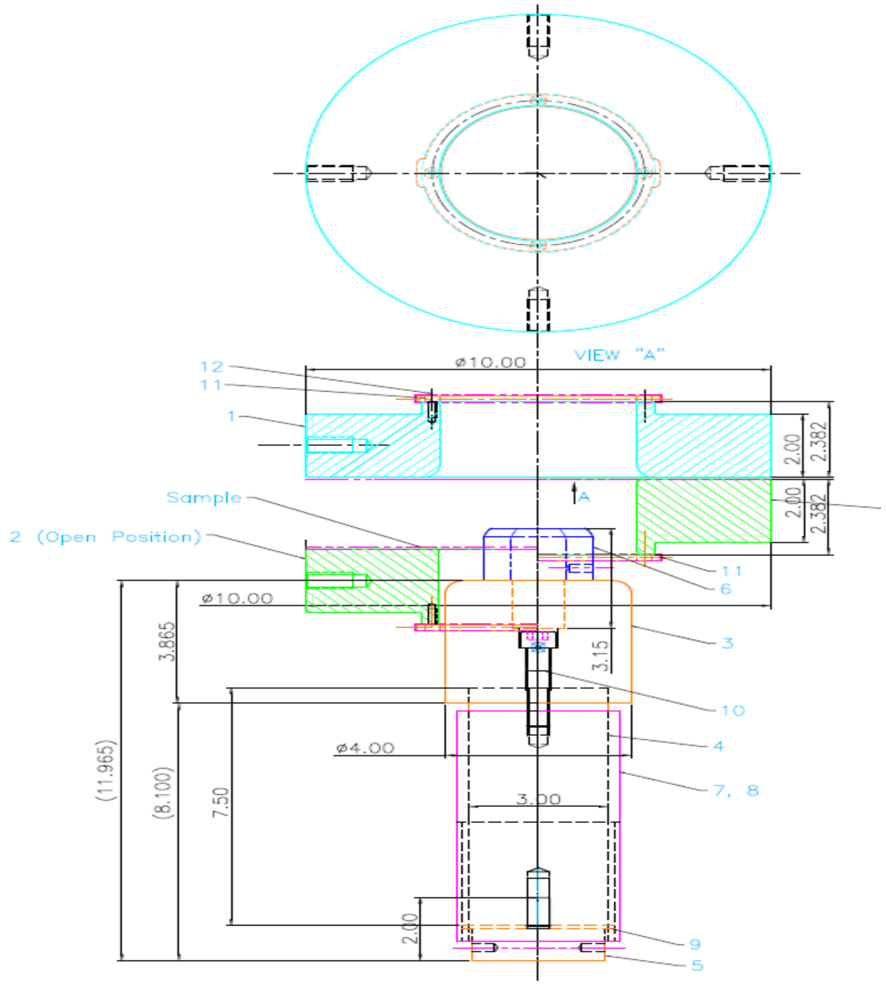
AHSS Hole Punch Force and Edge Cracking

Approach:

1. Hole punch force measurements with the following variables:
   - punch size (10, 30, 60mm)
   - punch shape (flat, conical)
   - clearance tolerances (6, 12,25%)
   - surface finish (rough, smooth)

2. HER tests will be run using DIC with multiple steels:
   - DQ
   - HSLA
   - AHSS 980

Hole Expansion Die Design for Phase II



AHSS Hole Punch Force and Edge Cracking

Deliverables:

1. Punch design for making the best quality cut edge
2. Evaluation of edge stretchability and its controlling factors

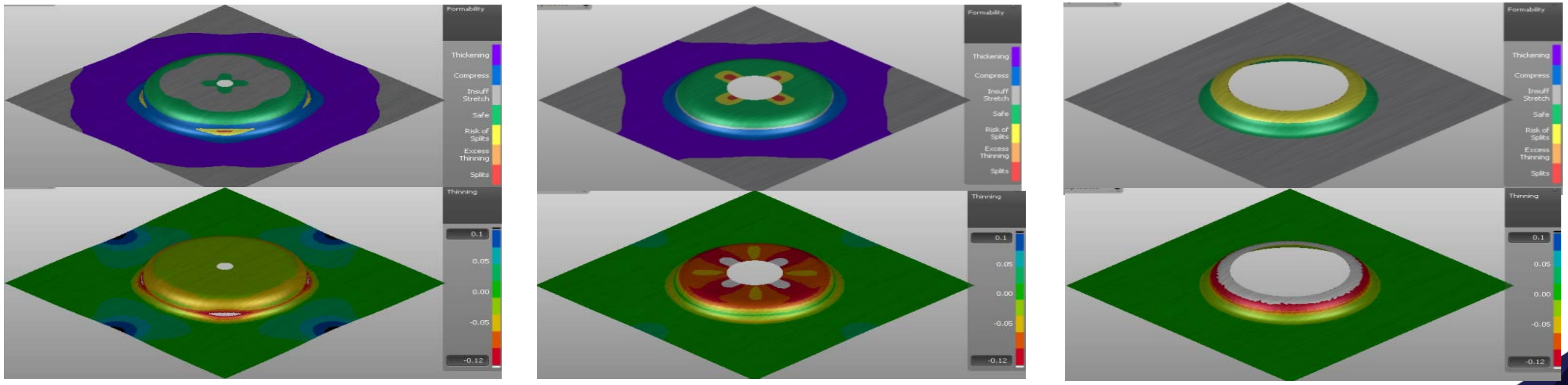
Status:

1. Hole piercing dies are ready, awaiting 980 and 1180 steel material
2. HER die design complete and currently being built
3. FEA has been performed on HER test

10 mm diameter (draw 17mm) | 30 mm diameter (draw 13mm) | 60 mm diameter (draw 15mm)

Formability

Thinning



Conclusions

- The automotive industry will continue to be challenged to meet more stringent fuel efficiency and safety regulation
- AHSS offer performance, value and sustainable solutions to meet these challenges
- A/SP stamping tooling optimization team provided tooling material/coating solutions to stamp steels of over 1000 MPa
- A/SP will continue to study other challenges such as Hole Punch Force and Edge Cracking for AHSS

Thank You

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