AHSS Edge Cracking Criteria Development for Sizable Stampings with a Large Cutout

Dajun Zhou, Changqing Du & John Siekirk III
- Chrysler Group LLC
Ken Schmid - General Motors Corporation
Ming Chen - United States Steel Corporation

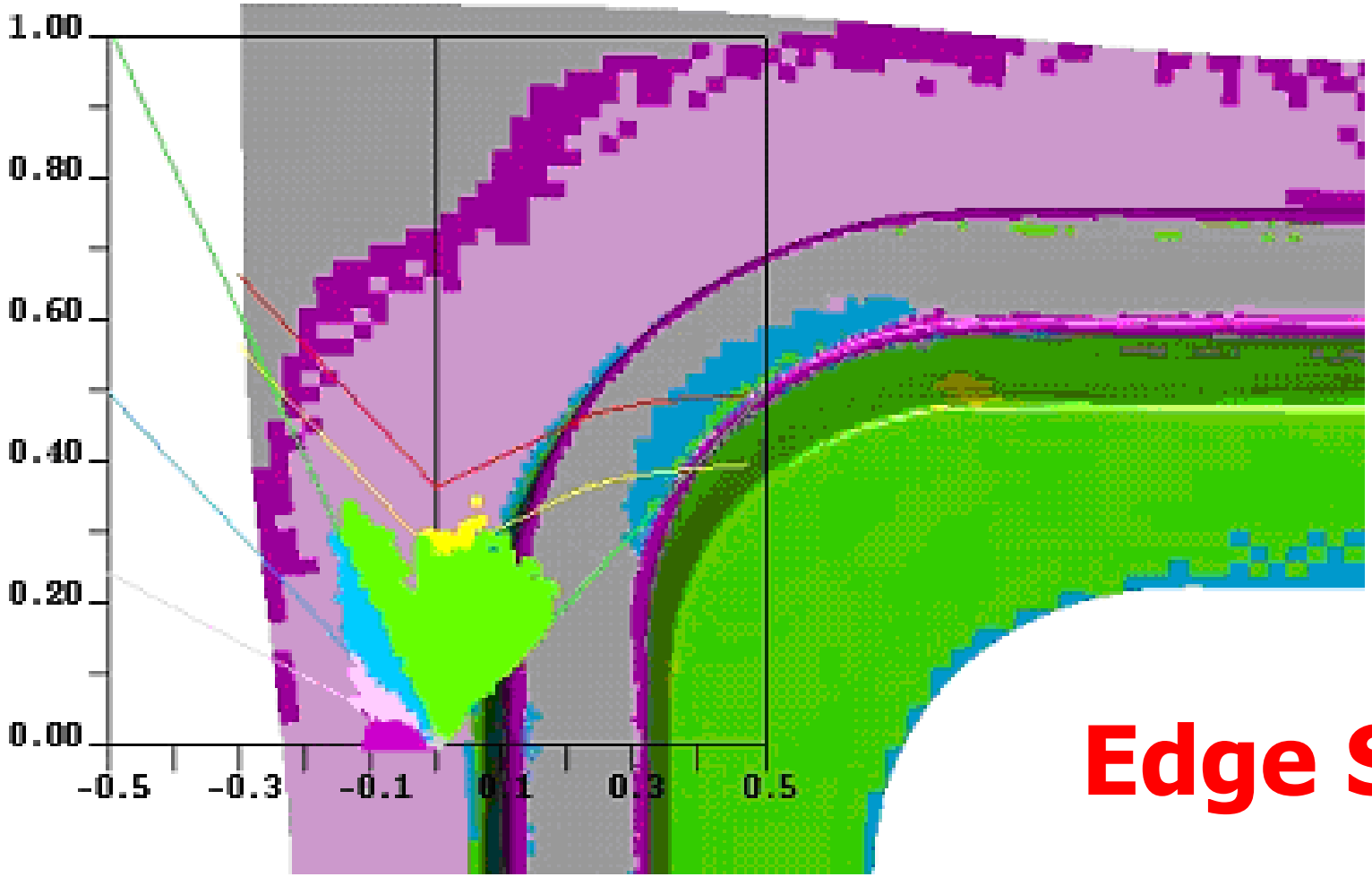
Project Review

- Measurement techniques for gathering thinning data.
- Traditional experimental tools vs full size application testing
- Experimental Results
- Summary

Introduction

- **Conventional laboratory edge stretching tests used very small hole diameters and were not very useful for large panel with interior cutouts.**
- **New experimental method for predicting practical failure limits needed in die shop and stamping plant.**
- **It is easier to measure thickness by ultrasonic gage in shop floor than the circle gridding technology along edge.**

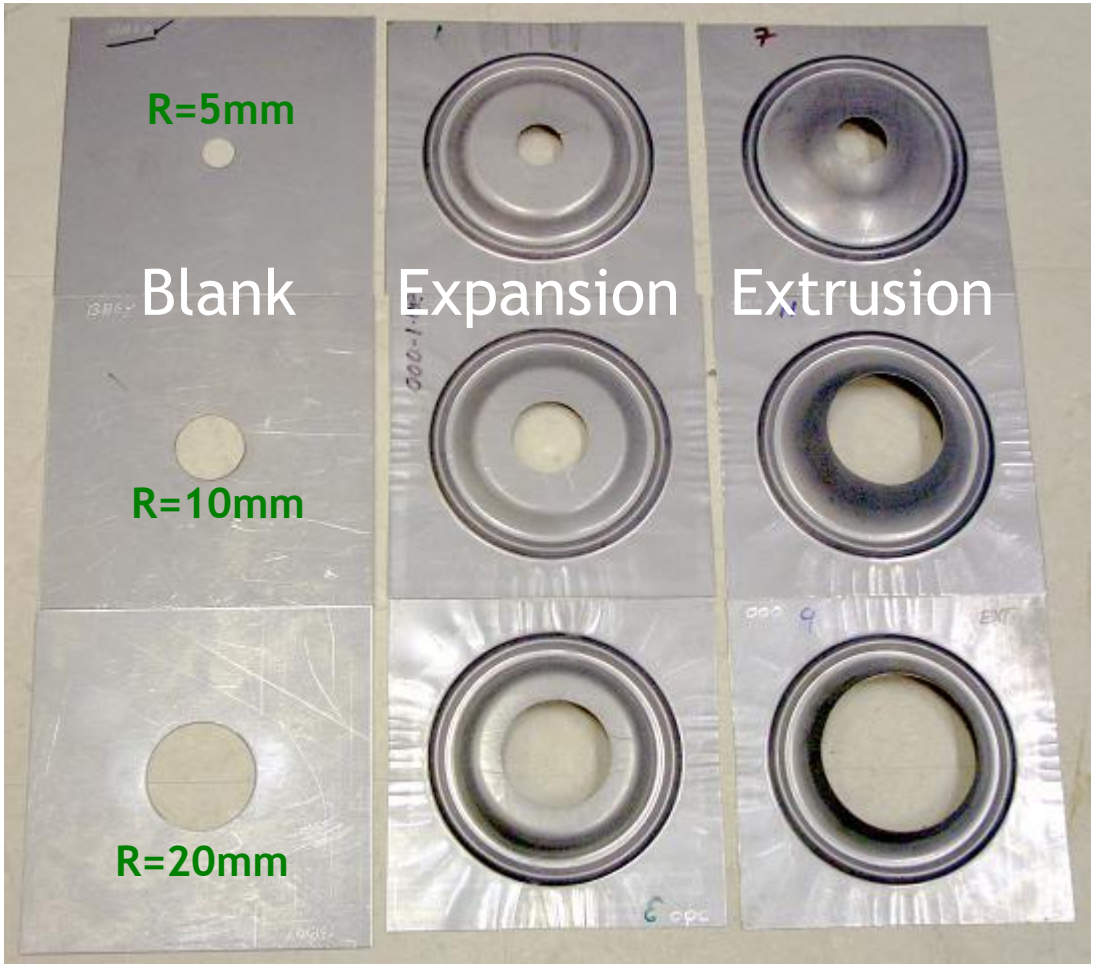
Forming Simulation



Edge Safe?

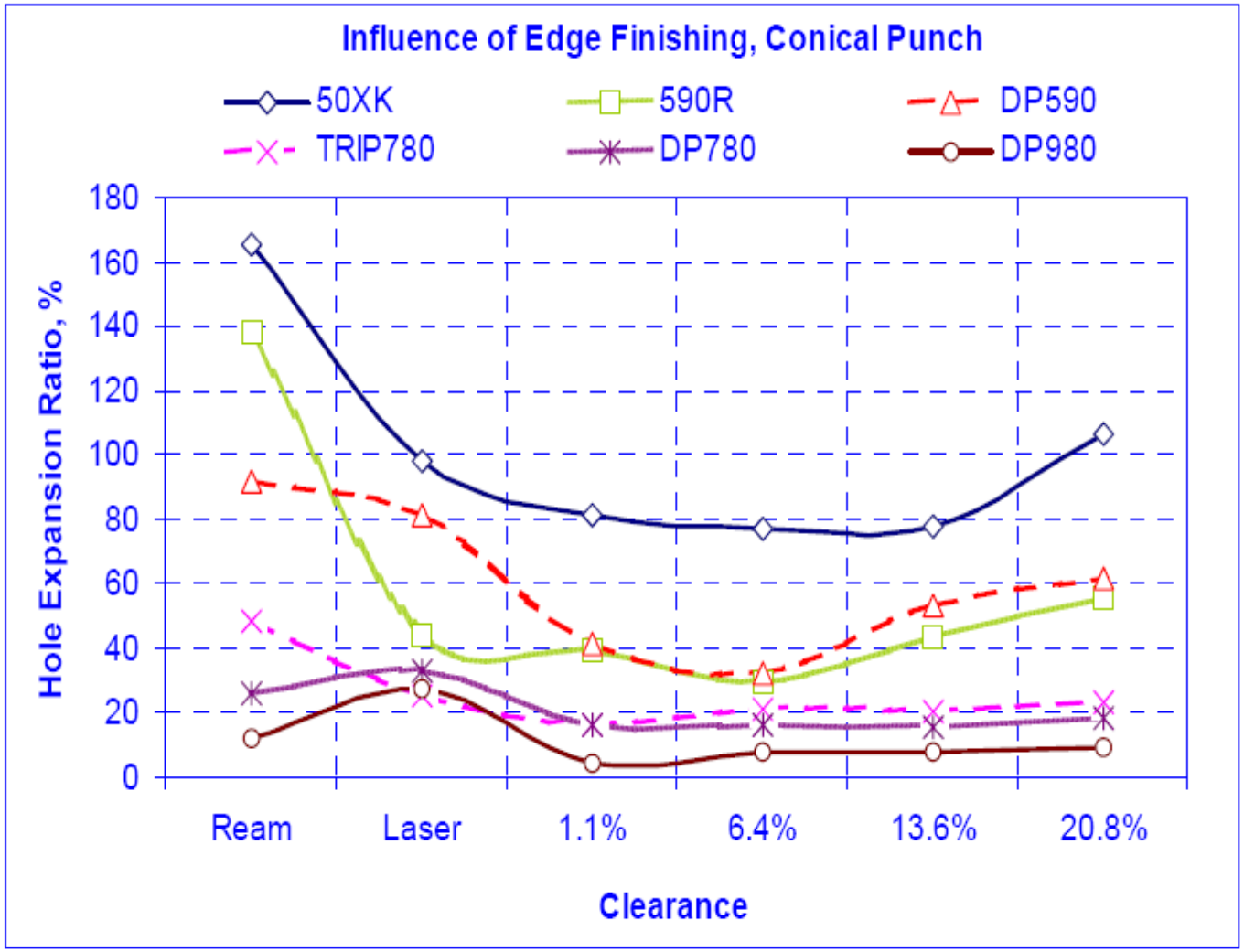
Lab Test – Hole Exp. vs. Ext.

ArcelorMittal Lab



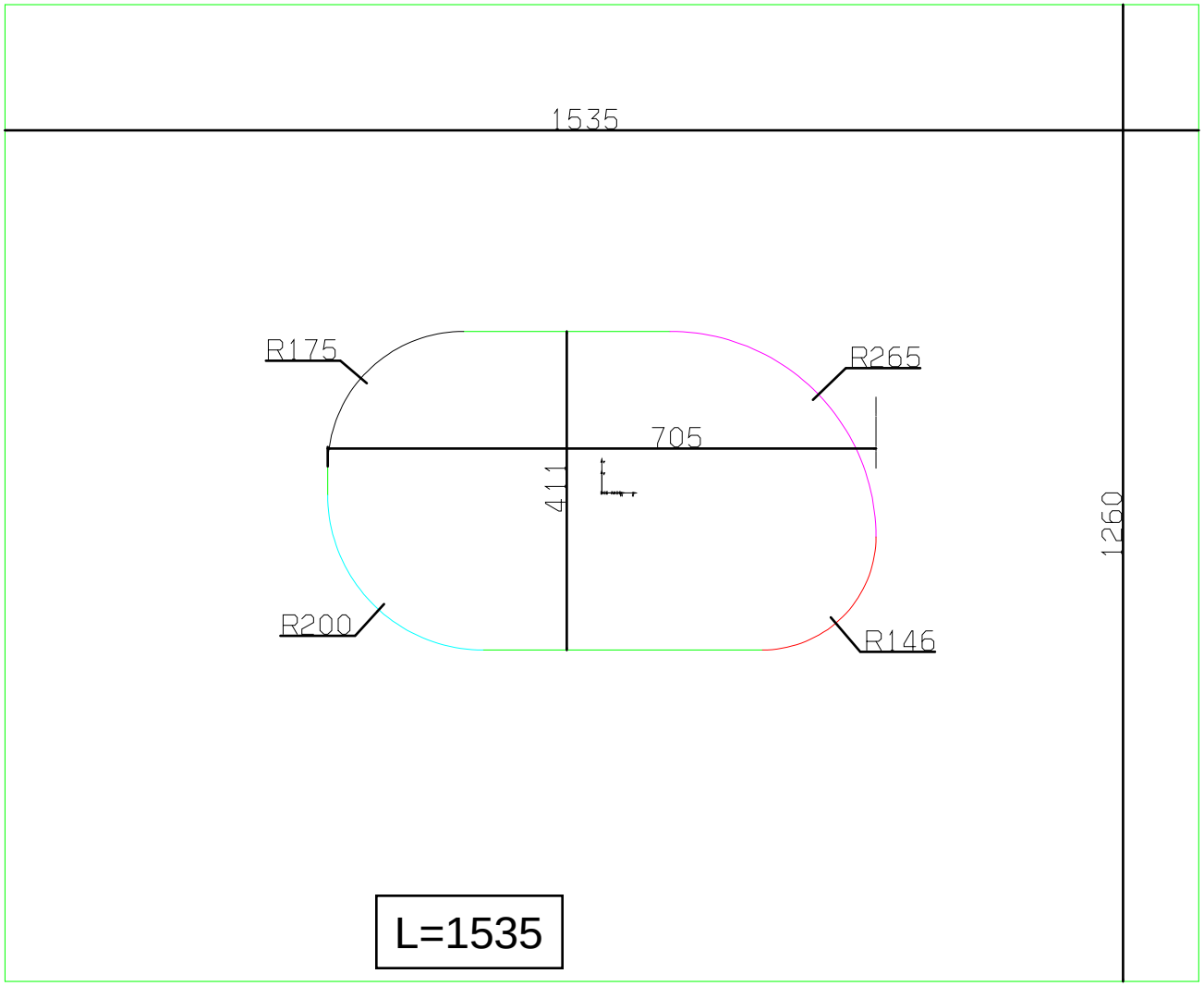
Blanks, Hole Expansion and Extrusion Samples

Edge Finish Effect



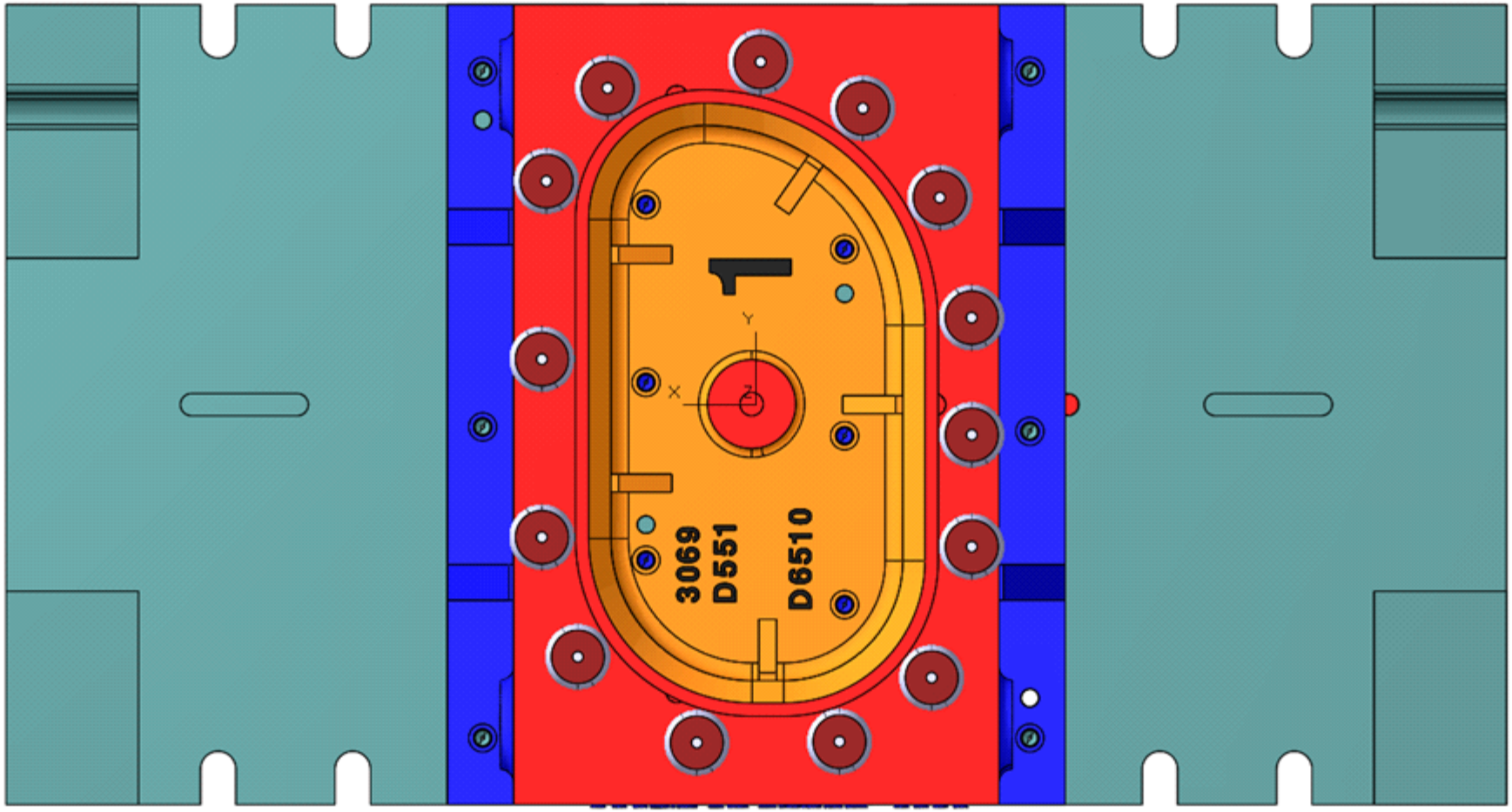
USS Lab

Blank Design



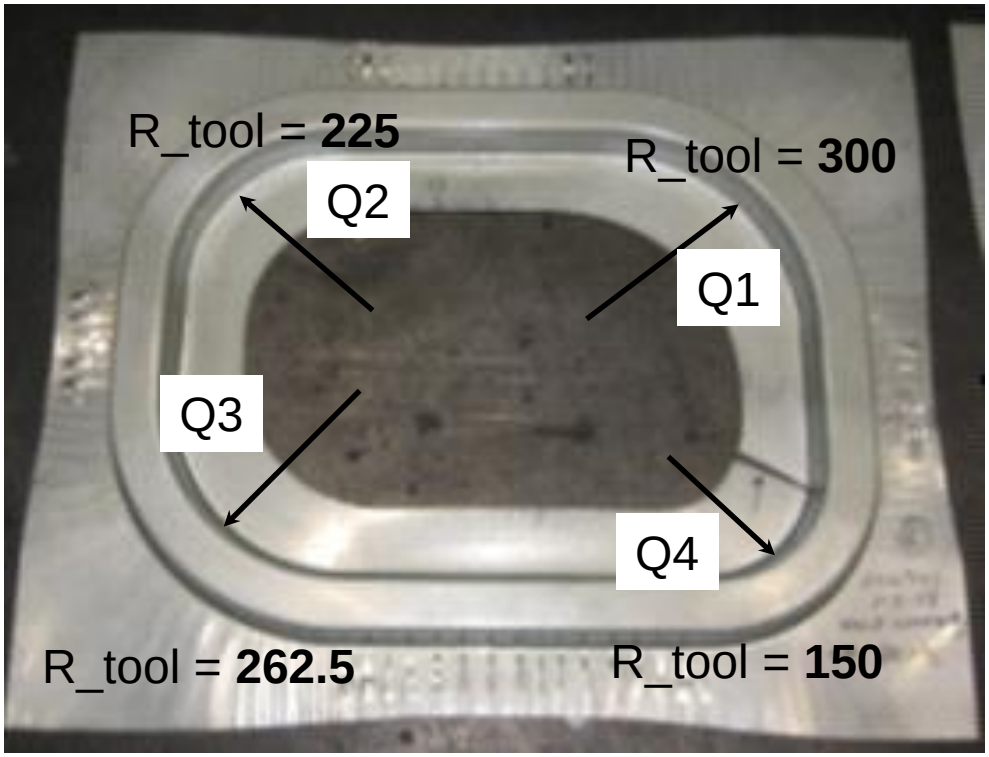
MBTA-306945 REV5 MASTER BLANK 08JAN08

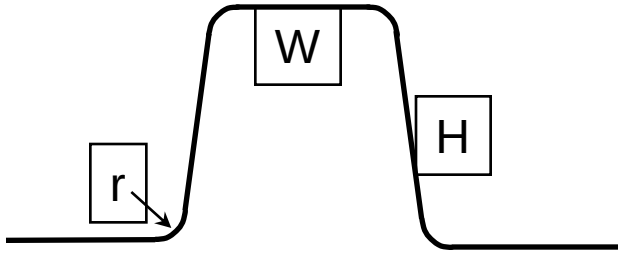
Blanking Die Design



14 Polyurethane Spring:
OD = 60 mm, ID = 14 mm, Compress 20 mm, Total holding force = 22.4 ton

Forming Die Design





Typical Punch section:
H = W=75mm
All r = 5.6
Draft angle = 10°

Baseline sheet thickness T_0=1.47mm

Draw die binder force: 1200psi, 16cylinders

Cutting clearance 5%, 10%, 15%, 20%, & 25%

Sheet Composition & Properties

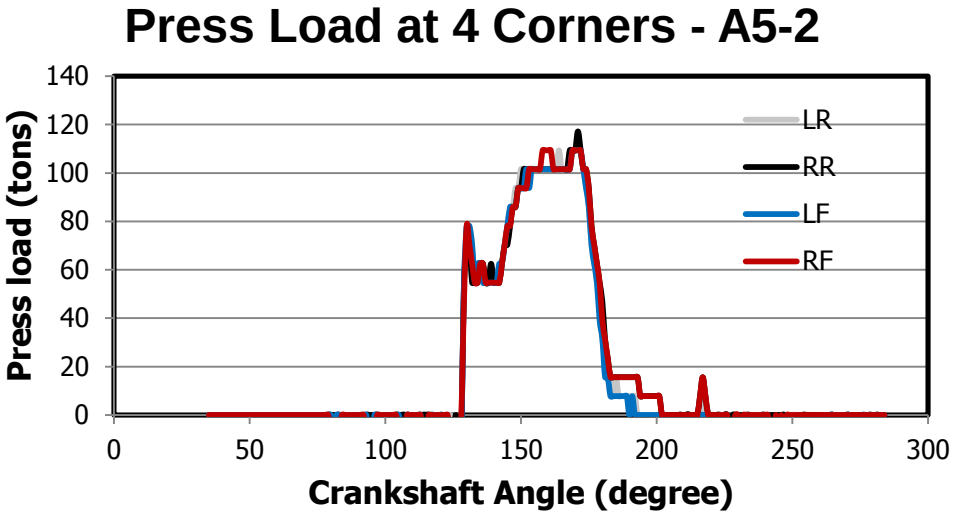
Sample	Material	Measured T0 (mm)	C	Mn	P	S	Si	Al	Nb	TS	.2% YS	UE%	TE%	n^1 4-6%	n^2 10-20%	r-
A	DP600 GA	1.02	0.08	2	0.011	<.003	0.03	0.04	<.003	589.0	339.8	15.8	22.975	0.195	0.155	0.975
B	DP980 GA	1.03	0.1	2.1	0.013	<.003	0.01	0.04	<.003	1018.8	612.5	8.925	11.775	0.105		0.95
C	DP980 GA	1.44	0.1	2.1	0.013	<.003	0.02	0.03	<.003	975.5	537.5	10.55	14.6	0.15		0.835
D	DP980 CR	1.04	0.13	1.3	0.013	0.006	0.28	0.04	<.003	1142.8	695.3	6.75	10.075	0.0825		1.1025
E	DP980 CR	1.46	0.09	1.3	0.014	0.005	0.28	0.03	<.003	993.5	648.8	8.95	13.35	0.12		1.15
F	DP980 CR	1.88	0.14	1.3	0.01	0.006	0.27	0.03	<.003	1103.8	664.3	8	12.325	0.1075		1.2775
G	TRIP780 GA	1.09	0.14	1.5	0.01	<.003	0.06	1.1	0.017	773.0	451.0	22.85	28.75	0.27	0.25	0.885
H	TRIP780 GA	1.41	0.13	1.8	0.01	<.003	0.04	1.2	<.003	792.3	462.8	17.725	23.275	0.255	0.1975	1.0075
I	DP780 GA	1.03	0.09	1.8	0.016	<.003	0.01	0.03	<.003	871.5	516.0	11.5	15.825	0.15	0.115	1.165
J	DP780 GA	1.39	0.08	1.8	0.014	<.003	0.01	0.04	<.003	818.5	513.0	11.4	16.575	0.15	0.11	1.175
K	DP780 GA	1.78	0.08	1.8	0.015	<.003	0.01	0.04	<.003	837.8	507.0	10.75	16.05	0.1375	0.105	1.17
L	DP600GI	1.23	0.09	1.6	0.01	<.003	0.34	0.03	<.003	611.0	353.5	17.425	24.575	0.22	0.18	1.095
M	DP600GI	1.57	0.07	1.6	0.019	0.003	0.01	0.04	<.003	633.3	395.3	15.375	22.8	0.1775	0.1525	1.165
N	590RGI	1.21	0.13	1.4	0.013	0.005	0.12	0.03	0.04	565.0	401.3	14.85	22.425		0.1475	1.025
P	590RGA	1.59	0.13	1.4	0.012	0.004	0.1	0.04	0.034	578.0	437.5	14.7	23.775		0.15	1.145
Q	DP780GI	1.61	0.11	1.8	0.017	<.003	0.03	0.04	<.003	784.5	480.0	12.525	17.75	0.1725	0.135	1.075
R	HSLA50GI	1.04	0.08	0.52	0.012	0.008	<.01	0.03	0.016	447.0	366.0	18.8	27.65		0.18	1.2425
S	HSLA50GA	1.23	0.07	0.73	0.012	0.008	0.44	0.04	0.036	498.8	404.0	14.275	24.625		0.1425	1.1475
X	DP600GI	1.21	0.09	1.8	0.014	<.003	0.22	0.04	<.003	697.0	403.5	16	22.825	0.21	0.1675	1.165

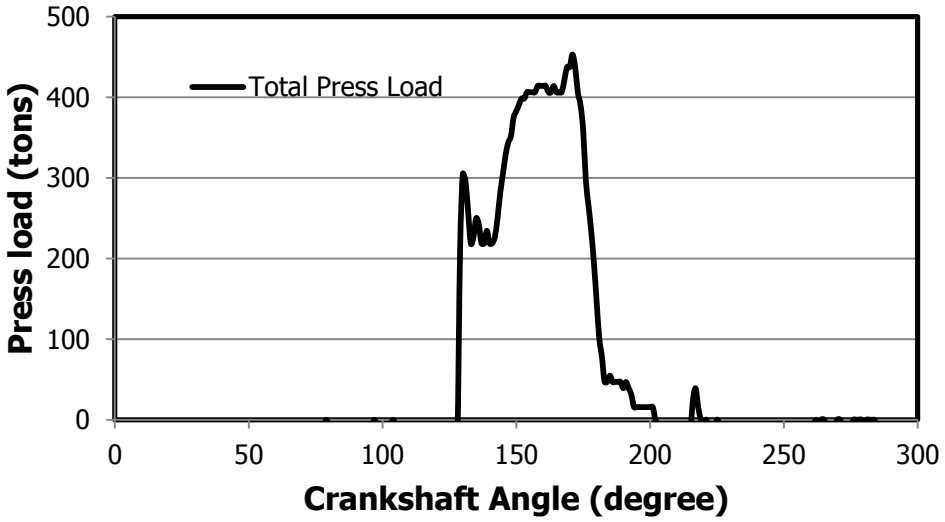
GM Mat. Lab.

Formed Panel List (236 total)

Mat. ID	**Material**	**T0**	5%	10%	15%	20%	25%	Total #
A	DP600GA	1	3	3	3	3	3	15
B	DP980GA	1	5	3	3			11
C	DP980GA	1.4	2	2	3		3	10
D	DP980CR	1	3	3	3			9
E	DP980CR	1.4	3		3		3	9
F	DP980CR	1.8			3	3	3	9
G	TRIP780GA	1	3	4	3	2	3	15
H	TRIP780GA	1.4	2	2	3		3	10
I	DP780GA	1	3	3	2			8
J	DP780GA	1.4	1	2	2		4	9
K	DP780GA	1.8	4	2	3	3	3	15
L	DP600GI	1.20	3	3	3			9
M	DP600GI	1.54	4		2		2	8
N	590RGI	1.20	4	4		5	5	18
P	590RGA	1.54	3	3	5	3	5	19
Q	DP780GI	1.50	6	6	5	5		22
R	HSLA50GI	1.0		1	1	1	2	5
S	HSLA50GA	1.14	4	4	5	5	5	23
X	DP600GI	1.2	3	3	3	3		12

Forming Load Recording

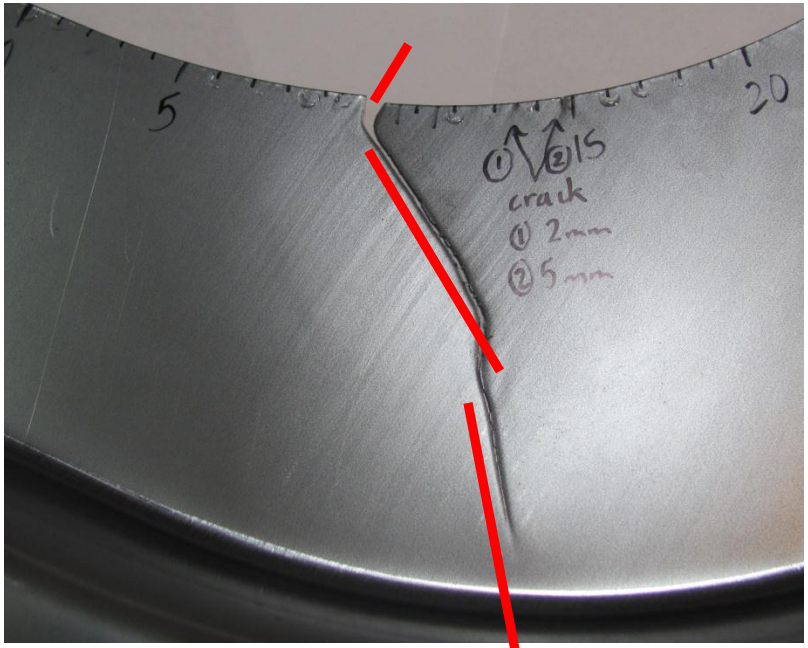


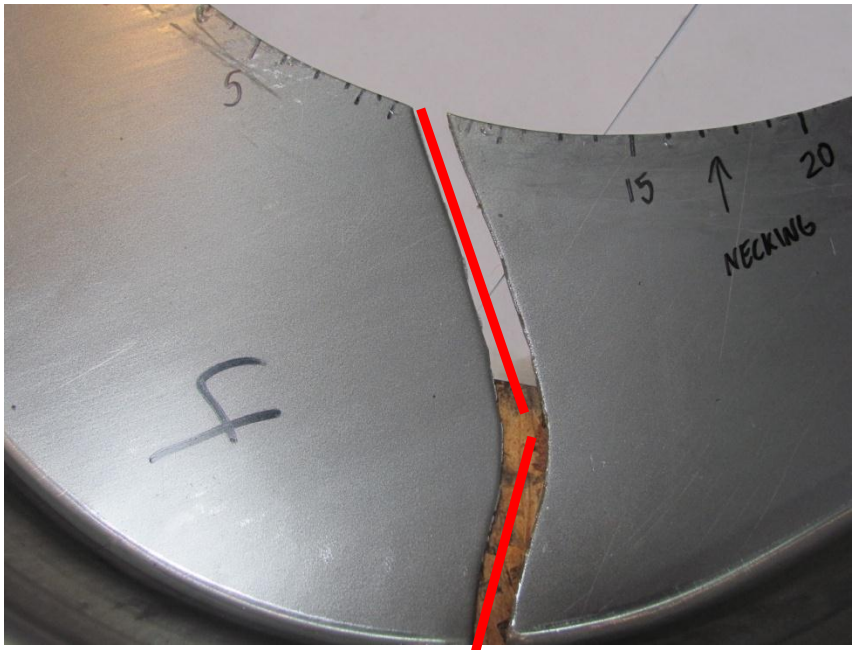


Curved Cracks

Large Curved Crack as A Combination of More Simple Straight Cracks

Edge thinning and inside thinning are two kind of competing processes, they initiated and grow individually in their own stress / strain environment, may combine together eventually to make a big curved crack

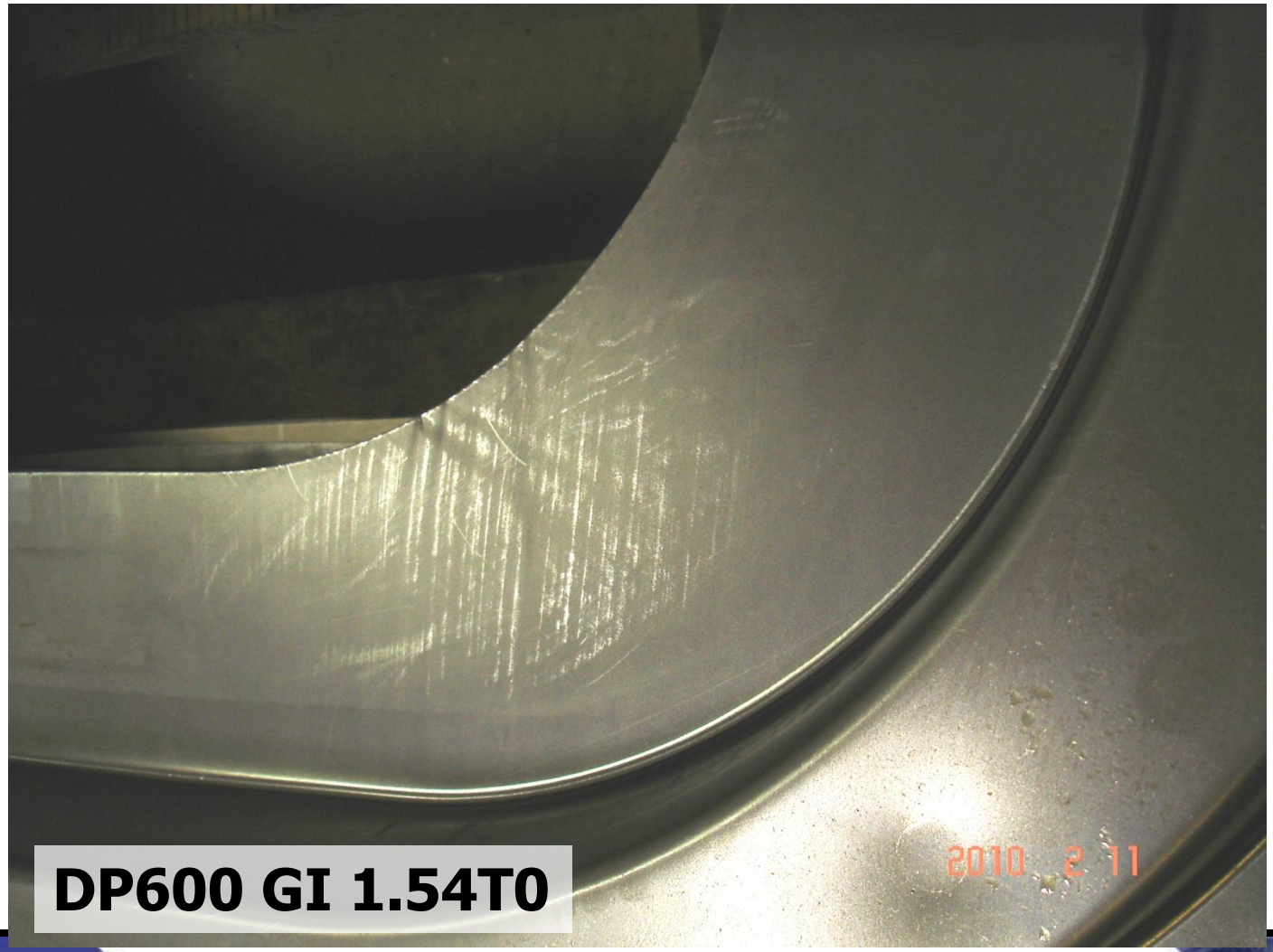




DP600 GI 1.54T0

Multiple Necking

Typical Multiple Necking along Rolling Direction and Edge V-shape Necking



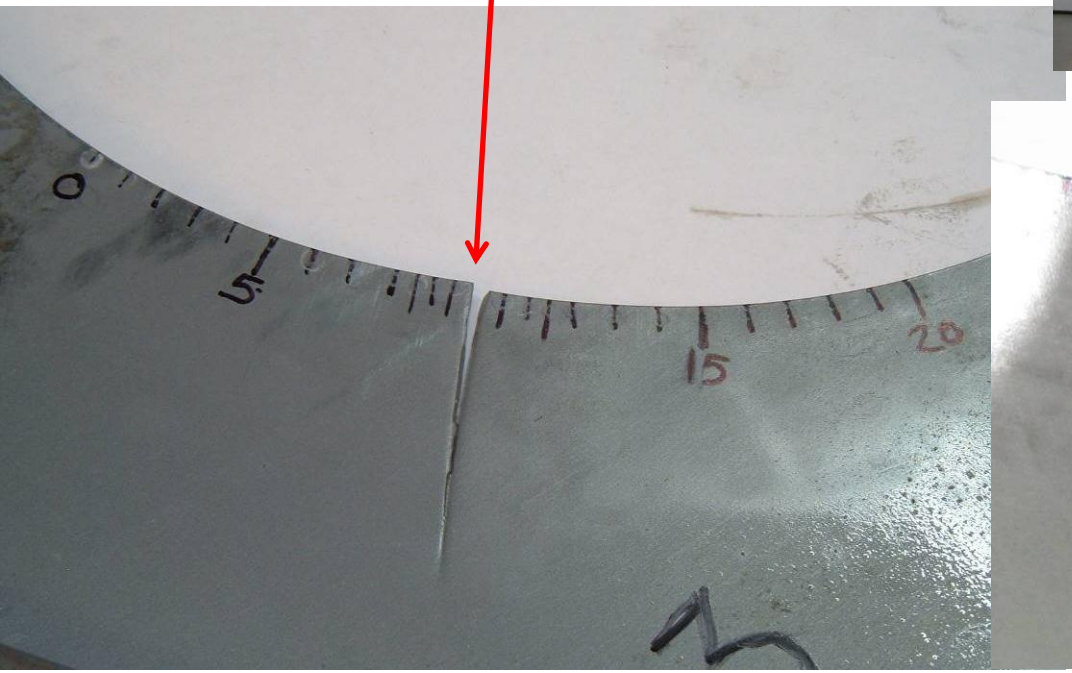
Ultrasonic Thickness Measurements

Sensor contact head 5 mm diameter
Measure along panel edge

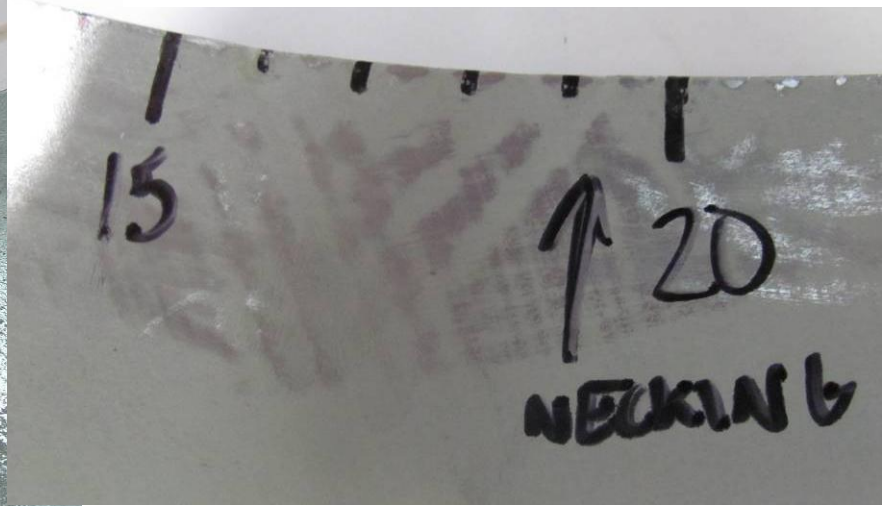
Measured @AET

Measurement

Measurement point marked with 5 mm spacing near the crack / necking, 10 mm spacing in no crack / necking zone.



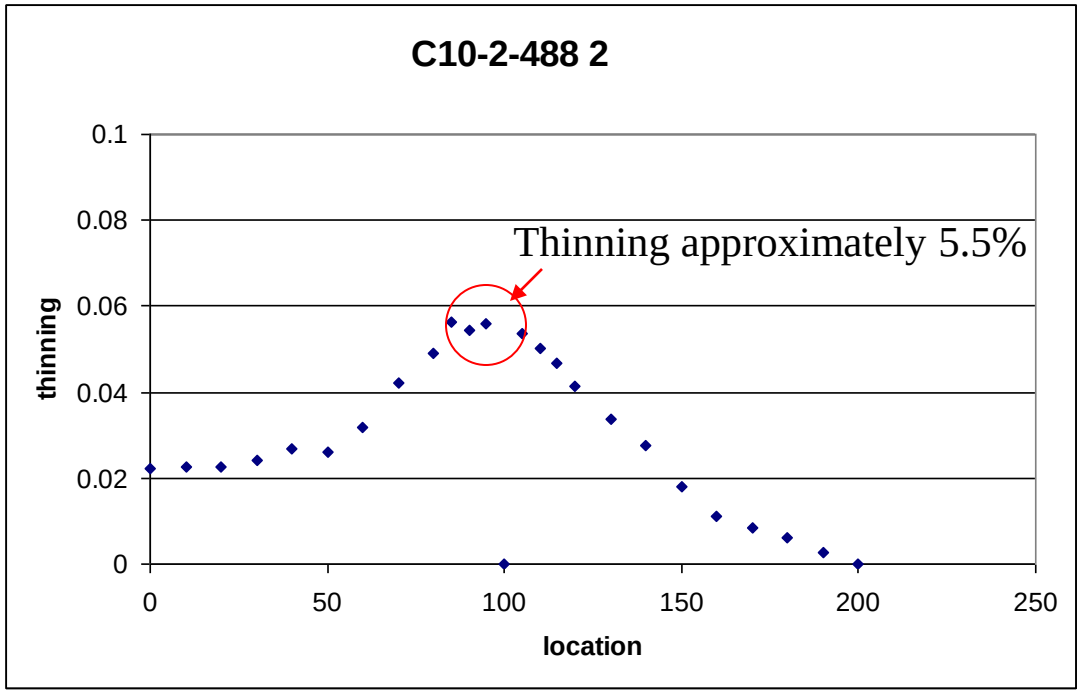
Slight stoning to highlight necking



Thinning Record & Plot

crack number	2	
rolling direction	1 - 2	
panel height (mm)	49	t0
crack length	100+	1.451

Point	Thickness (mm)	Eng Thinning
0	1.419	0.022053756
10	1.418	0.022742936
20	1.418	0.022742936
30	1.416	0.024121296
40	1.412	0.026878015
50	1.413	0.026188835
60	1.405	0.031702274
70	1.39	0.042039972
80	1.38	0.048931771
85	1.369	0.05651275
90	1.372	0.05444521
95	1.37	0.05582357
100	crack	
105	1.373	0.05375603
110	1.378	0.050310131
115	1.383	0.046864232
120	1.391	0.041350793
130	1.402	0.033769814
140	1.411	0.027567195
150	1.425	0.017918677
160	1.435	0.011026878
170	1.439	0.008270159
180	1.442	0.006202619
190	1.447	0.00275672
200	1.451	0

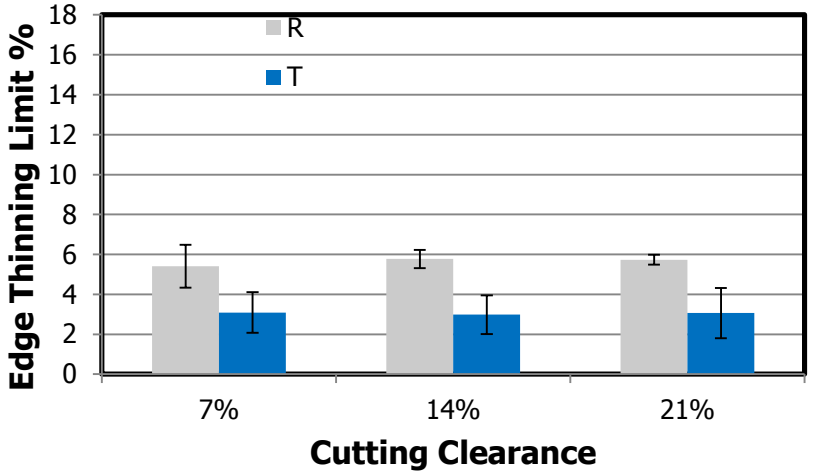


Typical Test Record Sheet

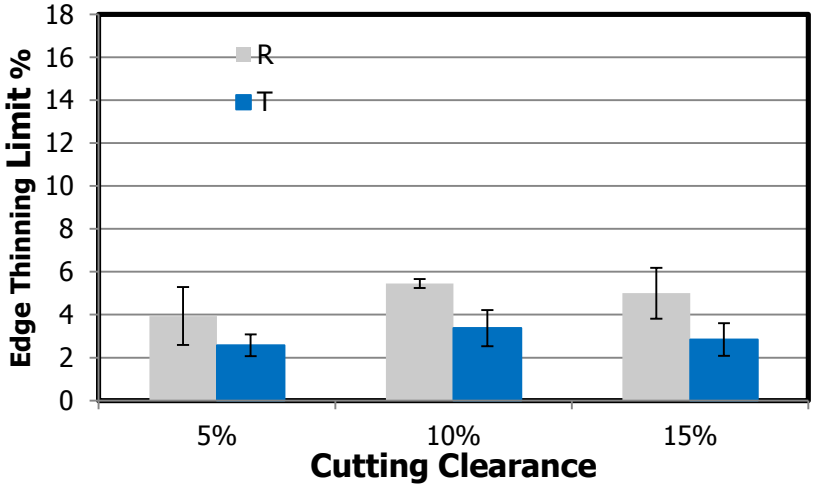
A 1.0 t DP600GA	Cut force	Ram ton	Roll dir	Panel height	Q1R	Q1T	Q2R	Q2T	Q3R	Q3T	Q4R	Q4T	note
5-1-465	140	465	↔	75						10.3		8.4	c3 c4 ck=100, c3 ck=4
5-2-461	138	461	↔	74						8.2		9.4	c3 c4 ck=100
5-3-465	142	465	↔	74				5.7		5.4		7.5	c4 ck100, c2 ck5, c3 ck4
10-1-500	138	500	↔	75						9.2		9.2	c4 ck=100, c3c k=10
10-2-469	133	469	↔	74				9.3	11.6 nk	10.5nk	12.2 nk	12.8	c2 ck=1, c4 ck=100
10-3-465	132	465	↔	74						9.7		9	c4 ck=100, c3 ck=5
15-1-453	133	453	↔	74						10.1		10.3	c4 ck=100
15-2-445	136	445	↔	74						10.7		13	c3 c4 ck=100
15-3-453	134	453	↔	74					12 nk	10.5 nk		10.1	c4 ck=100
20-1-465	132	465	↔	75				8.1	8.5	9.5		9.8	c4 c3 c2 ck100
20-2-465	131	465	↔	75					10.3	9.9		8.7	c4 c3 ck100
20-3-469	128	469	↔	74					10.1	11		8.6	c4 ck100 c3 2-ck100
25-1-465	135	465	↔	75			9 max	10.5 nk		9.5		6.1	c4 c3 ck100
25-2-465	131	465	↔	75				10.5	11.5 nk	9.0 nk		7.9	c4 c2 ck100
25-3-469	135	469	↔	74			12.1 nk	10 .0 nk	11.8 nk	11.6 nk		7.2	c4 ck100

Test Results

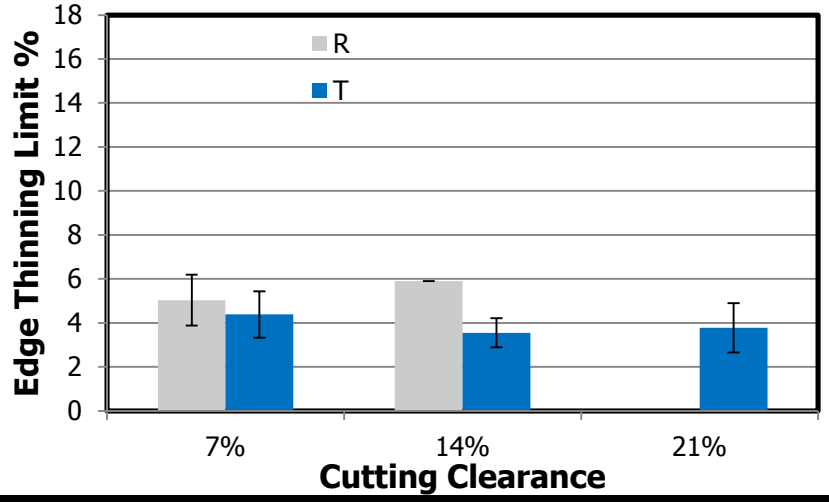
B 1.0t DP980GA



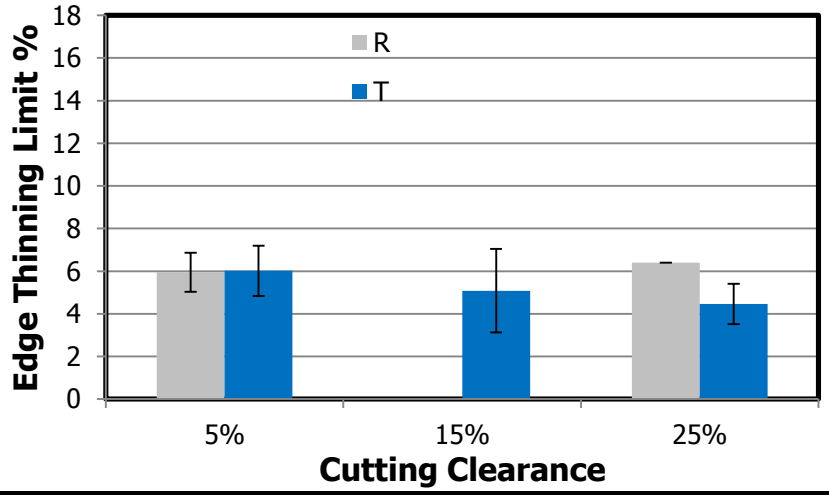
C 1.4t DP980GA



D 1.0t DP980CR

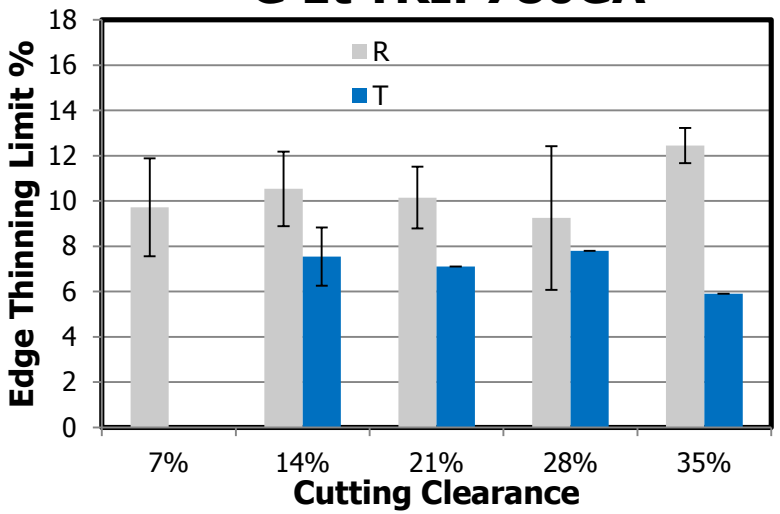


E 1.4t DP980CR

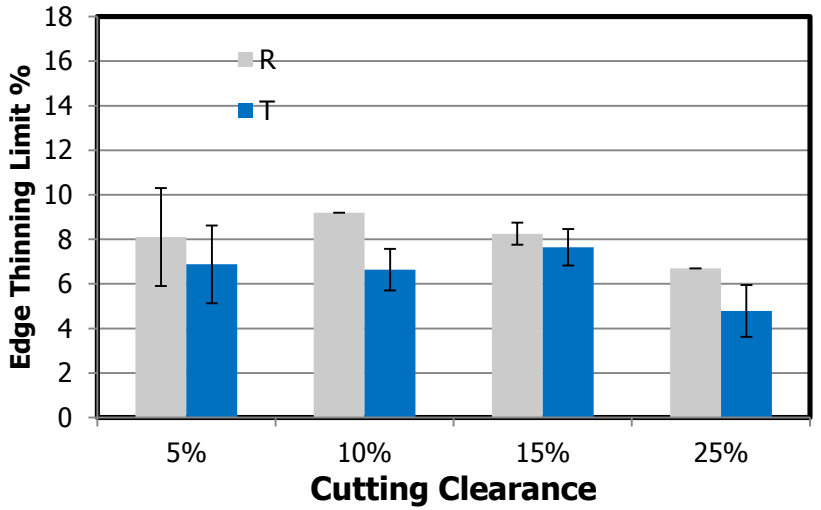


Test Results

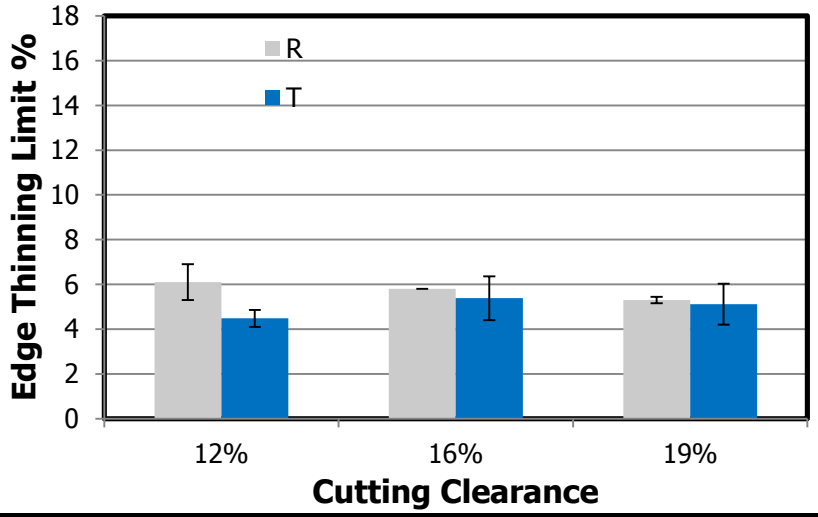
G 1t TRIP780GA



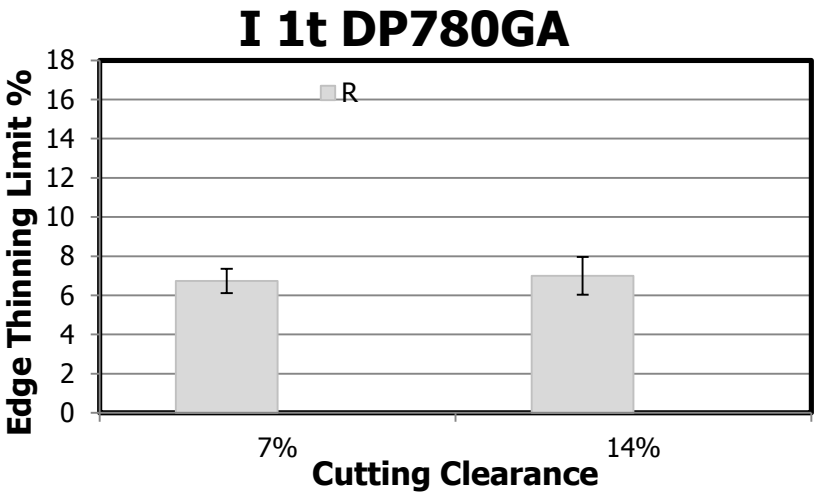
H 1.4t TRIP780GA

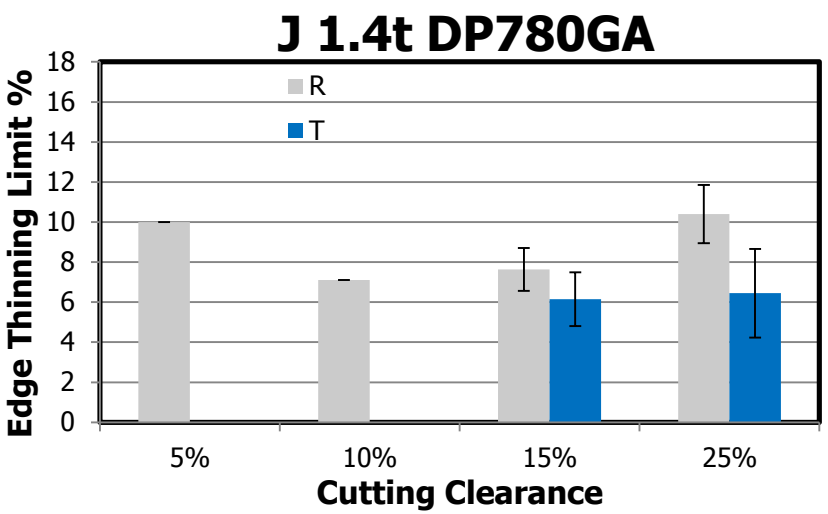


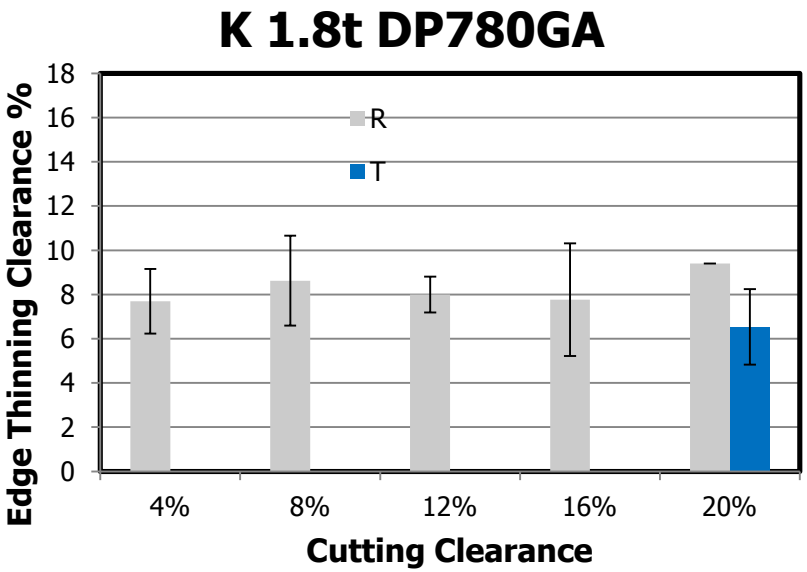
F 1.8t DP980CR

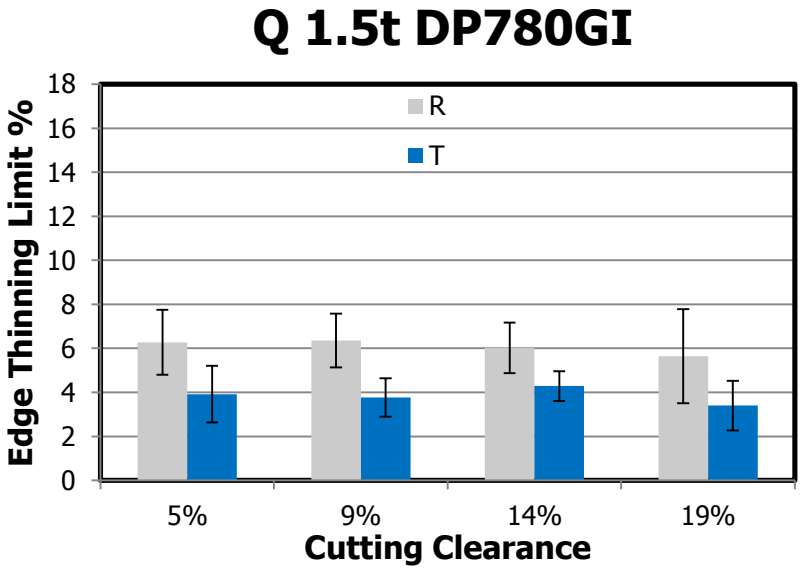


Test Results



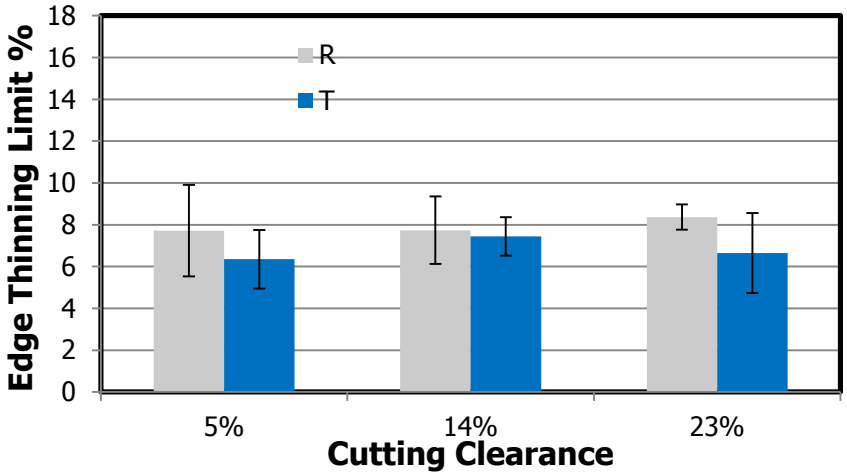




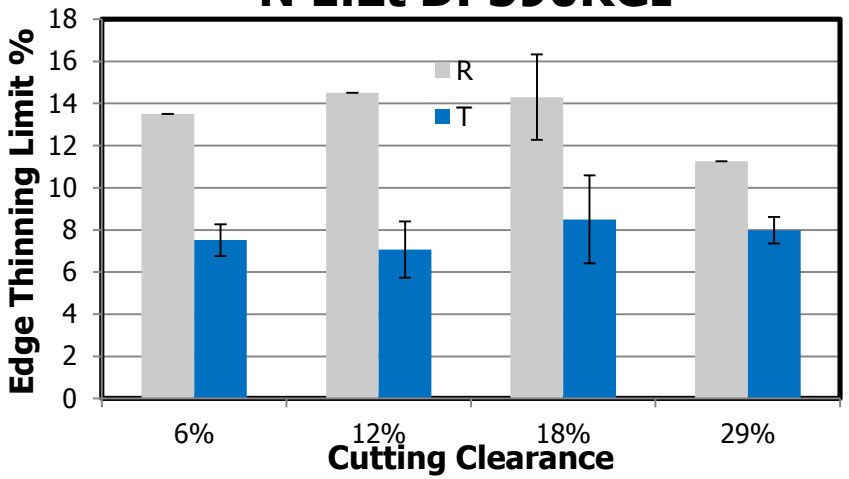


Test Results

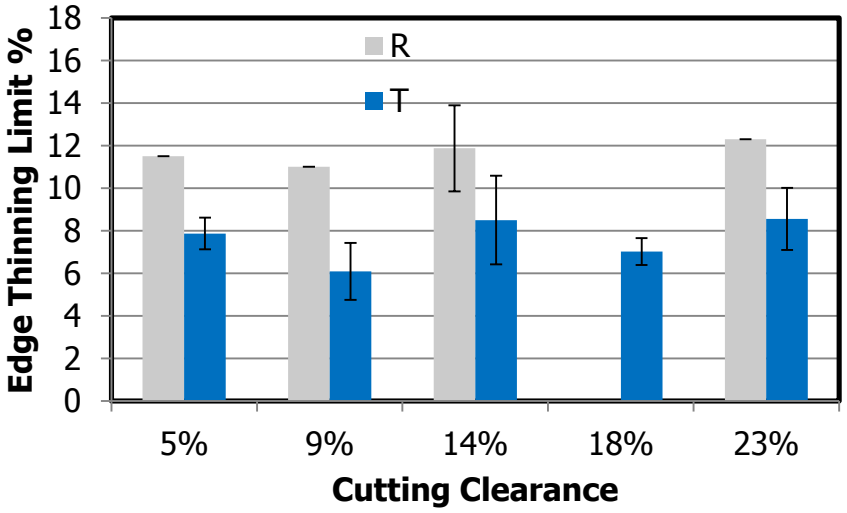
M 1.54t DP600GI



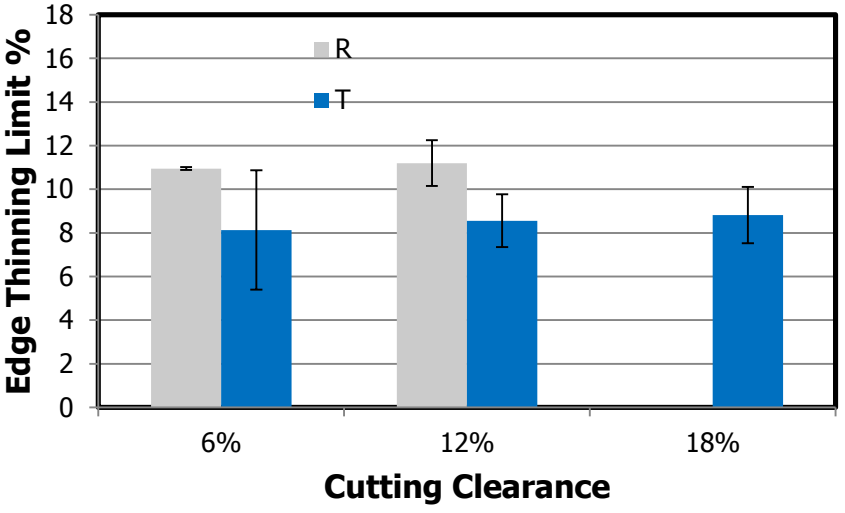
N 1.2t DP590RGI



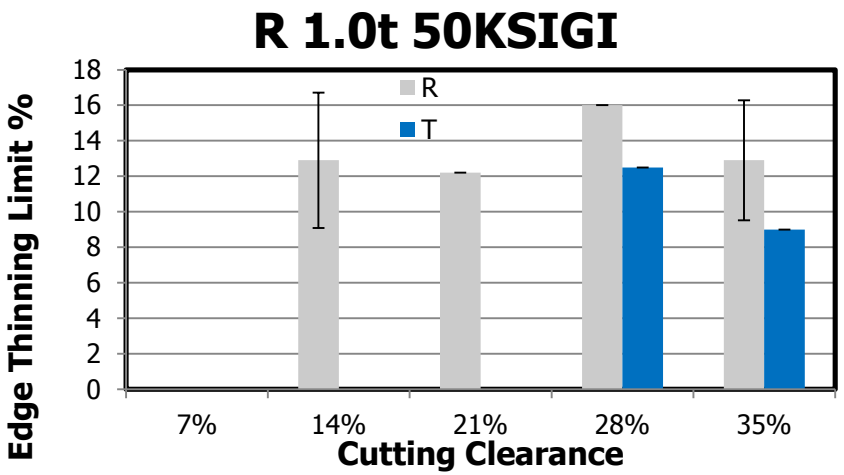
P 1.54t DP590RGA

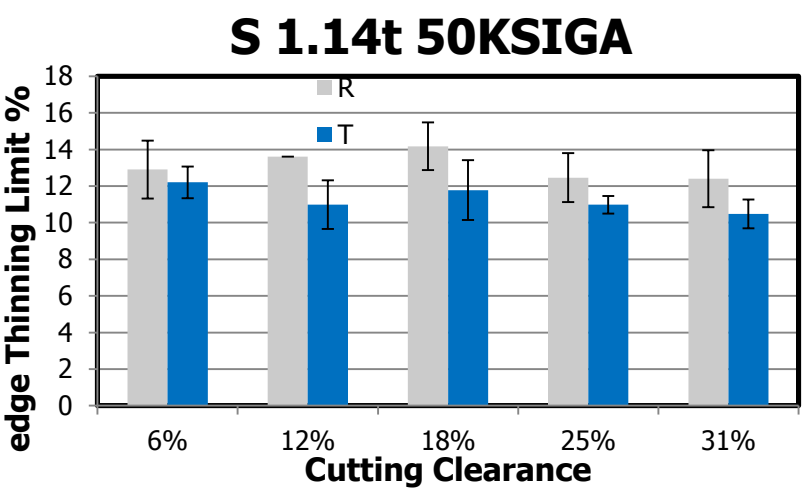


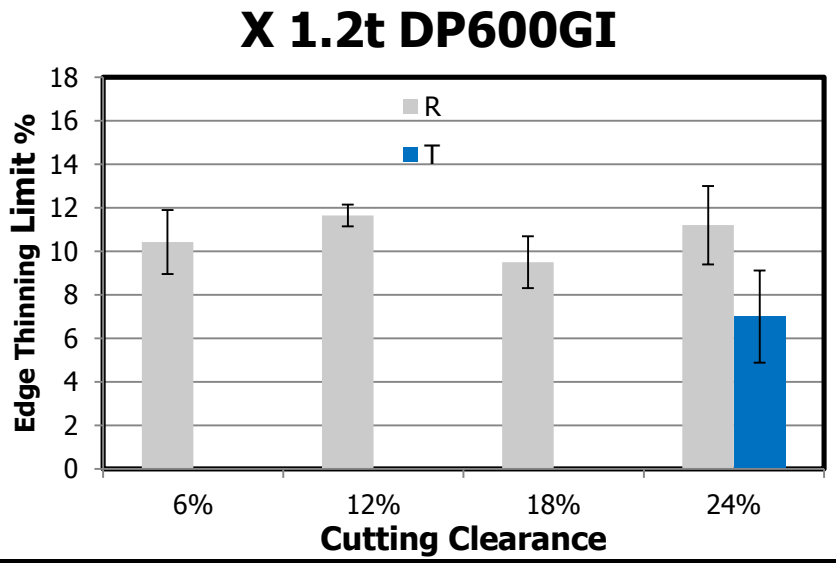
L 1.2t DP600GI

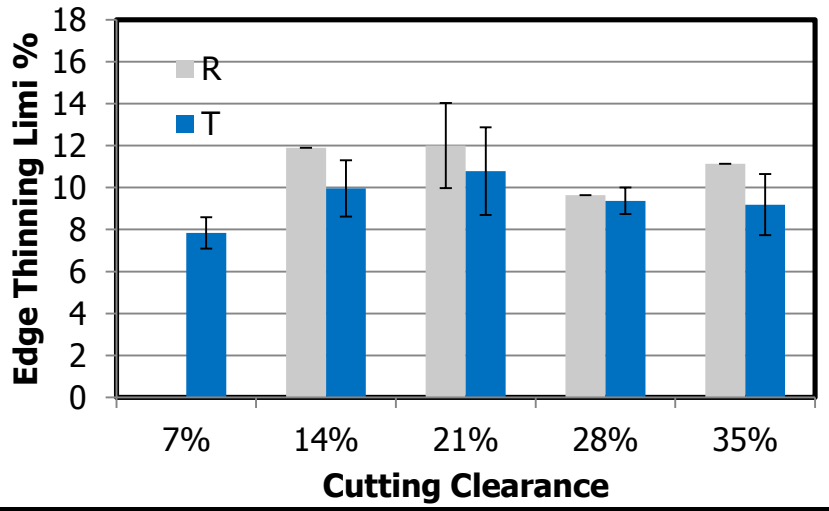


Test Results





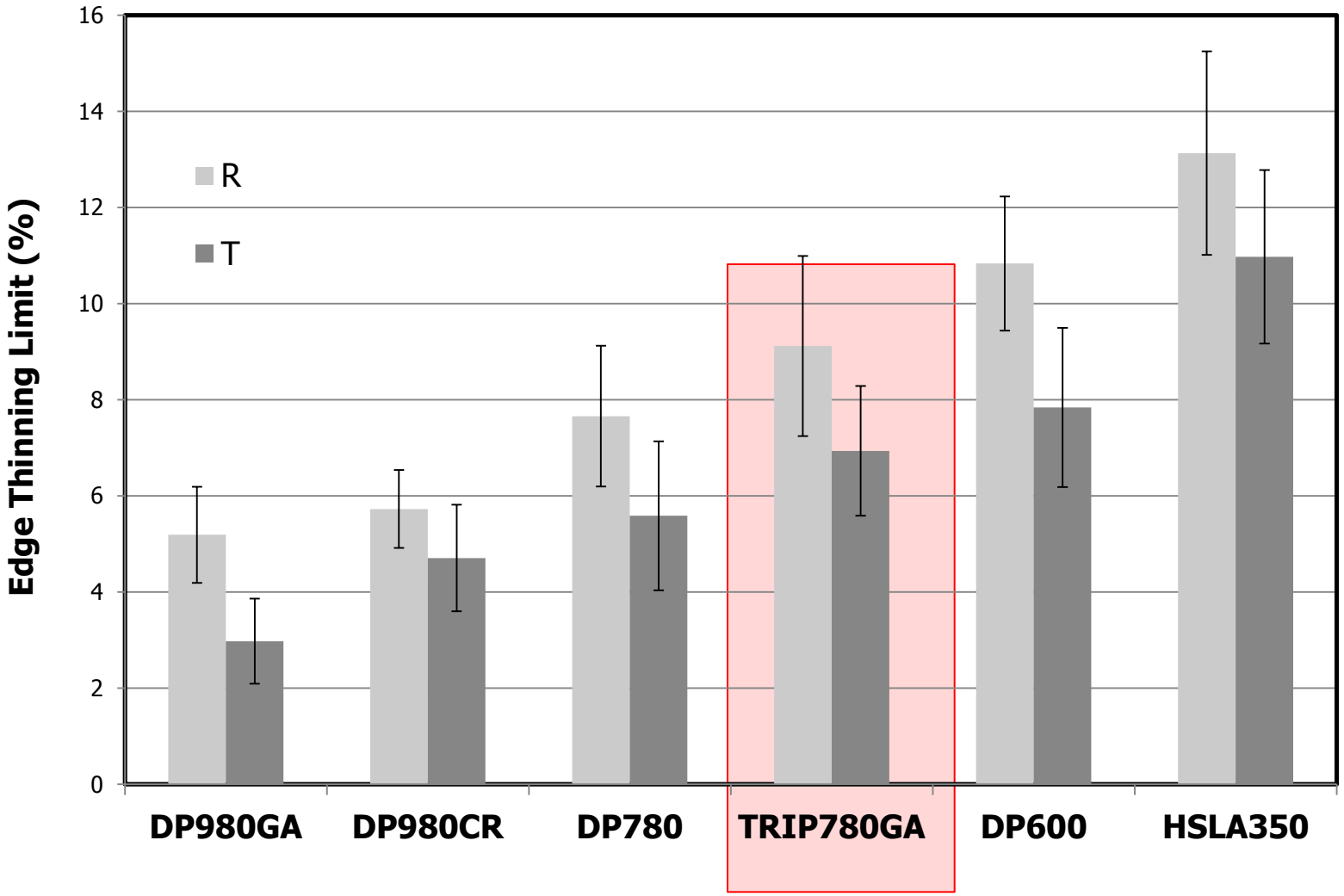




Edge Thinning Limit

			Edge Stretch Thinning Limit %			
Material	Material	Thick (mm)	T_avg	R_avg	T_std	R_std
B	DP980GA	1.03	3.05	5.57	1.02	0.81
C	DP980GA	1.44	2.90	4.81	0.75	1.19
	DP980GA		2.98	5.19	0.89	1.00
D	DP980CR	1.04	3.91	5.25	0.98	1.04
E	DP980CR	1.46	5.19	6.10	1.49	0.70
F	DP980CR	1.88	5.02	5.83	0.86	0.69
	DP980CR		4.71	5.73	1.11	0.81
G	TRIP780GA	1.09	7.31	10.13	1.14	2.15
H	TRIP780GA	1.41	6.56	8.10	1.56	1.60
	TRIP780GA		6.94	9.12	1.35	1.88
I	DP780GA	1.03		6.91		0.93
J	DP780GA	1.39	6.38	8.65	1.94	1.74
K	DP780GA	1.78	6.54	8.00	1.71	1.68
Q	DP780GI	1.61	3.84	7.07	1.00	1.50
	DP780		5.59	7.66	1.55	1.46
L	DP600GI	1.23	8.51	11.12	1.76	0.82
M	DP600GI	1.57	6.63	7.86	1.34	1.67
X	DP600GI	1.21	7.00	10.56	2.12	1.50
A	DP600GA	1.02	9.37	10.91	1.68	1.35
N	590RGI	1.21	7.81	12.80	1.41	1.54
P	590RGA	1.59	7.71	11.76	1.64	1.49
	DP600		7.84	10.84	1.66	1.40
R	HSLA350GI	1.04	10.75	13.24	2.48	2.79
S	HSLA350GA	1.23	11.20	13.02	1.13	1.44
	HSLA350		10.98	13.13	1.81	2.12

AHSS Edge Stretch Thinning Limit



Summary

- Edge thinning limit is proposed / measured for evaluating edge stretching failure for AHSS panel with interior cut.
- The knowledge / data can be used in FEA evaluation, die tryout, and monitoring production parts.
- For the AHSS sheets in this study, the edge thinning limit after shearing increase with reducing tensile strength in general.
- The edge thinning limit for of TRIP780 is greater than that of DP780
- The edge thinning stretched along rolling direction is higher than that along transverse direction.

Questions ?