ADHESIVE BONDING PERFORMANCE OF GA COATED 590 MPa TENSILE STRENGTH STEELS

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Background

- Light weighting in the automotive industry is a constant objective that is increasingly obtained using:
  - Advanced high strength steels (AHSS)
  - Crash resistant and fracture toughened adhesives
- In crash sensitive applications, adhesives are generally avoided on galvanneal (GA) coated steels.
- GA coated 780 MPa AHSS were shown to have cohesive failure and good bond strength.
- The subject study focused on the adhesive bonding performance of GA 590 MPa materials bonded with adhesives of different moduli of elasticity.
- GA coated IF EDDS steels were included for comparison.

Test Materials

- GA coated test materials include
  - 590Y (dual phase) – 0.7 & 1.6 mm
  - 590R (high yield to tensile ratio) – 1.2, 1.5, 1.7 mm
  - 590T (TRIP) – 1.5 mm
  - 270E (IF EDDS) – 0.7 & 1.5 mm

- Test materials were bonded with up to three adhesives.
  - BETAMATE™ 1488, crash resistant structural, modulus 1400 MPa.
  - BETAMATE™ 1022DUS, fracture toughened structural, modulus 2000 MPa.
  - BETAMATE™ 73305GB, structural, hem flanging, modulus 4100 MPa.

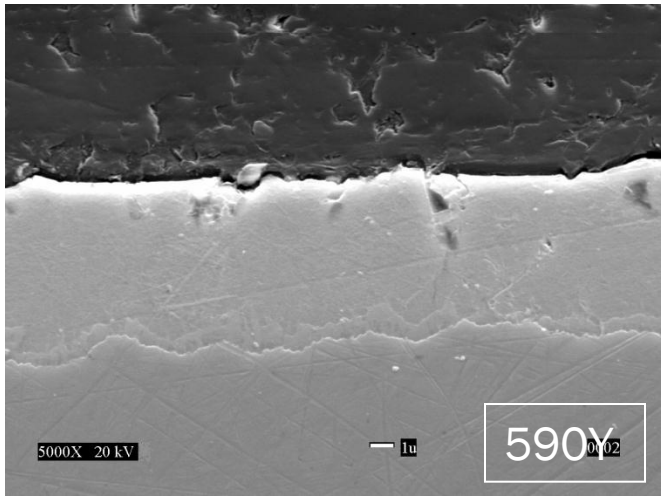
Test Materials

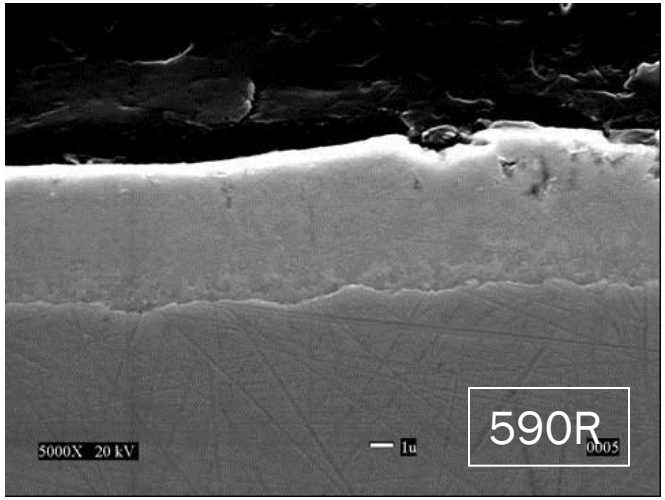
Material Code	Gauge (mm)	Coating Wt (g/m^2)	% Fe	Fe Content (g/m^2)	Width of GA removed by tape in 60° V-Bend Test (mm)	Residual Stress (MPa)
590Y-C	0.7	37.5	10.5	3.9	2	-26
590Y-96	1.6	53.7	12.6	6.8	9	-35
590Y-97	1.6	51.3	12.4	6.4	3	-53
590R-61	1.2	40.1	10.8	4.3	2	-85
590R-98	1.5	39.2	11.6	4.5	3	-64
590R-12	1.5	38.9	9.7	3.8	3	-82
590R-53	1.7	38.8	11.3	4.4	3	-58
590T-05	1.5	53.1	11.7	6.2	5	-50
590T-897	1.5	43.6	12.1	5.3	8	-82
270E-35	0.7	47.1	10.8	5.1	3	-3
270E-19	1.5	39.2	12.1	4.7	3	-50
270D-06	1.5	37.3	10.8	4.0	3	-33

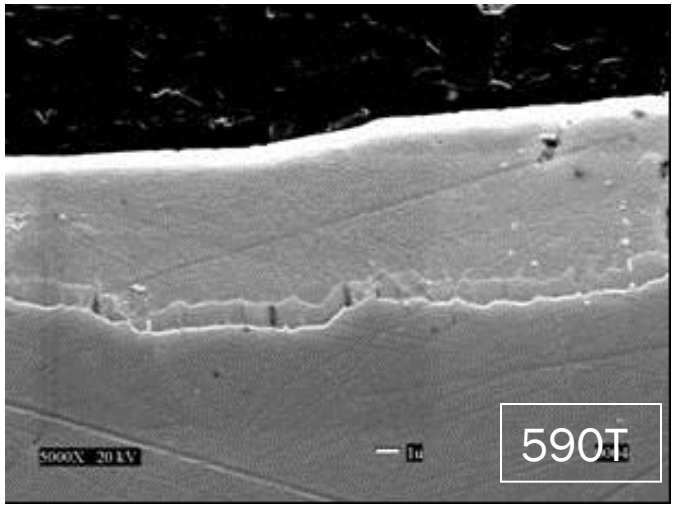
Residual Stress Measured by XRD

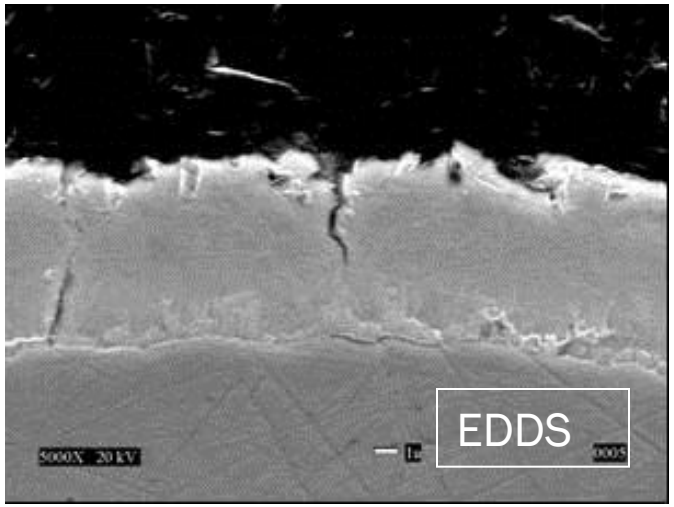
- Opposite stresses are felt on both sides of the interface; i.e. compressive stress on substrate leads to a tension stress on the coating.
- Results show that there is a moderate to high compressive stress on the steel surface for all materials, except the thin gauge EDDS.
- Typically, a larger lattice mismatch exists between IF EDDS and the Γ phase in the GA, which may cause breakage of the lattice bonding at the interface to release the residual stress.

Residual Stress – Cracks in Coating



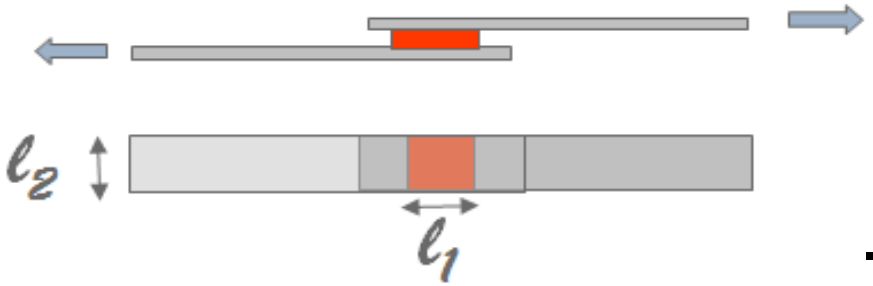






Lap Shear Test Method

- The 25 x 102 mm samples were solvent wiped before bonding.
  - 12 test materials were bonded with BETAMATE™ 1488.
  - 6 test materials were bonded with BETAMATE™ 1022DUS & BETAMATE™ 73305GB.
- In some cases, backing plates of 1.6 mm sheet steel were bonded to the back of each specimen.
- The average joint had an overlap of 12.7 mm and a bond thickness of 0.25 mm controlled by glass beads.
- The adhesive was cured for 20 minutes at 170°C.
- Specimens were pulled on an Instron tensile test machine at 50 mm/minute at room temperature.
- The shear strength in MPa and the failure mode as % cohesive failure were reported.



Lap Shear Test Method

- Evaluation of failure mode

OK

*Cohesive Failure **(CF)** = failure in the adhesive*

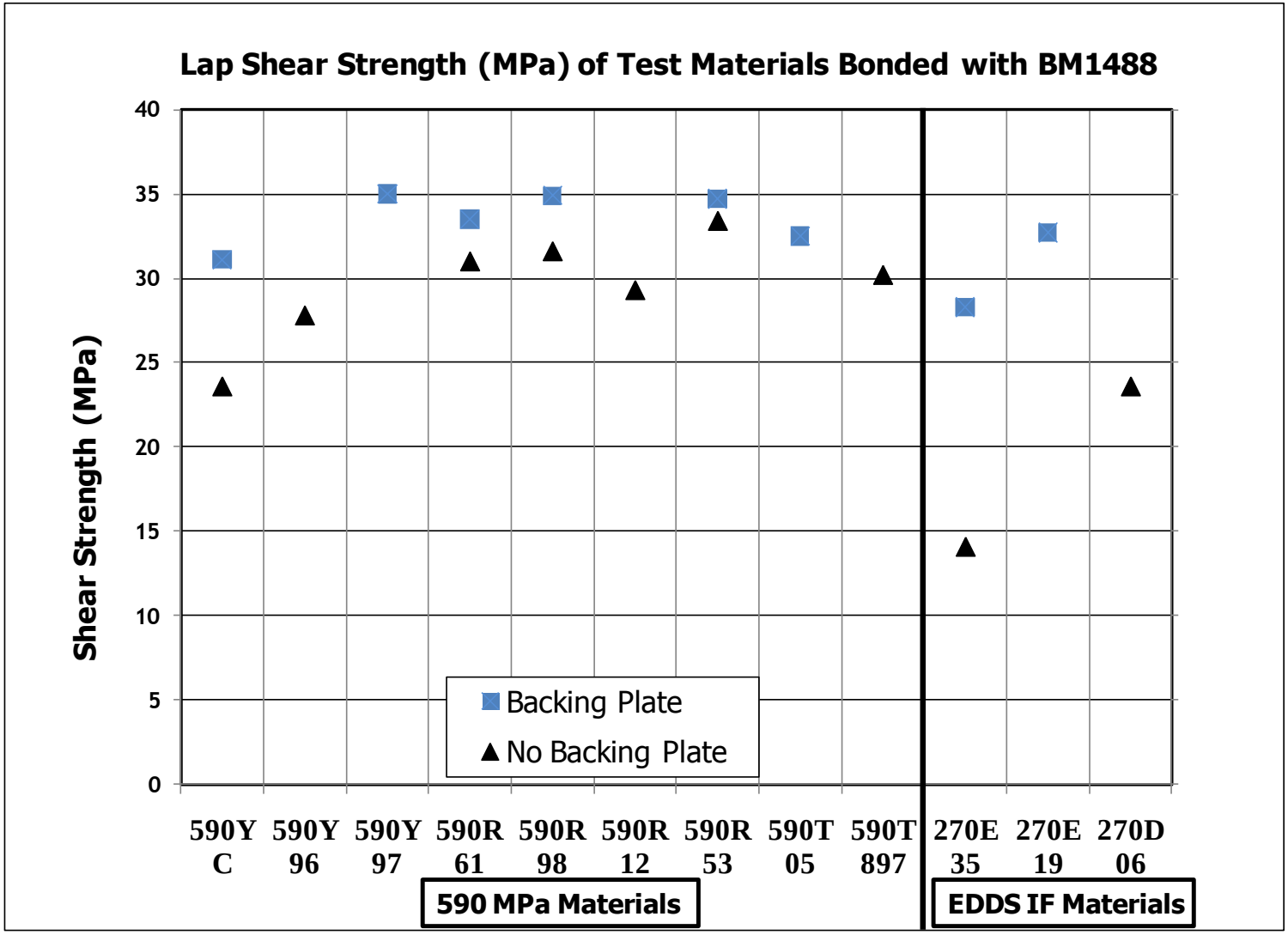
Avoid

May be OK if bond strength is good.

Not OK Coating Delamination

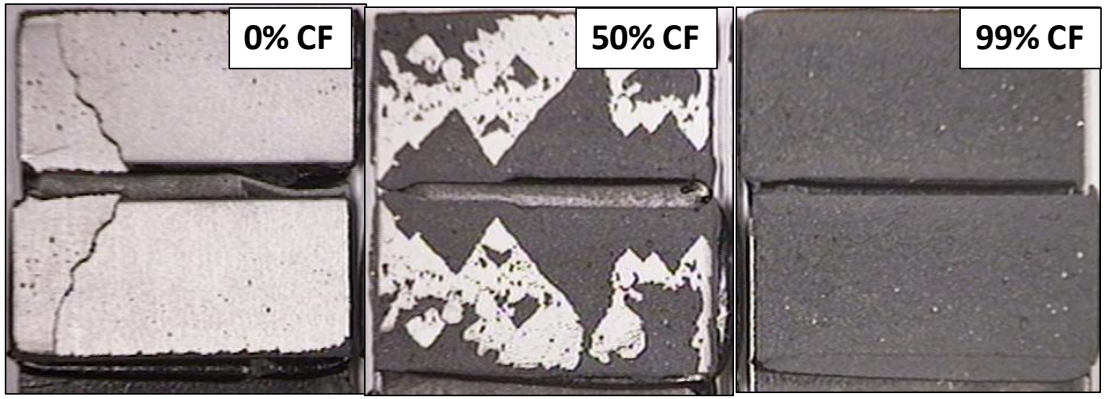
Adhesive Failure = failure of adhesive to substrate

Results – DOW BETAMATE™ 1488



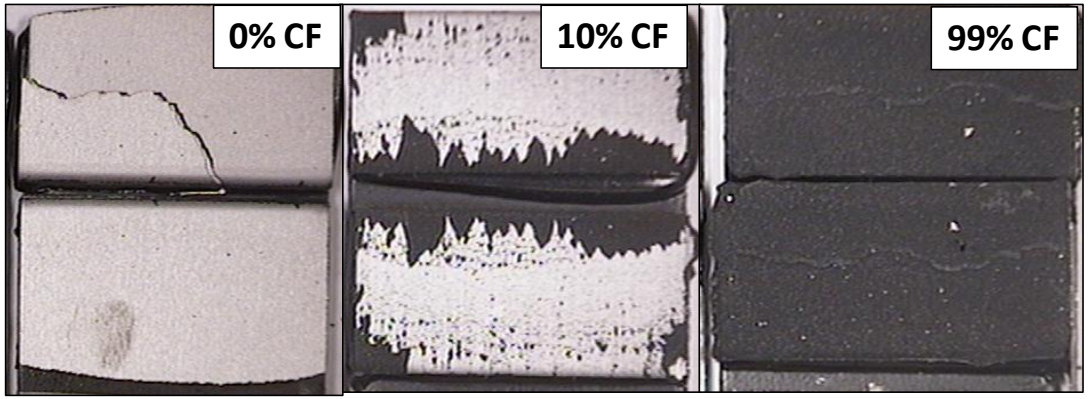
Results – DOW BETAMATE™ 1022DUS

Material Code	No Backing Plates				Backing Plates			
	Shear Strength		Cohesive Failure		Shear Strength		Cohesive Failure	
	MPa	σ	%	σ	MPa	σ	%	σ
590Y-C	25	0.4	96	2	33	1.0	99	1
590Y-96	31	1.0	73	14				
590R-12	34	1.2	99	0				
590T-897	34	1.0	96	2				
270E-35	13	0.4	0	0	29	1.0	0	0
270D-06	24	0.6	77	23				

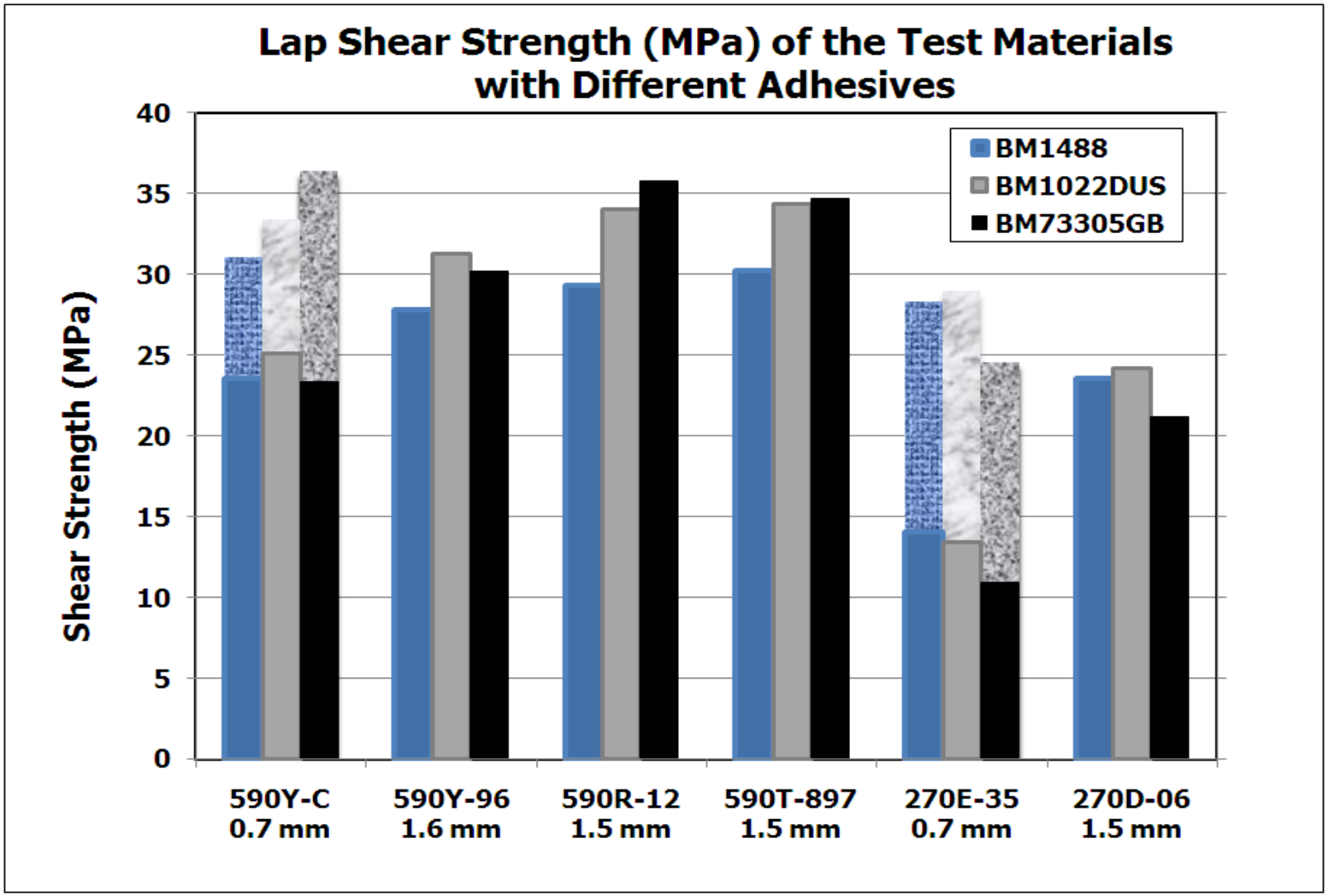


Results – DOW BETAMATE™ 73305GB

Material Code	No Backing Plates				Backing Plates			
	Shear Strength		Cohesive Failure		Shear Strength		Cohesive Failure	
	MPa	σ	%	σ	MPa	σ	%	σ
590Y-C	**23.4**	0.8	**58**	19	**36.4**	0.8	**96**	4
590Y-96	**30.2**	1.2	**5**	0				
590R-12	**35.8**	0.8	**95**	4				
590T-897	**34.7**	35	**10**	2				
270E-35	**10.9**	0.5	**0**	0	**24.6**	2.4	**0**	0
270D-06	**21.2**	0.8	**2**	3				



Results – Three Adhesives



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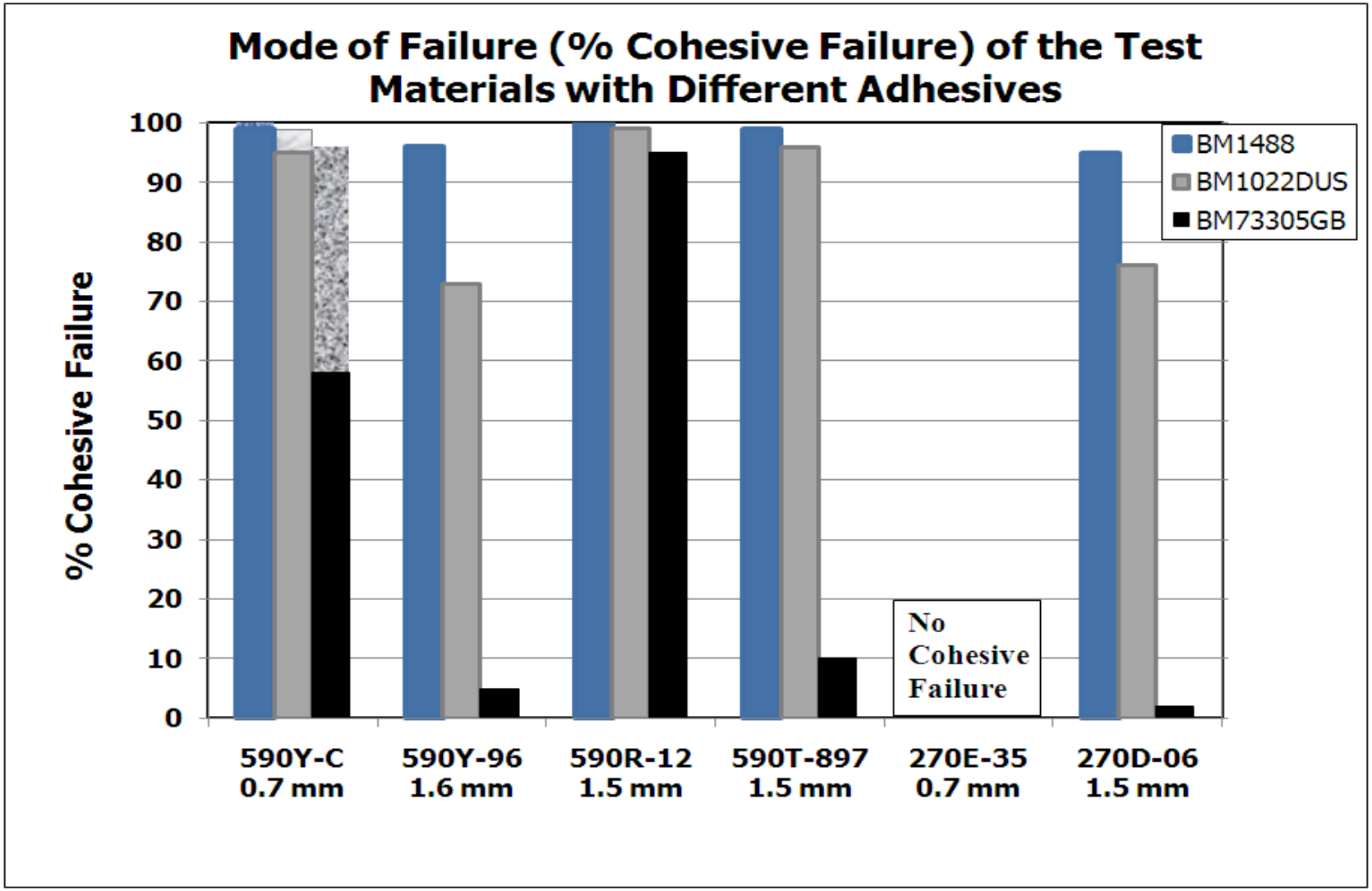

Results – Three Adhesives

- BETAMATE™ 1488, with the lowest E-modulus, was the only adhesive to exhibit excellent cohesive bonding performance for all test materials except the thin gauge IF EDDS material.
- Lap shear performance using adhesives with a higher modulus was fair or poor, despite good adhesion at the steel/coating interface, suggesting that other coating and adhesive characteristics influenced the mode of failure.
- All test materials fell within acceptable variation of GA coated product and the low modulus adhesive appeared to compensate for subtle variations in the GA coated product.

Conclusions

- All 590 materials exhibited excellent adhesive bond strengths with all adhesives even when the mode of failure was less than optimal.
- The amount of cohesive failure decreased as the E-modulus of the adhesive increased.
- A low modulus, crash resistant adhesive has potential to be used with GA coated AHSS structures to reduce weight while maintaining or improving crash performance.
- The recommendation would remain to avoid joining GA IF EDDS steels with adhesives in crash sensitive applications.