Thermal Integrated Clinching Process- Innovative Joining of Next Gen. of AHSS

Mark A. Savoy[1], Hassan Ghassemi-Armaki[2]

[1]Utica International Inc., [2]ArcelorMittal Global R&D

Strategic Development Partners

ARCELORMITTAL:

- ArcelorMittal is the leading supplier of quality steel in automotive market.
- Global R&D EC provides mechanical and metallurgical support and testing support for process window and optimization of AHSS Thermal Integrated joining
- Technical support on requirements of joining strength for light-weighting and occupant safety

TOX PRESSOTECHNIK:

- Supply clinch tooling and electro-mechanical drives
- Collaboration investigating the process for mechanical joining a complete vehicle
- Global technical support

COHERENT Inc.

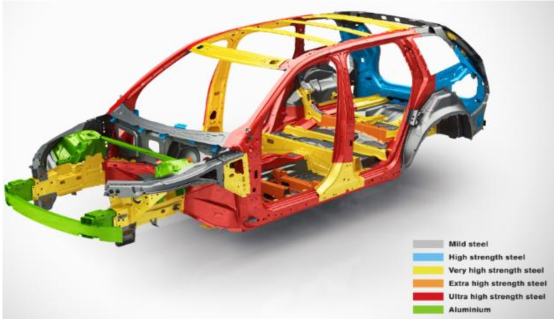
- Manufacture of our Diode Lasers
- Design and supply of Collimators and Optics
- Global technical support

Applications and Objective

Fasteners attachment during assembly ⟷ Down gauging for light weighting

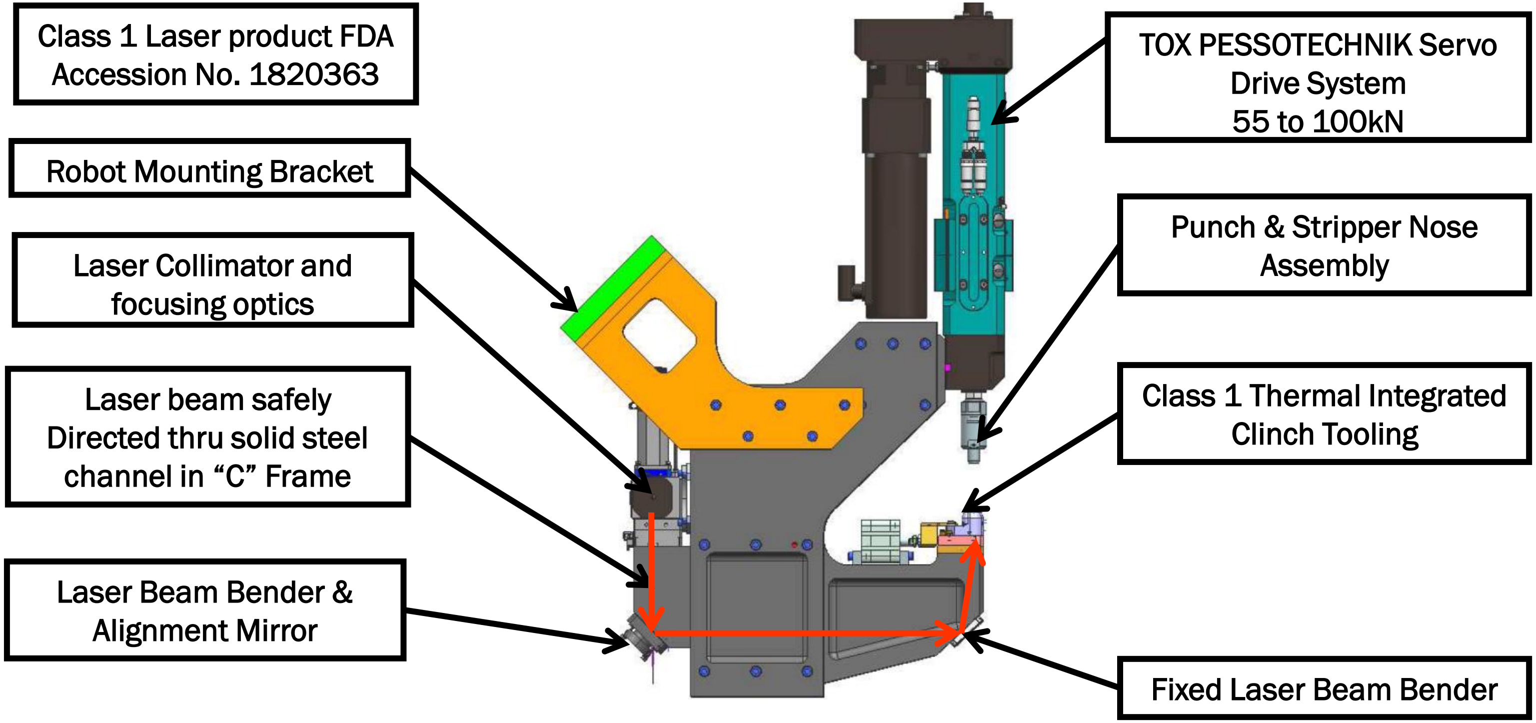
→ Need for joining technology for a wide range of steel stack ups and complex BIW assemblies

- **Clinching | Mechanical Joining:**
  - Non additive widely accepted mechanical joining technique
  - Reduce energy consumption and CO_2 emissions
  - Capable of joining 3G AHSS
- **Self Pierce Riveting | Mechanical Joining:**
  - Aluminum and thin sheets to AHSS
  - Mechanical joining of 3 & 4T stack-ups
- **Thermal Integrated Clinching Assembly™**
  - Apply controlled heat zone for mechanical joining
  - Exceptional Joint Strength & Dynamics
  - Suitable for complex AHSS and UHSS
  - Compatible with existing facility layout.



Example AHSS BIW - VOLVO XC-90 Platform

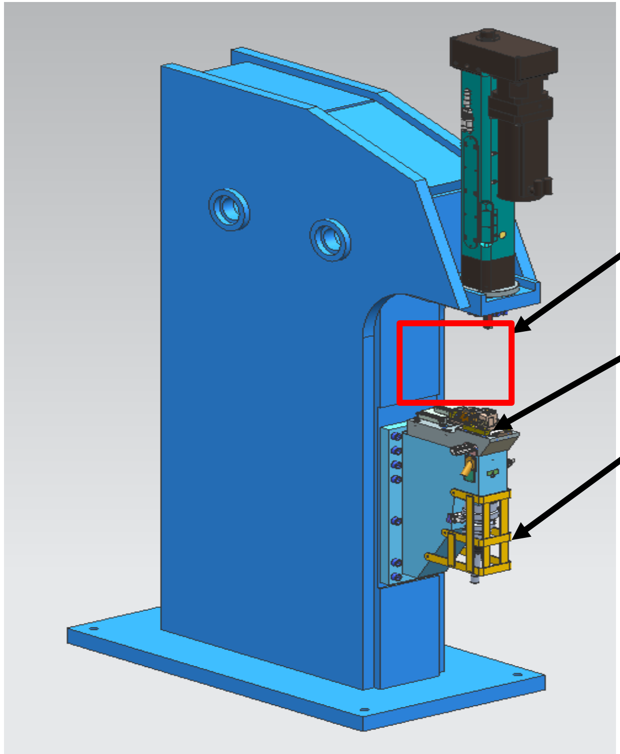
Robotic Thermal Clinching Assembly™



A complete Class 1 Laser product integrated on assembly floor with no laser booth requirements and is mounted and easily interfaces to any 210KG robot. **Available throughout North America April 2018.**

Pedestal Fixture - Clinching Large Assemblies & Clinch Nuts

100 TO 500kN – 10 TO 50 Tons Pedestal Frames



Part opening 300 to 450mm
Part depth 300 to 1050mm

Class 1 Laser Thermal Clinch Assembly

2 to 4 KW COHERENT | DILAS **Direct Diode Laser**

This Pedestal Fixture is designed for Thermal Clinching of part depths up 42" and Thermal Integrated clinching and all types of clinch nuts to AHSS and UHSS materials.

Class 1 Validation Test

ALLOWABLE EMISSION TESTING								
Wave length		980 nm			Date:	28-Mar-18		
Hold down Force		2.5KN			Material:	Coupon 1	Usobor-1500 1.5mm	
						Coupon 2	Usobor-1500 1.5mm	
Test Engineer: R. Lemanski					Allowable limits: ≥1.72 mill watts (mW)			
	Power							
Sample	Watts	Time/seconds		Radiation	Radiation	Radiation	Radiation	Radiation
				Pos 1	Pos 2	Pos 3	Pos 4	Ave.
1	3KW	3		61.6	59.74	56.72	59.69	59.44
1	3KW	3.5		59.71	40.33	55.73	57.82	53.40
				All values are in MICRO Watts (μW)				

- The UTICA Thermal Clinching Assembly emits much less radiation then a typical laser pointer

Robotic Thermal Integrated Clinching

TICA

Thermal Integrated Clinch Assembly™

Potential Energy Savings Clinching Vehicle

11.7% Overall Energy Reduction – Based on 500K units

COMPARISON OF AVERAGE RATES (IN CENTS PER kWh)
FOR MPSC-REGULATED ELECTRIC UTILITIES IN MICHIGAN
April 1, 2017

Ref. US DOE, Argonne National Laboratory study ANL/ESD/10-6

	RESIDENTIAL			SMALL COMMERCIAL		LARGE COMMERCIAL			INDUSTRIAL		
kW				5	25	100	100	100	1,000	10,000	50,000
kWh	250	500	1,000	1,000	5,000	21,600	28,800	36,000	432,000	4,320,000	21,600,000
INVESTOR OWNED											
ALPENA POWER	14.48	13.29	12.69	13.00	12.15	12.49	11.21	10.32	8.45	6.65	6.06
CONSUMERS ENERGY	17.06	15.47	14.68	15.15	13.49	13.70	12.54	11.84	9.56	9.00	8.04
DTE ELECTRIC	18.44	16.74	16.66	14.51	13.42	12.78	12.73	12.04	8.73	7.88	7.62
AEP (I&M) COMBINED	14.59	12.35	11.23	13.66	11.65	10.77	9.95	9.46	8.36	7.94	9.39
NORTHERN STATES POWER	15.33	13.39	12.42	12.55	11.51	12.70	11.52	10.82	10.53	10.43	10.42
UPPER PENINSULA POWER	27.01	24.01	22.51	18.58	16.89	12.08	11.53	11.20	10.26	9.57	8.76
UPPER PENINSULA POWER IRON RIVER	26.11	23.11	22.42	18.58	16.89	12.08	11.53	11.20	10.26	9.57	8.76
UMERC (FORMERLY WEPCO)	18.28	16.15	15.08	17.20	14.89	14.51	14.46	12.32	10.67	10.22	7.88
UMERC (FORMERLY WPSC)	14.78	12.38	11.18	13.08	10.82	10.55	10.46	10.41	8.51	8.10	7.51
AVERAGE INVESTOR OWNED	18.45	16.32	15.43	15.15	13.52	12.41	11.77	11.07	9.48	8.82	8.27

Source: Michigan Public Service Commission Utility Rate Books
Compiled by the Regulated Energy Division

Average manufacturing energy usage per Generic 3,370 pound vehicle, Stamping &Assembly Plant usage only:

Total kWh per vehicle	684
Vehicles per month	41,666
Total kWh per month	28,500,000
Yearly kwh usage	342,000,000
Yearly energy cost:	**$26,060,400.00**

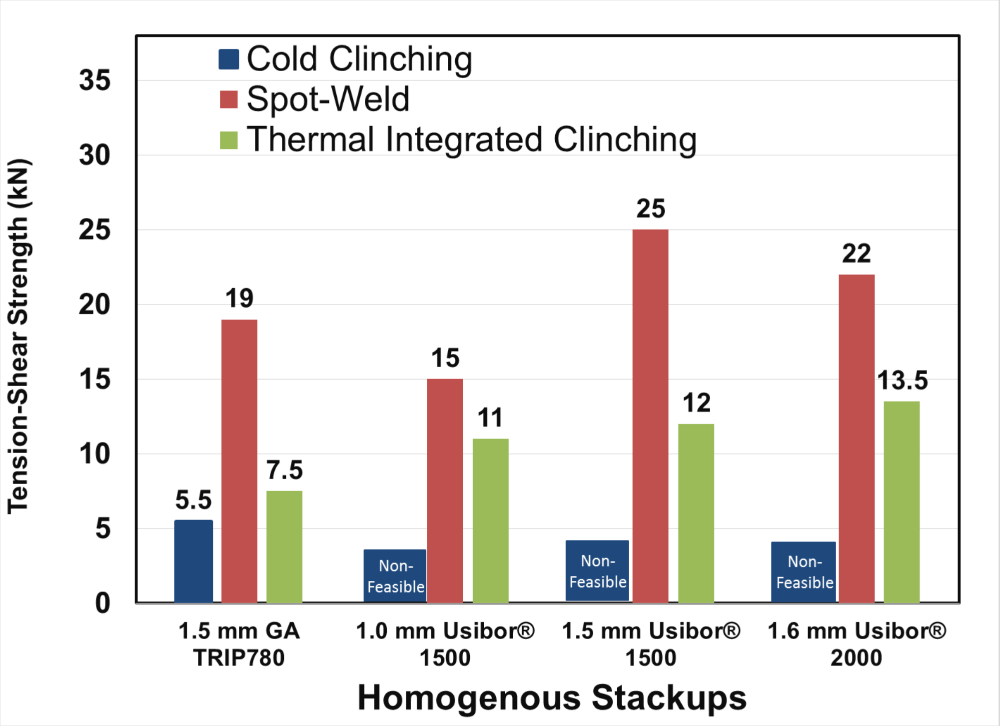
Average welding energy usage at assembly for generic 3,370 pound vehicle, assumes 4,000 joints:

Total kWh per unit	80
Units per month	41,666
Total kWh per month	3,333,280
Yearly kwh usage	39,999,360
Yearly energy savings:	$3,047,951.00

Process Optimization

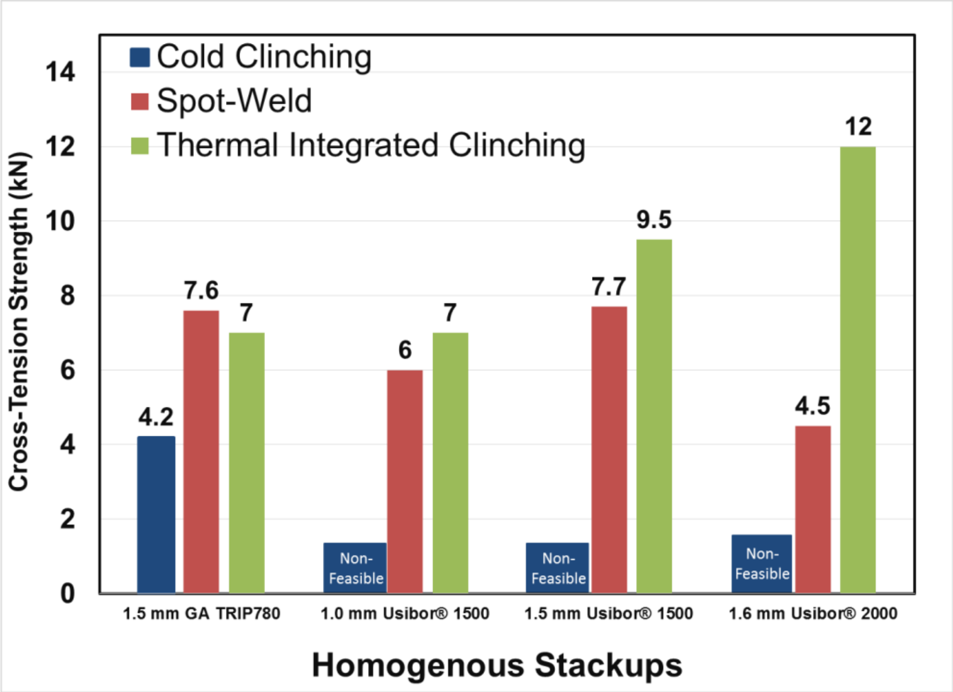
- **Process optimization and mechanism understanding for joint strength/quality:**
  - Majority of work focused on Usibor®1500 and Usibor® 2000 process optimization for:
    - Feasibility of Clinching for AHSS beyond 1000 MPa
    - Improvement of TSS
    - Improvement of CTS
    - Mechanism understanding of process optimization
  - Studied homogenous stackups:
    - 1.5mm GA TRIP780
    - 1.5 mm Usibor®1500
    - 1.0 mm Usibor®1500
    - 1.6 mm Usibor® 2000

Joint Strength: Tension Shear Strength



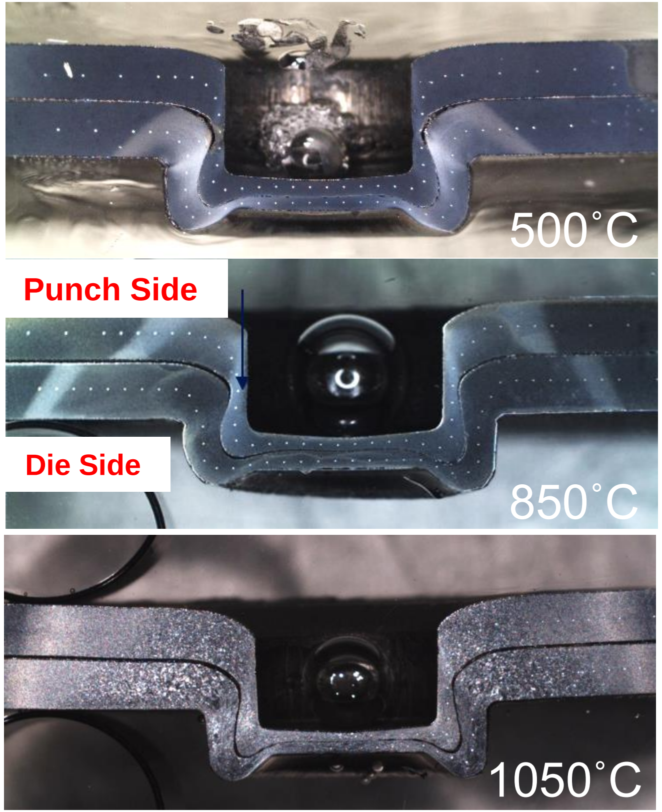
- Tension-Shear strength improvement by thermal Integrated Clinching compared to Cold Clinching.

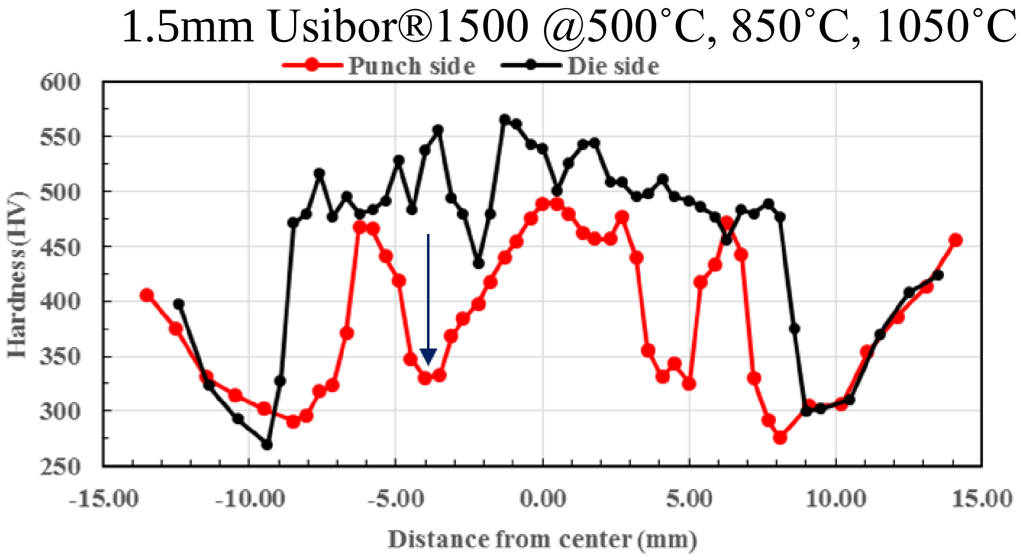
Joint Strength: Cross-Tension Strength



- Cross-Tension Strength Improvement By Thermal Integrated Clinching

Mechanism for Process Optimization

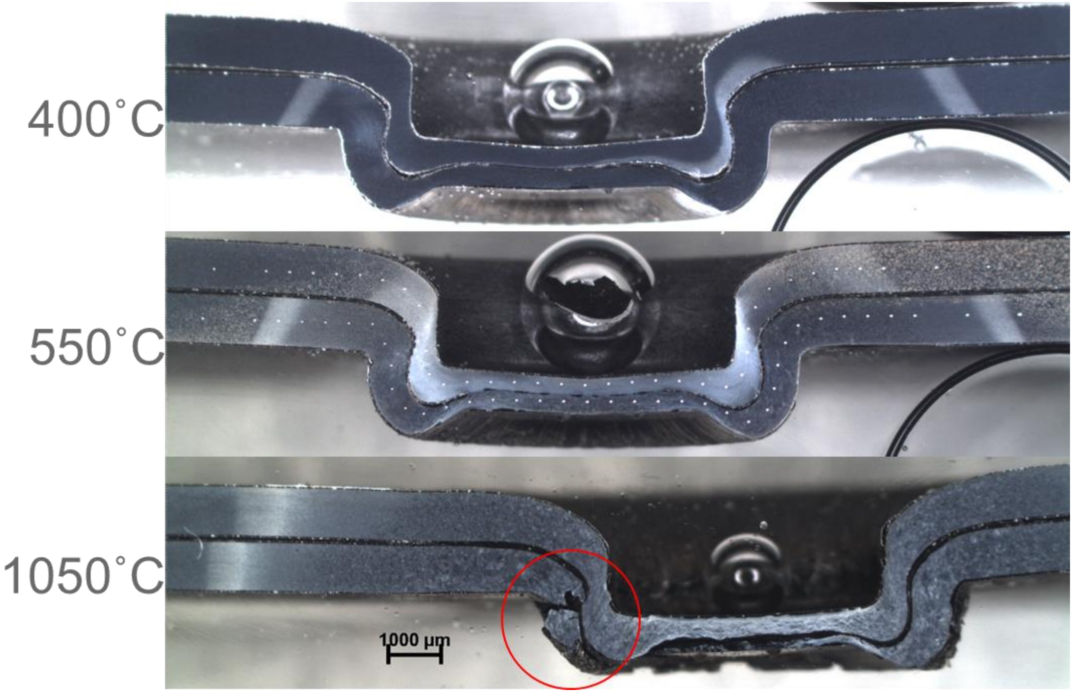




- Too low temperature couldn't soften the top sheet enough at the necking area for material flow.
- Too high temperature with coarse/brittle microstructure should be avoided.

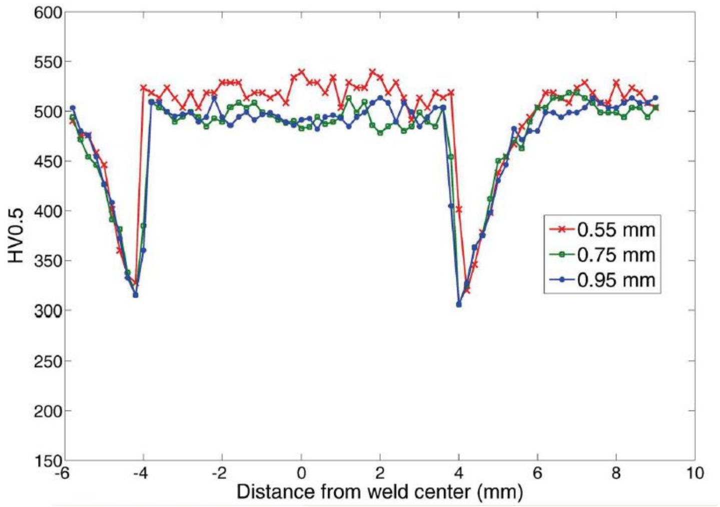
Mechanism for Process Optimization

1.0mm Usibor®1500 @ 500˚C, 850˚C, 1050˚C

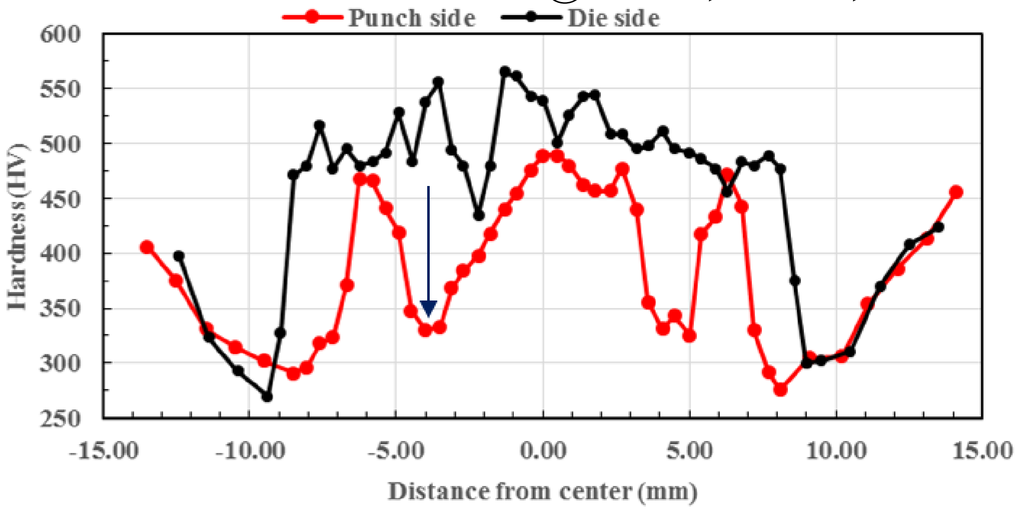


- Too high temperature for thin sheets can damage bottom sheet.

Mechanism for Process Optimization



1.5mm Usibor®1500 @500˚C, 850˚C, 1050˚C

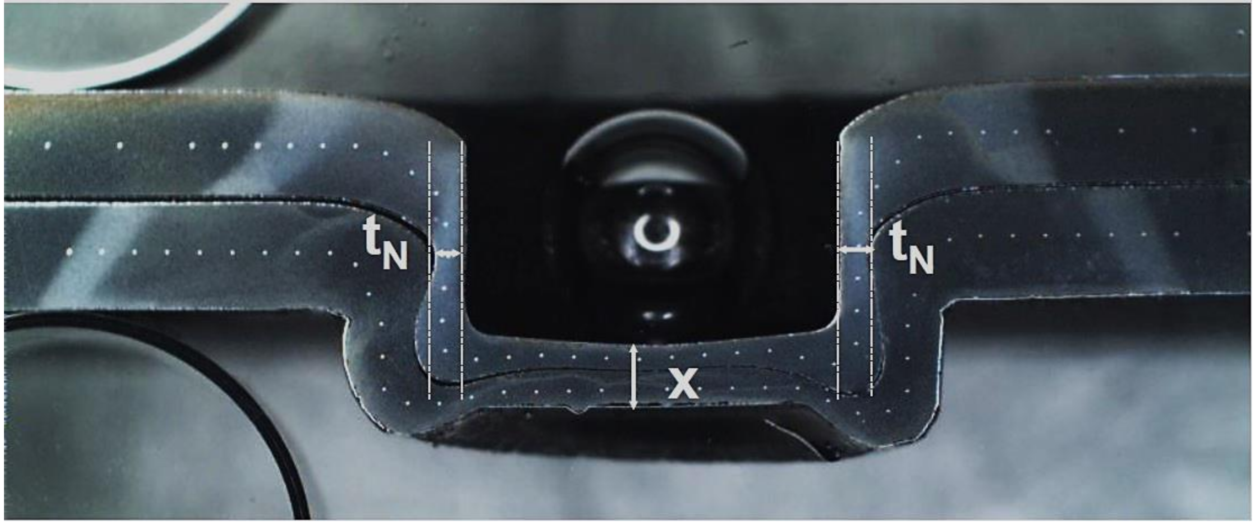


- Spot welds have a soft heat-effected zone which is surrounded by a hard nugget and makes it susceptible to failure.

- Extreme temperatures causing coarse/brittle microstructure can be avoided with the Thermal Integrated Clinching method.

Mechanism for Process Optimization

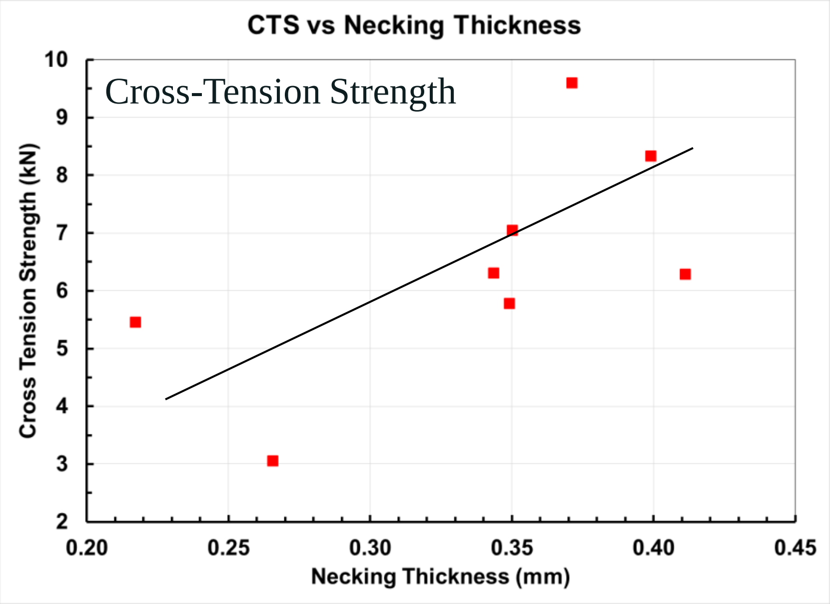
Representative Cross Section

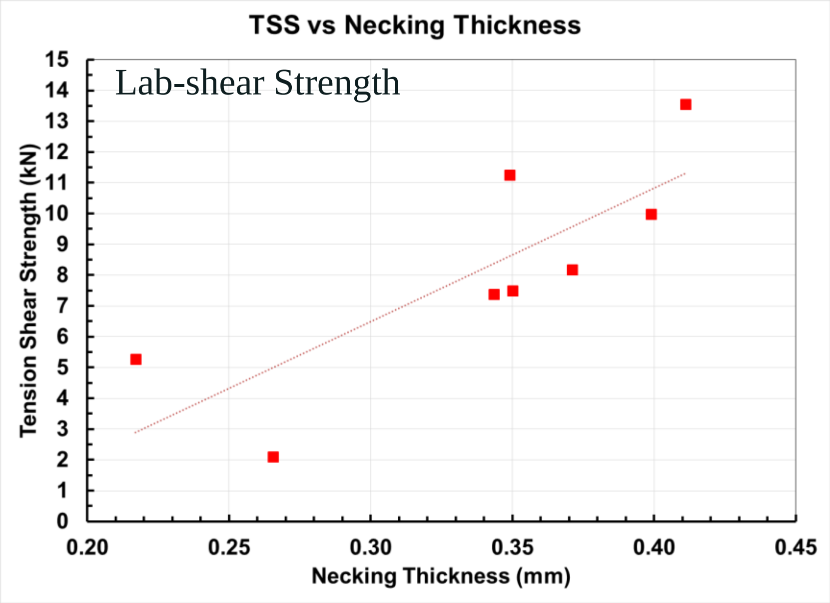


- Upper sheet neck thickness t_N determines joint strength in most applications.
- Remaining combined thickness X is controlled and closely related to t_N.

Mechanism for Process Optimization

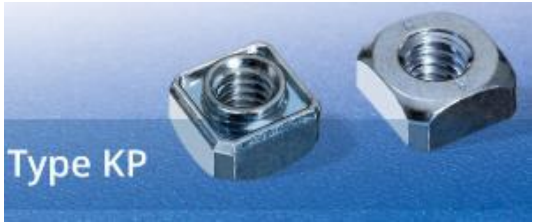
Necking Thickness

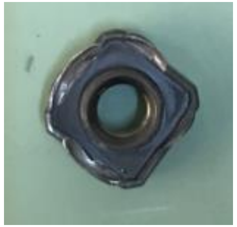


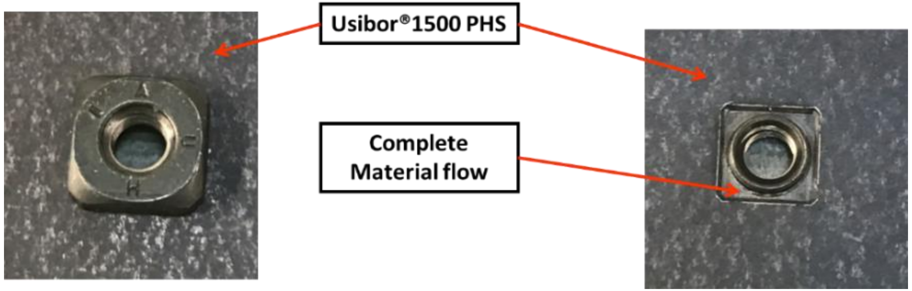


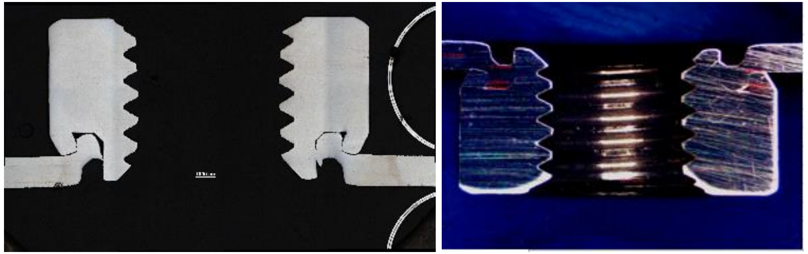
- Increasing of necking thickness increases TSS and CTS.

Thermal Integrated Clinch Nuts









Cross-section of clinch nut

- Thermal Clinch Joint is stronger than class 10 clinch nuts.
- Class-12 Pierce Clinch Nuts are being developed now.

PHS Thermal Integrated Clinch Nut Results

Push out force and torque data for self-piercing clinch nut.

Material	Thickness	Nuts	Push out force (N)	Torque (N.m)
Usibor® 1500	1.0 mm	KP 6-S-10	1260	30
Usibor® 1500	1.5 mm	KP 8-H-10	7000	66
Usibor® 2000	1.6 mm	KP 8-H-10	7400	67

Clinched nuts pushout strength exceed OEMs specification.

Summary

- Thermal Integrated Mechanical Joining is suitable for current and Next Gen. AHSS where resistance spot-weld fails regarding strength and weld quality.
- Thermal Integrated Clinching process does not require laser booth for operator safety.
- There are benefits in case of energy and cost saving over the time as compared to resistance spot-weld methodology.
- Influencing parameters for determination of Thermal Integrated Clinching windows process was developed :
  - Temperature/heat should be high enough to ensure the top sheet is ductile enough to deform, especially at the total width of the necking area.
  - Too high temperature/time should be avoided to avoid tempering of martensite extensively and surface breaking especially for thin material.
- A good combination of Joining Strength (Cross-Tension and Tension–Shear Strength "CTS and TSS") was achieved after process optimization.

Next Steps

- Continue the study on next Gen. AHSS (Zn Coated 3rd Gen. AHSS).
- Working with OEMs to adequately implement alternative joining solution where resistance spot-weld fails for Next Gen. AHSS.
- Dissimilar Thermal Integrated clinching of AHSS & PHS with Al and with adhesives.
- Thermal Integrated joining corrosion mitigation study.
- Other Advanced laser-assisted mechanical joining:
  - Development of Thermal Integrated Self Pierce Rivet process.
  - Development of Thermal Integrated Flow Drill Screw & Flow Push process.

For More Information

Mark Savoy

Utica International Inc.

+1 248-764-4500

msavoy@uticaenterprises.com

Hassan Ghassemi-Armaki

ArcelorMittal

401-572-0427

Hassan.ghassemi@arcelormittal.com