



## Recent Developments on Laser Beam Welding of High Strength Multiphase Steels

B. Brenner\*, A. Jahn\*, J. Standfuß\*, B. Winderlich\*  
S. Wischmann\*\*, J. Phla\*\*

\* Fraunhofer IWS Dresden

\*\* ThyssenKrupp Steel Duisburg

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## Topics:

1. Introduction
2. Challenges in Laser welding of high strength multiphase steels
3. Laser Induction Welding Technology
4. Welded Blanks Properties Survey
5. Application Potential
6. Future Outlook

## Market Trends in Steel made BIW:

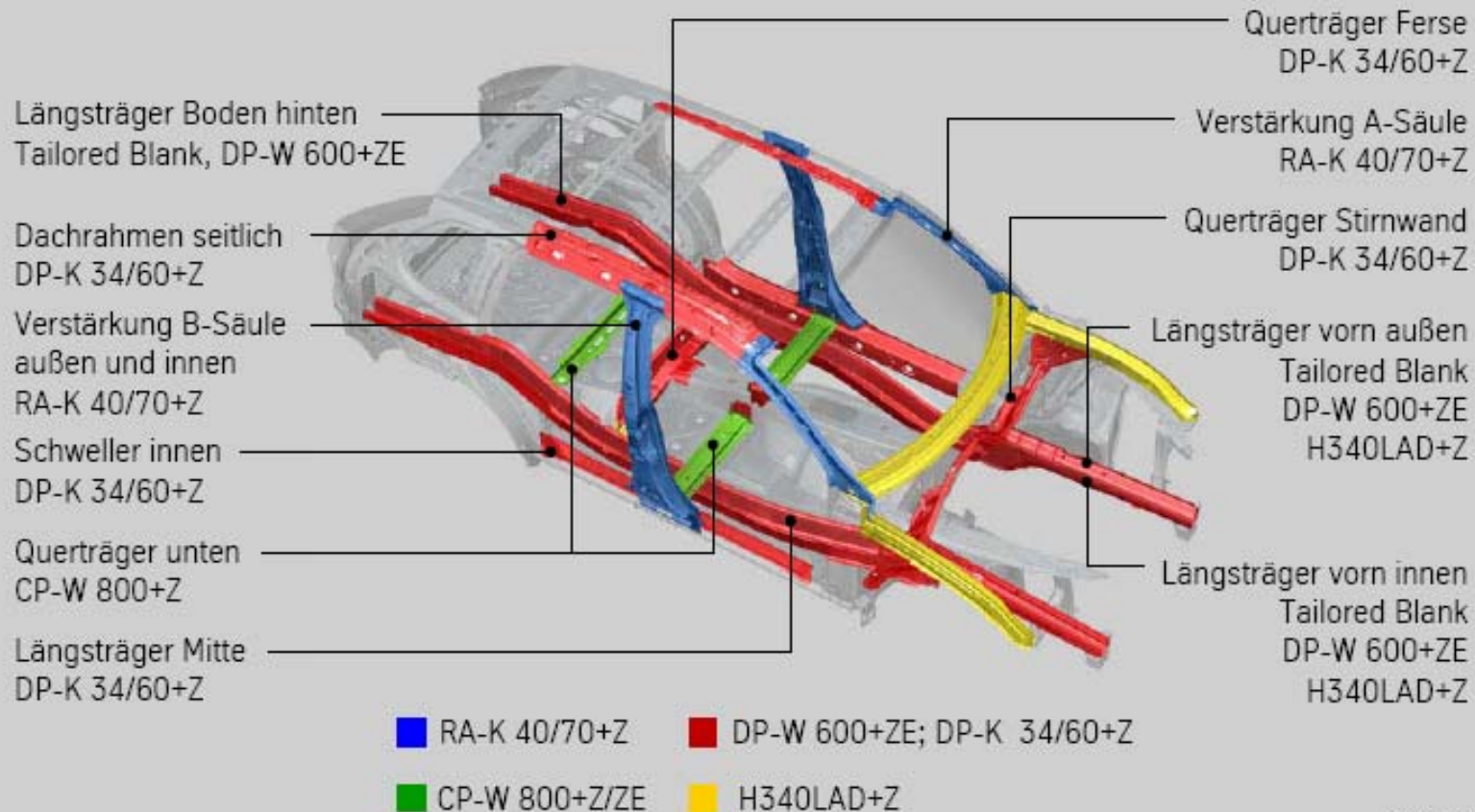
### Trends

- ➔ More than proportional increase of use of HSMS
- ➔ Higher demands in formability
- ➔ Smaller dimensional tolerances
- ➔ Combination of different materials
- ➔ Reduced sheet thickness
- ➔ Higher demands in corrosion resistance

### Technological Needs

- ➔ Improved welding technologies
- ➔ Improved crash safety of welded components
- ➔ Improved formability of weld joints
- ➔ Low heat joining techniques
- ➔ Improved welding technologies and knowledge
- ➔ Reduced welding residual stresses
- ➔ Low damage in corrosion protection coating

# Moderne Mehrphasen-Stähle in der Karosseriestruktur VW Touareg und Porsche Cayenne



Quelle: Porsche

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## Steel Material Studied:

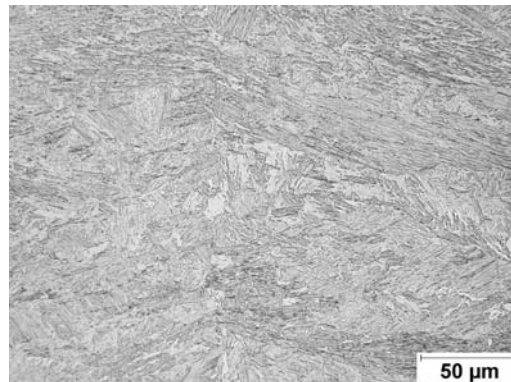
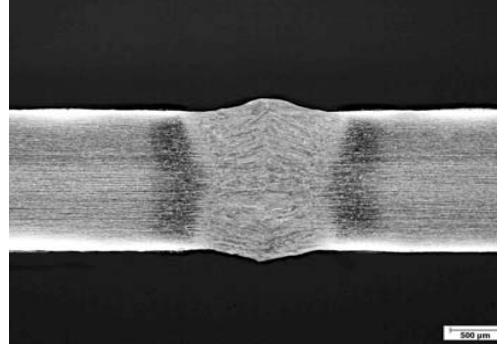
material			properties (reference values)			
steel grade	steel type	t [mm]	R <sub>m</sub> [MPa]	R <sub>p0,2</sub> [MPa]	A <sub>80</sub> [%]	CET [%]
DP-K30/50	dual phase steel ferrite, martensite	0,6 ; 1,5	500	300 – 370	24	0,25
DP-K34/60	dual phase steel ferrite, martensite	0,6 ; 0,8 ; 1,5	600	340 - 410	22	0,30
RA-K40/70	retained austenite steel ferrite, bainite, martensite, retained austenite	0,6 ; 0,8 ; 1,5	700	410 - 510	24	0,41
CP-W800	complexe phase steel ferrite, bainite, martensite	2,5	800	680	10	0,29
MS-W1200	martensite phase steel predominantly martensite	1,5 ; 3,0	1200	900	5	0,37

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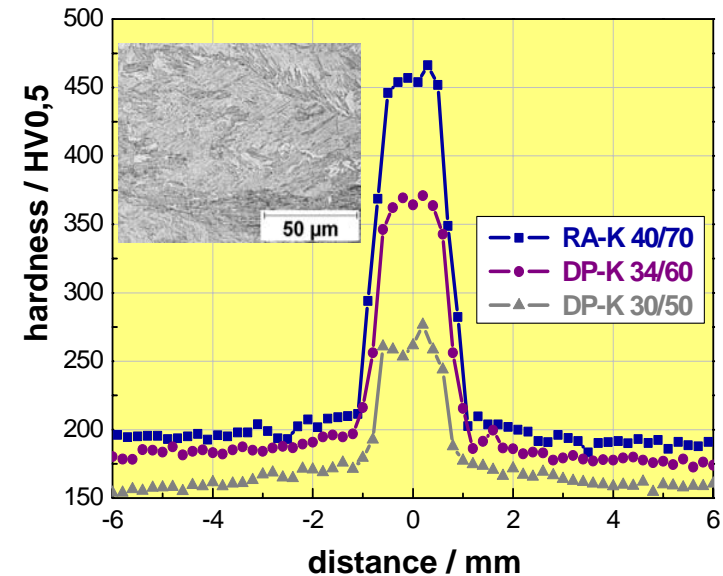
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## Welding Results:

- Excellent and failure free weld seams  
→ good weldability
- No hardness drop within HAZ at non cold-worked sheets
- Strong hardness increase within WZ and inner HAZ
- Increases with CET-carbon equivalent
  - Falling short of lower critical  $t_{8/5}$  - times



RA-K40/70; 1,5 mm

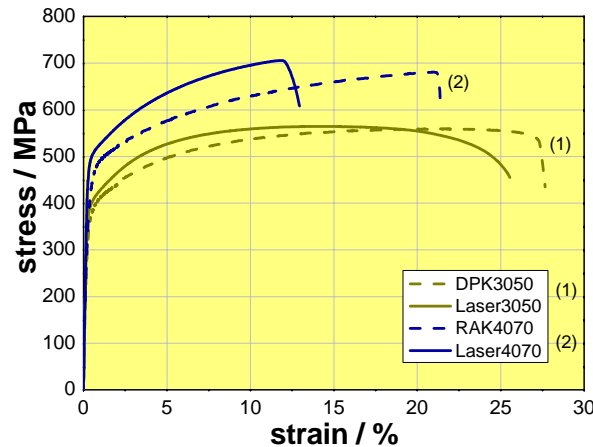




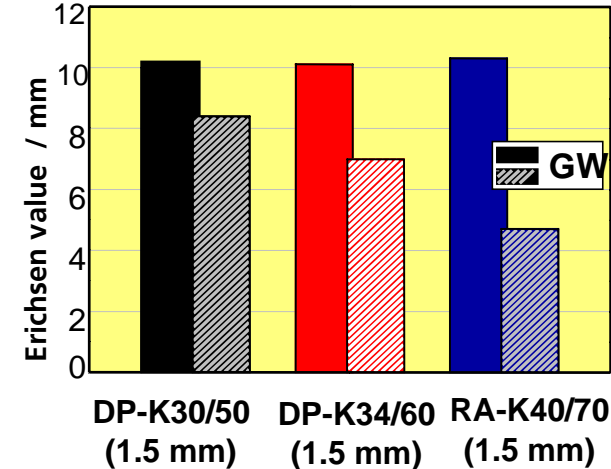
## Critical Issue: Reduced Mechanical Properties and Formability of Welded Sheets

- Higher hardening combined with higher UTS and reduced fracture strain
- Lowering of the Erichsen value
- Worsening of formability increases with strength

**Tension Test**  
(perpendicular to the seam)

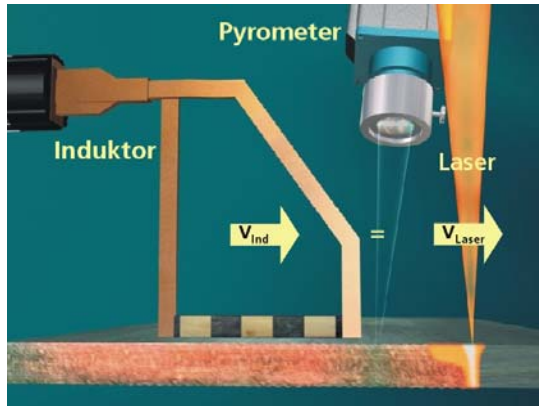


**Erichsen-Test**  
(including the seam)



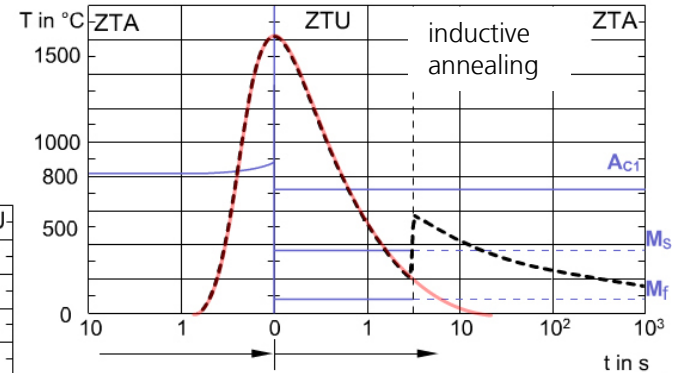
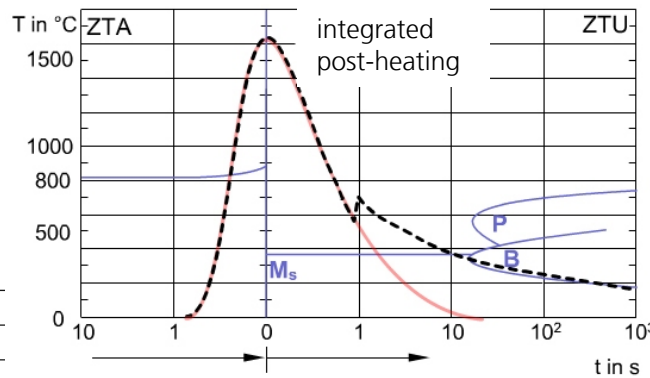
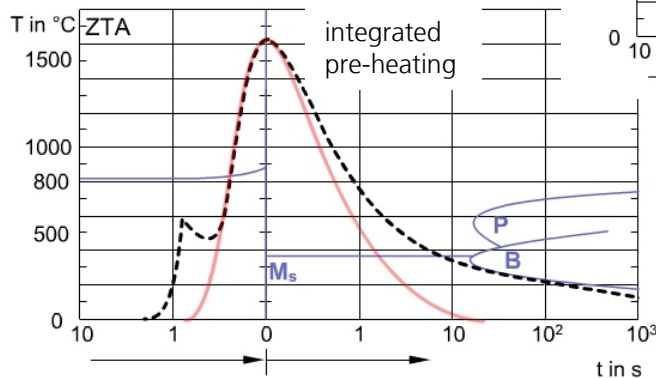
## Solution: Laser Beam Welding with Integrated Inductive Heat Treatment

### Test arrangement



$$V_{ind} = V_{Laser}$$

### variants for T-t-control



**very flexible choice of heat treatment cycle possible**

## Laser Beam Welding with Integrated Inductive Heat Treatment:

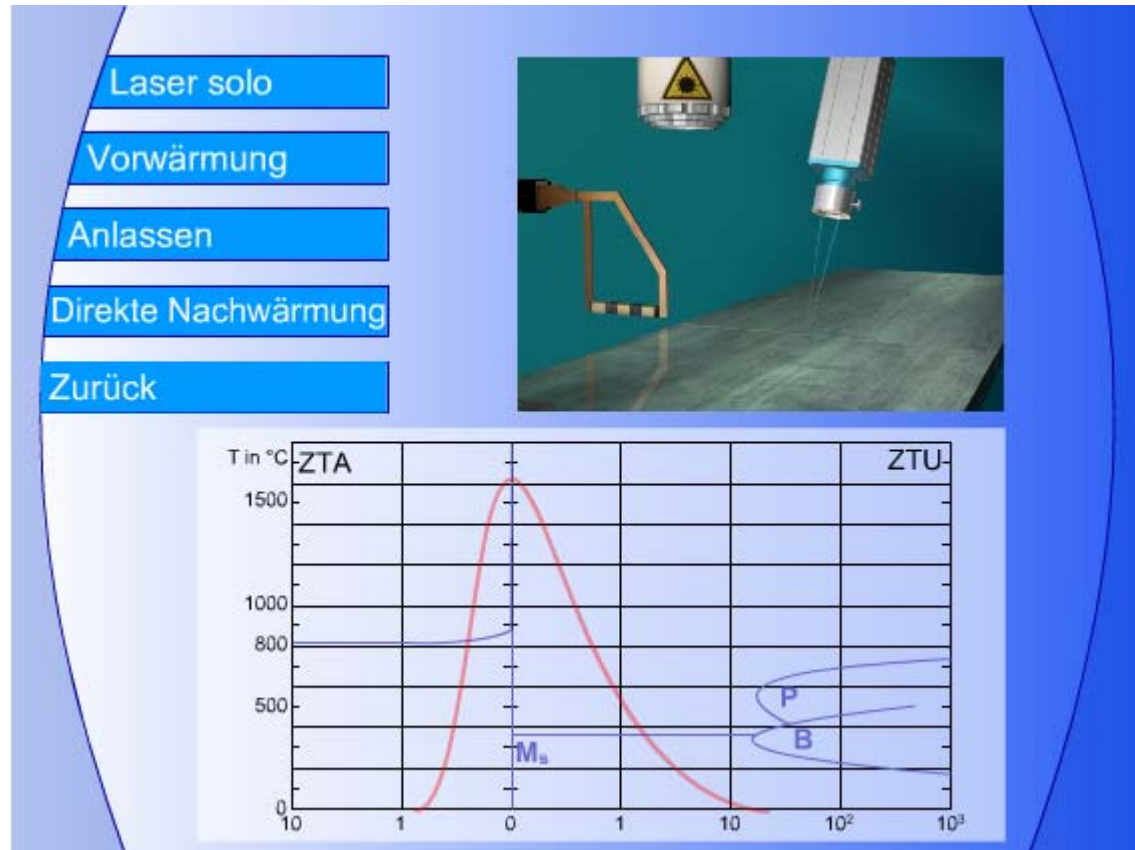
### ■ variants:

- integrated pre-heating
- integrated post-heating
- integrated annealing

### ■ metal-physical advantages:

- control of phase transformations
- specific influencing of joint properties

➔ **best variant:**  
inductive annealing



## Laser Beam Welding with Integrated Heat Treatment: Weld Properties (I):

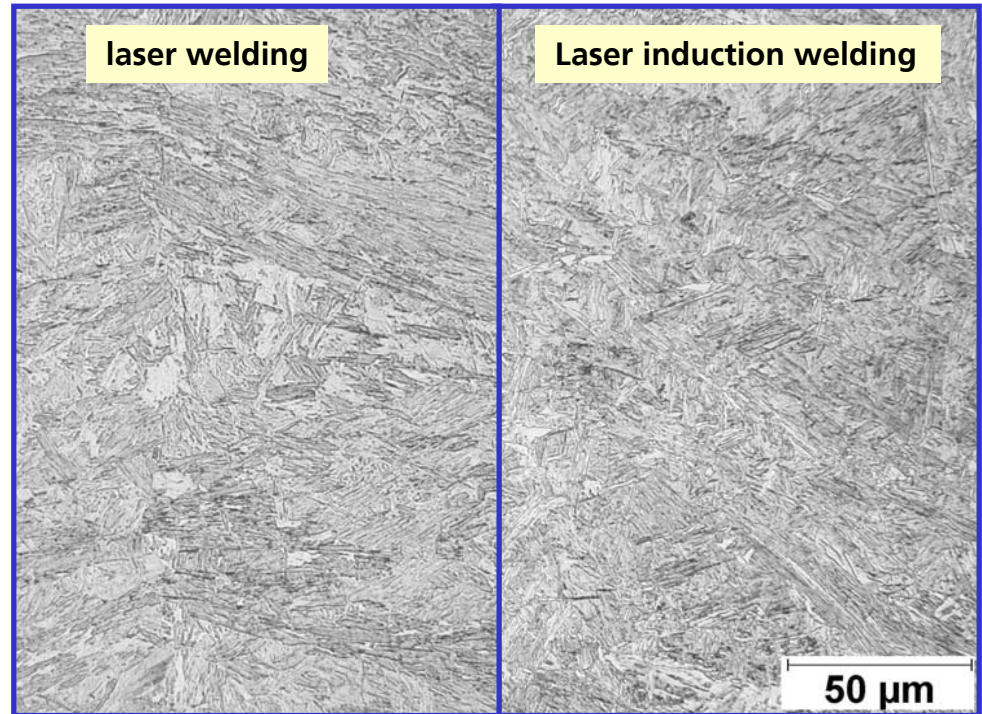
### Structure:

- fine grained annealed martensite

### Hardness:

- significant hardness lowering within WZ and HAZ
- hardness lowering can be controlled by inductive power

### Weld Structure Butt weld RA-K40/70 (TRIP700); 1.5 mm



## Laser Beam Welding with Integrated Heat Treatment: Weld Properties (II):

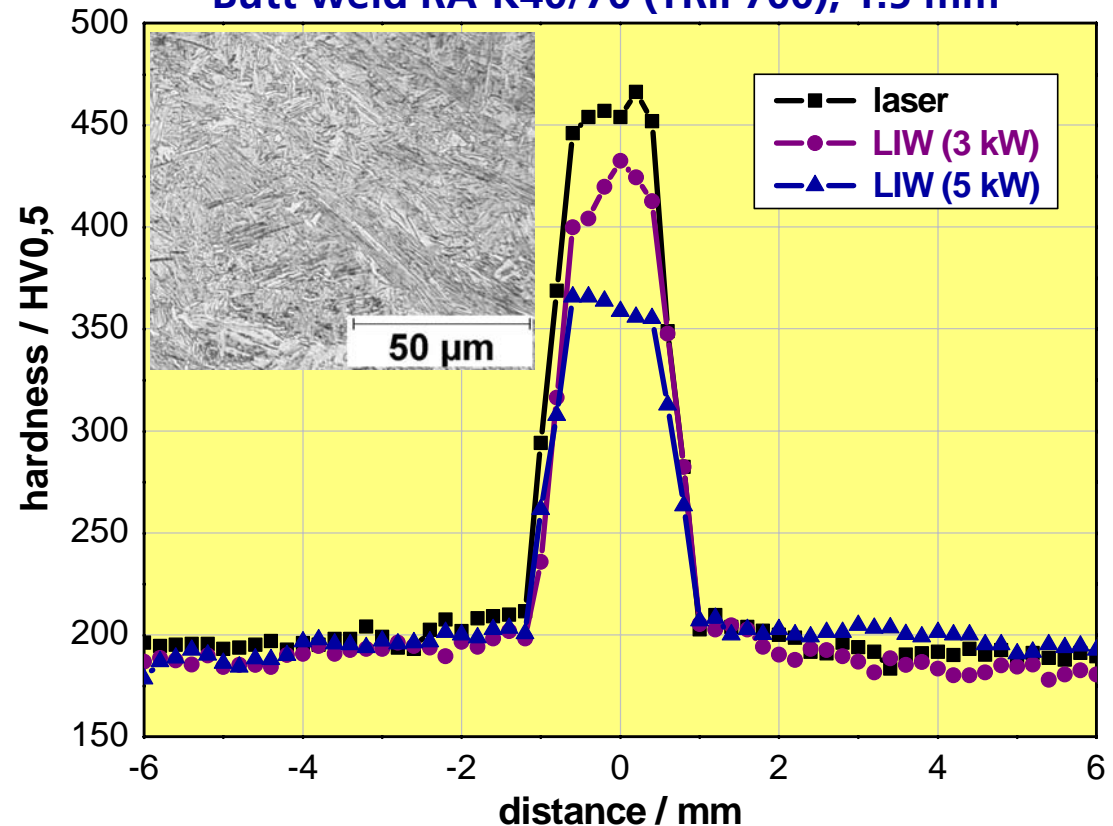
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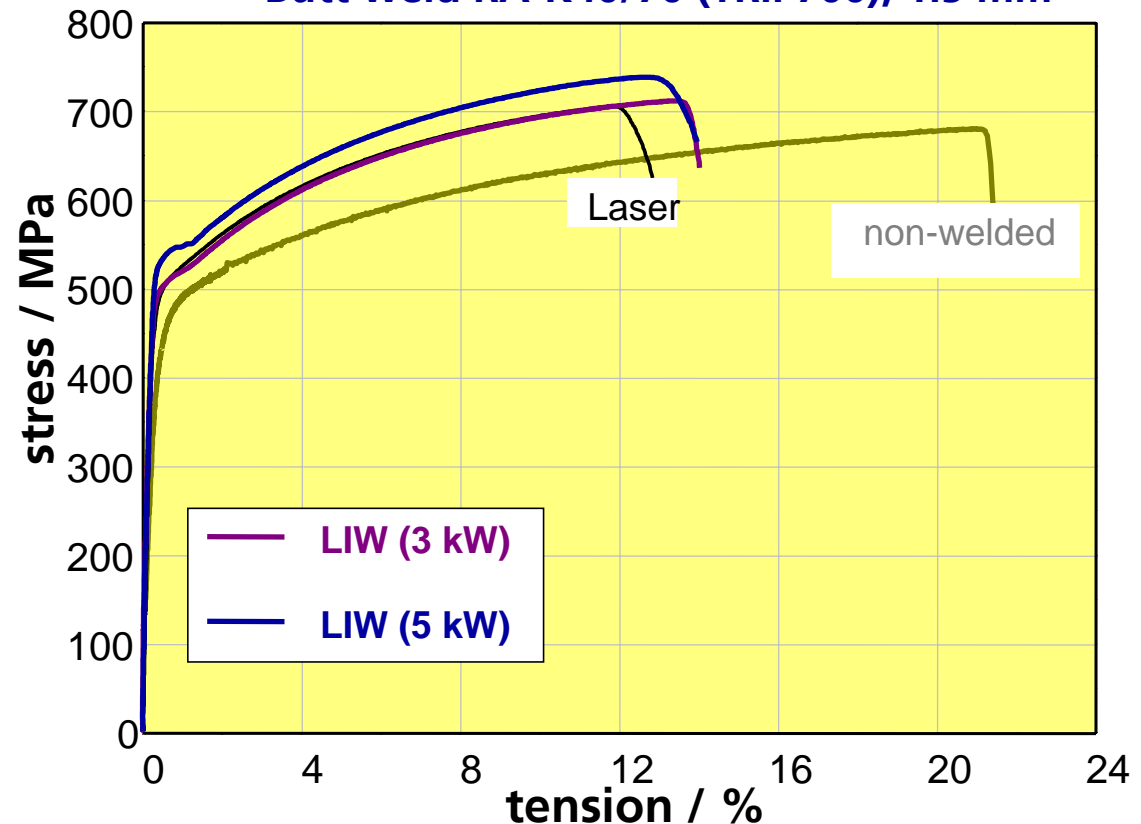
Hardness spreading over the weld seam  
Butt weld RA-K40/70 (TRIP700); 1.5 mm



## Laser Beam Welding with Integrated Heat Treatment: Weld Properties (III):

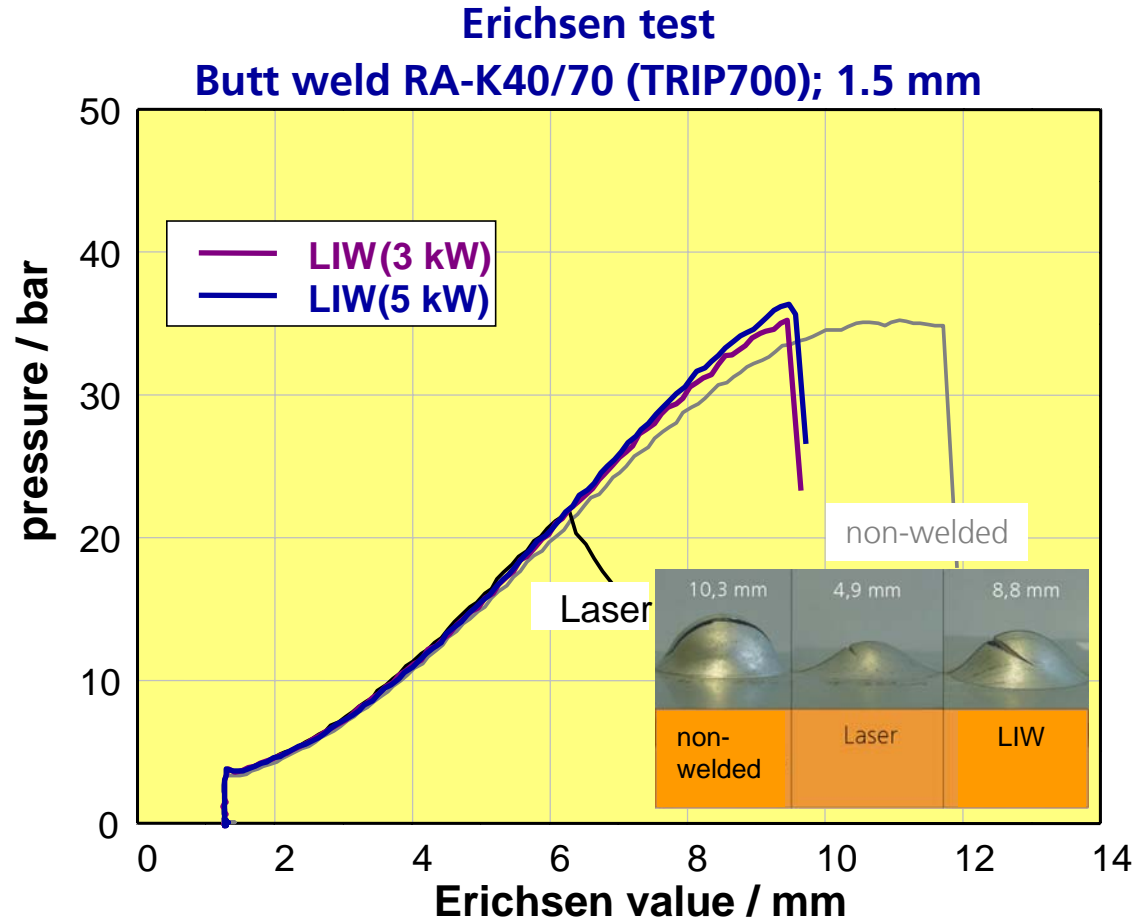
- greater fracture strain at greater UTS (in comparison to laser alone)
- no fracture within WZ and HAZ
- cause for better mechanical properties
  - higher ductility of short time annealed martensite
  - smaller over-matching

Tension test perpendicular to the seam  
Butt weld RA-K40/70 (TRIP700); 1.5 mm



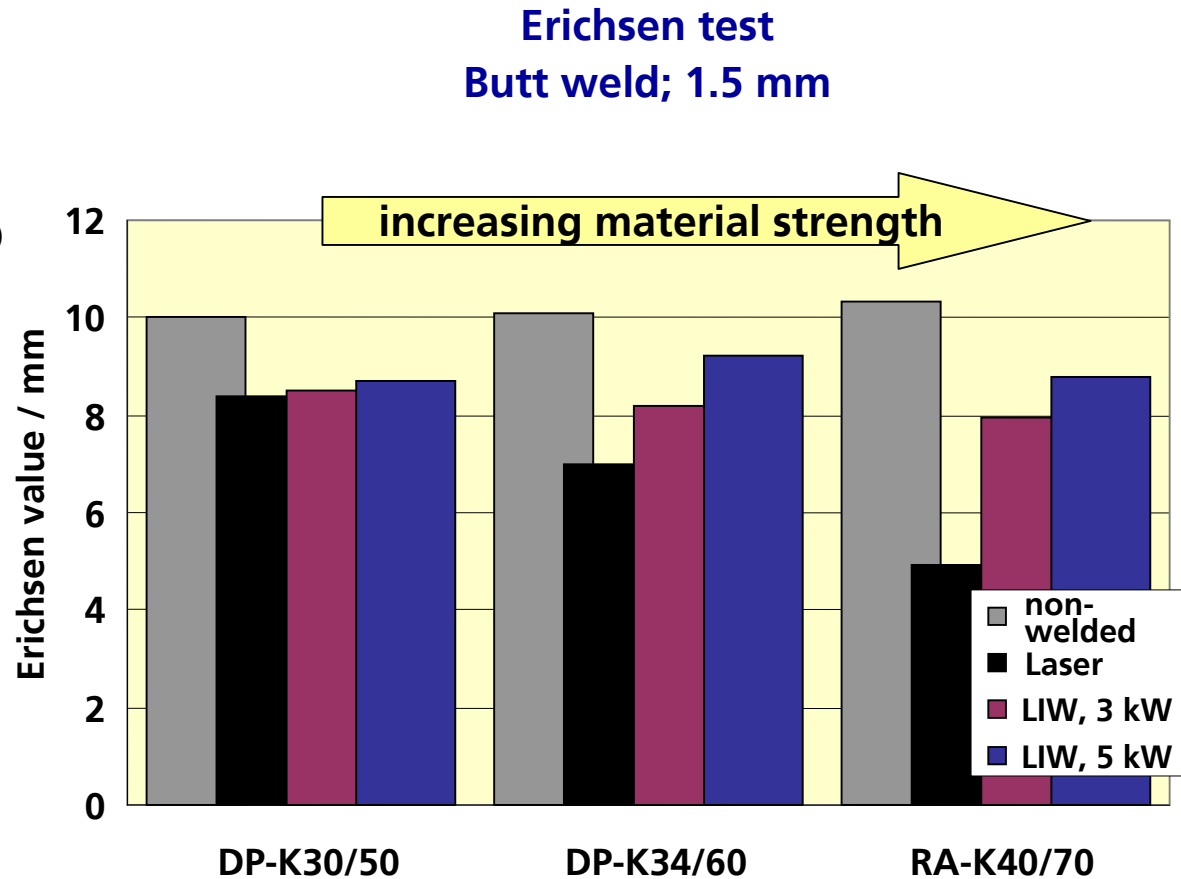
## Laser Beam Welding with Integrated Heat Treatment: Weld Properties (IV):

- remarkable increase of Erichsen value  
(up to 85 % of non-welded sheet)
- Erichsen value increases with UTS!
- more ductile deformation
  - better crash behaviour and higher energy absorption potential can be expected



## Laser Beam Welding with Integrated Heat Treatment: Weld Properties (V):

- remarkable increase of Erichsen value  
(up to 85 % of non-welded sheet)
- Erichsen value increases with UTS!
- more ductile deformation
  - better crash behaviour and higher energy absorption potential can be expected



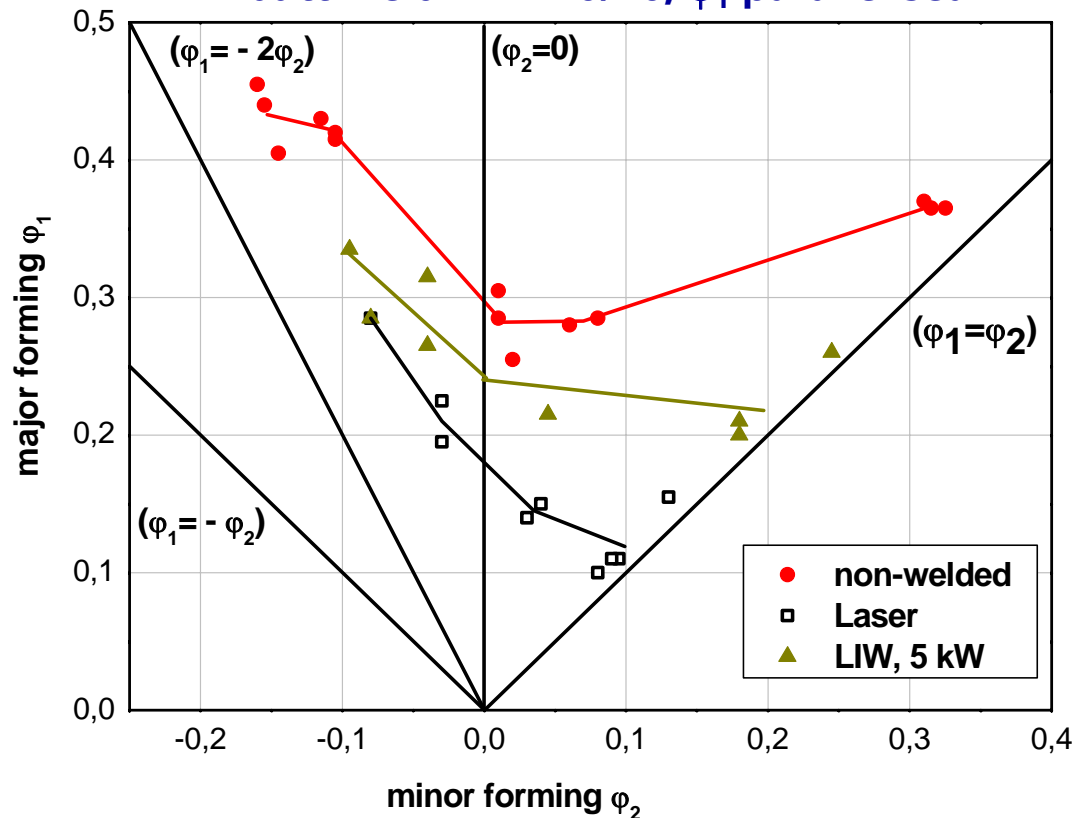


## Laser Beam Welding with Integrated Heat Treatment: Weld Properties (VI):

forming limit curves  
butt weld RA-K40/70,  $\varphi_1$  parallel seam

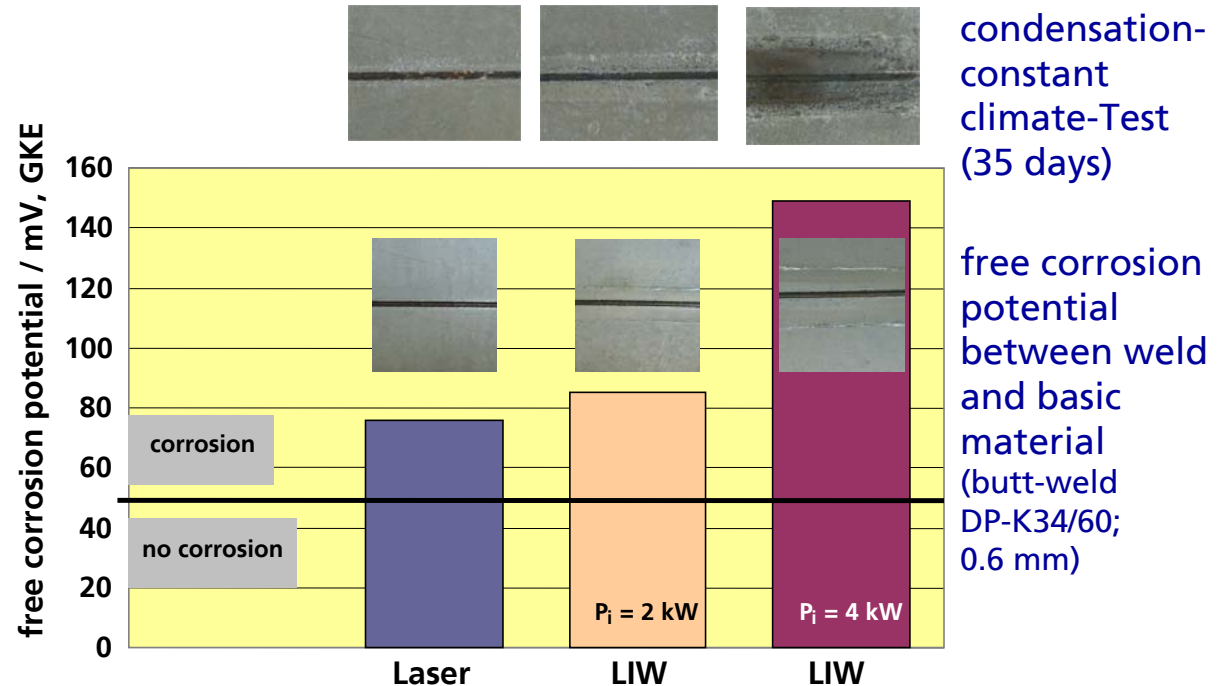
■ considerable improvement of formability at all forming conditions:

- stretch forming
- plain strain
- uniaxial tensile
- deep drawing

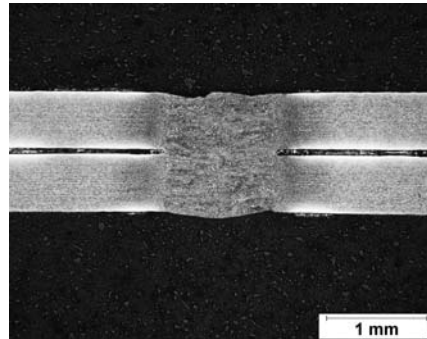


## Laser Beam Welding with Integrated Heat Treatment: Weld Properties (VII):

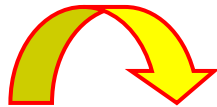
- corrosion properties
  - only small worsening
  - enhanced corrosion only above a critical annealing temperature
  - further improvement by optimized T-t-cycles expected



## Laser Beam Welding with Integrated Heat Treatment: Overlap Welding:

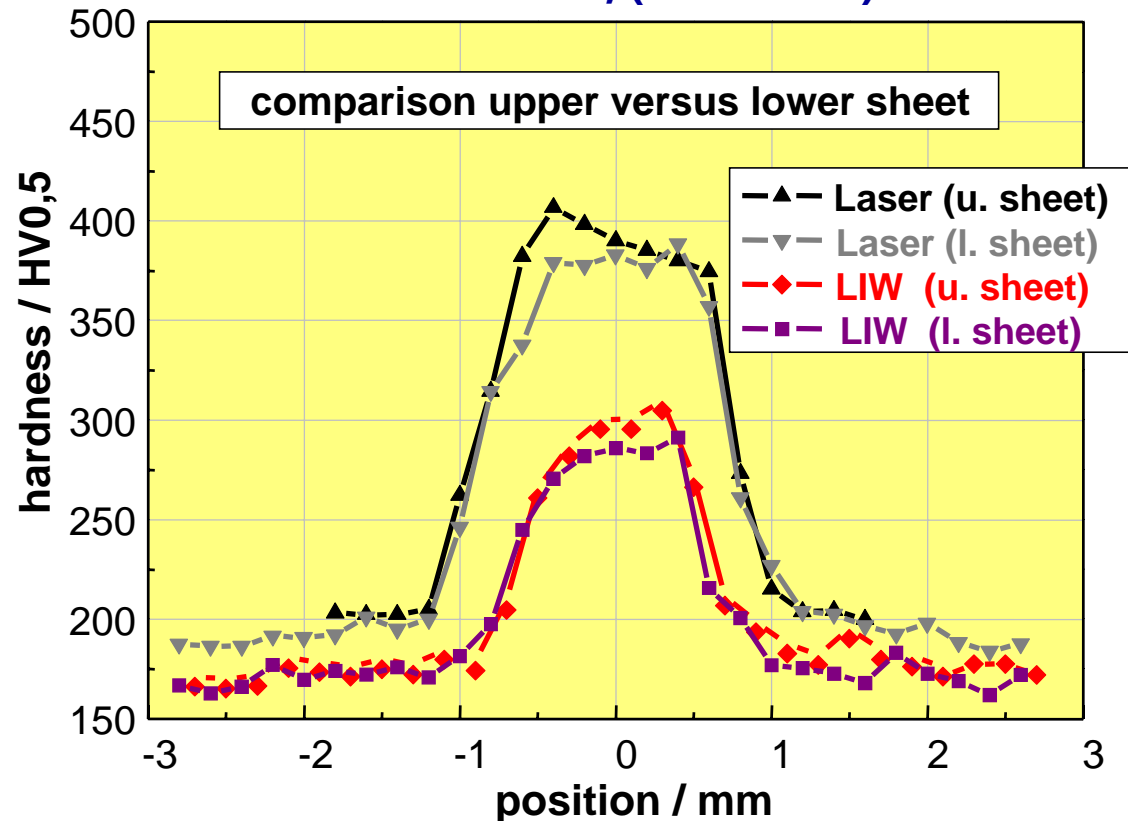


■ same hardness drop in upper and lower sheet



■ technology suited for overlap-welding in BIW

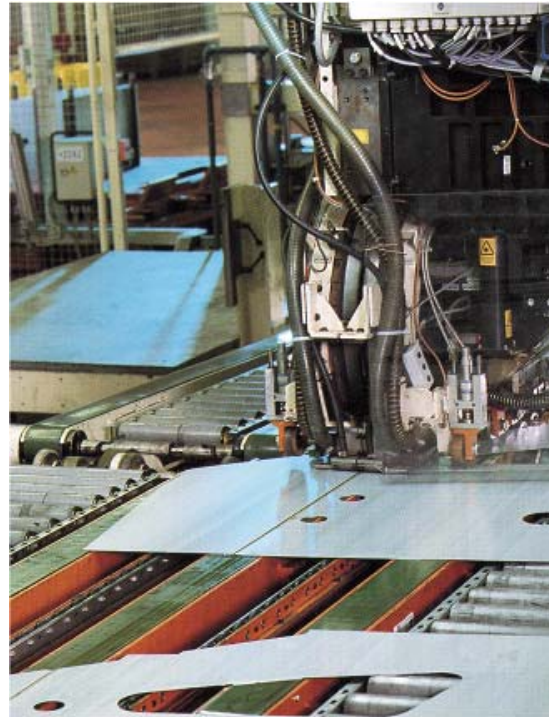
Overlap-welding  
DP-K34/60; (2 x 0.6 mm)



## Laser Beam Welding with Integrated Heat Treatment: Potential Industrial Applications:

- semi-finished parts with higher formability, e. g.
  - tailored blanks
  - tailored tubes
  - engineered blanks
- components with better crash behaviour, e. g.
  - B-pillar
  - shock-absorber
  - impact protective plates
  - body reinforcements door intrusion beams
  - side members a. s. o.

tailored welded blanks



source: TKS

B-pillar-demonstrator



source: IWS / IWU

body shop

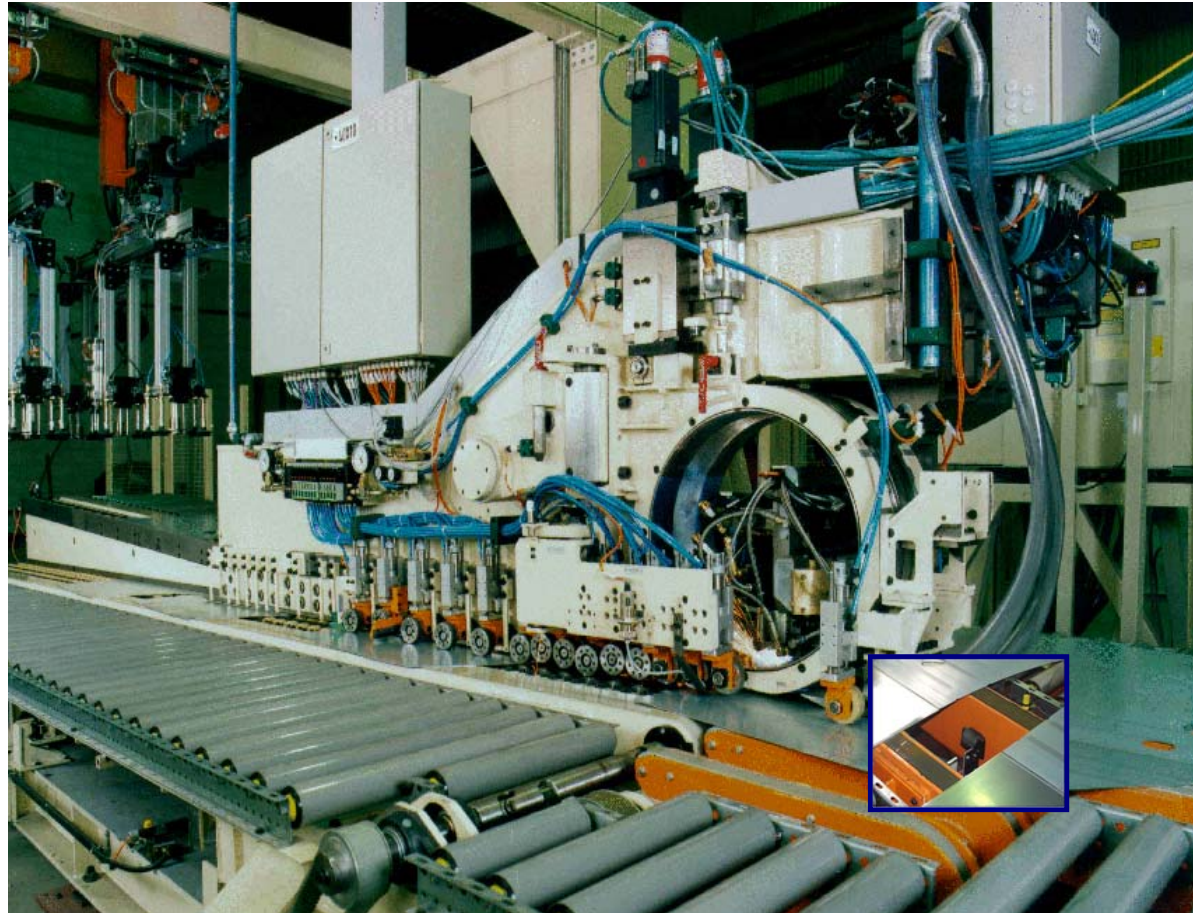


source: IWS

## Tailored Blank Laser Welding Machine with Integrated Inductive Annealing (I):

### ■ Equipment

- conventional TB-welding machine
- additional induction station
- inductor arranged at the weld root side
- pyrometric temperature control



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Fraunhofer  
Institut  
Werkstoff- und  
Strahltechnik

Ein Unternehmen  
von ThyssenKrupp  
Steel

ThyssenKrupp Stahl



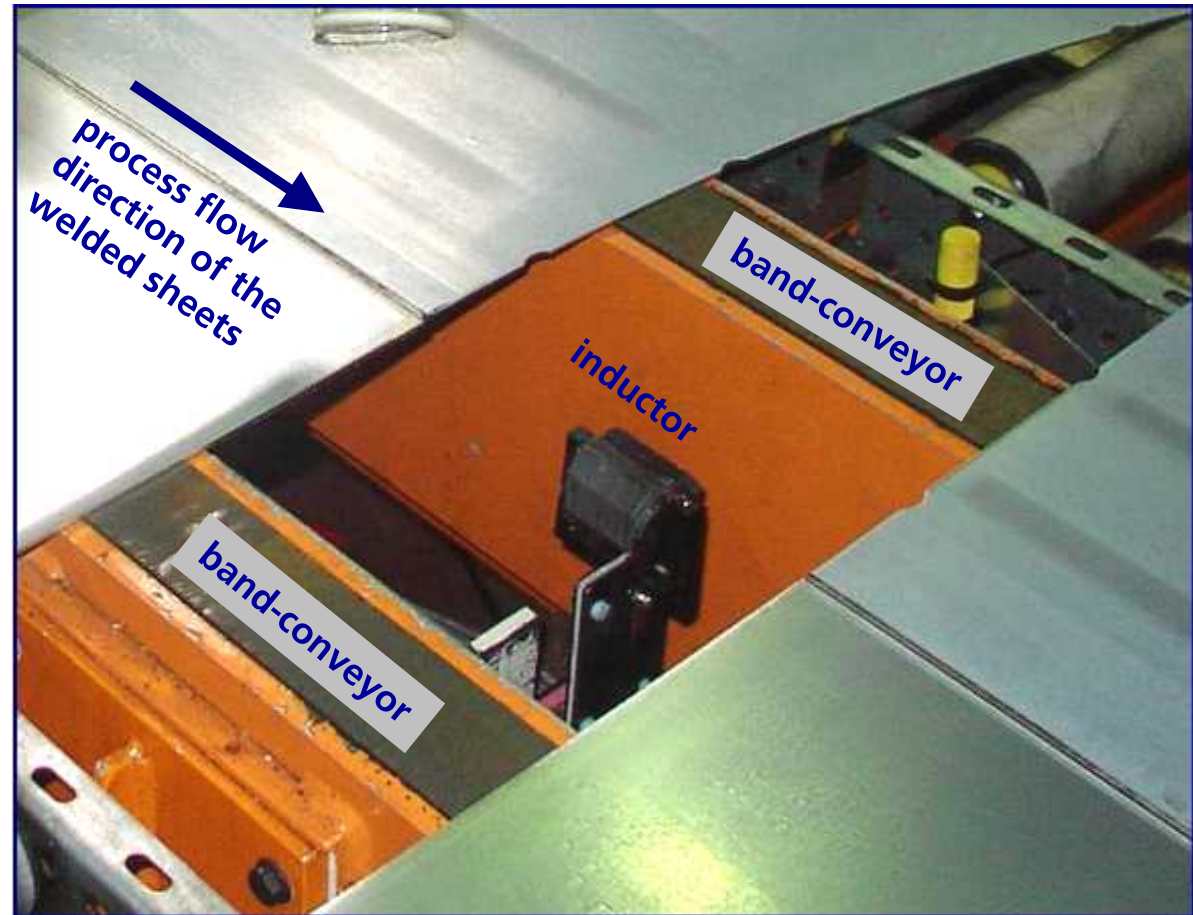
## Tailored Blank Laser Welding Machine with Integrated Inductive Annealing (II):

### ■ Material

- high strength steel
- sheet thickness 3 mm

### ■ Parameters

- laser: 8 kW CO<sub>2</sub>
- induction: appr. 10 kW MF
- $v_{ind.} = \text{appr. } 10\text{m/min}$



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Strahltechnik

Ein Unternehmen  
von ThyssenKrupp  
Steel

ThyssenKrupp Stahl



## Conclusions (I):

- An integrated inductive short time annealing improves the mechanical properties of laser welded high strength steel sheets considerably.
- It offers an interesting industrial potential both for improving of
  - formability of semi-finished parts and
  - crash behaviour of welded structures.

## Conclusions (II):

- This process offers a simple and effective possibility for an integration in tailored blank welding machines or for 2D-component welding.
- Future challenges are:
  - process development for cold rolled sheets
  - improvement of the 3D-capability



# Thank you for your attention!

➤ **contact person:**  : Prof. Dr. Berndt Brenner

phone: +49 (0)351-2583-207

email: [berndt.brenner@iws.fraunhofer.de](mailto:berndt.brenner@iws.fraunhofer.de)



: Stefan Wischmann

phone: +49 (0)20352 – 44552

email: [stefan.wischmann@tkcs.thyssenkrupp.com](mailto:stefan.wischmann@tkcs.thyssenkrupp.com)

