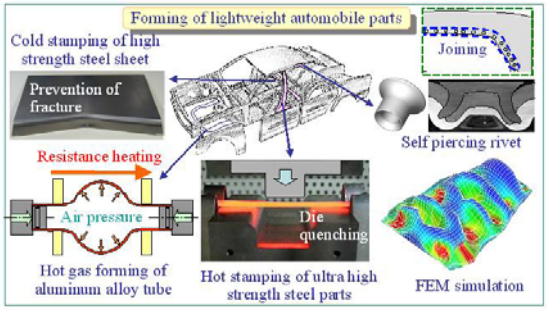
Hot Stamping of Ultra-High Strength Steel Parts

Toyohashi University of Technology
Ken-ichiro Mori



Ken-ichiro Mori
Professor
Department of Mechanical Engineering,
Toyohashi University of Technology
CIRP fellow, forming processes

Scopus (from 1995)
Number of papers: 205, Number of citations: 2516, h-index:28
Web of Science (from 1993)
Number of papers: 172, Number of citations: 1419, h-index:19

Numiform 2001,
Metal Forming 2010,
ICTP 2014

Toyohashi

Aichi prefecture:
- Nagoya, Toyohashi, etc.
- 11.4% of industrial goods
- Automobile industry

Population:
380,000
Area: 630 km²

Toyohashi University of Technology

National university
Found in 1976
Undergraduates: 1,190
Postgraduates: 989
Academic staff: 229
5 departments, 1 research institute and 6 research centers
Area: 355,606 m²

History of research works

Software: rapid development of computers

1980
- Formulation of rigid-plastic finite element method
- Application to forging, rolling, extrusion, drawing, sheet metal forming, powder forming, etc.

1990
- Knowledge engineering: expert system, fuzzy control, neural network, GA
- Microscopic analysis: microscopic FEM, DEM, Monte Carlo method

1997: Toyohashi University of Technology
Hardware: automobile lightweighting

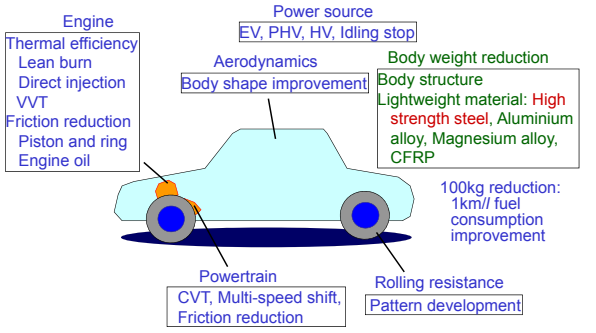
2000
- Stamping of high strength steel sheets, hot stamping
- Joining by plastic deformation: self-pierce riveting, mechanical clinching

2010
- Pulsating forging and hydroforming
- Plate forging for thickening and thinning
- Stamping of titanium, magnesium, aluminium sheets

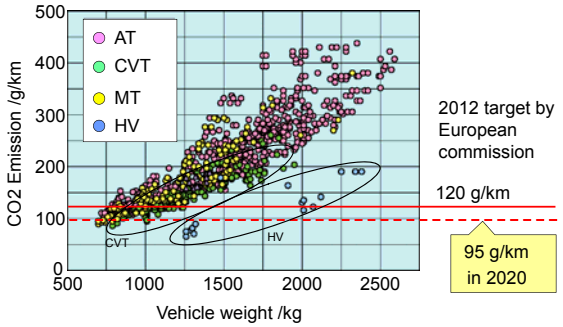
Hot Stamping of Ultra-High Strength Steel Parts

1. Reduction in car weight
2. Hot stamping
3. Material and oxide prevention
4. Heating
5. Stamping
6. Die quenching

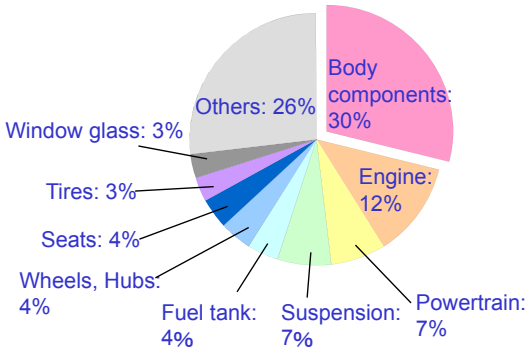
Approaches of environmentally friendly automobiles



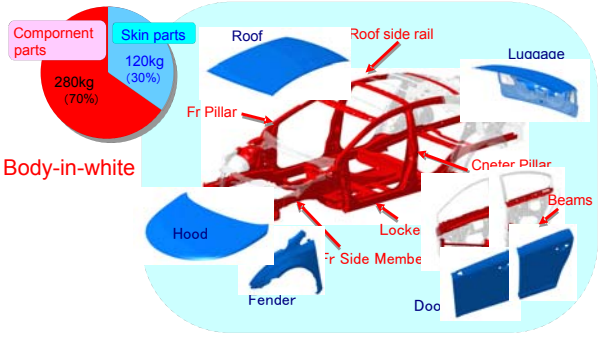
Relationship between CO2 emission and automobile weight



Weight percentage of automobiles parts



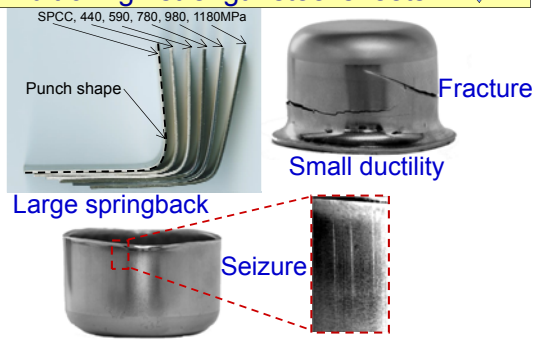
Body parts of automobiles



Specific strength for various sheet metals

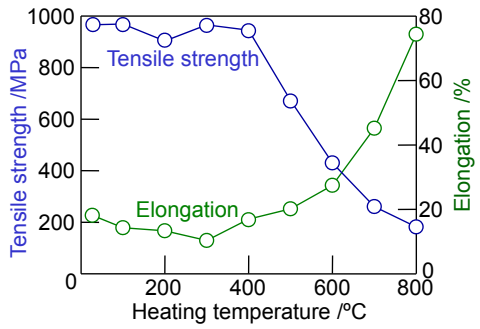
Sheet	Tensile strength	Specific gravity	Strength-to-specific gravity ratio
Ultra−high strength steel	980 - 1470MPa	7.8	126 - 188MPa
High strength steel	490-790MPa	7.8	63-101MPa
Mild steel SPCC	340MPa	7.8	44MPa
Aluminium alloy A6061(T6)	310MPa	2.7	115MPa

Problems in cold stamping of ultra-high strength steel sheets

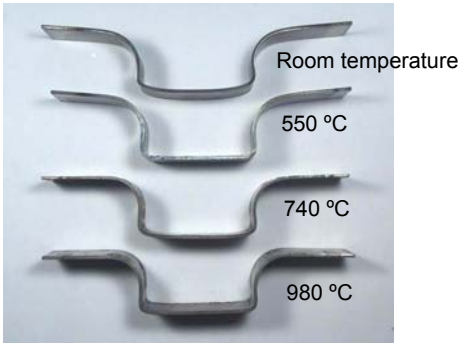


Cold stamping of steel sheets having tensile strength more than 1.2GPa is difficult.

Variations in tensile strength and elongation with temperature for SPFC980Y



Hat-shaped bent sheets of SPFC980Y at different heating temperatures



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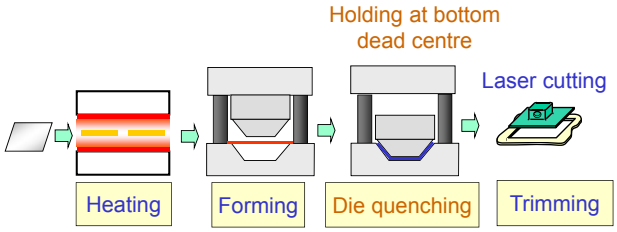
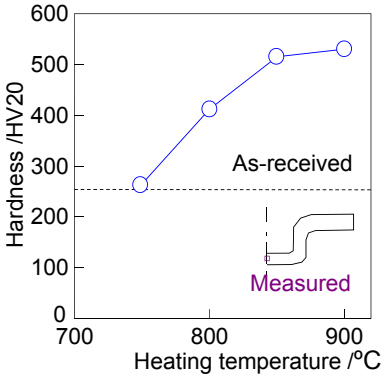
Hot stamping for ultra–high strength steel products



Hot press forming, press hardening

Increase in hardness by die quenching



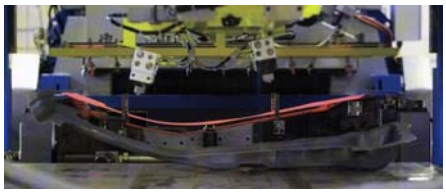
Quenching by tools: 1.5GPa

Hot stamping process for ultra-high strength steel products

Miyazu Malaysia

Hot stamping

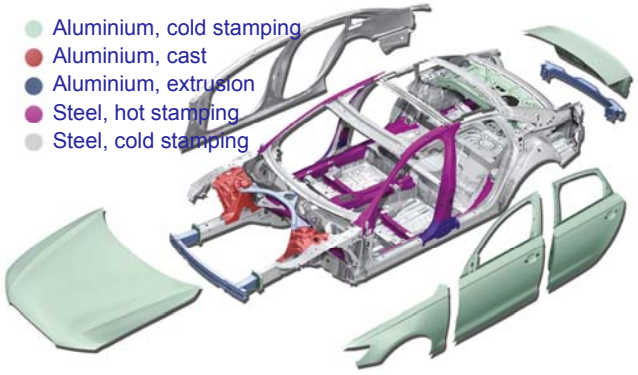
Hot stamping



Volkswagen Passat

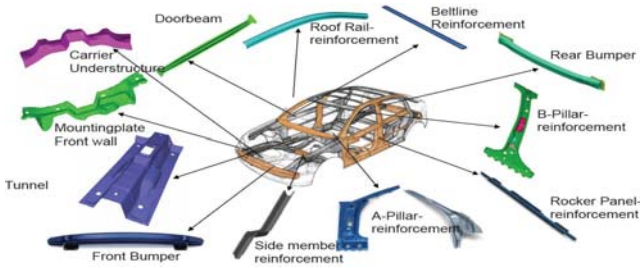
Volkswagen Passat
16% of body components

Audi A7 Sportback



Center pillar in Honda N BOX

Hot stamping in Germany, Benteler



Hot stamping in Canada, Magnum




Hot stamping in Japan, Aisin Takaoka


Door beam reinforcement


Roof reinforcement


Bumper reinforcement member

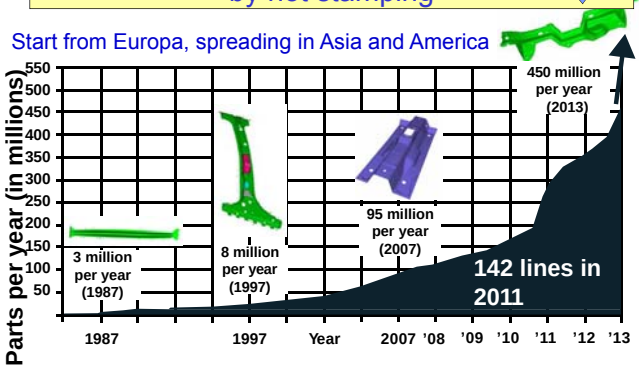

Dash lowercross member

Centre pillar


A pillar reinforcement

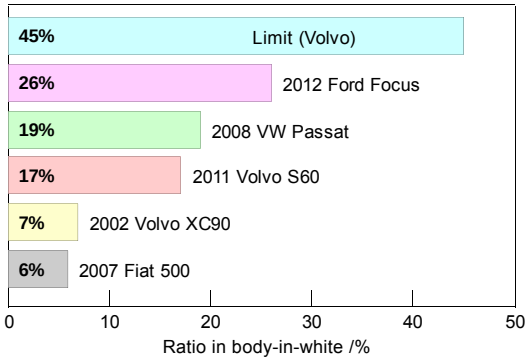
Number of parts produced by hot stamping

Start from Europa, spreading in Asia and America



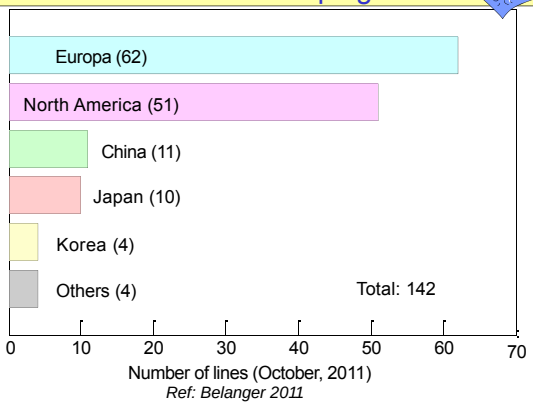
Ref: Hund 2011, Belanger 2011

Ration of hot stamped part in body-in-white



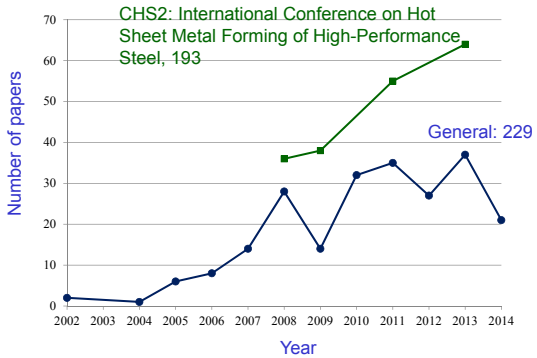
Ref: Holzkamp 2011, Hover 2011, Lucia 2011, Wästlund 2011.

Number of hot stamping lines



Ref: Belanger 2011

Papers for hot stamping



Advantages of hot stamping

- Decrease in forming load
- Prevention of springback
- Increase in formability
- Formed products having 1.5GPa in tensile strength

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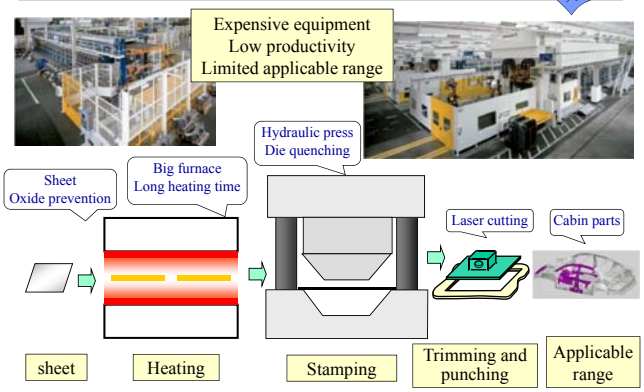
Problems in conventional hot stamping

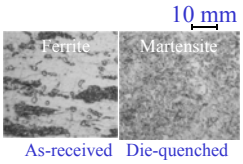


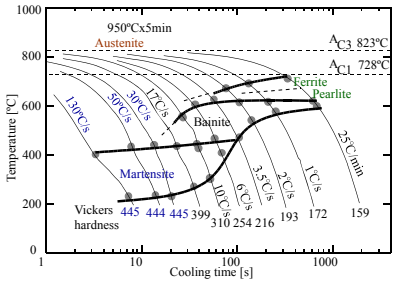
Phase transformation

Manganese boron steel 22MnB5: 1.5 GPa

C	Si	Mn	P	B
0.21	0.25	1.2	0.015	0.0014

Ferrite→austenite →martensite
pearlite, bainite





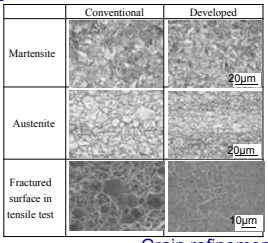
Increase in strength

Increase in carbon: large strength

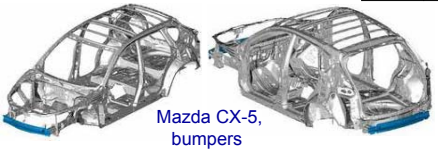
1.8 GPa

1.5 GPa
0.2%C-B
No fracture
1.8 GPa
0.3%C-Mn
Partial fracture
2 GPa
0.4%C-B
Complete fracture

Low toughness



Grain refinement

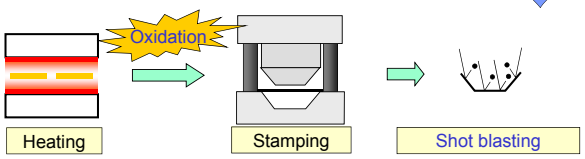


Mazda CX-5, bumpers

2 GPa: ArcelorMittal

Martensitic stainless steel

Conventional treatments for oxidation



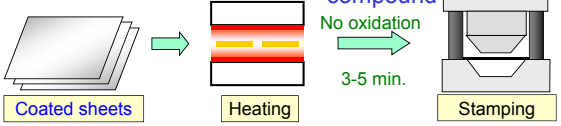
Increase in processes, accuracy reduction

Aluminium and zinc coatings

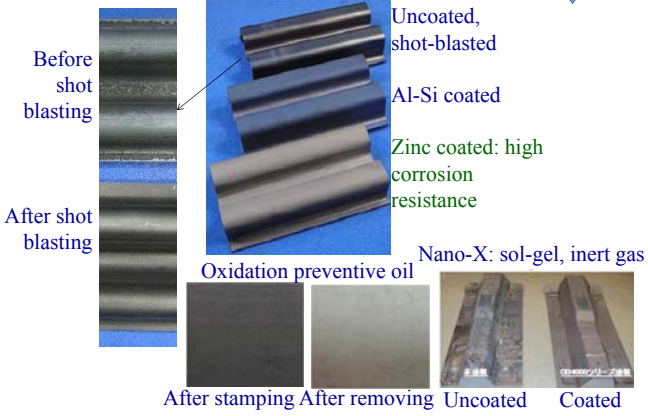
Intermetallic compound

No oxidation

3-5 min.



Oxidation treatment



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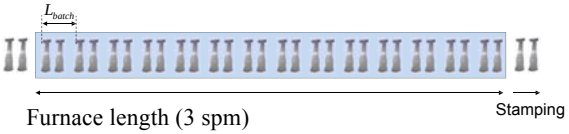
Furnace size



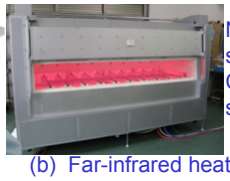
Furnace length (3 spm)

$$\frac{t_{heating}}{t_{cycle}} L_{batch} = \frac{330\text{sec}}{20\text{sec}} \text{x} 1.6\text{m} \cong 26.4\text{m}$$

Ref: Eriksson 2010

New heating processes

(a) Furnace heating



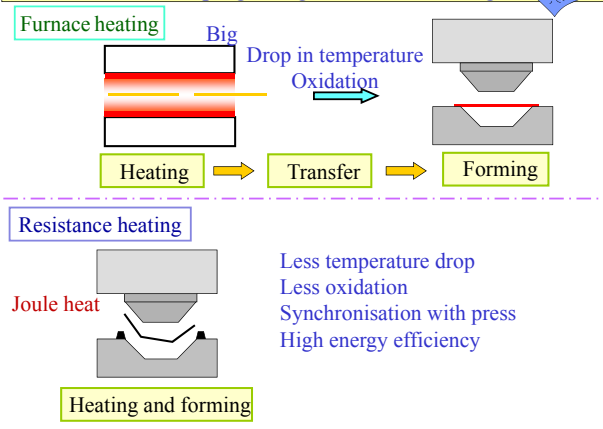
(b) Far-infrared heating

Non-coated sheet: 49 s
Coated sheet: 72 s

(c) Induction heating

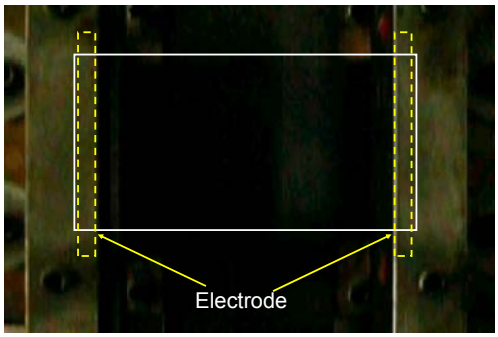
Multistage furnace: small space

Hot stamping using resistance heating



Resistance heating

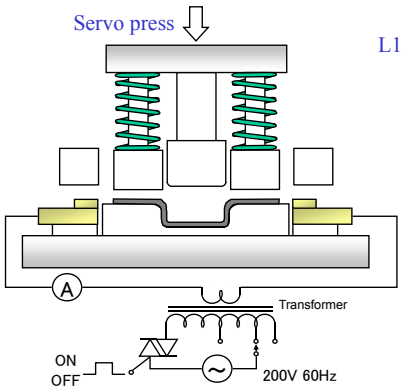
SPFC980, thickness: 1.2mm, Power: 85kJ (10V, 2sec)



Linkage of power supply and servo press

Power supply Servo pre Power supply Servo press

Hat-shaped bending using resistance heating



L130 × W20 × t1.2

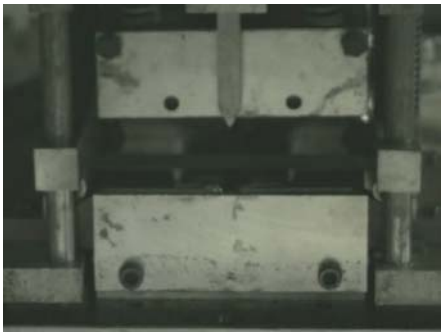
Heating: 0.96s

0.26s

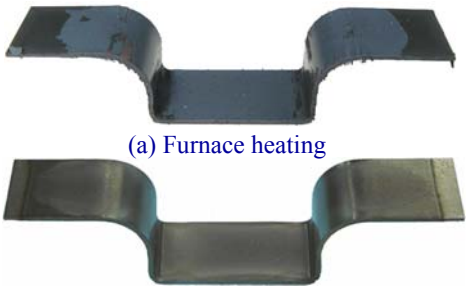
Forming

Holding: 3.5s

Hat-shaped bending using resistance heating at 980 ºC



Hat-shaped bent sheet at 980 ºC



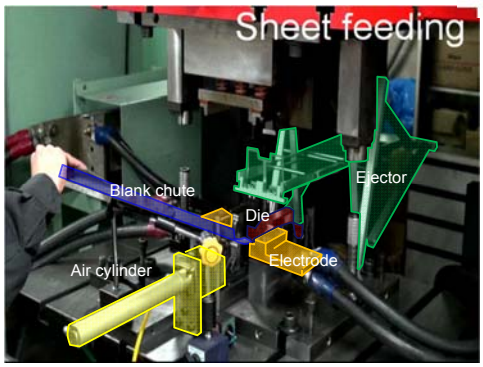
(a) Furnace heating

(b) Resistance heating

Hot stamping using resistance heating

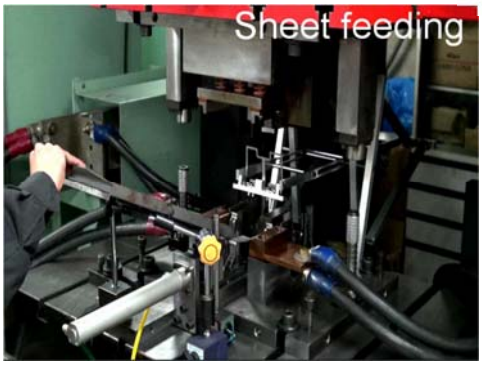
Heating 850 ºC, 3.3 s ➡ Transfer 2 s ➡ Forming 1 s ➡ Holding 5 s

Repeated resistance heating hot stamping



Transferring ⇨ Resistance heating, stamping + die quenching ⇨ Products

Repeated resistance heating hot stamping

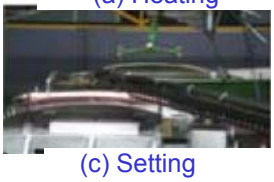


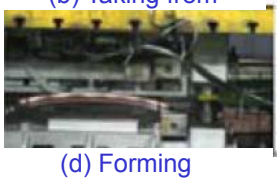
Transferring ⇨ Resistance heating, stamping + die quenching ⇨ Products

Real production using resistance heating

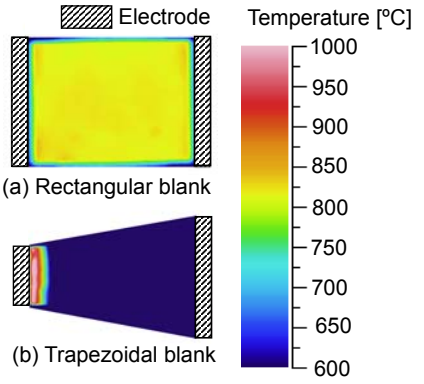

(a) Heating


(b) Taking from


(c) Setting


(d) Forming

Limitation of resistance heating to rectangular sheets



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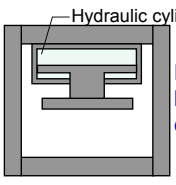
Hydraulic press used for hot stamping

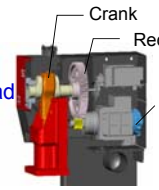
Hydraulic press



Holding at bottom dead centre

• Low slide speed

Mechanical servo press



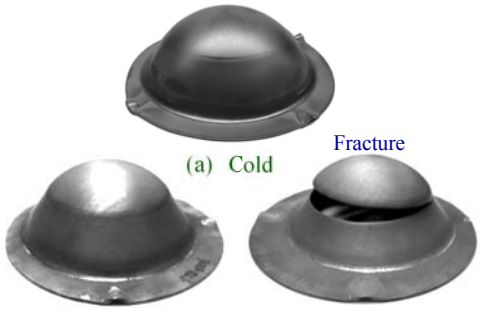
• High slide speed
• Flexible slide motion

Hot stamping for different forming speeds

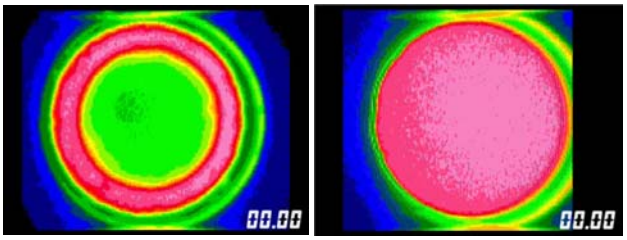

(a) Low speed (26 mm/s)


(b) High speed (149 mm/s)

Effect of forming speed on formability

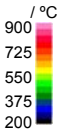


Temperature distribution in hot stamping

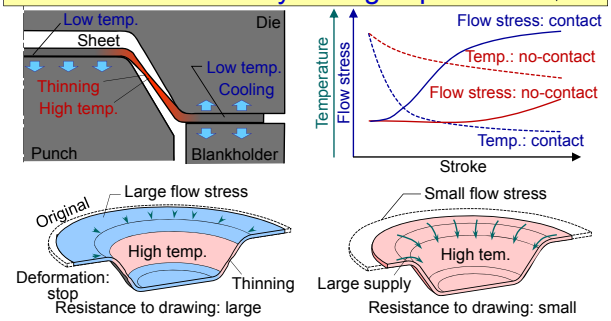


(a) 149 mm/s (b) 26 mm/s

High speed stamping by mechanical servo press

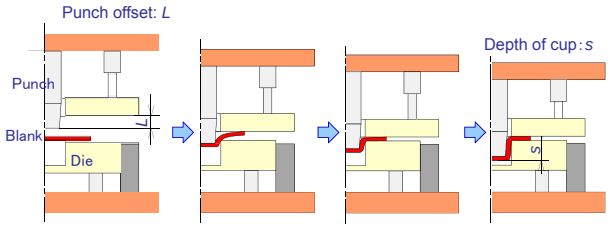


Mechanism of improvement of formability for high speed



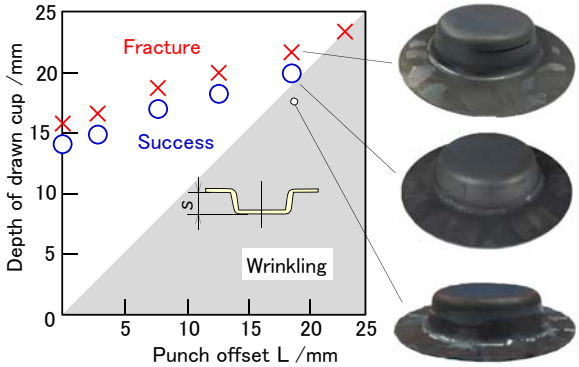
(a) Low speed: low formability (b) High speed: high formability

Improvement of formability by delay of sheet holding

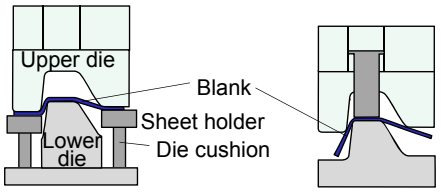


(a) Start (b) Former stage (c) Latter stage (d) End

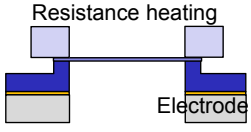
Effect of punch offset on formability



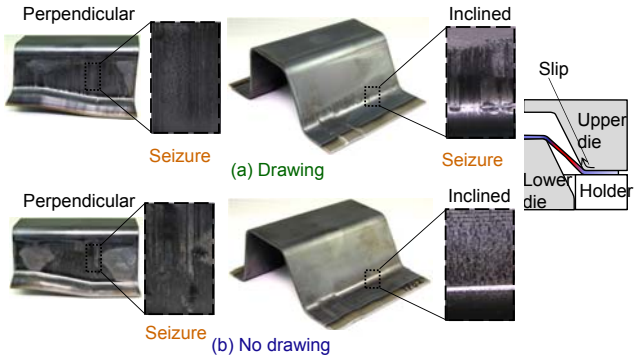
Effect of drawing in hot stamping



(a) Drawing: sheet holder (b) No drawing: no sheet holder



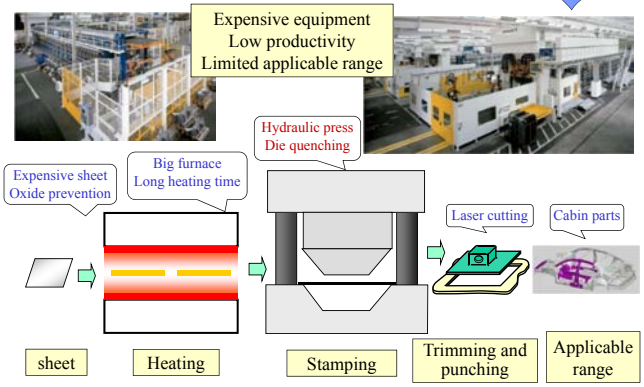
Seizure in no drawing



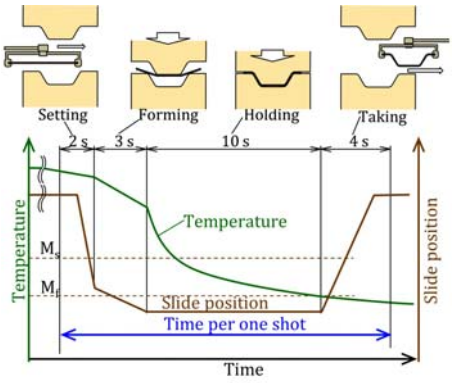
Hot Stamping of Ultra-High Strength Steel Parts

1. Reduction in car weight
2. Hot stamping
3. Material and oxide prevention
4. Heating
5. Stamping
6. Die quenching

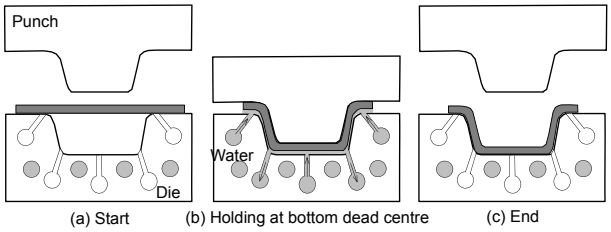
Problems in conventional hot stamping



Productivity of hot stamping operation

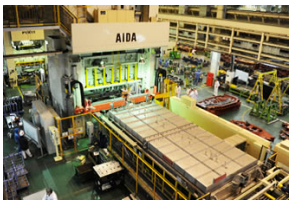


Water direct quenching

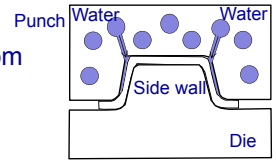


Nippon Steel & Sumitomo Metal, Unipres

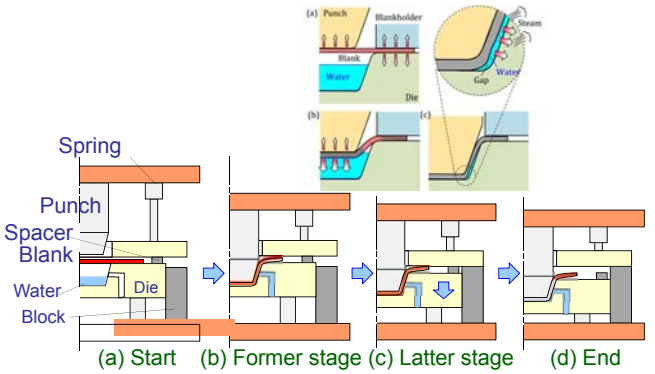
Application of servo press and direct water quenching in Honda



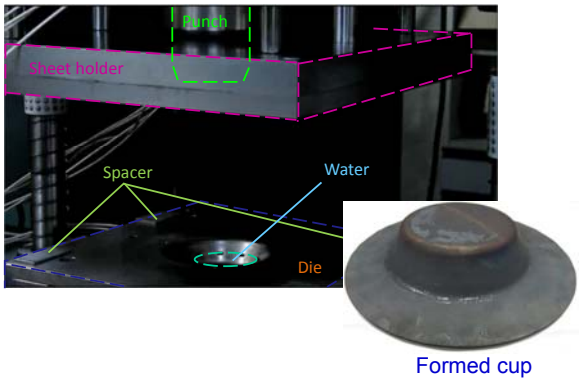
Increase in productivity: 8 spm
Conventional: 2 or 3 spm



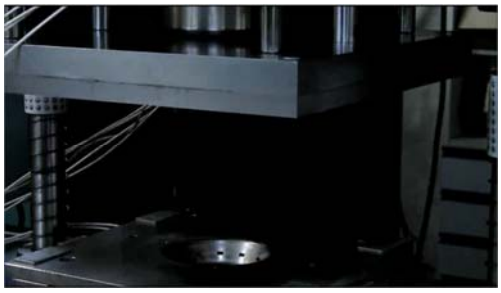
Direct water quenching and delay of sheet holding



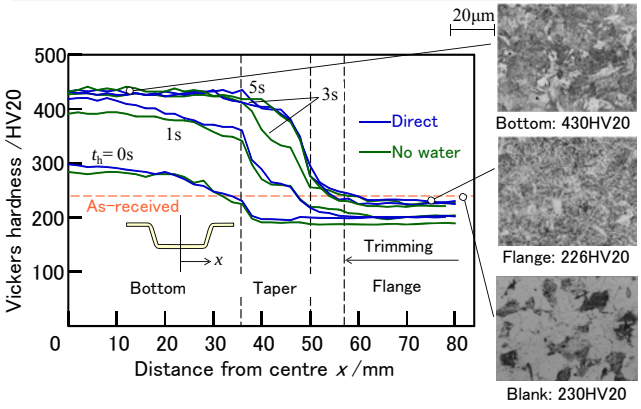
Direct water quenching in hot stamping



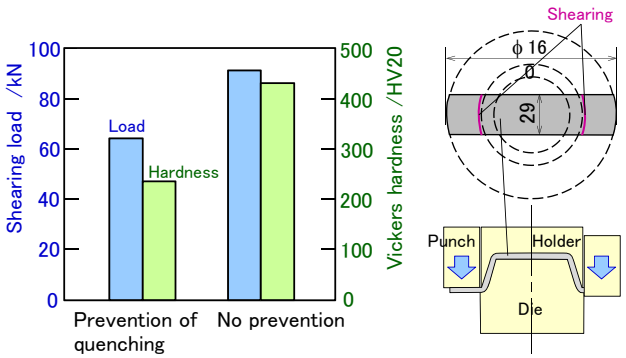
Direct water quenching in hot stamping



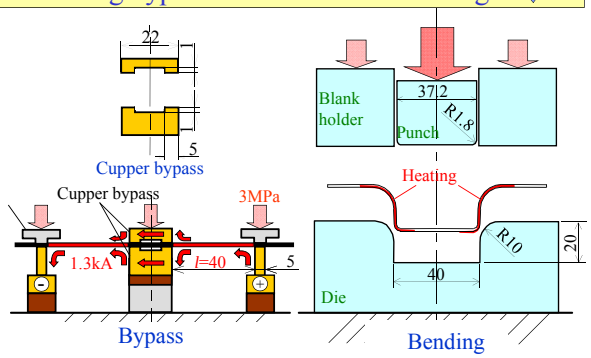
Effect of direct water quenching on Vickers hardness



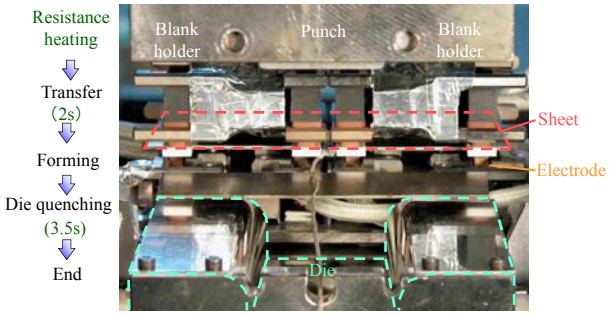
Effect of prevention of die quenching on shearing load



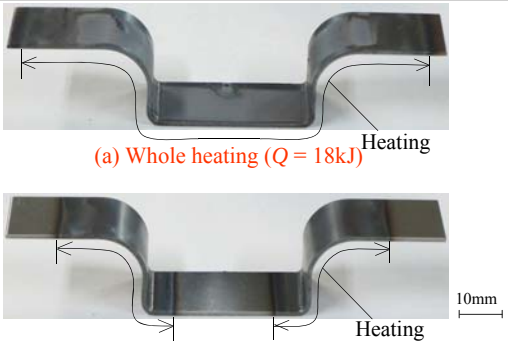
Hat-shaped bending using bypass local resistance heating



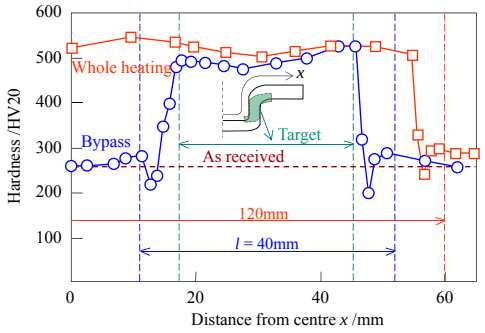
Hat-shaped bendng



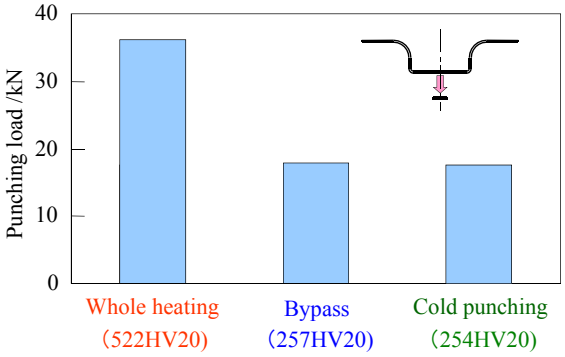
Hat-shaped bent sheets by whole heating and local heating



Hardness distribution in longitudinal direction



Punching load at bottom centre



Hot Stamping of Ultra-High Strength Steel Parts

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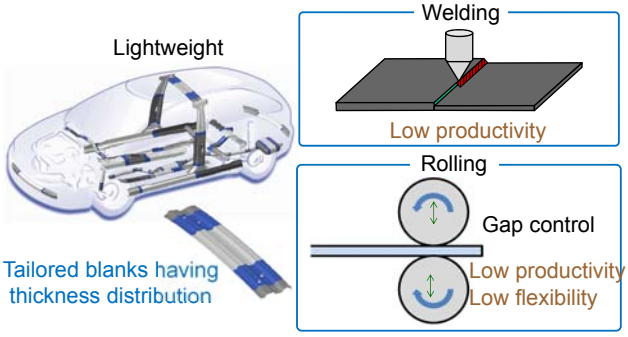
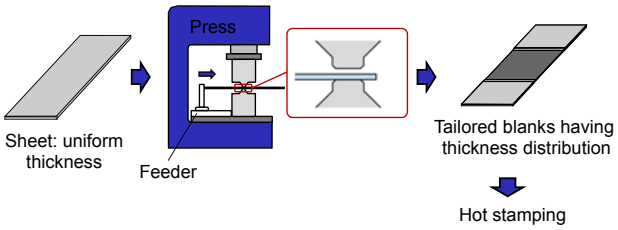
Successive forging of tailored blanks having thickness distribution for hot stamping

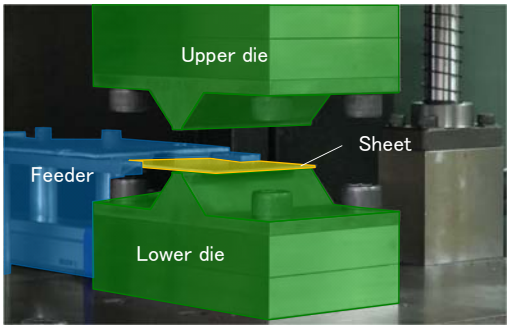


Successive forging of tailored blanks

Increase in production flexibility
Production by forming companies

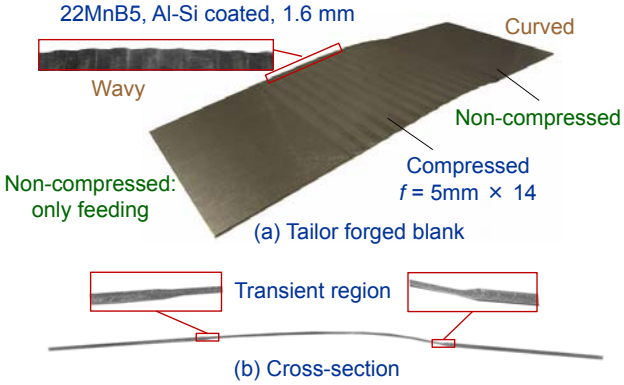


Successive forging of tailored blanks

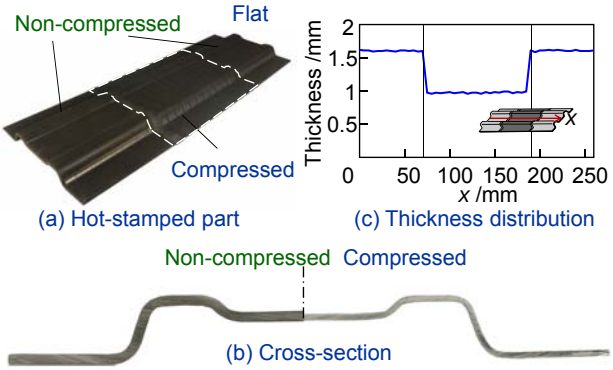


Successive forging of tailored blanks

Tailored blank having two thicknesses produced by successive forging



Roof rail produced by hot stamping



Advices for reachers

1. Generate ideas.
2. Change situation.
3. Write English journal papers.

Citation of papers in scientific databa

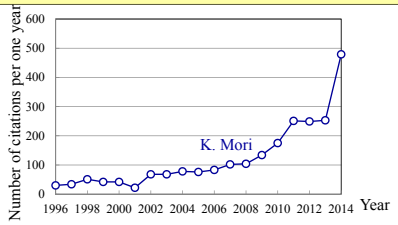
Scientific paper database: Web of Science, Scopus, Google Scholar, Science Direct

Citations: number cited in references of other papers

Impact factor: number of citations for journal, evaluation of journal and not individual papers

Papers of Mori cited in Scopus

Variation in number of citations in Scopu



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Joining by plastic deformation: "58", Abe, Y., Kato, T., Mori, K., Joinability of aluminium alloy and mild steel sheets by self piercing rivet, Journal of Materials Processing Technology, (2006), "41", Abe, Y., Kato, T., Mori, K., Self-piercing riveting of high tensile strength steel and aluminium alloy sheets using conventional rivet and die, Journal of Materials Processing, (2009)

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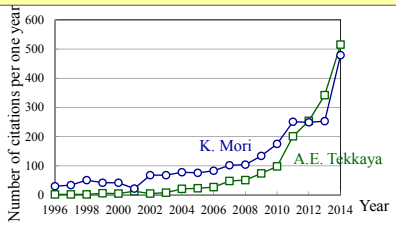

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Thank you very much