Stamping of High Strength Steel Sheets

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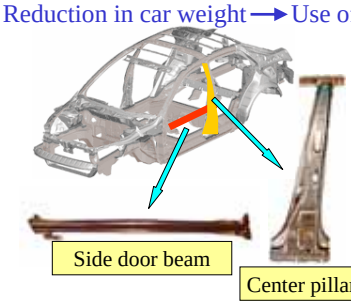
Reduction in car weight → Use of high strength steel sheets



Ultra high strength steel sheet > 1GPa

1) Ultra high strength steel sheets
2) Reduction in springback using servo press
3) Improvement of formability in stretch flanging
4) Resistance heating
5) Warm and hot stamping
6) Warm and hot spline forming
7) Prevention of oxidation in hot stamping using oxidation preventive oil
8) Warm and hot shearing
9) Self pierce riveting of ultra high strength steel and aluminium alloy sheets

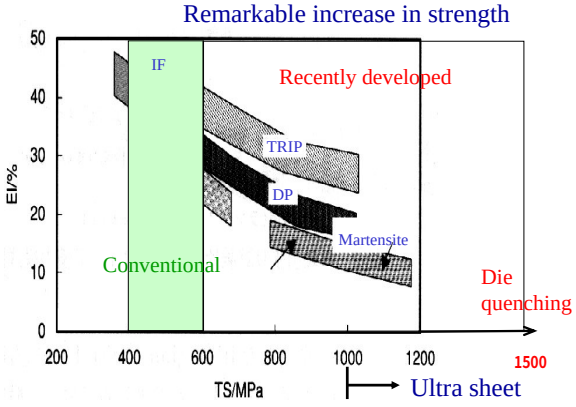
Specific strength for various sheet metals

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

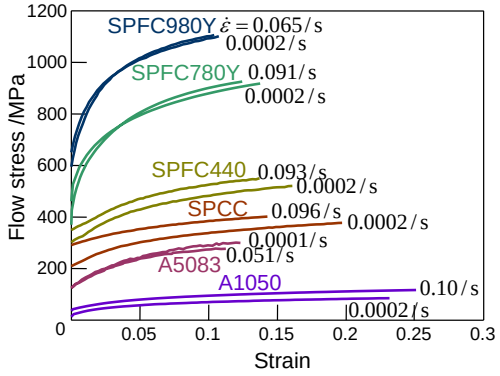
Cheaper and higher strength

Strength of high strength steel sheets

Remarkable increase in strength



Flow stress curve of sheets at room temperature



How are the sheets formed?

High strength steel sheets

High strength: large forming load, large springback, small tool life

Low formability: fracture

1) Cold stamping: no heating
2) Warm and hot stamping: heating

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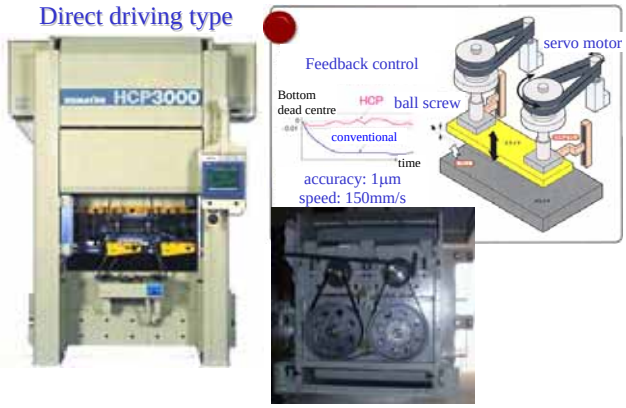
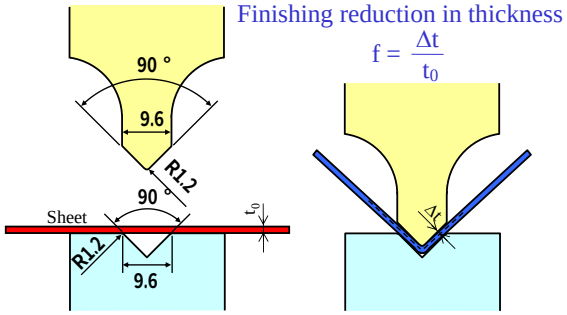
CNC Servo Press

Direct driving type



Reduction in springback in V-shaped bending



Finishing reduction in thickness

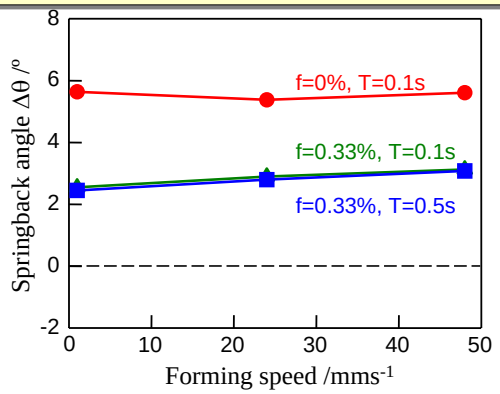
$$f = \frac{\Delta t}{t_0}$$

Deformation behaviour in V-shaped bending

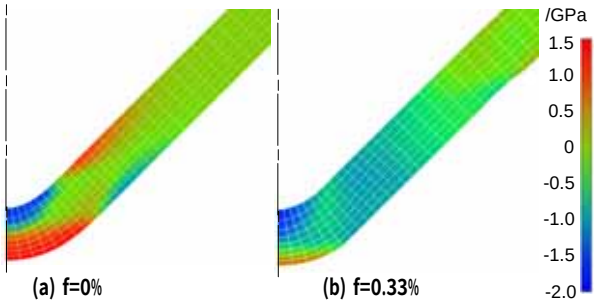
(a) SPCC (b) SPFC980Y

v=24mm/s, f=0%, T=0.5s
3 times slower

Effects of finishing reduction in thickness and holding time at bottom dead centre for SPFC980Y



Distribution of stress in width direction just after unloading for finishing reduction in thickness



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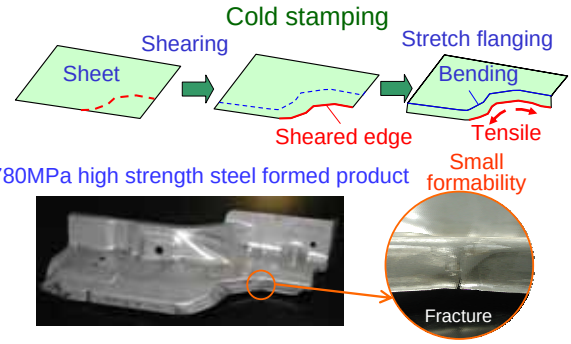
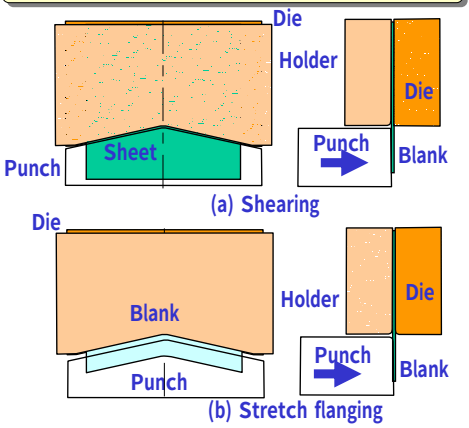
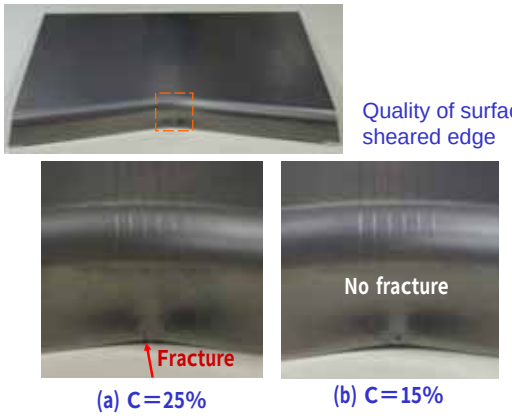
Fracture in stretch flanging of high strength steel sheets



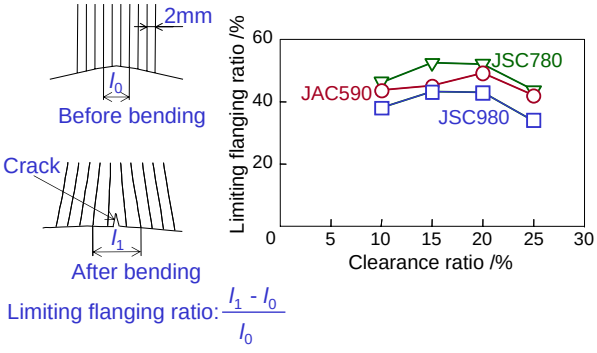
Shearing and stretch flanging



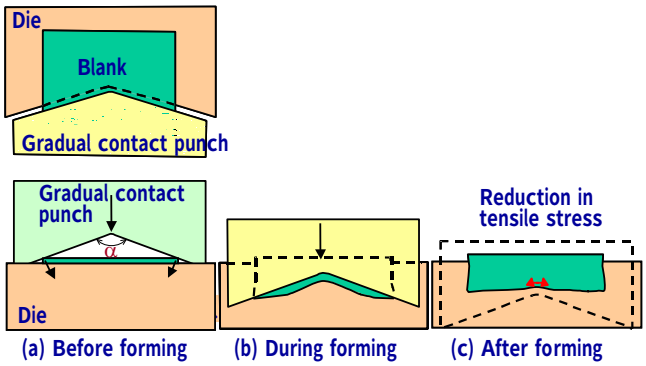
Effect of clearance in shearing of 780MPa sheet



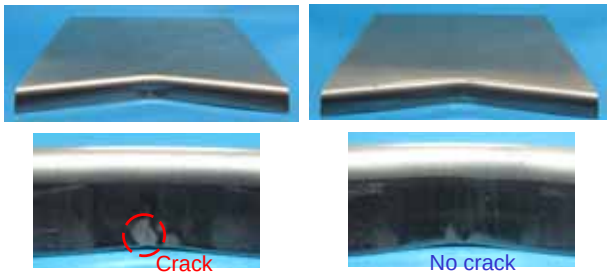
Relationship between limiting flanging ratio and clearance ratio



Reduction in tensile stress at corner using gradual contact punch



Prediction of fracture at corner of 980MPa sheet using gradual contact punch



(a) Flat punch, α=180º

(b) Gradual contact punch, α=170º

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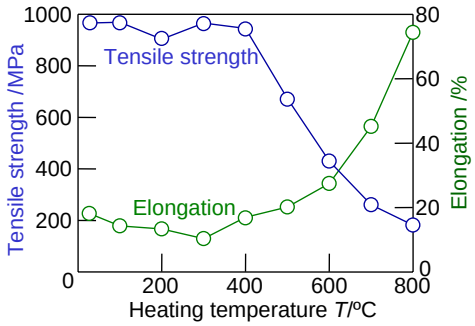
Variations in tensile strength and elongation with temperature for SPFC980Y

Thickness 1.2mm, strain-rate 0.4/s



Forming of ultra high strength steel sheets

Large load, large springback, small formability

Warm and hot stamping

Reduction in forming load

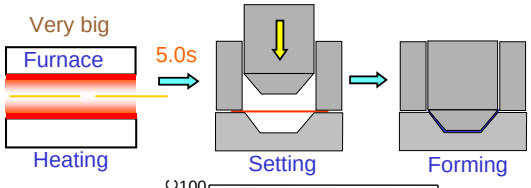
Increase in formability

Heating of sheet ?

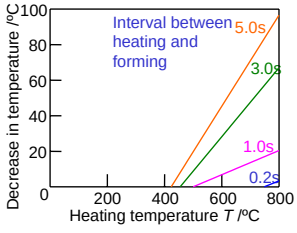
Al, Mg, stainless steel: low temperature

Steel: high temperature(>500ºC)

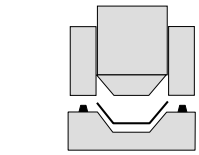
Conventional warm and hot stamping



- Decrease in temperature
- Oxidation



Warm and hot stamping using rapid resistance heating



Resistance heating and forming

Direct heating into dies

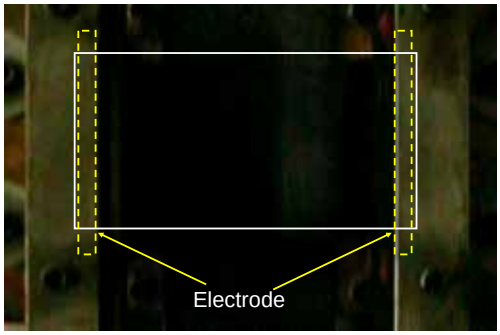
Joule heat

Prevention of drop in temperature

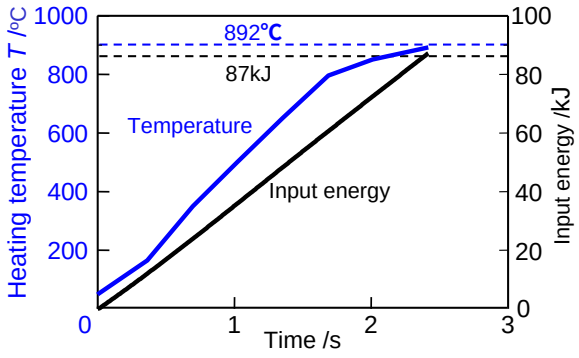
Reduction in oxidation

Resistance heating

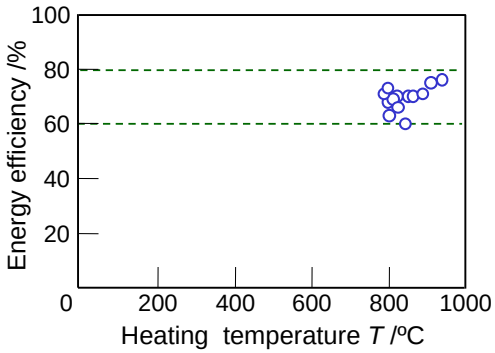
SPFC980, thickness: 1.2mm, Power: 85kJ (10V, 2sec)



Variations in temperature and input energy in resistance heating of SPFC980



Energy efficiency of resistance heating



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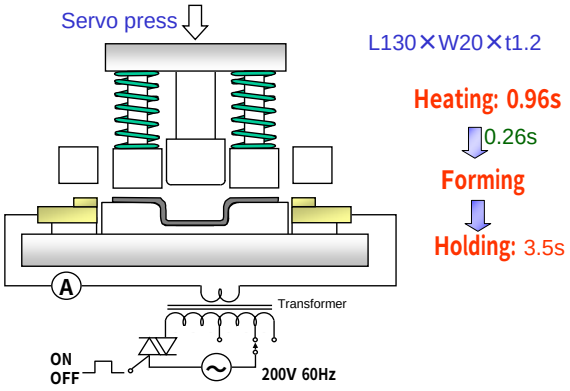
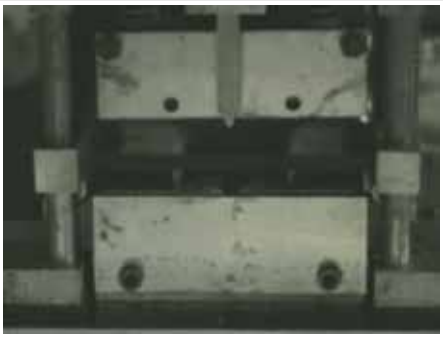
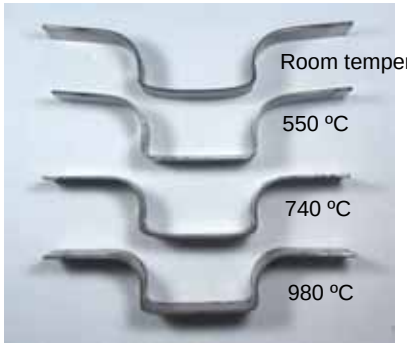
Hat-shaped bending using resistance heating



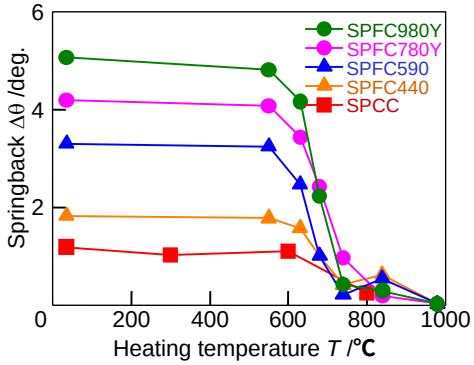
Hat-shaped bending using resistance heating at 980 °C



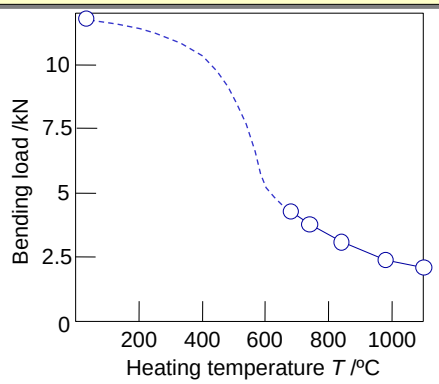
Products formed by hat-shaped bending of SPFC980Y at different heating temperatures



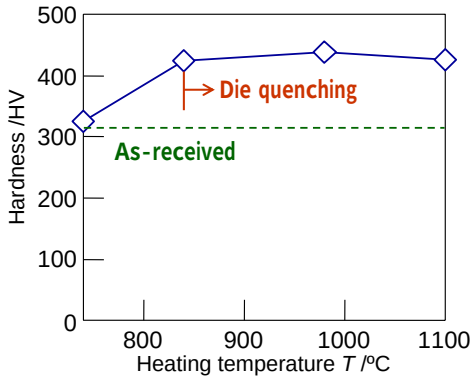
Relationships between springback and heating temperature in hat-shaped bending of various sheets



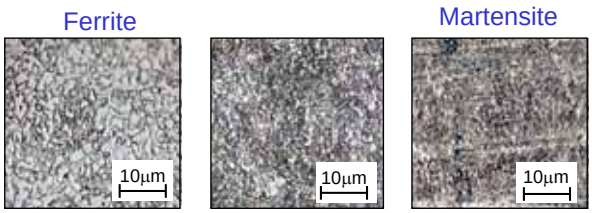
Relationship between bending load and heating temperature



Relationship between hardness of bent sheets and heating temperature



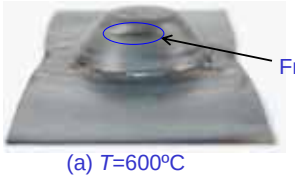
Microstructures in bottom of bent sheets



(a) *T*=740ºC (b) *T*=840ºC (c) *T*=980ºC

Deep drawing of SPFC980Y rectangular sheet for 800ºC

Formed products in deep drawing of SPFC980Y rectangular sheet



(a) *T*=600ºC

(b) *T*=800ºC

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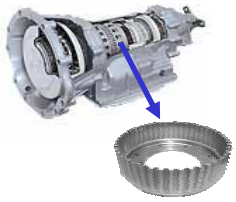
Spline forming of clutch drum



Clutch drum

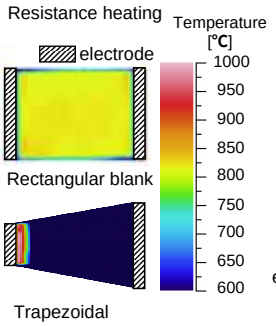
High strength steel

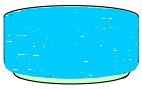
Plate forging

Cup → Drum

Spline forming

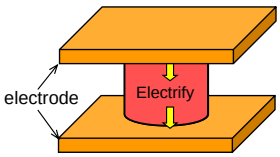
Uniform resistance heating of cup



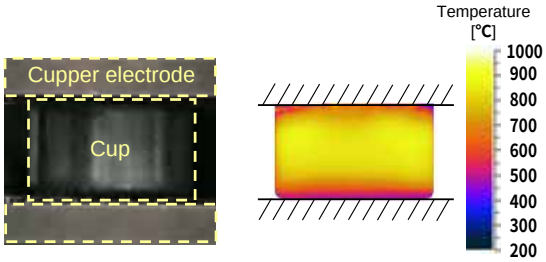


Cup

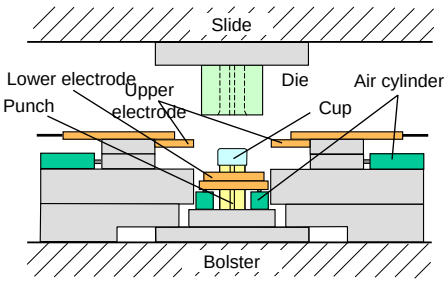
Side wall: uniform cross-section



Resistance heating of cup



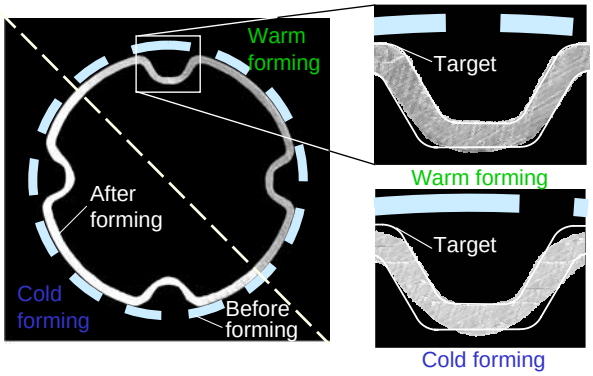
Spline forming of clutch drum



Spline-formed drum

(a) Before forming (b) After forming

Cross section of spline-formed drum



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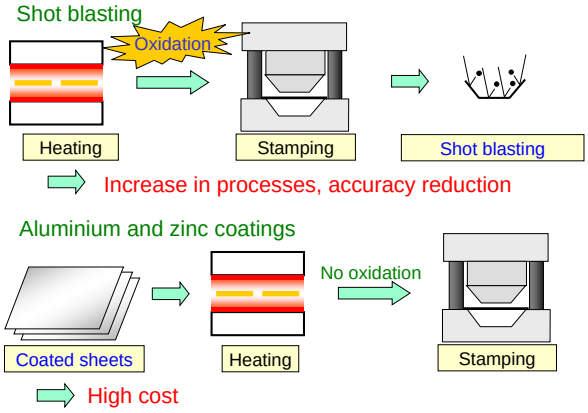
Conventional prevention of oxidation



Oxidation preventive oils used for hot stamping

Target: 900ºC, 10s

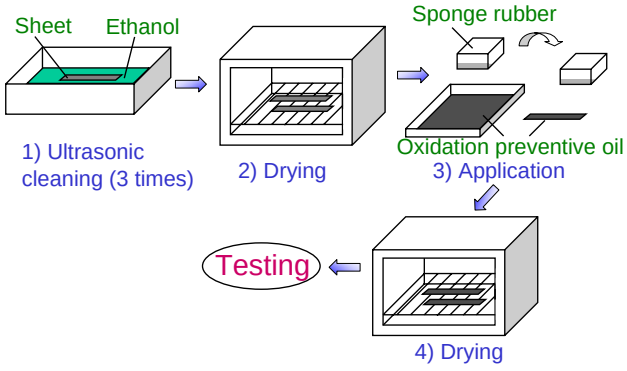
Quenchable steel sheet for hot stamping

C	Si	Mn	P	B
0.21	0.25	1.2	0.015	0.0014

Oxidation preventive oils

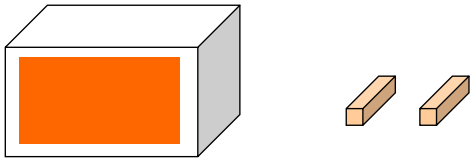
Oil	A	B
Lubricant	Stainless steel warm stamping	Titanium warm stamping
Element	K,B,C,Na	K,B,C,Na,P,Ca
Oxidation prevention	Liquefied film	Liquefied film

Coating of sheets with oxidation preventive oil



Evaluation test of oils under natural cooling

Heating temperature：800, 825, 850, 875, 900, 925ºC
Dimension: L130mm, W20mm, t1.2mm



Heating ⇨ Cooling by air

Evaluation test of oils under natural cooling

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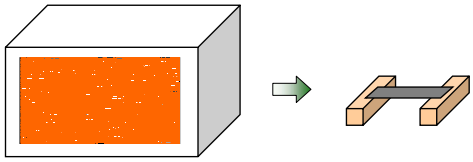
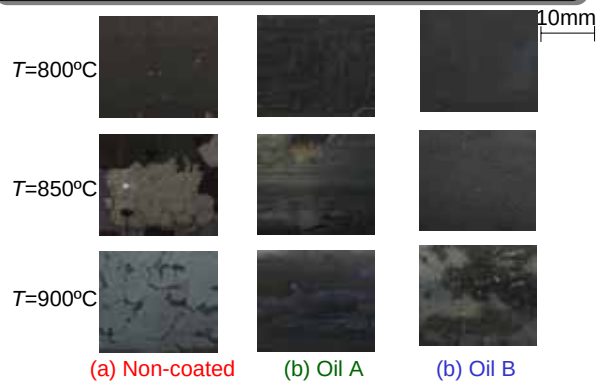
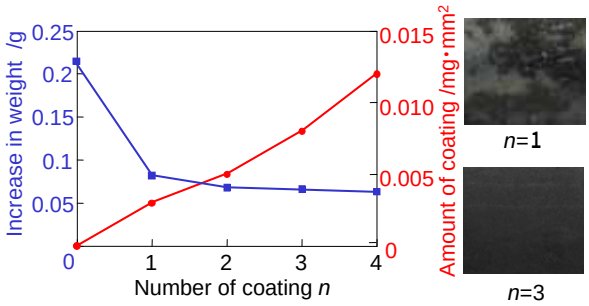


Heating ⇨ Cooling by air

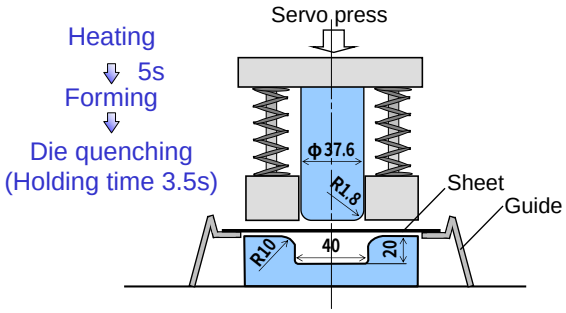
Oxidation on surface of heated sheet for different coatings



Improvement of oxidation prevention by repeating of coating (T=900ºC)

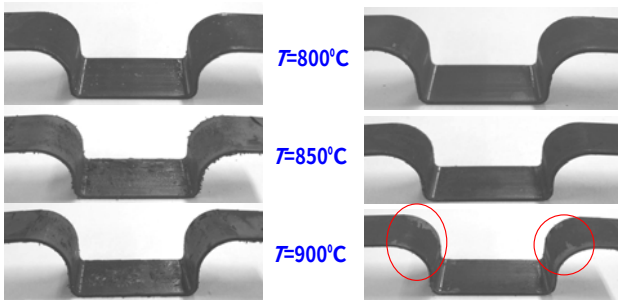


Hat-shaped bending for evaluating oxidation preventive oil



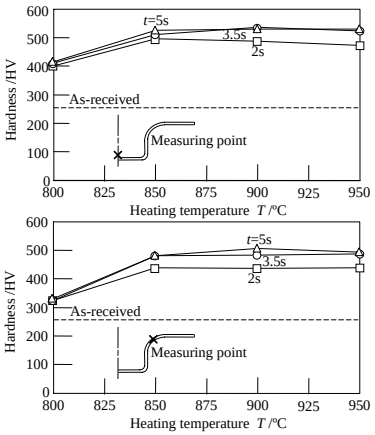
Hat-shaped bending of quenchable steel sheet

Hat-shaped bent sheets

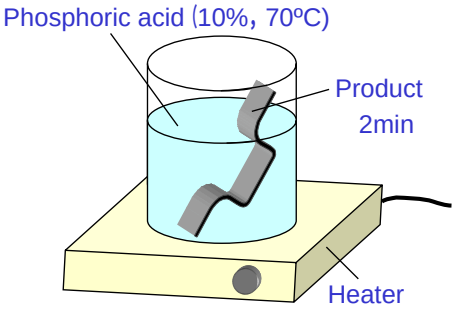


(a) n=1 (b) n=3

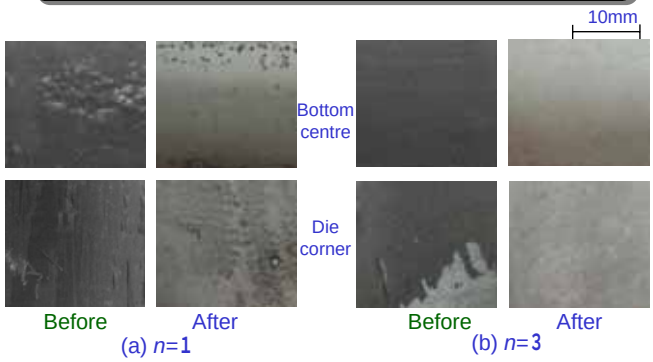
Hardness of bent sheets



Cleaning of layer remaining on surface of formed product by phosphoric acid



Scale on surface of sheet bent at T=900ºC and before and after cleaning



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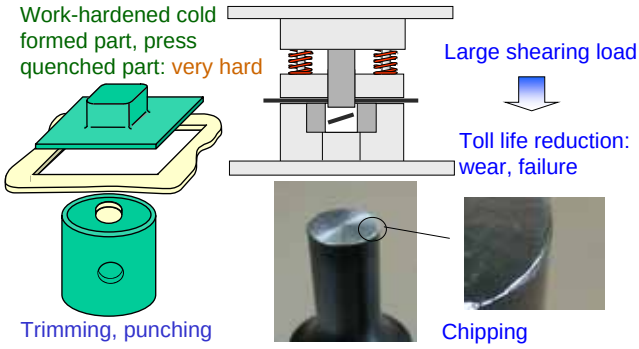
9) Self pierce riveting of ultra high strength steel and aluminium alloy sheets

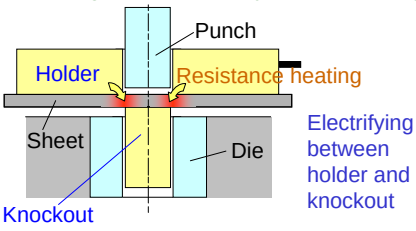
Shearing of ultra high strength steel sheet



Laser cutting: low productivity and high cost

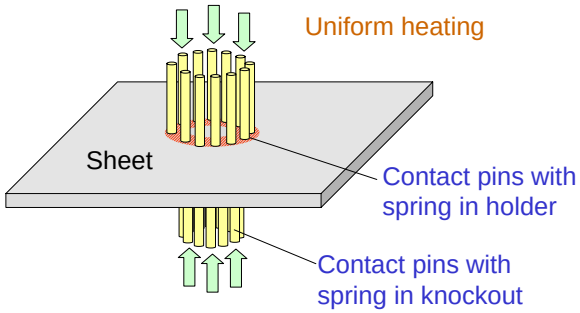
Warm and hot shearing using local resistance heating near shearing region

Whole heating: low efficiency and accuracy

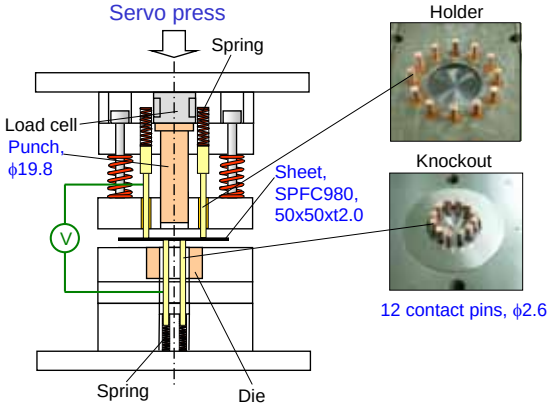


1) High heating efficiency
2) Compact apparatus
3) Small oxidation

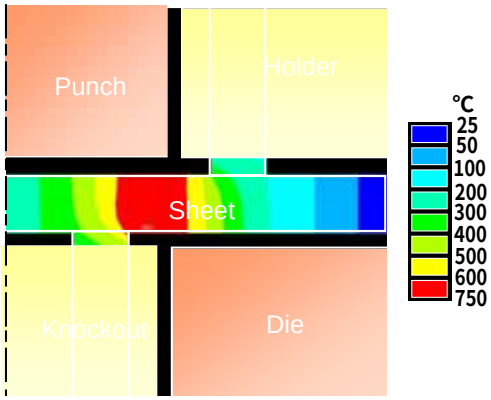
Contact pin electrodes used for local heating



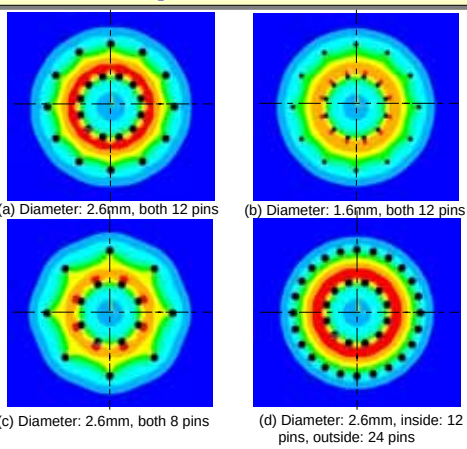
Local heating using contact pins



FEM simulation of temperature distribution in local heating



FEM simulation of temperature distribution in local heating



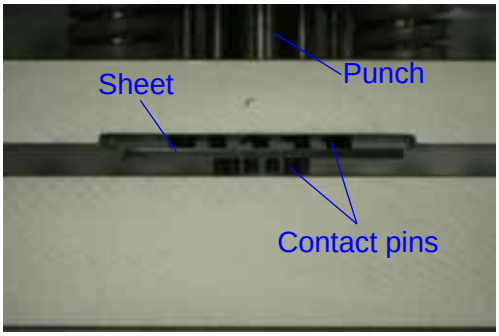
(a) Diameter: 2.6mm, both 12 pins

(b) Diameter: 1.6mm, both 12 pins

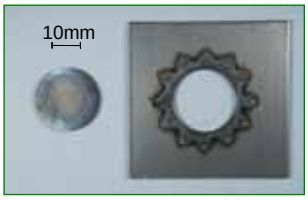
(c) Diameter: 2.6mm, both 8 pins

(d) Diameter: 2.6mm, inside: 12 pins, outside: 24 pins

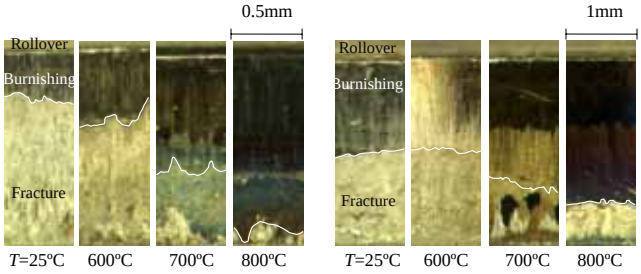
Local heating using contact pins for T=800 ºC



Punched sheet for local heating



Surface of punched edge for local heating

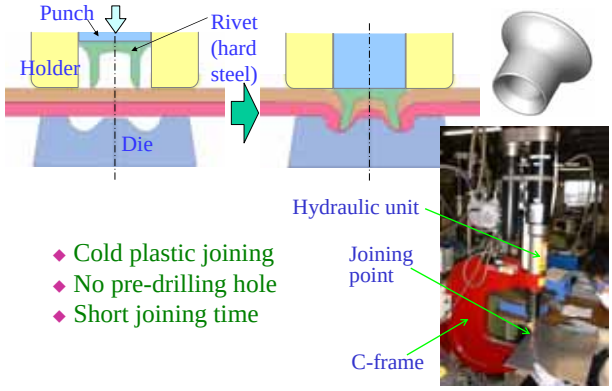


SPFC980, t=1.4mm

SPFC440, t=2.6mm

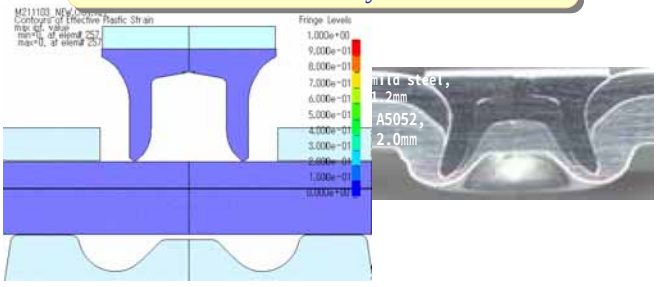
1) Ultra high strength steel sheets
2) Reduction in springback using servo press
3) Improvement of formability in stretch flanging
4) Resistance heating
5) Warm and hot stamping
6) Warm and hot spline forming
7) Prevention of oxidation in hot stamping using oxidation preventive oil
8) Warm and hot shearing
9) Self pierce riveting of ultra high strength steel and aluminium alloy sheets

Self pierce riveting of sheets



- Cold plastic joining
- No pre-drilling hole
- Short joining time

Self pierce riveting of mild steel and aluminium alloy sheets

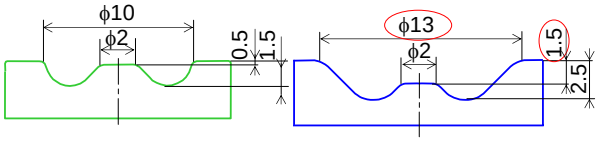


Requisites for joining

- Driving though upper sheet
- Spreading in lower sheet

Optimised die for joining of ultra high strength steel and aluminium alloy sheets obtained from inite element simulation

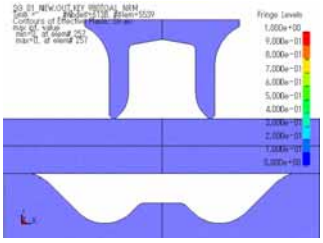
Diameter of cavity, depth of projection



(a) Conventional die

(b) Optimised die

Finite element simulation of self piercing riveting of ultra high strength steel and aluminium alloy sheets



Upper: SPFC980, 1.4mm
Lower: A5052-H34, 1.5mm

Self pierce riveting of ultra high strength steel and aluminium alloy sheet using optimised die

Conventional die → Optimised die

Cold stamping
Reduction in springback using servo press
Improvement of formability in stretch flanging
Self pierce riveting of high strength steel and aluminium alloy sheets

Warm and hot stamping
Warm and hot stamping
Warm and hot spline forming
Prevention of oxidation in hot stamping using oxidation preventive oil
Warm and hot shearing