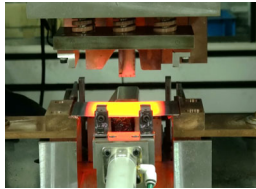


Hot stamping using resistance heating of quenchable steel sheet and tube

Tomoyoshi MAENO
YOKOHAMA National University
(JAPAN)



King Mongkut's University of Technology Thonburi - KMUTT
Department of Tool and Materials Engineering
28th May 2026



Yokohama Minatomirai (Port area)

Founded in 1874
5 Colleges: 7,500 Undergraduate Students
6 Graduate Schools: 2,500 Graduate Students

International Students: 800
Full-time Faculty: 600



Metal Forming Laboratory



Academic STAFF
Dr Maeno
Dr Fujikawa (Nissan)

Students
Master 7 people
Bachelor 4 people

Research Facilities



800 kN
Servo Press



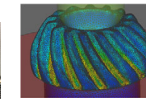
300 kN 2-axis
Servo Hydraulic
Press



Power Supply
Max. 10kA



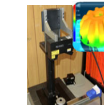
Heating
Furnace



FEM Software
SIMUFACT



Two-color
Thermography



Line Laser
3D Scanner



Surface
Roughness Meter



Planar Bending
Fatigue Tester



250kN
Universal Testing
machine



Two-color
Radiothermic
Thermometer



Lapping
Machine



SEM



Digital
Microscope

- Contact Heating Device
- Oil Bath
- Projection Shape Measuring Machine
- 1Mhz Data Loggers
- Noise-resistant Data Loggers
- Noise-resistant Dynamic Strain Meter
- Machine Tools (boring machine, Lathes, Etc.)
- Precision Cutting Machine
- Various Load Cells
- Non-contact Conductivity Meter

Hot stamping using resistance heating of quenchable steel sheet and tube

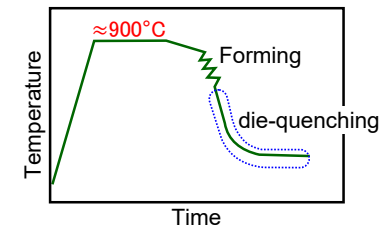
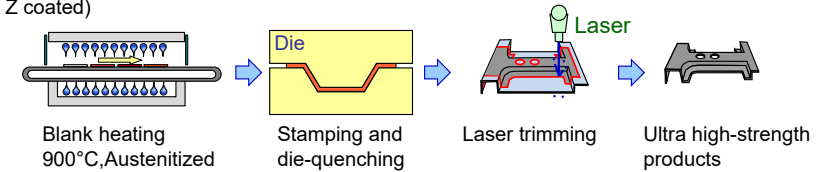
Hot stamping of quenchable steel sheet

- Outline of direct resistance heating in hot stamping
- Full hardening under rapid heating
- Heating of non-rectangle blank
- Tailor tempering by ceramic tip
- Hot stamping with hot blanking process
- Hot stamping and gas forming of quenchable steel tube
- Miscellaneous technique in resistance heating

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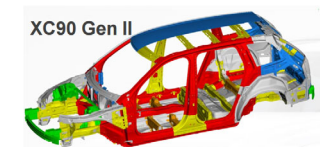
Hot stamping of quenchable steel sheet

22MnB5 quenchable steel sheet
(Bare, Al-Si and Z coated)



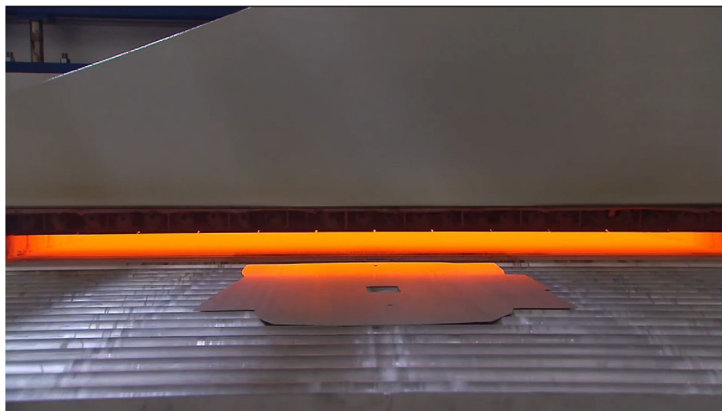
Advantages

- Tensile strength: 1.5~1.8GPa
- No-springback
- Large elongation



Red: hot-stamped panels

Hot stamping of quenchable steel sheet



Volkswagen Production - Press Shop , AP&T Group YouTube channel

Problems in hot stamping

Huge furnace



20~40 m

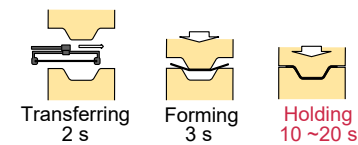
Oxidation



Al-Si coating
Zn coating

Heating time increased

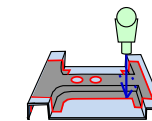
Low productivity



Hot stamping: 2~3 spm
Cold stamping: 6~16 spm

Trimming

Laser trimming and hole making $\Rightarrow$ high cost
Shearing $\Rightarrow$ tool life, delayed fracture



High cost

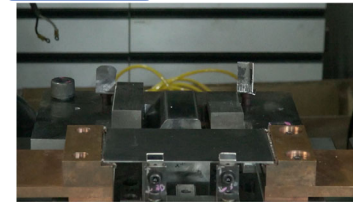
Hot stamping using resistance heating of quenchable steel sheet and tube

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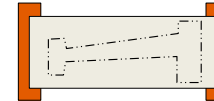
Advantages of direct resistance heating in hot stamping

Rapid heating



Small hot stamping line

Products size + Power source <20 m²



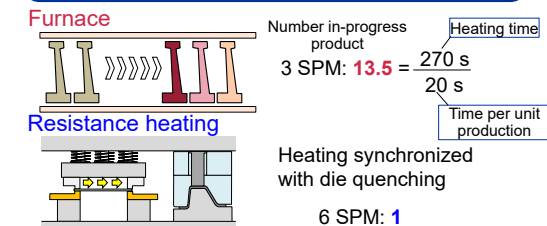
Resistance heating

100-200 m²



Furnace

High productivity with small in-progress product



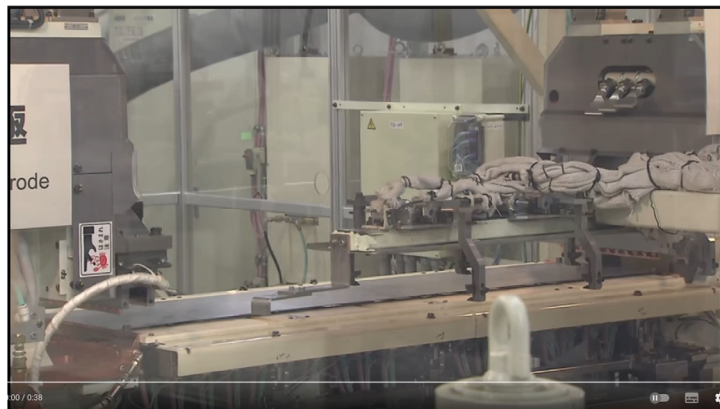
Flexible control of production

Furnace: heating and cooling time are a few days

24/7 running

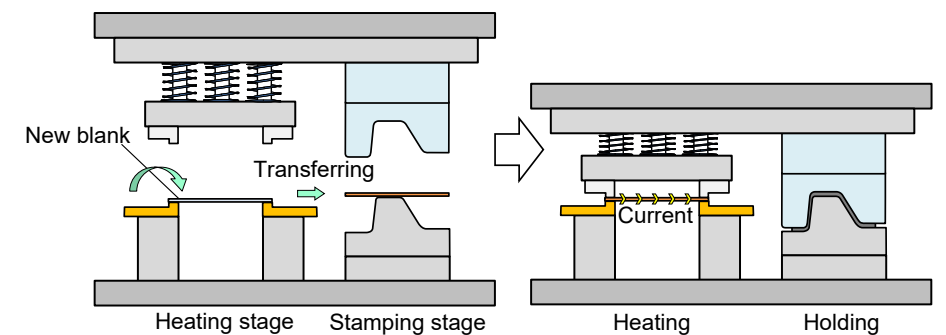
Resistance heating: No start-up and shut-down time

Hot stamping using resistance heating in Toyota Motor



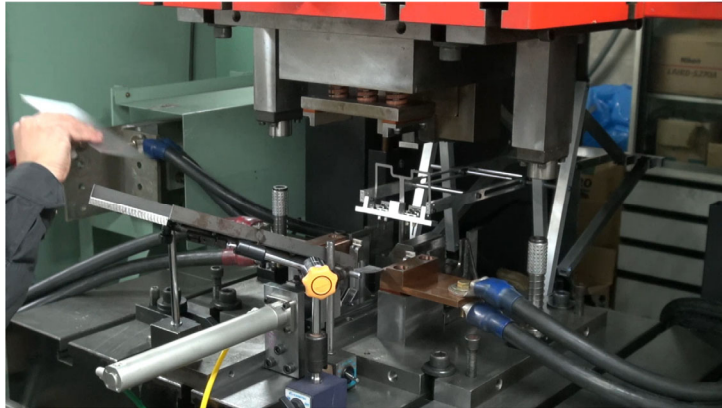
Hot stamping, TOYOTA MOTOR CORPORATION YouTube channel

Synchronization of heating and die quenching



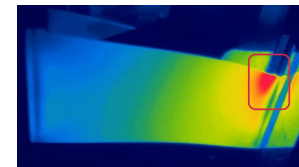
(1) Transferring and feeding of blanks → (2) Heating and stamping + die quenching

Video of synchronized hot stamping of heating and die quenching



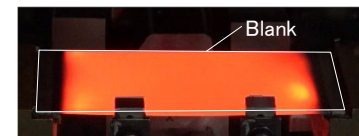
Limitation of direct resistance heating in hot stamping

Limited blank shape



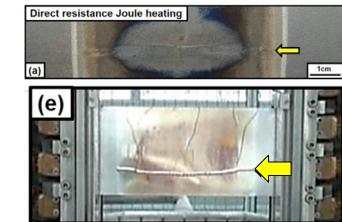
Trapezium

Non heated edge



Blank

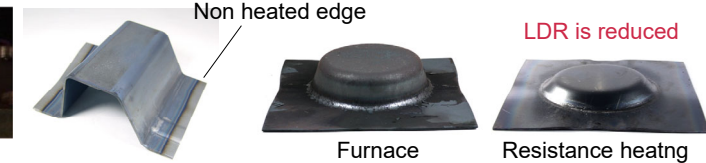
Melting of aluminum coating of sheet



Lee, C.W. et al., *Metall Mater Trans A* 47, 2875–2884 (2016).

Molten aluminum

Non heated edge



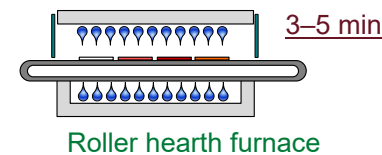
Furnace

Resistance heating

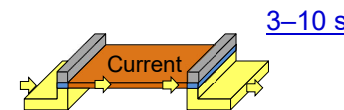
Hot stamping using resistance heating of quenchable steel sheet and tube

- Hot stamping of quenchable steel sheet
- Outline of direct resistance heating in hot stamping
- **Full hardening under rapid heating**
- Heating of non-rectangle blank
- Tailor tempering by ceramic tip
- Hot stamping with hot blanking process
- Hot stamping and gas forming of quenchable steel tube
- Miscellaneous technique in resistance heating

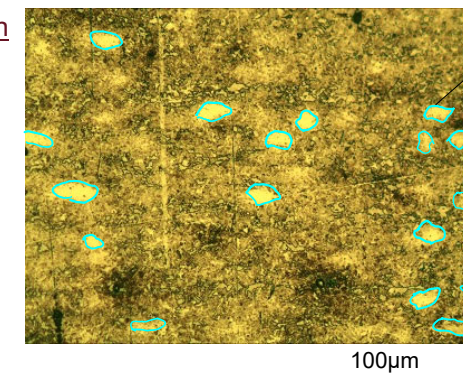
Insufficient austenitisation in rapid resistance heating



Roller hearth furnace

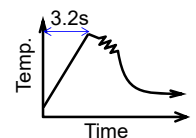


Resistance heating

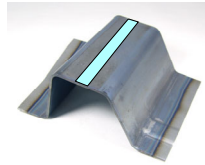
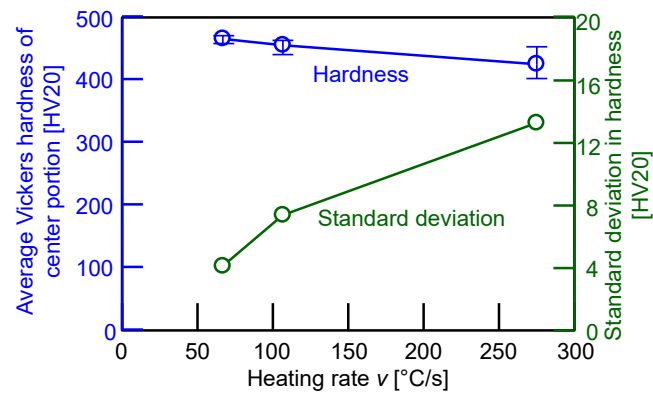


Ferrite from unaltered ferrite

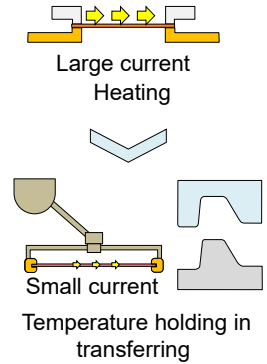
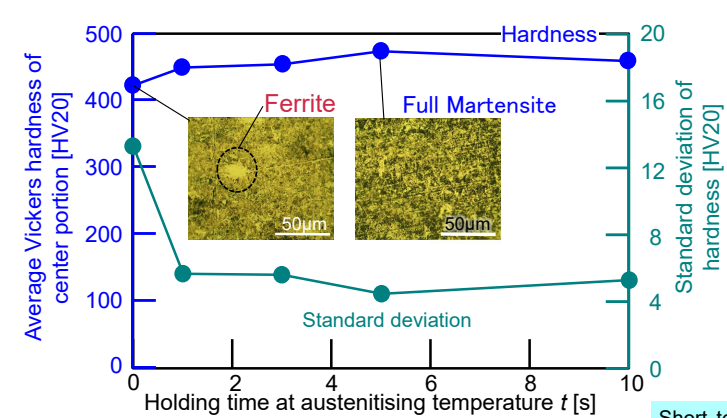
Insufficient austenitisation



Effect of heating rate on Vickers hardness and standard deviation



Effect of holding at austenitising temperature on Vickers hardness and standard deviation for $\nu = 275$ °C/s

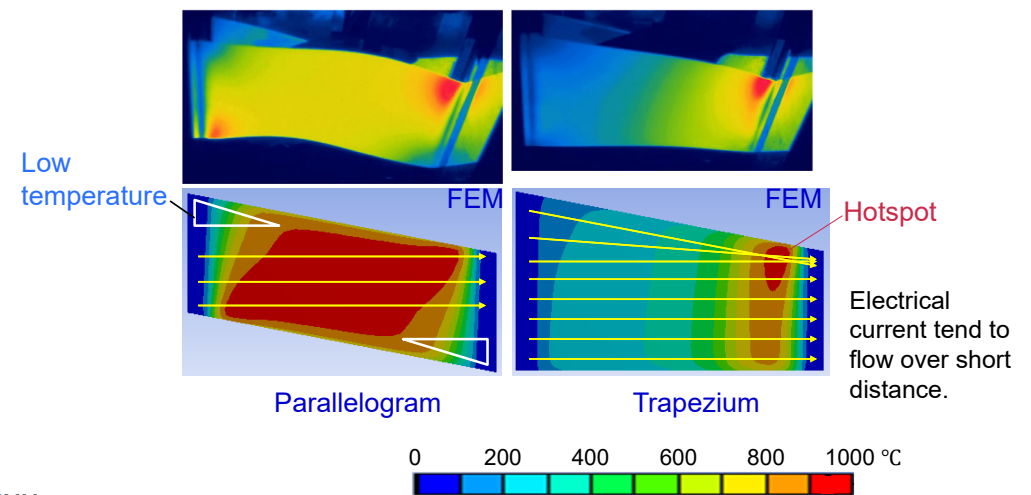


Short temperature holding remarkably improves quenchability .

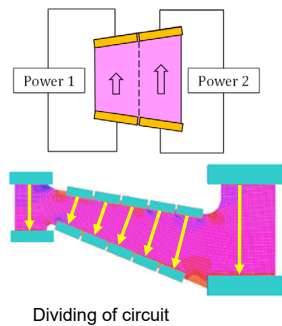
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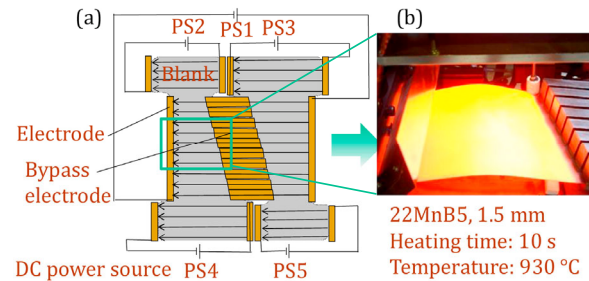
Resistance heating of non-rectangle blank



Uniform heating of non-rectangular sheet by divided circuit and bypass electrodes



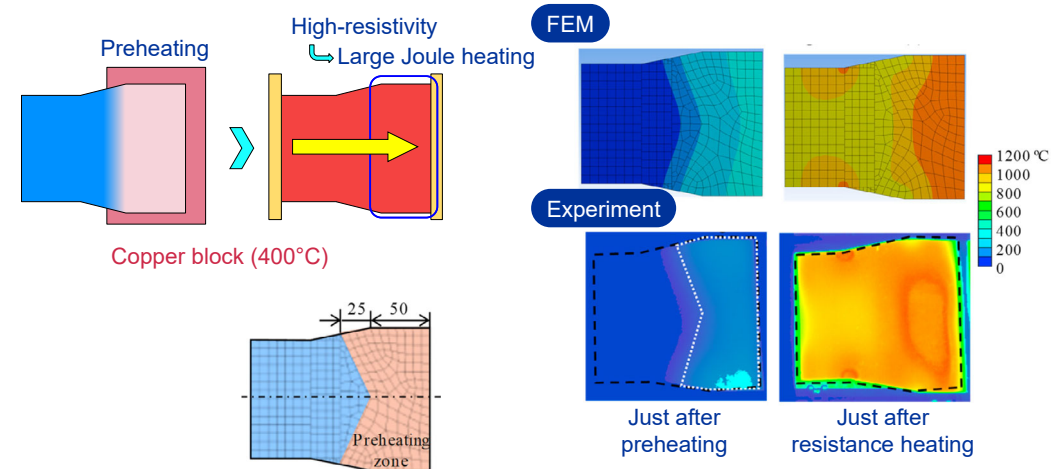
Divide the area and set an electrical circuit in each area. And the current amount of each power supply are adjusted that the current density is the same.



Separate bypass electrodes are installed in areas where the shape changes gradually. The number of circuits can be reduced.

B.A. Behrens et al. Proc. 5th Int. Conf. Accuracy in Forming Tech., Tronto (2015), pp. 157-173

Hot stamping of non-rectangular steel sheets using resistance heating by local preheating



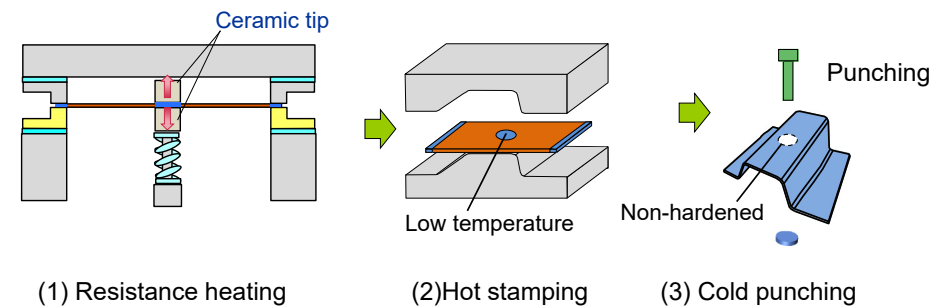
Y. Nakagawa et al., Procedia Manufacturing Volume 50, 2020, Pages 298-302

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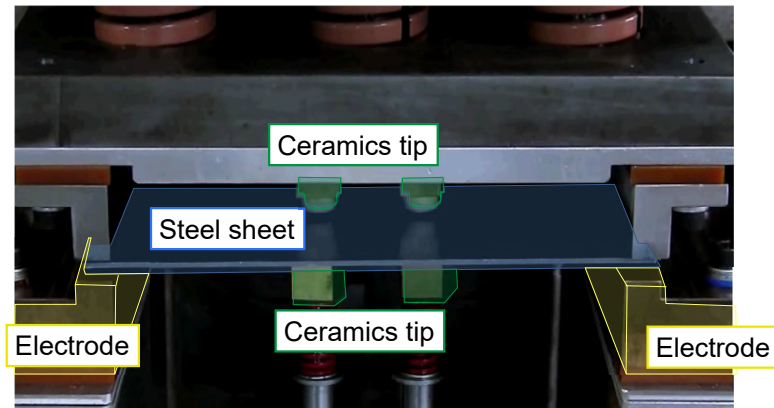
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Department of Tool and Materials Engineering
28th May 2026

Local prevention of hardening for punching of hot-stamped parts

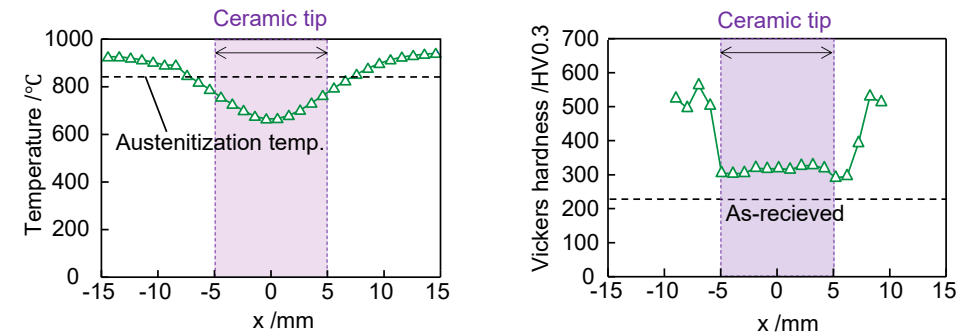


K. Mori, Key Engineering Materials, 639 (2015), 205-212.

Local cooling by contact with ceramics tool



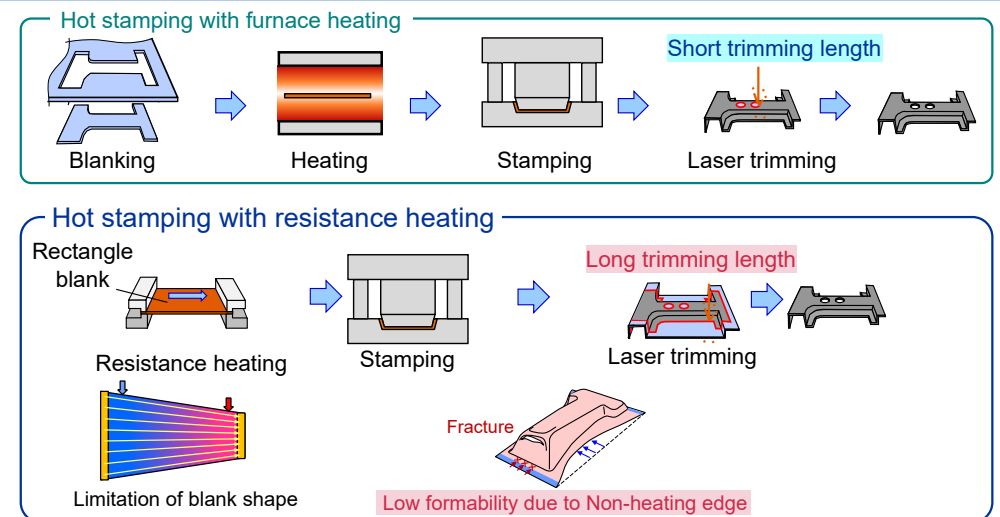
Temperature and hardness distribution of punching portion with local cooling



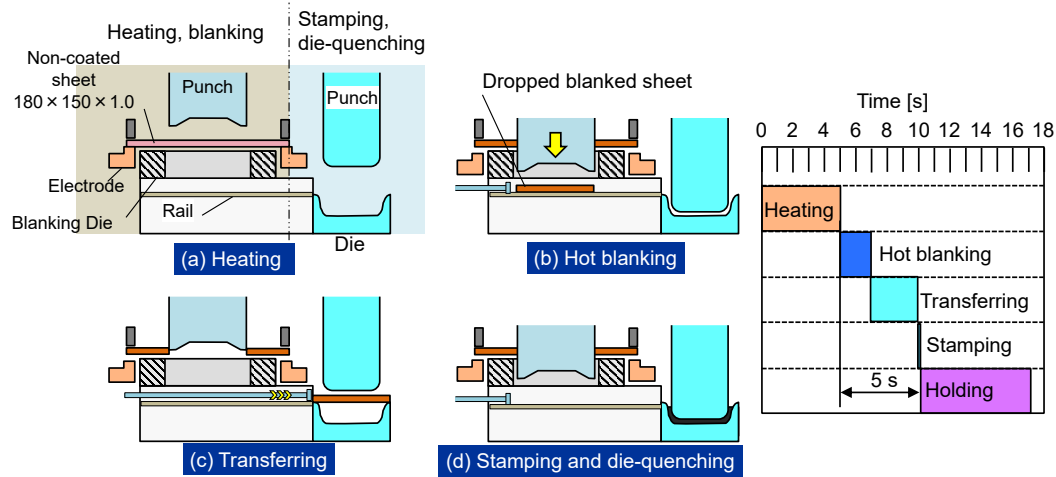
Hot stamping using resistance heating of quenchable steel sheet and tube

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Large trimming of hot stamped panel in resistance heating



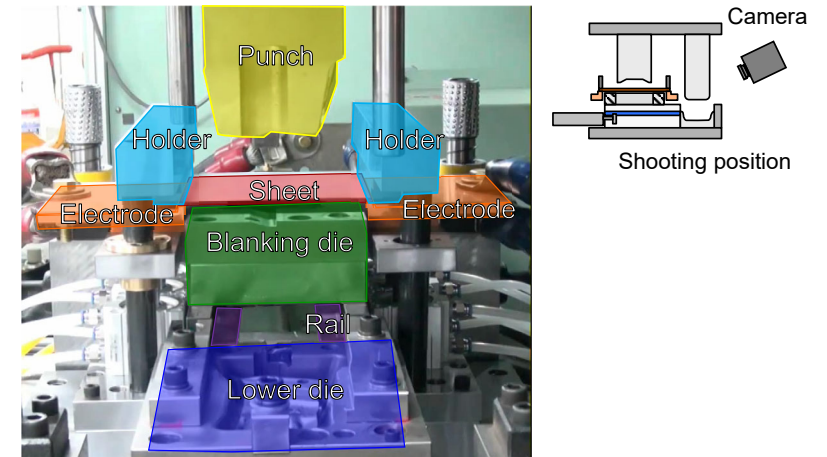
Hot stamping using blanking immediately after resistance heating



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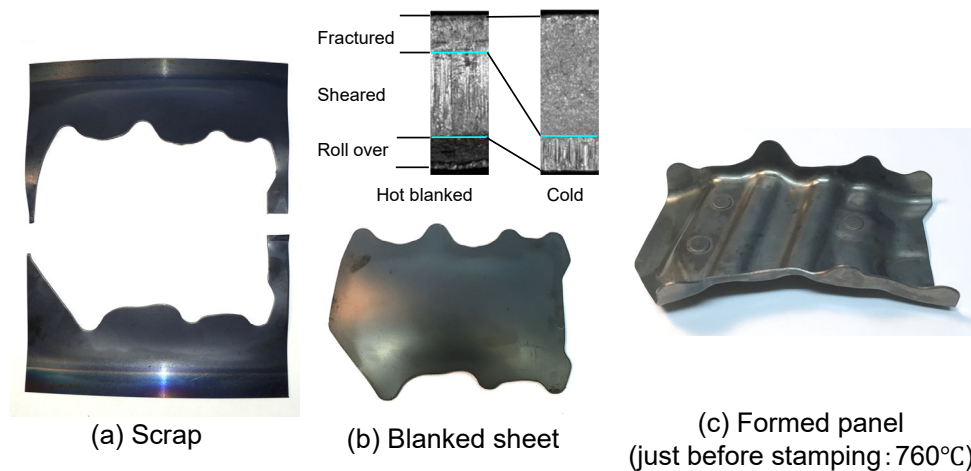
T Maeno et al., Int J Adv Manuf Technol 97(2018), 3827–3837.

Video of hot stamping of reinforcements using blanking immediately after resistance heating



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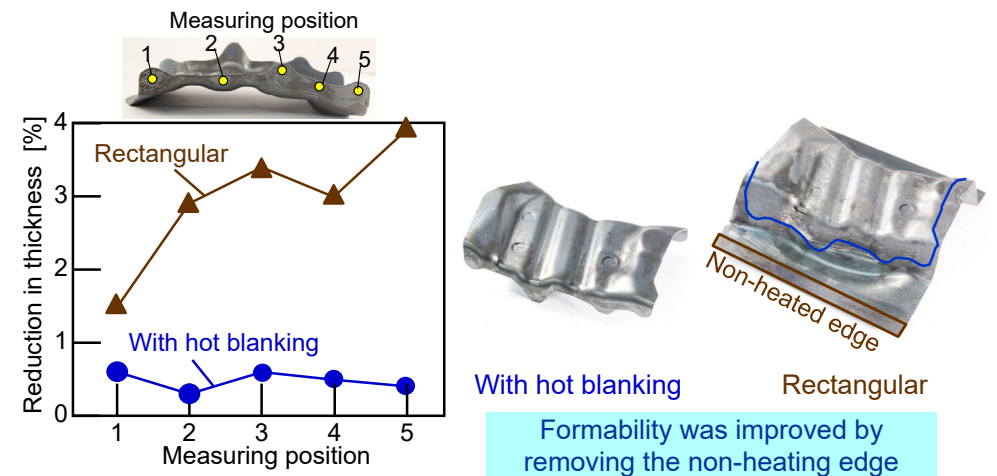
Appearance of hot stamped reinforcement parts



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T Maeno et al., Int J Adv Manuf Technol 97(2018), 3827–3837.

Reductions in thickness of flange portions of the hot-stamped reinforcements using hot-blanked and rectangular sheets



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T Maeno et al., Int J Adv Manuf Technol 97(2018), 3827–3837.

Uncoiled plate

(a) Resistance heating

(b) Blanking & punching

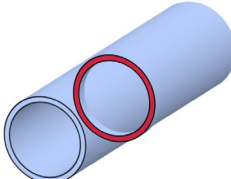
(c) Inserting

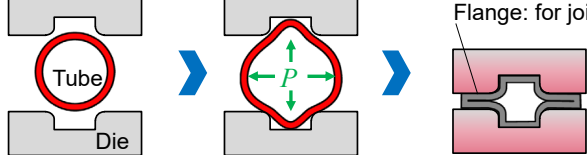
Feeding

(d) Bending & die quenching

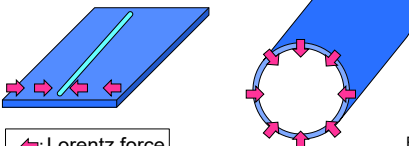


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 Tube: uniform cross section


 Resistance heating 1st Blowing (Bulging) 2nd Blowing (calibration) die closing
 Flange: for joining


 Hollow products with flange

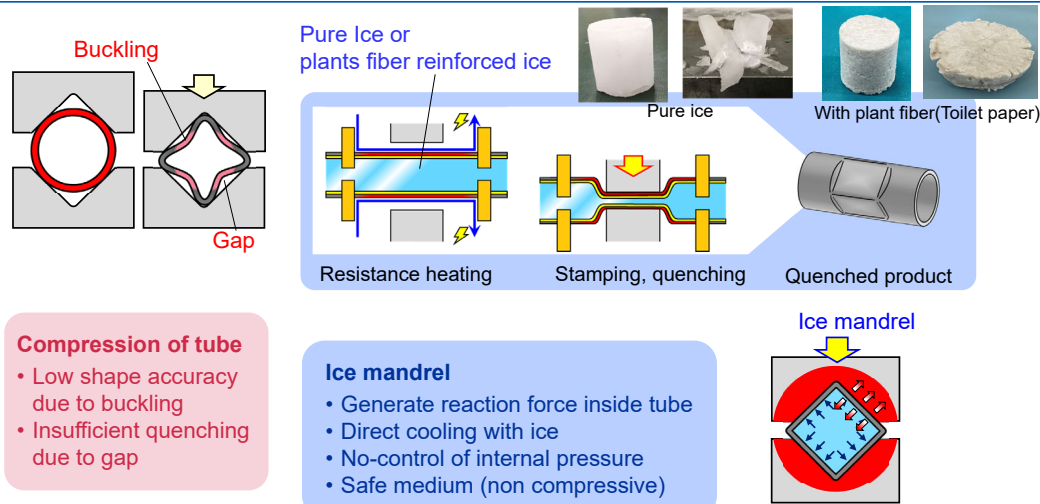

 Melted coating is not moved
 Al-Si coated steel pipe Available
 Lorentz force

R. Funada, Presented at Global Automotive

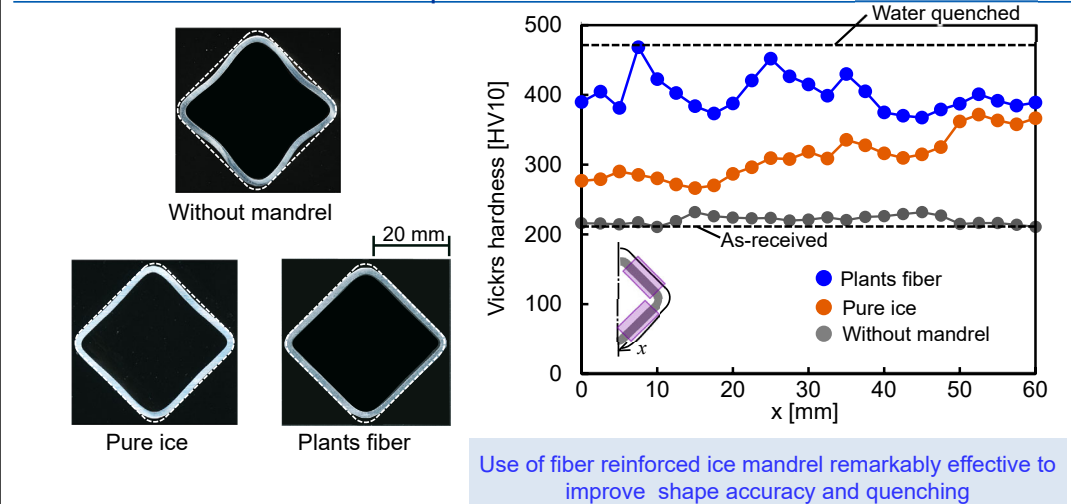
R. Funada, Presented at Global Automotive Lightweight Materials, Detroit, 2019.
K. Nogiwa, *Plastos*, 5-55(2022), 448-452

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Hot stamping of steel tube using with fiber reinforced ice mandrel



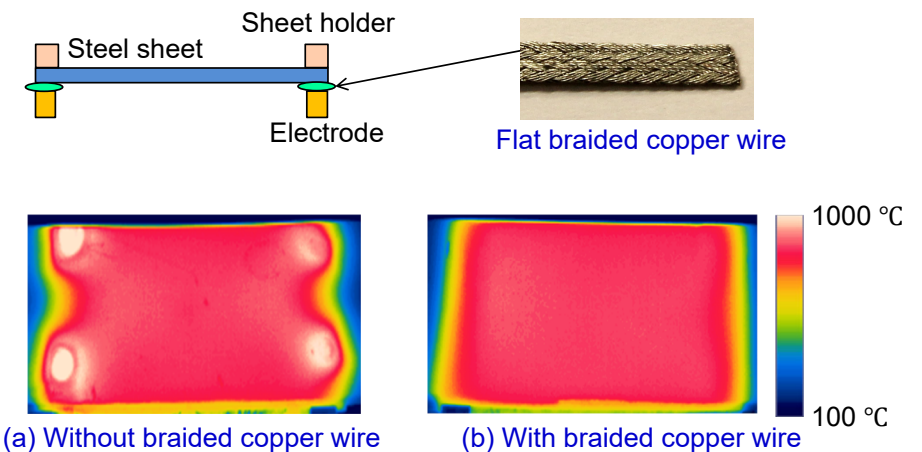
Effect of ice mandrel on cross sectional shape and quenched hardness



Hot stamping using resistance heating of quenchable steel sheet and tube

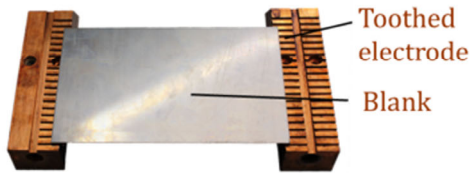
- Hot stamping of quenchable steel sheet
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Improvement of fitting of electrode with flat braided copper wire



Reduction of non- heated edge with toothed electrodes

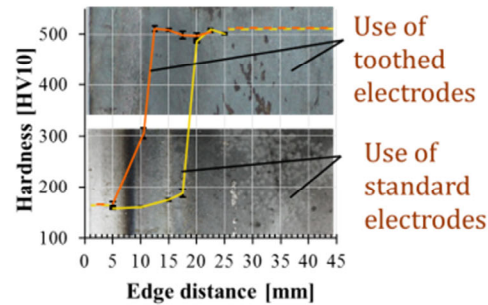
Toothed electrodes system



22MnB5
930 °C

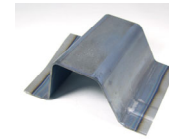
- Width of Non heated edge is reduced, and hardened area is increased.
- Material yield will be increased.

Hardness measurement



B.A. Behrens et al., Patent application, PCT/EP2015/053382.

Temperature measurement in rapid resistance heating with Two-color thermometer (Ratio thermometer, Multi-wavelength thermometer)



Small oxidation:
degree of oxidation is unstable

Emissivity changing during rapid heating

Radiation thermometers and thermography are not suitable for rapid heating.

Two-color thermometer:

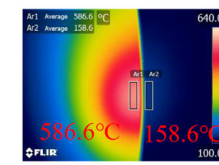
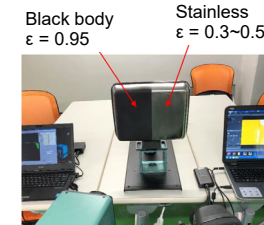
temperature is determined from the ratio of brightness at two different wavelengths, the influence of emissivity is eliminated.



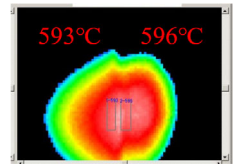
Camera 30,000-40,000 us\$



Spot pyrometer 2,500 us\$



IR thermography



Two-color thermography

YNU YOKOHAMA National University

Conclusion

- High productivity with small in-progress product
 - Less material waste in case of trouble
- Flexible control of production line
 - Suitable for medium volume production
- Combination with forming tool such as hot blanking, trimming and punching
 - Hot stamping can be applied to small parts
 - Limited production of hot stamping in the cold stamping line
- Limitation of blank shape is partially resolved
- Tube material is suitable for resistance heating due to uniform heating and coating

- Non-heated edge is unavoidable
 - Material yield becomes small
- Al-Si coating is not available
 - Removing of thin oxide layer is required

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Hot stamping using induction heating / Dai-ichi Kiden Co.,Ltd.

