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Hot stamping using resistance heating of quenchable steel sheet and tube

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9th BrDDRG Congress in 42° SENAFOR
5th October 2023

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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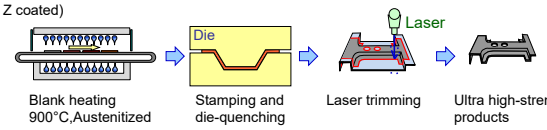
Hot stamping of quenchable steel sheet

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

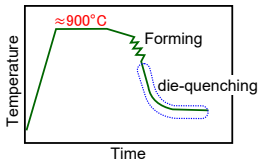


Blank heating
900°C,Austenitized

Stamping and
die-quenching

Laser trimming

Ultra high-strength
products



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

Red: hot-stamped panels

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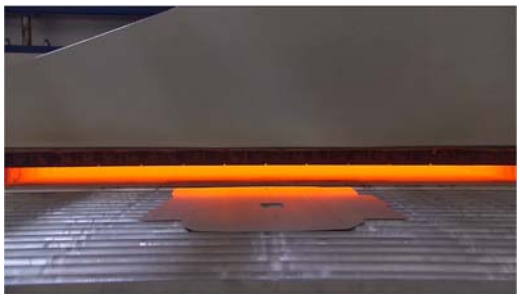
Hot stamping of quenchable steel sheet



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

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Problems in hot stamping

Huge furnace

20–40 m

Oxidation

Al-Si coating
Zn coating

Heating time increased

Low productivity

Transferring
2 s

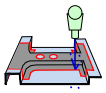
Forming
3 s

Holding
10 ~20 s

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

Trimming

Laser trimming and hole making ⇨ high cost
Shearing ⇨ tool life, delayed fracture



High cost

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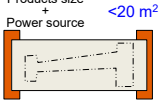
Advantages of direct resistance heating in hot stamping

Rapid heating

Small hot stamping line

Products size + Power source

<20 m²



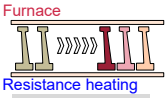
Resistance heating

100-200 m²

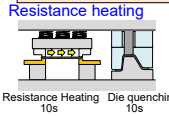
Furnace

High productivity with small in-progress product

Furnace



Resistance heating



Resistance Heating 10s Die quenching 10s

Number in-progress product = Heating time / Time per unit production

3 SPM: 13.5 = 270 s / 20 s

Heating synchronized with die quenching

6 SPM: 1

Flexible control of production

Furnace: heating and cooling time are a few days

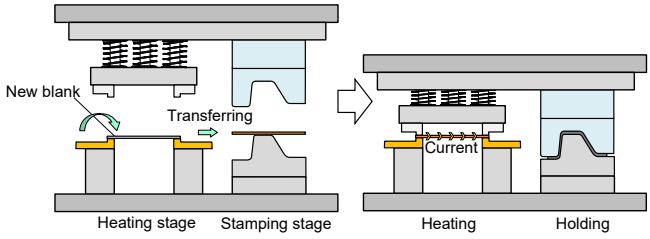
↳ 24/7 running

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

Hot stamping using resistance heating in Toyota Motor

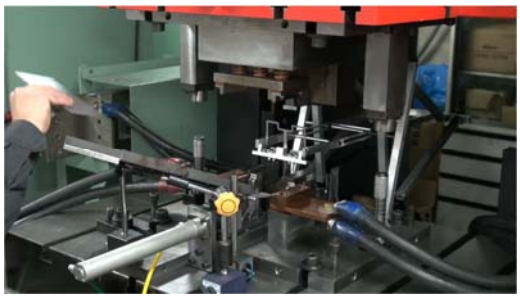
Hot stamping, TOYOTA MOTOR CORPORATION YouTube channel

Synchronization of heating and die quenching



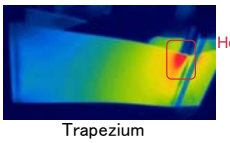
(1) Transferring and feeding of blanks ⇒ (2) Heating and stamping +die quenching

Video of synchronized hot stamping of heating and die quenching



Limitation of direct resistance heating in hot stamping

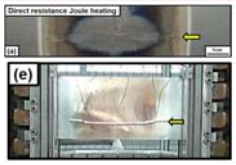
Limited blank shape



Hot spot

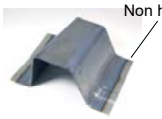
Trapezium

Melting of aluminum coating of sheet



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

Non heated edge



Non heated edge

Furnace

LDR is reduced

Resistance heatng

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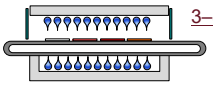
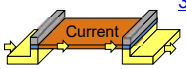
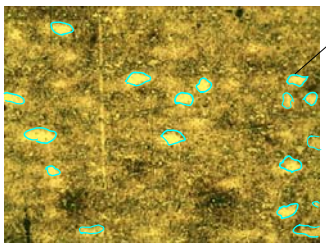
Insufficient austenitisation in rapid resistance heating

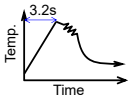


Roller hearth furnace



Resistance heating





Insufficient austenitisation

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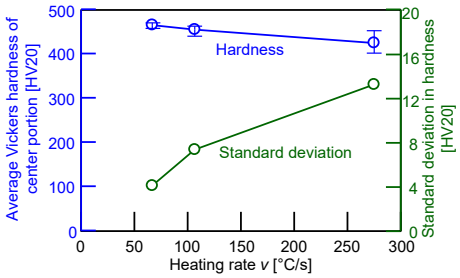
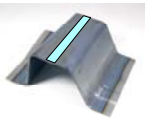
T. Maeno et al., J. Manuf. and Mater. Proc, 4-3(2020), 80.

Effect of heating rate on Vickers hardness and standard deviation





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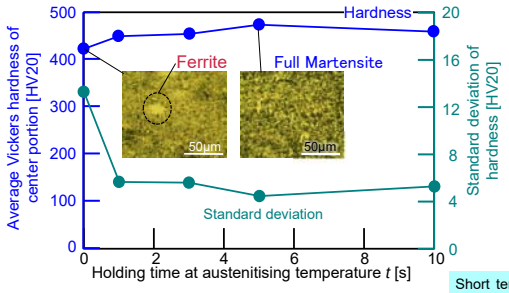
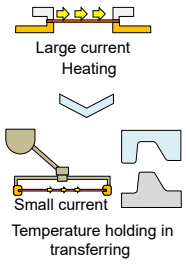
Effect of holding at austenitising temperature on Vickers hardness and standard deviation for v = 275 °C/s





Short temperature holding remarkably improves quenchability .

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T. Maeno et al., J. Manuf. and Mater. Proc, 4-3(2020), 80.

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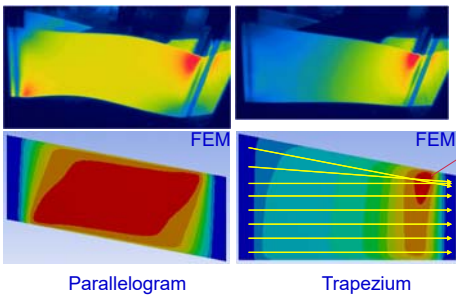
Resistance heating of non-rectangle blank



Electrical current tend to flow over short distance.

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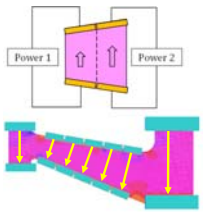
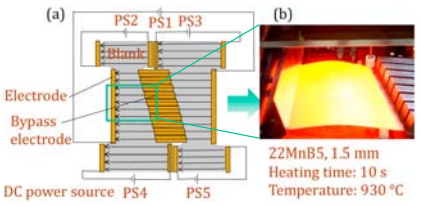
Uniform heating of non-rectangular sheet by divided circuit and bypass electrodes



Dividing of circuit

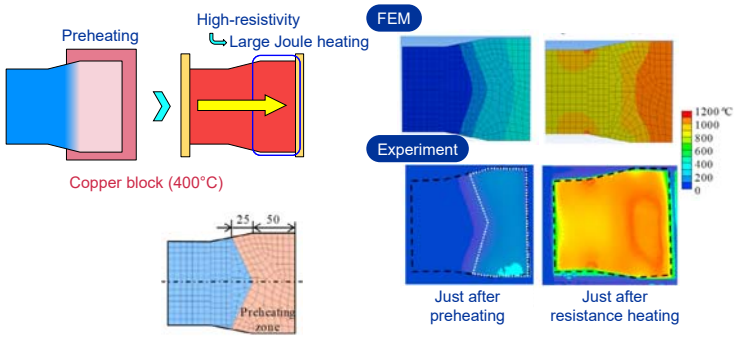


Divide the area and set an electrical circuit in each area. And the current amount of each power supply are adjusted that the current density is the same.

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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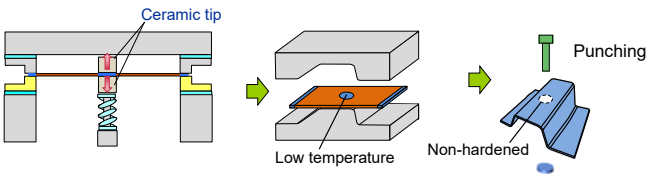
Local prevention of hardening for punching of hot-stamped parts



(1) Resistance heating (2)Hot stamping (3) Cold punching

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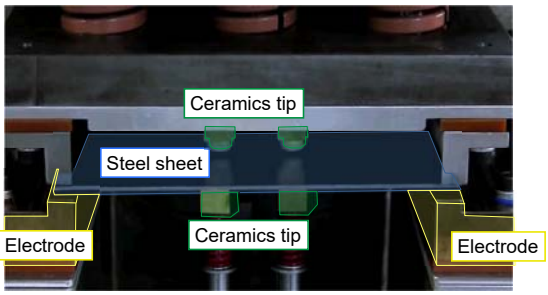
K. Mori, Key Engineering Materials, 639 (2015), 205-212.

Local cooling by contact with ceramics tool



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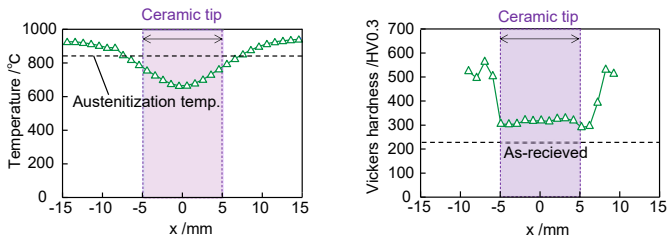
K. Mori, Key Engineering Materials, 639 (2015), 205-212.

Temperature and hardness distribution of punching portion with local cooling



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

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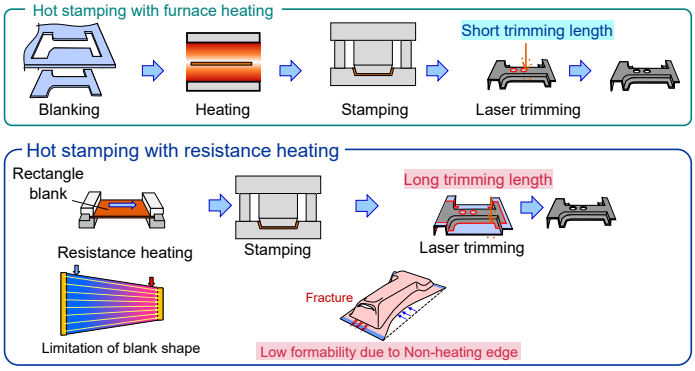
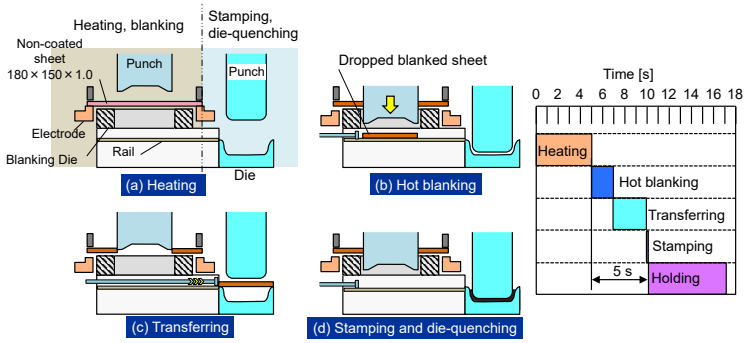
Large trimming of hot stamped panel in resistance heating



Hot stamping using blanking immediately after resistance heating



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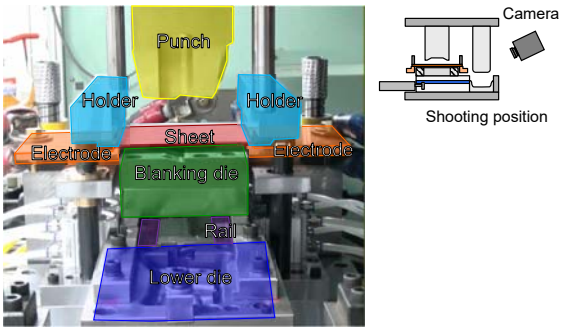
T Maeno et al., Int J Adv Manuf Technol 97(2018), 3827–3837.

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



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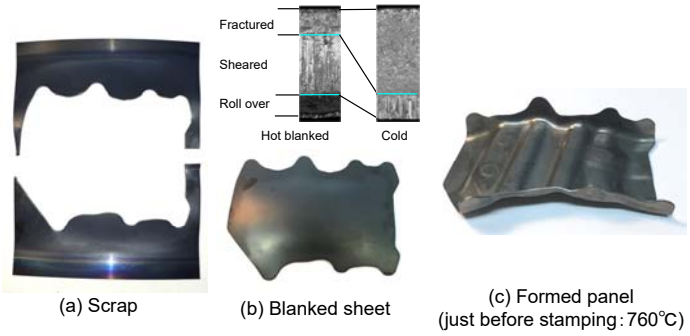
Appearance of hot stamped reinforcement parts



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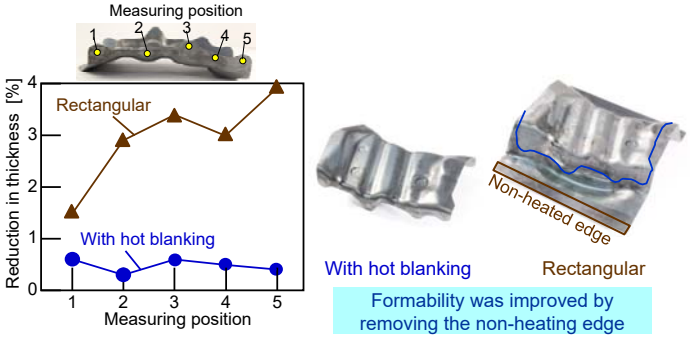
T Maeno et al., Int J Adv Manuf Technol 97(2018), 3827–3837.

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



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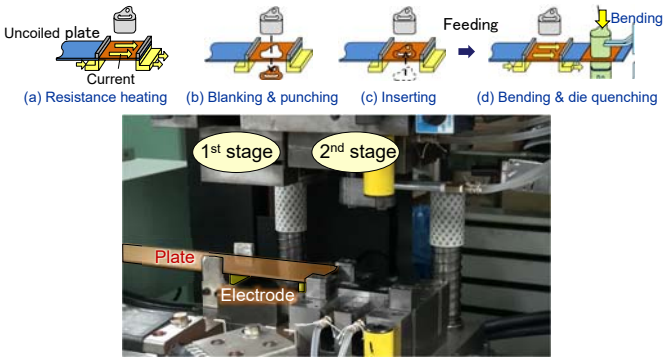
T Maeno et al., Int J Adv Manuf Technol 97(2018), 3827–3837.

2-stage progressive-die hot stamping of small products using resistance heating



K Mori et al., Procedia Engineering 207 (2017) 681–686

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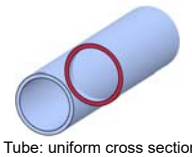
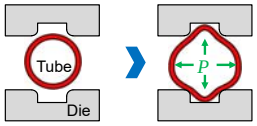
Steel Tube Air Forming process (STAF) / Sumitomo Heavy Industries, Ltd.

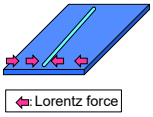


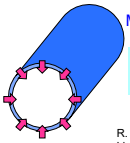
Tube: uniform cross section



Resistance heating 1st Blowing (Bulging) 2nd Blowing (calibration) die closing

Hollow products with flange





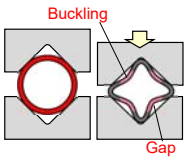
Melted coating is not moved

Al-Si coated steel pipe Available

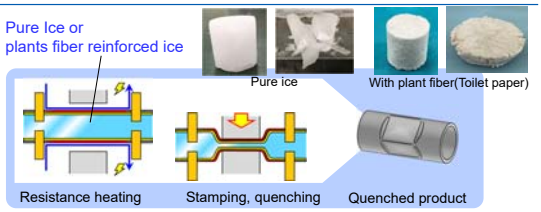
R. Funada, Presented at Global Automotive Lightweight Materials, Detroit, 2019.
K. Nogiwa, Plastos, 5-55(2022), 448-452

Steel Tube Air Forming process (STAF) by SUMITOMO heavy indust

Hot stamping of steel tube using with fiber reinforced ice mandrel



Pure Ice or plants fiber reinforced ice

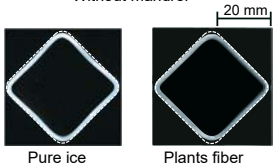


Compression of tube
- Low shape accuracy due to buckling
- Insufficient quenching due to gap

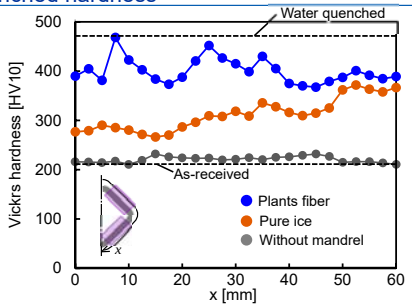
Ice mandrel
- Generate reaction force inside tube
- Direct cooling with ice
- No-control of internal pressure
- Safe medium (non compressive)

Effect of ice mandrel on cross sectional shape and quenched hardness

Without mandrel



Pure ice Plants fiber



Use of fiber reinforced ice mandrel remarkably effective to improve shape accuracy and quenching

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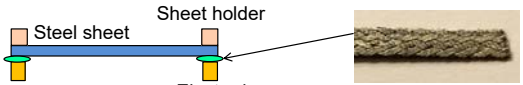
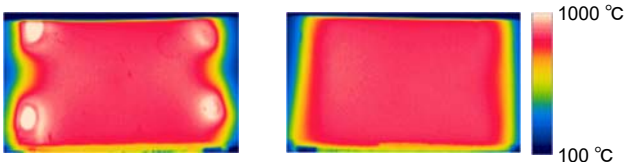
5th October 2023

Improvement of fitting of electrode with flat braided copper wire



Flat braided copper wire



(a) Without braided copper wire (b) With braided copper wire

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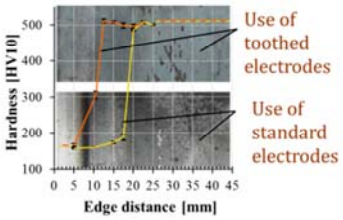
Reduction of non- heated edge with toothed electrodes

Toothed electrodes system

22MnB5
930 °C

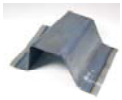
Hardness measurement



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

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

⇩

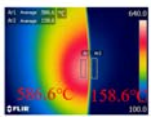
Emissivity changing during rapid heating

Radiation thermometers and thermography are not suitable for rapid heating.

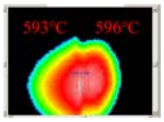
Two-color thermometer:
temperature is determined from the ratio of brightness at two different wavelengths, the influence of emissivity is eliminated.

Camera 30,000-40,000 US$

Spot pyrometer 2,500 US$



IR thermography



Two-color thermography

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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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