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Microstructure development and mechanical properties of a hot stamped low-carbon advanced high strength steel treated by a novel dynamic carbon partitioning process

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Layout

- Background
- Material and methods
- Experimental Results
- Conclusions

Background

Automobile light weighting

The preferred material

High strength steel

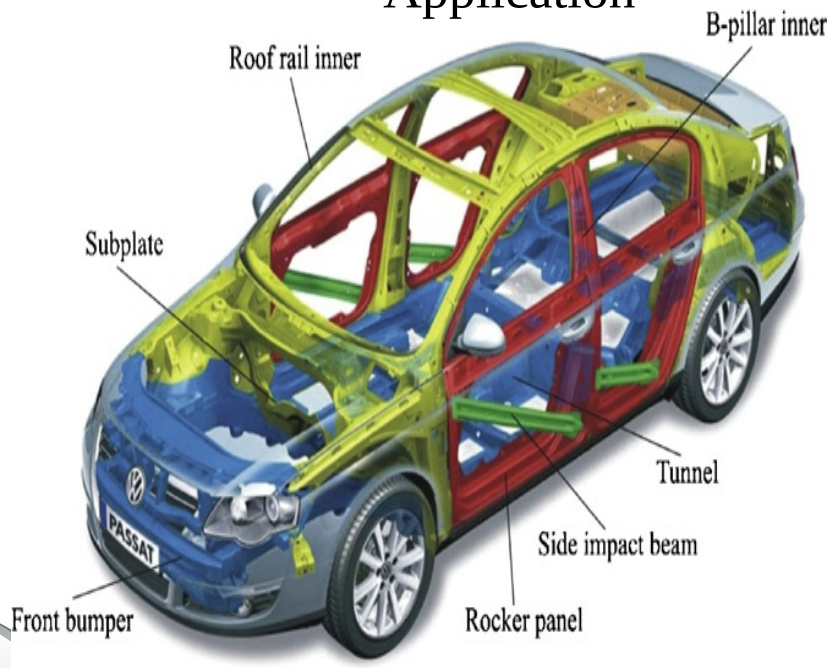
Conventional HSS

AHSS

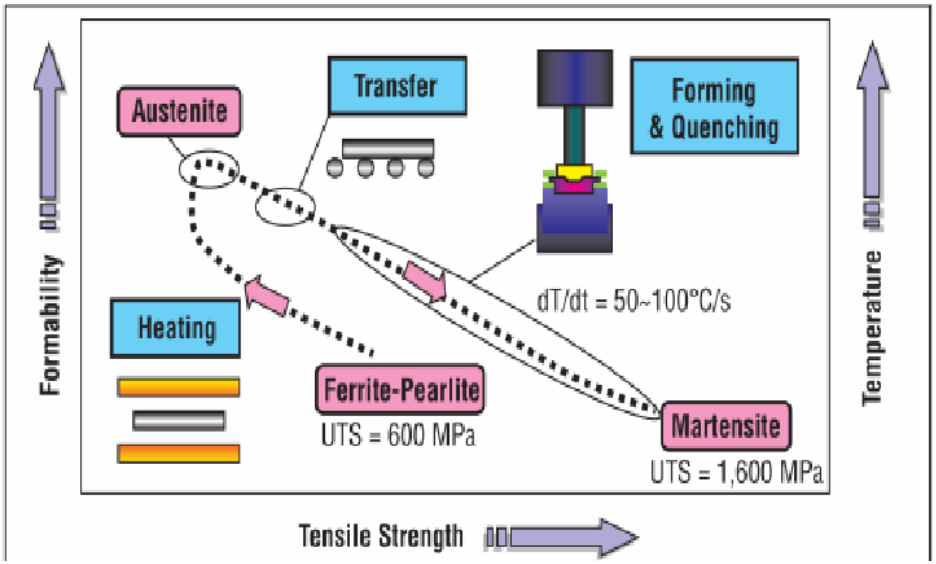
To protect driver safety

Environmental protection and weight loss

Application



Hot forming process of steel
can get high strength



Advantages of hot forming process

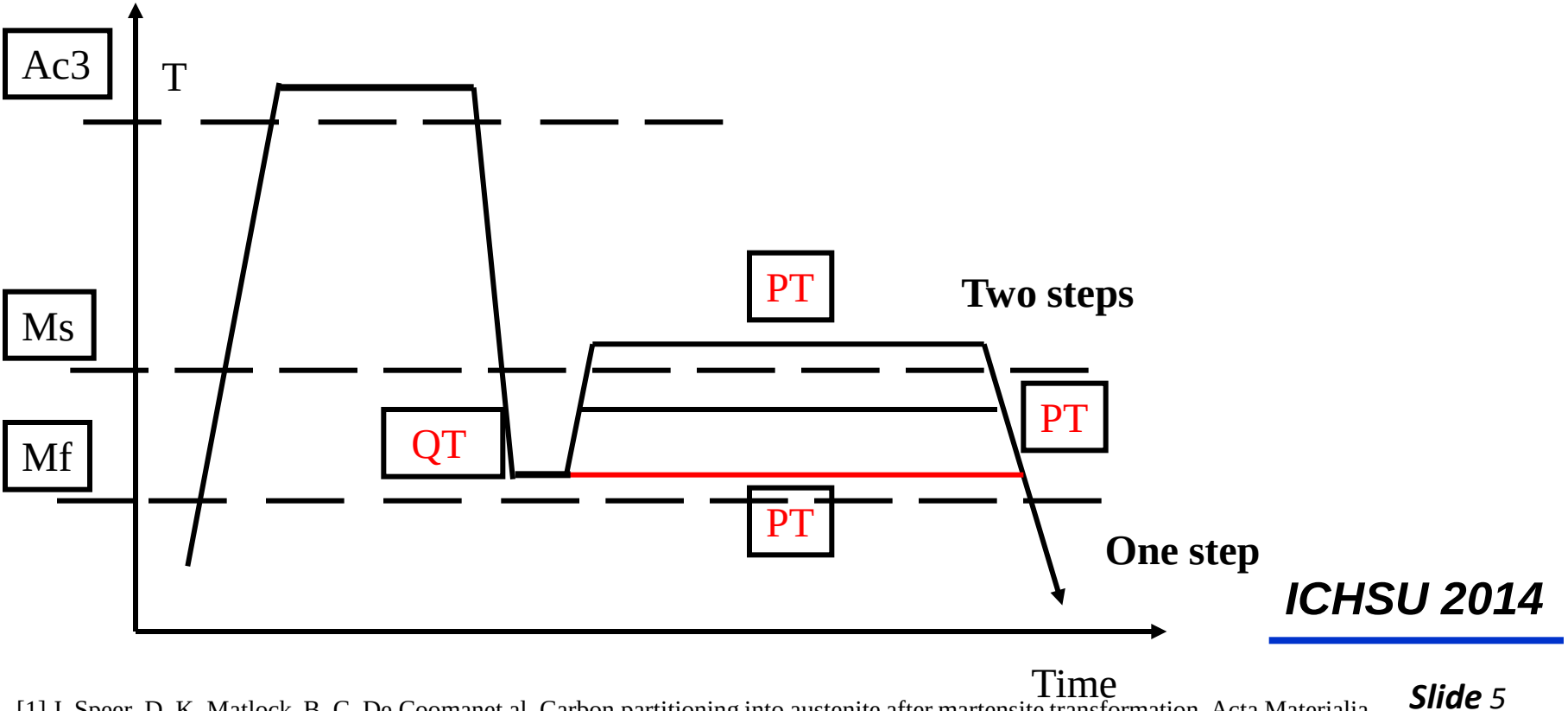
(1)Deformation resistance of smalland easy to forming
(2)Reduces the requirements for the mold and machine
(3)Shorten the production cycle

Limitations of hot forming process

(1)Seriously affecting the toughness of the material
(2)Impact performance cars and other products
(3) After hot forming, the quenching lack of control

QP (Quenching Partitioning)process

Speer and his partners had issued that *Carbon partitioning into austenite after martensite transformation* [1] at 2003, then QP process has proposed



[1] J. Speer, D. K. Matlock, B. C. De Coomanet al. Carbon partitioning into austenite after martensite transformation. Acta Materialia, 2003.

Faced problems

Lack of suitable steels, which are quenchable, weldable and with large product of strength and elongation, and corresponding treatment method.

The dynamic carbon partitioning

- The thermal stabilization[2] refers to the retarding martensite transformation of retained austenite which is stabilized by short isothermal treated during cooling.
- As Rao and Thomas [3] measured by high-resolution dot matrix, the carbon content could be as high as of 0.4% - 1.04% in retained austenite by quenching of a steel with 0.27% carbon content.
- According to previous studies and the comparison of time for martensite formation between calculation results of time required for the homogenized diffusion of carbon in martensite and austenite
- Some experimental evidence obtained support, such as that observed in the quenched martensite to austenite organization [3]

[2] T.Y. Hsu (Xu Zuyao), Martensitic and martensitic transformation, second ed.,Science Press, Beijing, 1999.

[3] B.V.N. Rao, G. Thomas, Transmission electron microscopy characterization of dislocated lath martensite, Cambridge, l979.

- Academician XU Zuyao [4,5] proposed the following conclusion: there may be carbon diffusion during martensite formation, but that is not a main or necessary process.

My jobs

Accordingly, based on the traditional hot stamping and Q&P processes, this paper proposes a new process called Hot Stamping - Dynamic Partitioning (HS-DP) process: quenching and carbon partitioning are completed dynamically during hot stamping and following cooling process.

[4] T.Y. Hsu (Xu Zuyao), Carbon Diffusion and Kinetics During the Lath Martensite Formation,1995.
[5] T.Y. Hsu (Xu Zuyao), X.M. Li, Diffusion of Carbon During the Formation of Low-Carbon Martensite.

Material and methods

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Material and methods

Chemical composition of the experimental steel (wt.%)

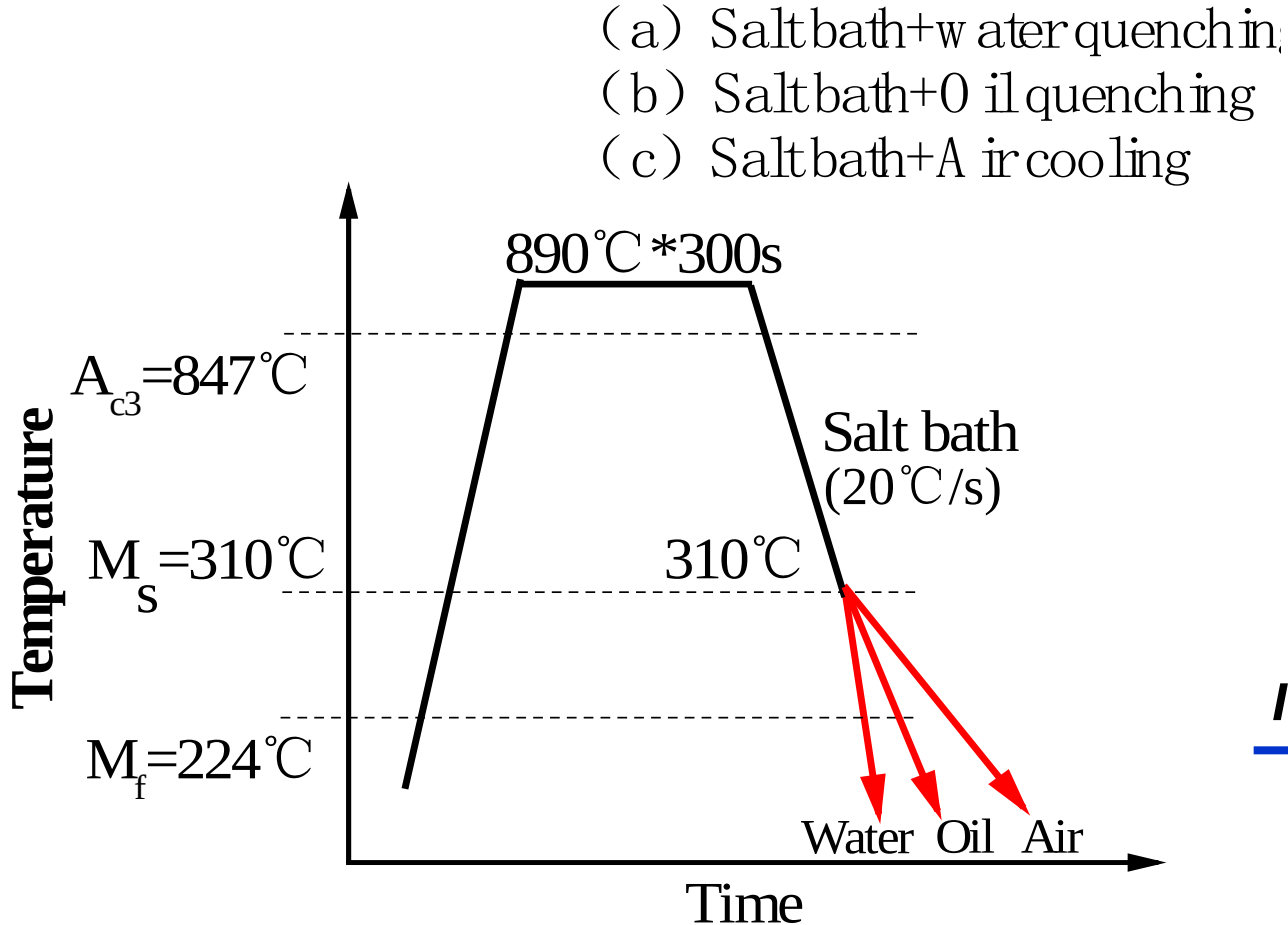
The experimental steel is an improved version of 22MnB5

C	Si	Mn	Ni	Cr	Mo	Cu	Ti	B	Al
0.19	1.55	1.53	0.95	1.01	0.45	1.01	0.033	0.0027	0.025

Experimental steel phase transition point

Ac1，℃	**Ac3，℃**	**Ms，℃**	**Mf，℃**	**The critical cooling rate**
720	**847**	**310**	**224**	**>0.5℃/s**

Schematic illustration of HS-DP heat treatments applied to the steels



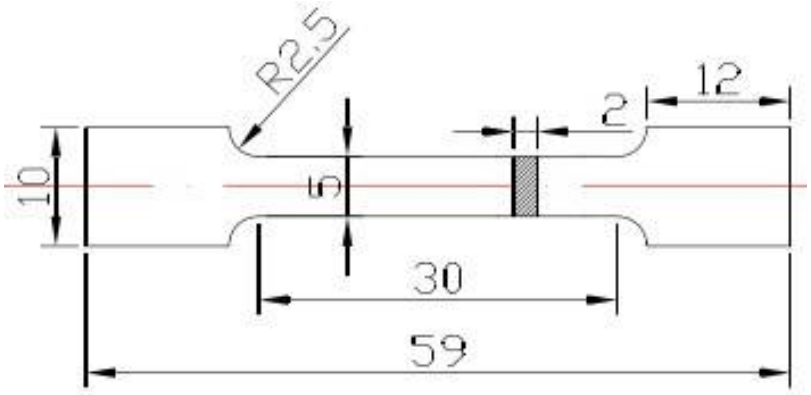
The carbon concent ration of the austenite was calculated by equation (1) :

$$a_\gamma = 3.556 + 0.0453 x_C$$

The austenite lattice parameter α_γ was determined from the positions of reflections according to equation (2):

$$a_\gamma = \frac{\lambda}{2\sin\theta}\sqrt{h^2 + k^2 + l^2}$$

An illustration of the sample dimensions for the tensile tests



Experimental Results

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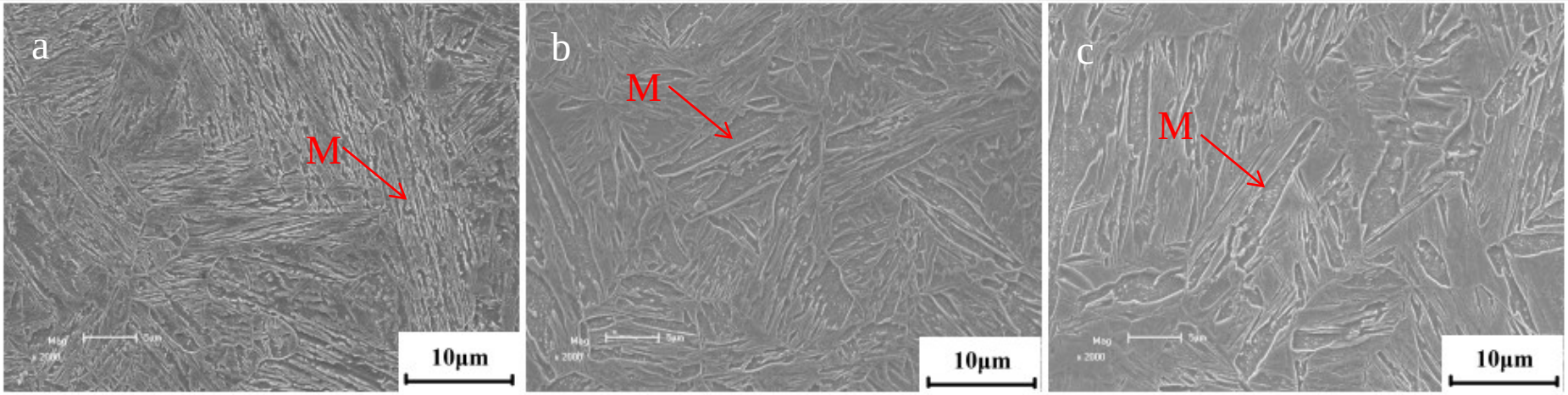
The Salt bath simulated experimental results

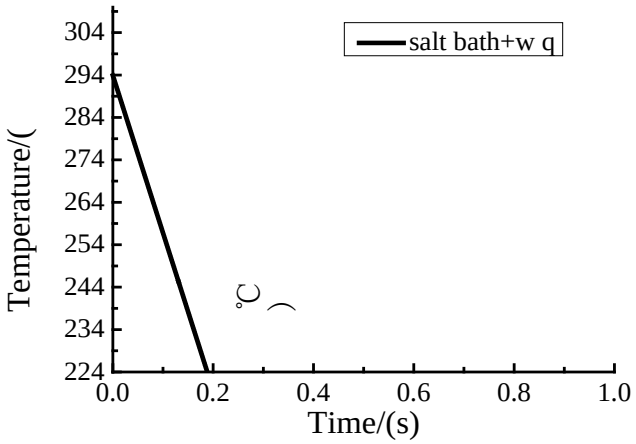
- **Microstructure characterization with SEM**

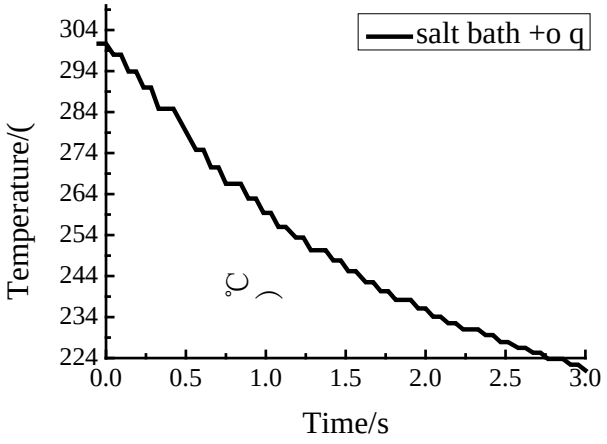


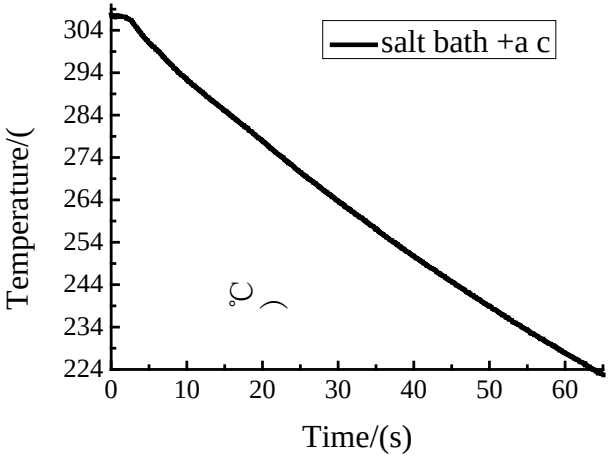
SEM micrographs showing the microstructures of steels after HS-DP process for (a) Salt bath + water quenching; (b) salt bath + oil quenching; (c) salt bath + air cooling

With wider lath martensite, the strength decreased, the elongation increases

The cooling characters of HS-DP process







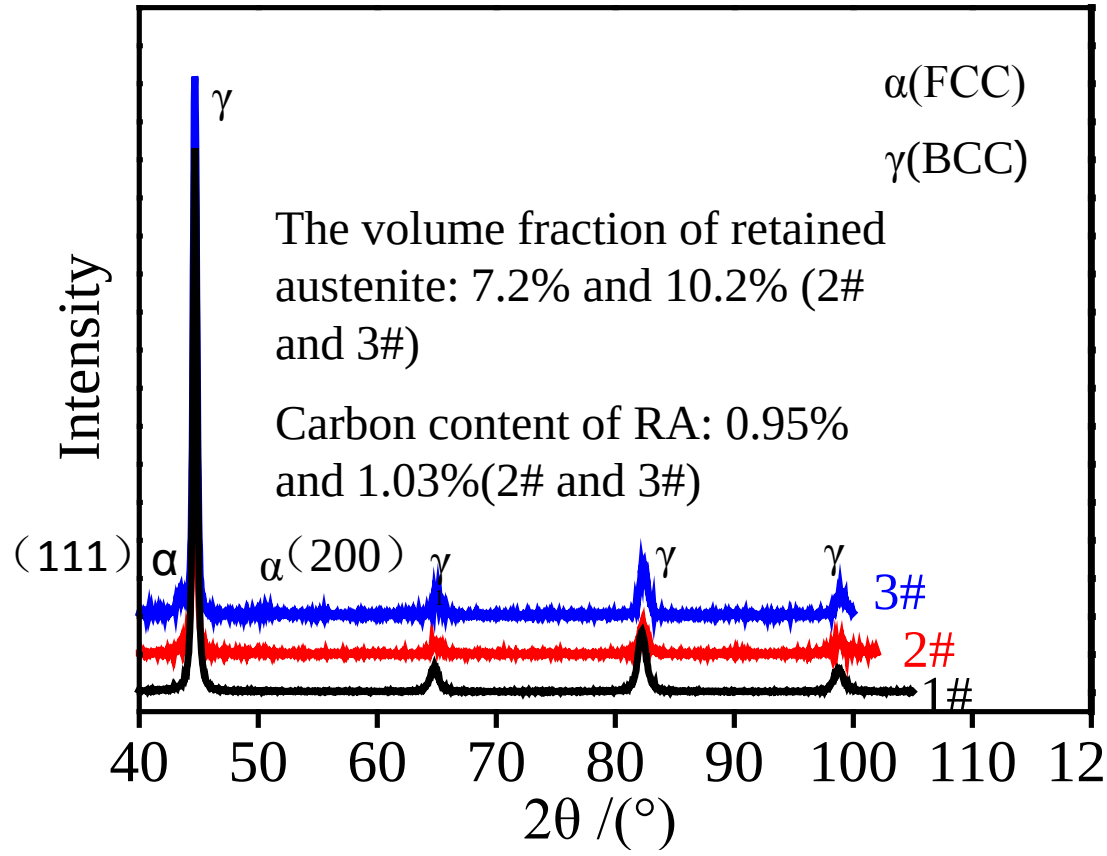
Heat treatment approach	The average cooling rate in the temperature range Ms>T>Mf (℃/s)
1#（salt bath + water quenching）	401.0
2#（salt bath + oil quenching）	27.1
3#（salt bath+air cooled ）	1.33

$V_{Water} > V_{oil} > V_{air}$

Mechanical properties of steel after HS-DP processes

Heat treatment process	strength(MPa)	Elongation (%)	The product of Strength and Plasticity (MPa·%)
1#（salt bath + water quenching）	1636	9.47	15493
2#（salt bath + oil quenching）	1527	11.11	16964
3#（salt bath+air cooled ）	1520	11.32	17206

Steel heat treatment process experimental XRD patterns



Conclusions

- This paper presents a novel one step method for forming-Q&P integration—Hot Stamping-Dynamic Partitioning (HS-DP) process.
- The designed physics simulating experiments indicates carbon partition occurs quenching process of the designed steel and thus hot stamping-dynamic carbon partition process can be achieved in the experimental steel.
- This excellent mechanical properties of experiment steel illustrates the promising application potential of the hot stamping -dynamic carbon partitioning process.

Acknowledgment

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Thank you