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Martensitic Stainless Steel as Alternative for Hot Stamping Steel with High Product of Strength and Ductility

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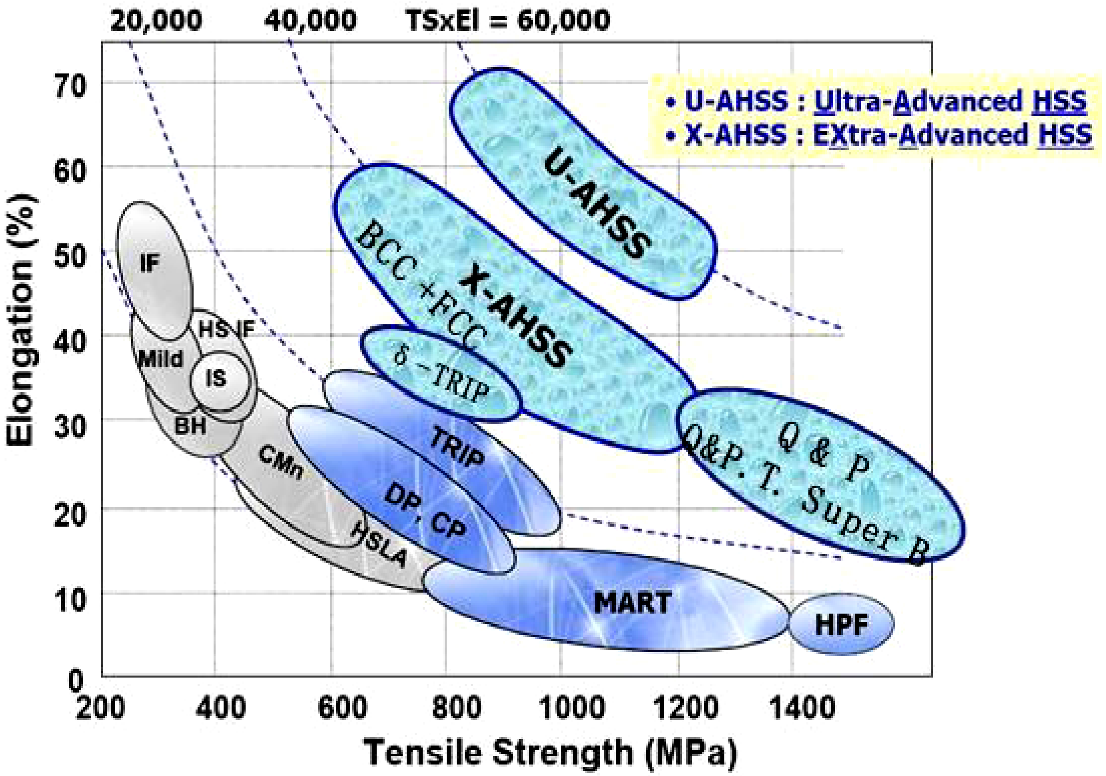
Contents

Advanced high strength steel (AHSS) are required in automobile components



The tensile strength-elongation relationships of automobile steels

Hot stamping are indispensable in components manufacturing

Advantages:

Increasingly high strength

Good formability

Shape accuracy

Disadvantages:

Poor ductility

Complex mould design

Expensive die cost

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The main phases or microstructures and corresponding features in automobile steel

Ferrite（IF steels）

Rel=150MPa，Rm=300MPa, A=45%

Rm×A=14000MPa%

Good formability, low strength, low security

Bainite（B_F+R_A，CFB steels）

Rel=800MPa，Rm=1100MPa, A=21%

Rm×A=23000MPa%

High product of strength and ductility, high strength, poor formability

Martensite（M1500 steel）

Rel=1200MPa，Rm=1500MPa, A=8%

Rm×A=12000MPa%

High strength, low ductility, low security

Austenite（TWIP steel）

Rel=450MPa，Rm=1000MPa, A=60%

Rm×A=60000MPa%

High product of strength and ductility, low strength

Principles for designing new generation advanced high strength steels (AHSS)

- **Microstructures**

  （ferrite+bainite +austenite）→(martensite+austenite↑)

  DP,TRIP,ART-MMS → Q&P

- **Alloying**

  More alloying elements that stabilize austenite to rise the volume fraction of it

  C-Mn-Si → C-(Cr,Ni)-Mn-Si   low alloy steels→stainless steels

- **Properties**

  Higher strength and ductility

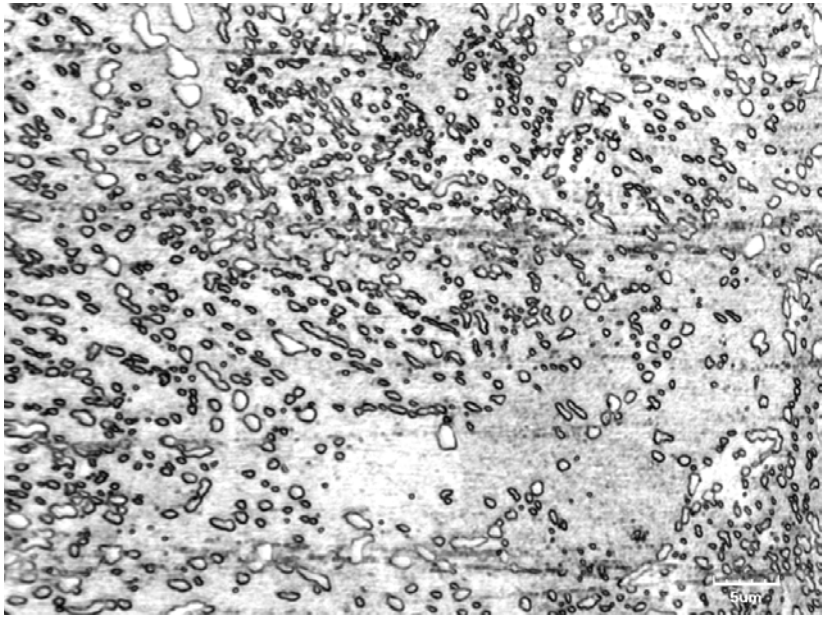
  (15000~25000)MPa% →(30000~40000)MPa%

Experimental Procedures

Experimental materials: 40Cr13, 30Cr13 and 20Cr13

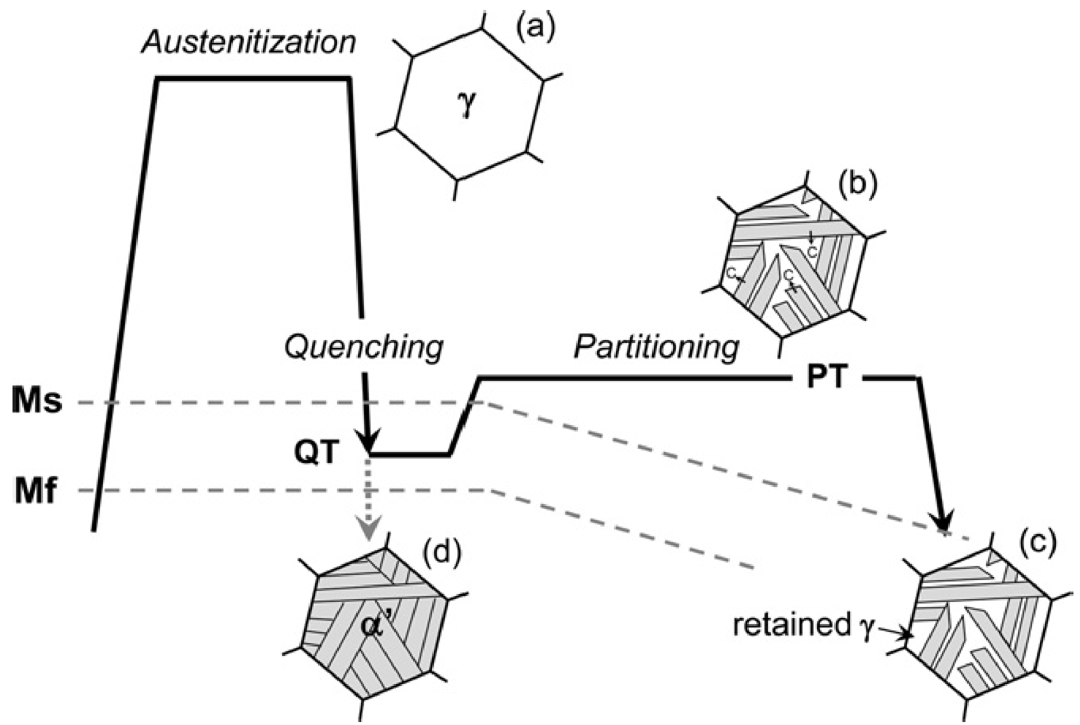
Preparation: hot forging, hot rolling, annealing

Final treatment: Quenching & Partitioning



Microstructures of 30Cr13 Steel as annealed

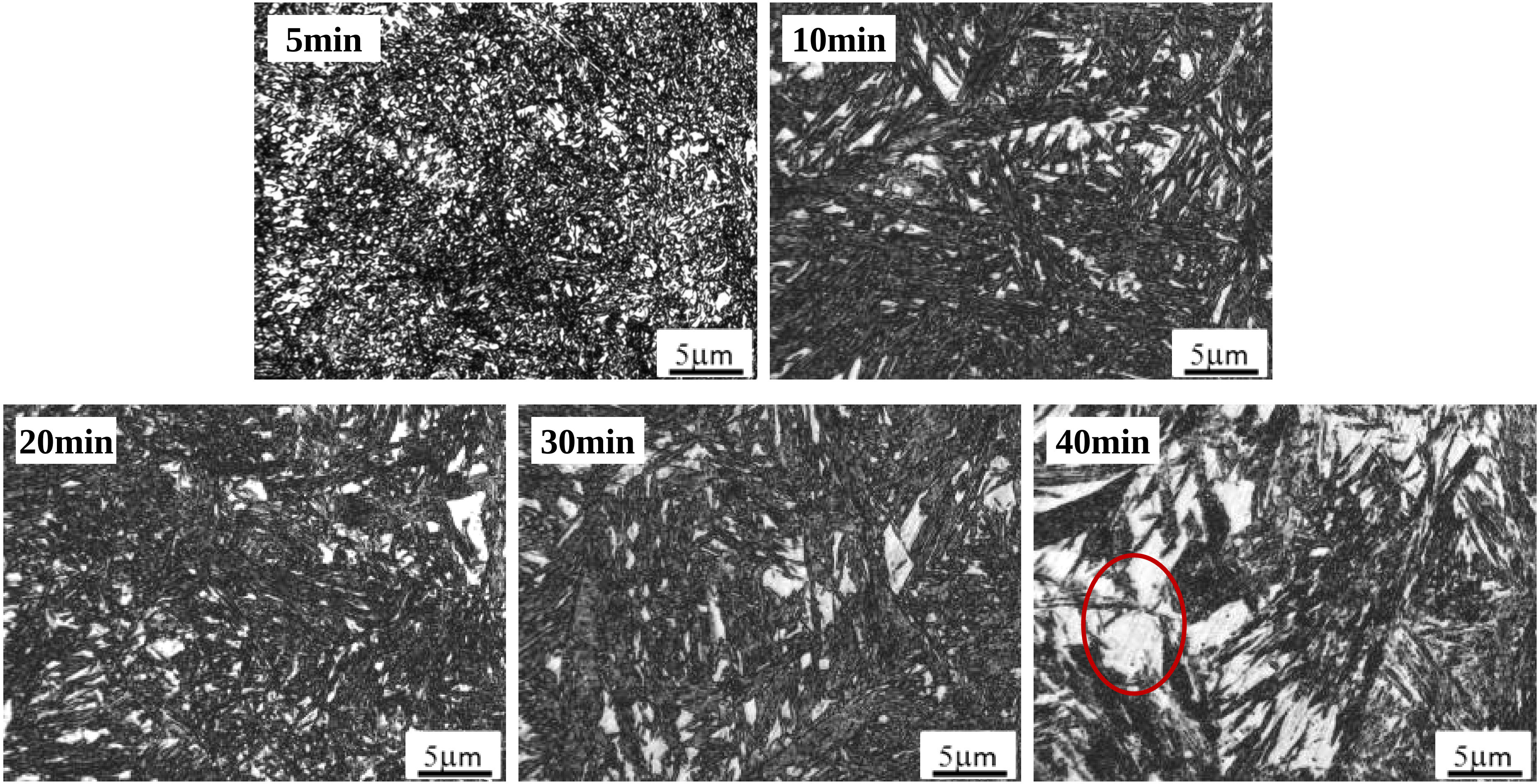
Approach to obtain (M’+A_R)microstructures through quenching and partitioning (Q&P) process



Schematic heat-treatment diagram of quenching and partitioning (Q&P) process

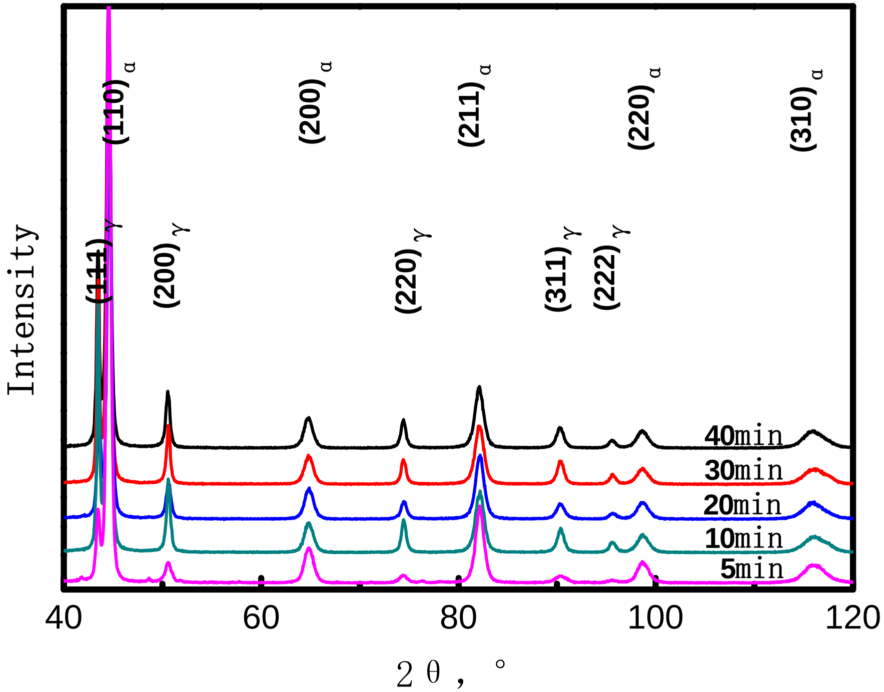
D.V. Matlock, V.E. Brautigam, J.G. Speer, Proc. THERMEC’2003, Material Science Forum, vols. 426–432, 2003, pp. 1089–1094

Experimental results of 40Cr13 steel

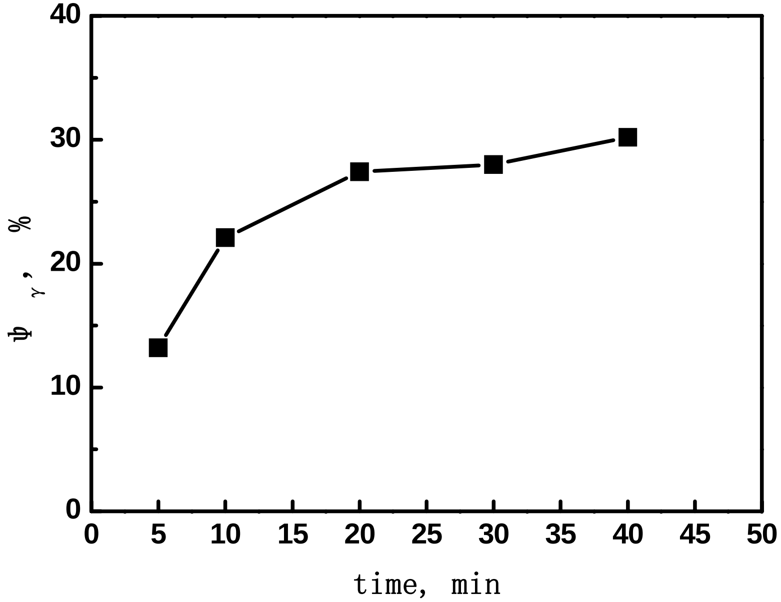


Microstructures of 40Cr13 steel subjected to Q&P after soaking for various time

Experimental results of 40Cr13 steel

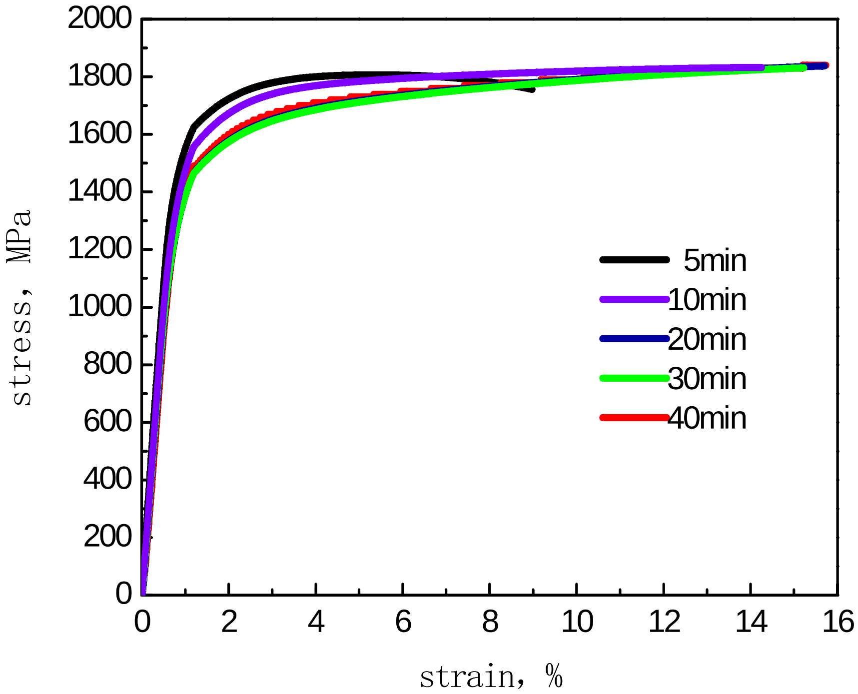


XRD spectrum of 40Cr13 steel subjected to Q&P treatment after soaking for various time



Curves of volume fraction of austenite vs heating time

Experimental results of 40Cr13 steel

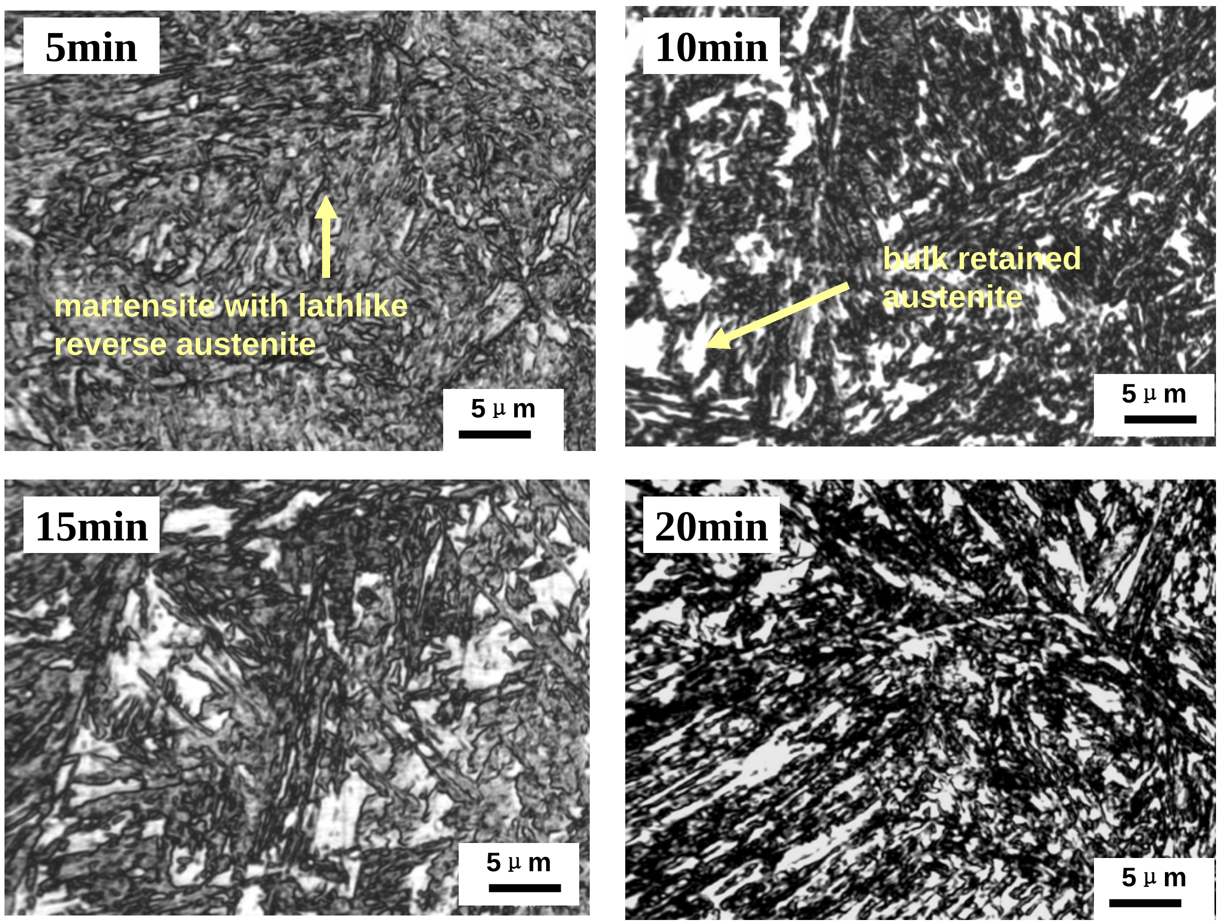


Tensile strain-stress curves of 40Cr13 steel subjected to Q&P treatment after soaking for various time

Mechanical properties of 40Cr13 steel subjected to Q&P treatment after soaking for various time

Time min	Rel MPa	Rm MPa	A %	Rm×A MPa·%
5	1485	1790	7.7	17005
10	1420	1824	13.3	24259
20	1319	1839	13.3	24459
30	1328	1832	13.3	24366
40	1326	1850	13.3	24605

Experimental results of 30Cr13 steel



Microstructures of 30Cr13 steel subjected to Q&P after soaking for various time

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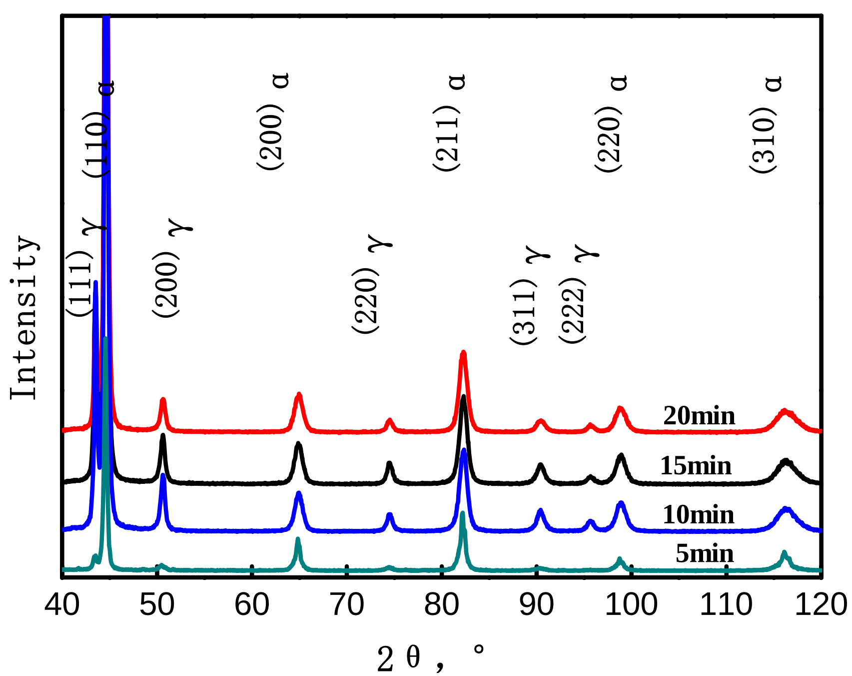
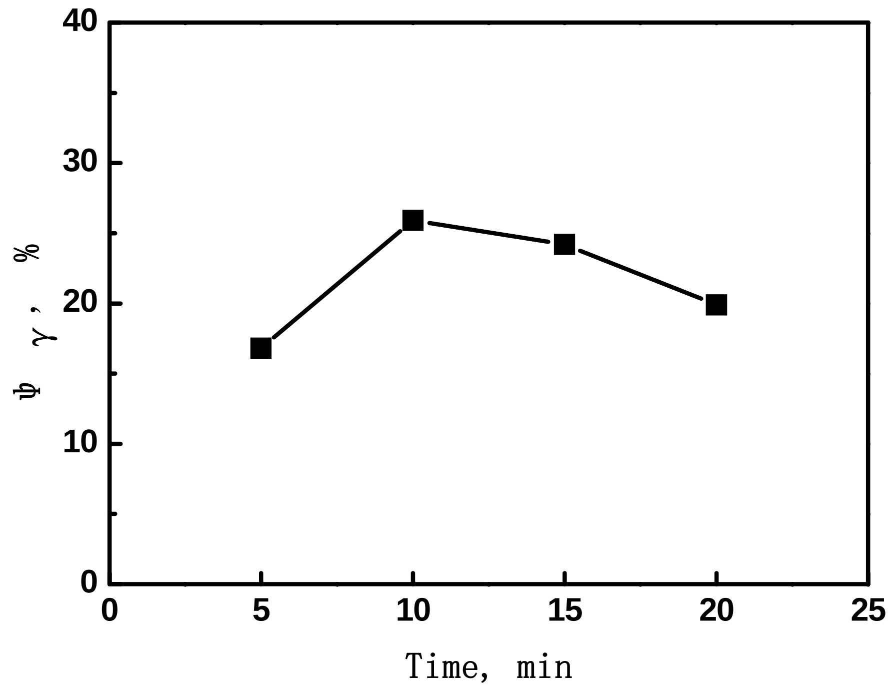
Experimental results of 30Cr13 steel



XRD spectrum of 30Cr13 steel subjected to Q&P treatment after soaking for various time



Curves of volume fraction of austenite vs heating time

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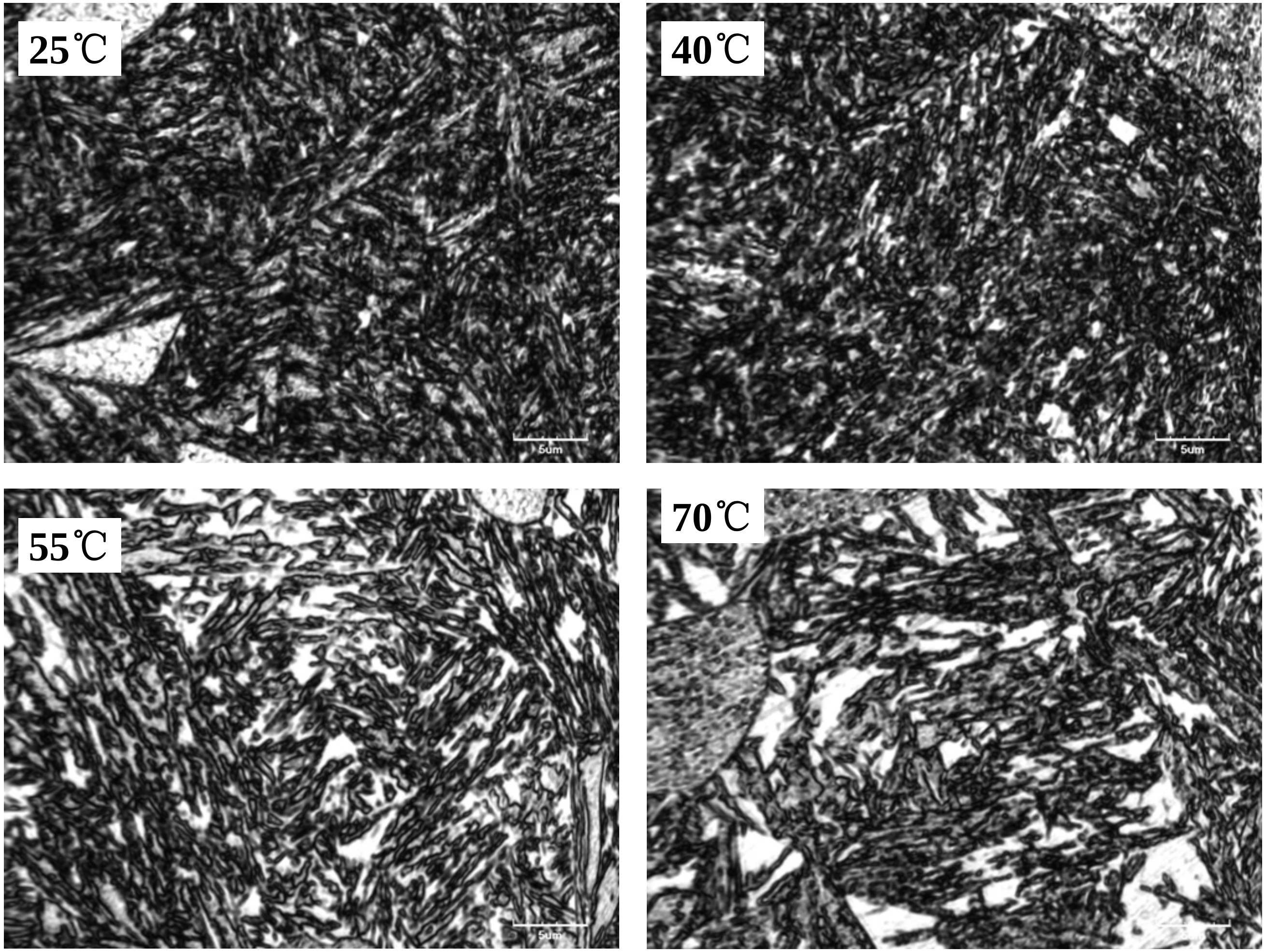
Experimental results of 30Cr13 steel

Mechanical properties of 30Cr13 steel subjected to Q&P treatment after soaking for various time

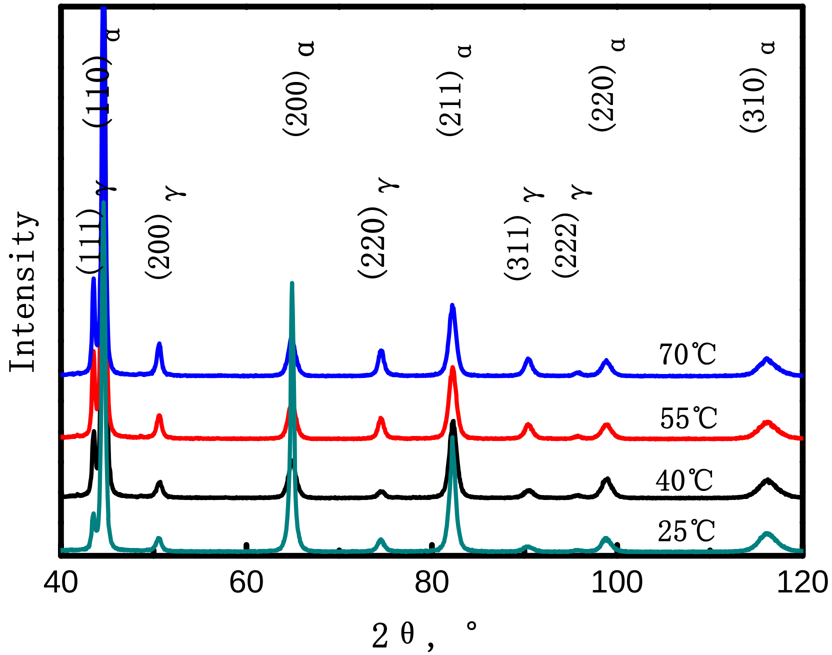
Time min	Rel MPa	Rm MPa	A %	Rm×A MPa·%
5	1280	1560	8.0	12480
10	1360	1710	10.2	17442
15	1350	1740	17.5	30450
20	1370	1770	12.8	22656

Experimental results of 20Cr13 steel

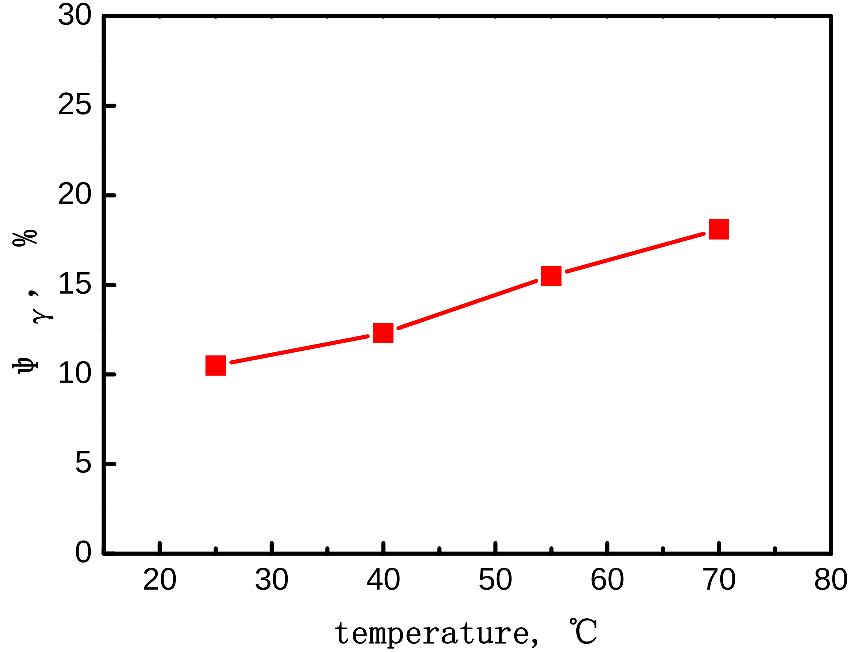


Microstructures of 20Cr13 steel subjected to quenching to 25~70℃ plus partitioning after soaking

Experimental results of 20Cr13 steel

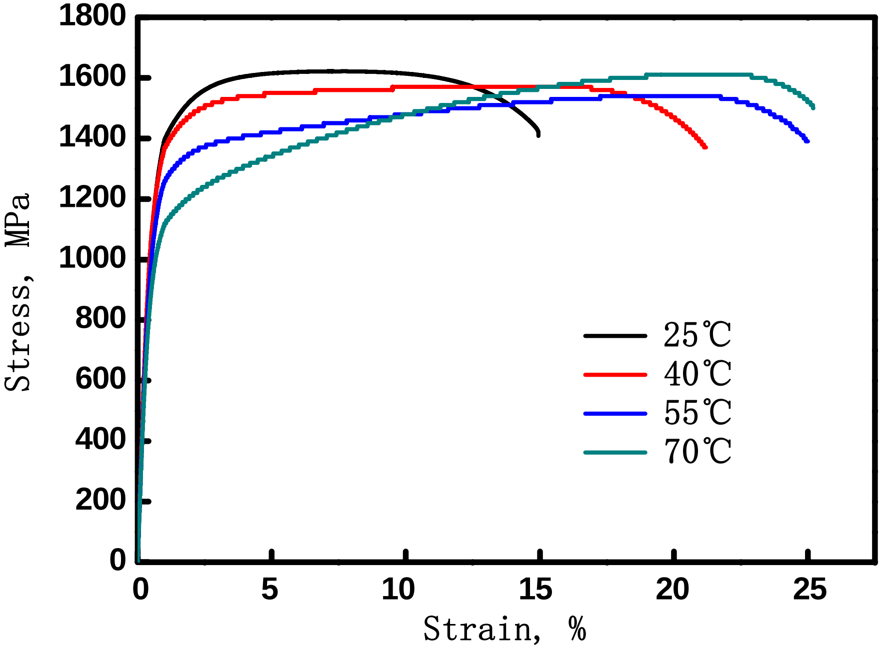


XRD spectrum of 20Cr13 steel subjected to Q&P treatments



Curves of volume fraction of austenite vs heating time

Experimental results of 20Cr13 steel

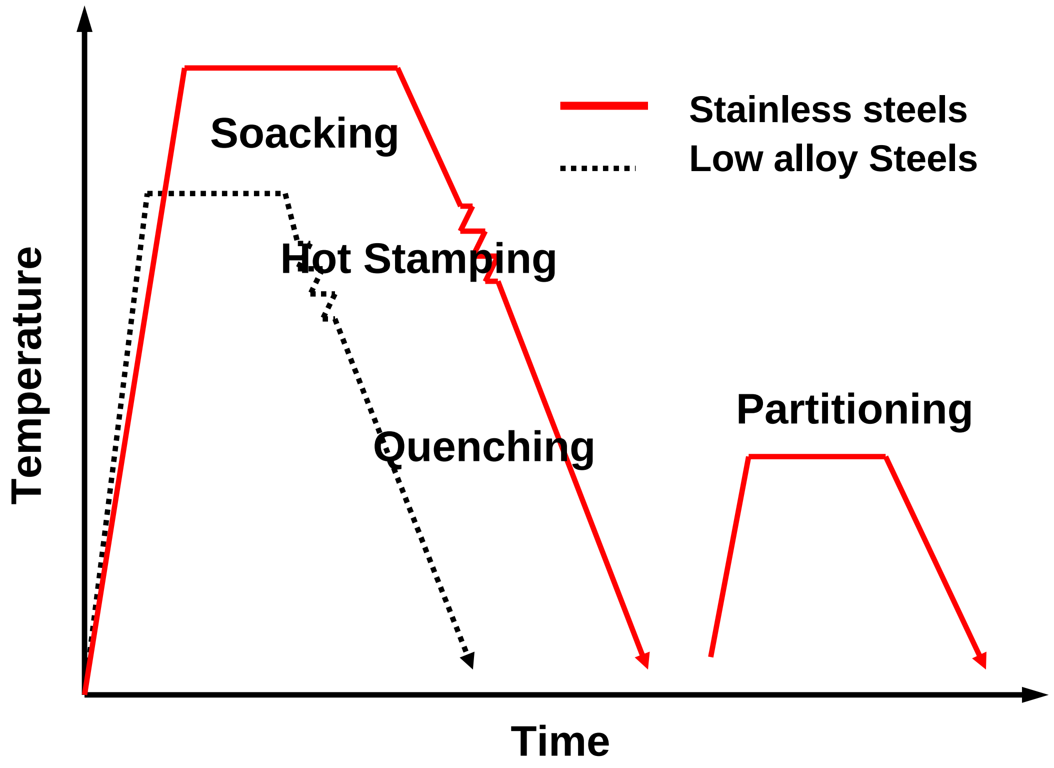


Tensile strain-tress curves of 20Cr13 steel subjected to Q&P treatments

Mechanical properties of 20Cr13 steel subjected to Q&P treatments

Temperature ℃	Rel MPa	Rm MPa	A %	Rm×A MPa·%
25	1220	1630	16.0	26080
40	1150	1560	21.8	34000
55	1060	1530	25.0	38250
70	920	1610	23.9	38480

Perspective –feasibility of MMSs as HS steels



Schematic diagram of HS-Q&P integrated processing

Challenges

Annealing

High temperature soaking

Off-die transformation

Off-line partitioning

Conclusions

1. When the as annealed 30Cr13 steel undertook Q&P after soaking for various time, yield strength and ultimate tensile strength increase rapidly with time until reaching a stable level, then change slightly; however, the elongation increases with time until a maximum value, and then decreases gradually.

2. In comparison with those of 22MnB5 steel, significantly improved comprehensive mechanical properties can be achieved in 30Cr13 MSS through appropriate Q&P treatment, and the best properties obtained are Rel=1350MPa, Rm=1740MPa, and A=17.5%.

3. Due to the unique phase transformation conditions of MSSs, more investigations with respect to the processing parameters of heating, hot stamping, quenching and portioning and according equipments of soaking furnace, die and partitioning furnace are to be carried out.

Thank you for attention!

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