

Chapter III Heat Treatment of Steel

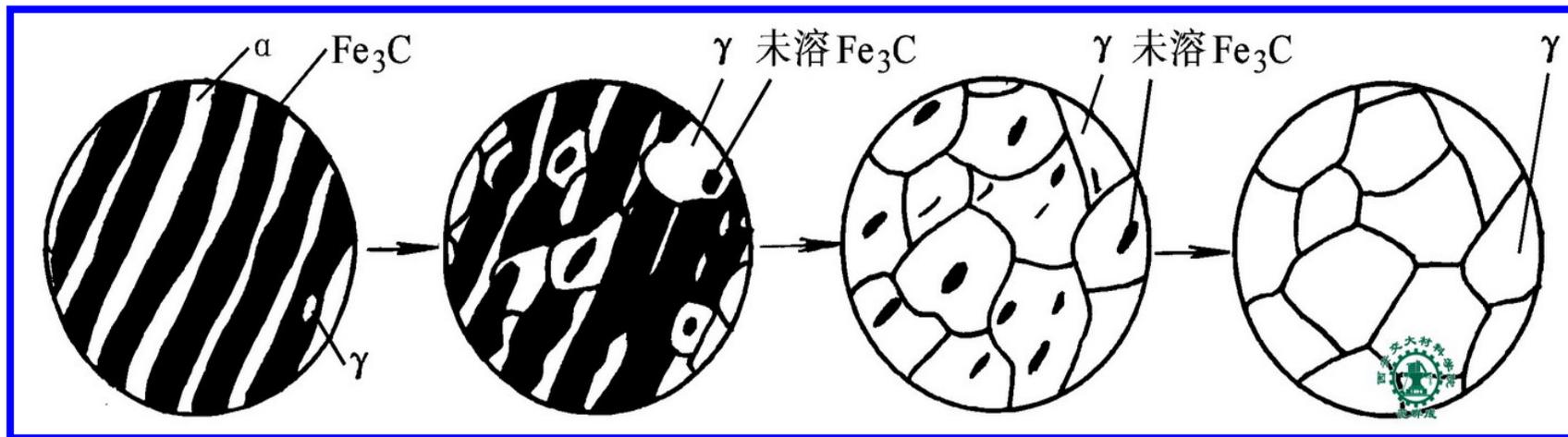
- What is the heat treatment
- Why does steel be heat treated
- Heat treatment
 - Common heat treatment
 - Annealing
 - Normalizing
 - Quenching
 - Tempering
 - Surface heat treatment
 - Surface quenching
 - Surface chemical heat treatment
 - Special heat treatment
 - Vacuum heat treatment
 - Controlled atmosphere heat treatment
 - Deformation heat treatment

THE END

§ 3-1 Transformation of steel as being heated

3.1.1 Formation of austenite

1. The forming process of austenite for eutectoid steel



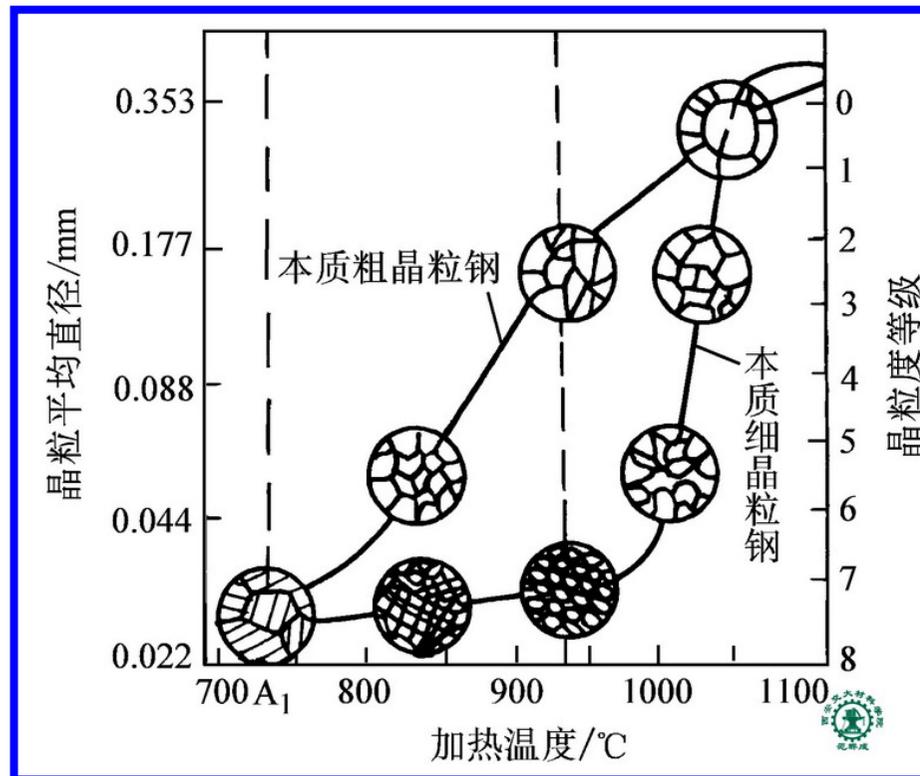
Schematic of forming process of austenite in eutectoid steel

2. The forming process of austenite for hypoeutectoid and hypereutectoid steels

THE END

3.1.2 Size of austenite grains

1. Practically grain degree of austenite
2. Essentially grain degree of austenite



Schematic showing essentially grain degree of steel

3. Factors affecting essentially grain degree of steel

- Alloy elements

THE END

§ 3-2 Transformation diagram of austenite

3.2.1 Isothermal transformation diagram of austenite

1. Measurement principle of isothermal transformation diagram of austenite

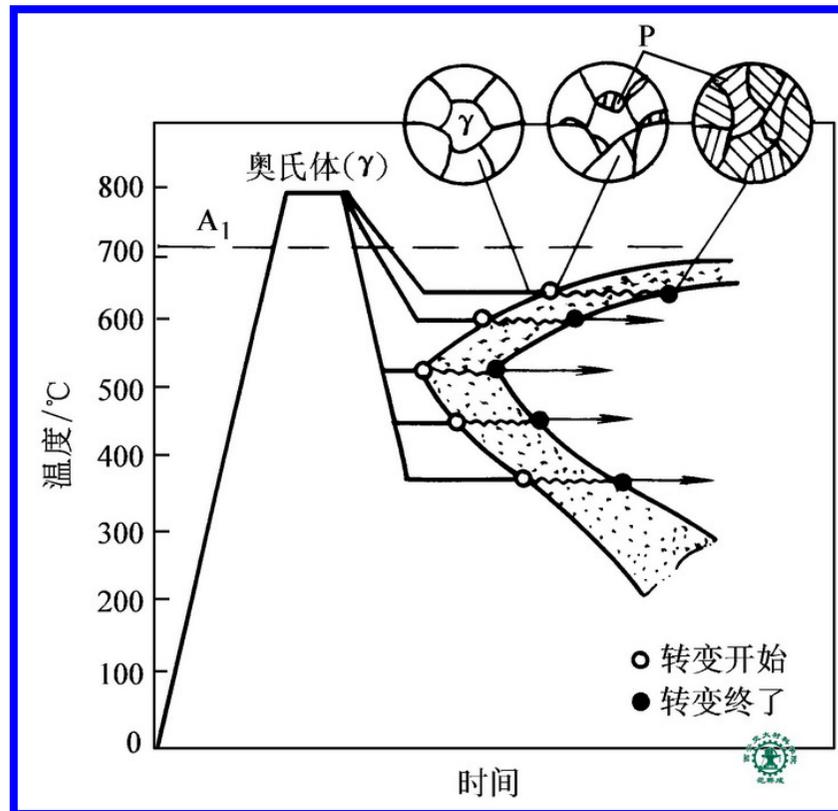
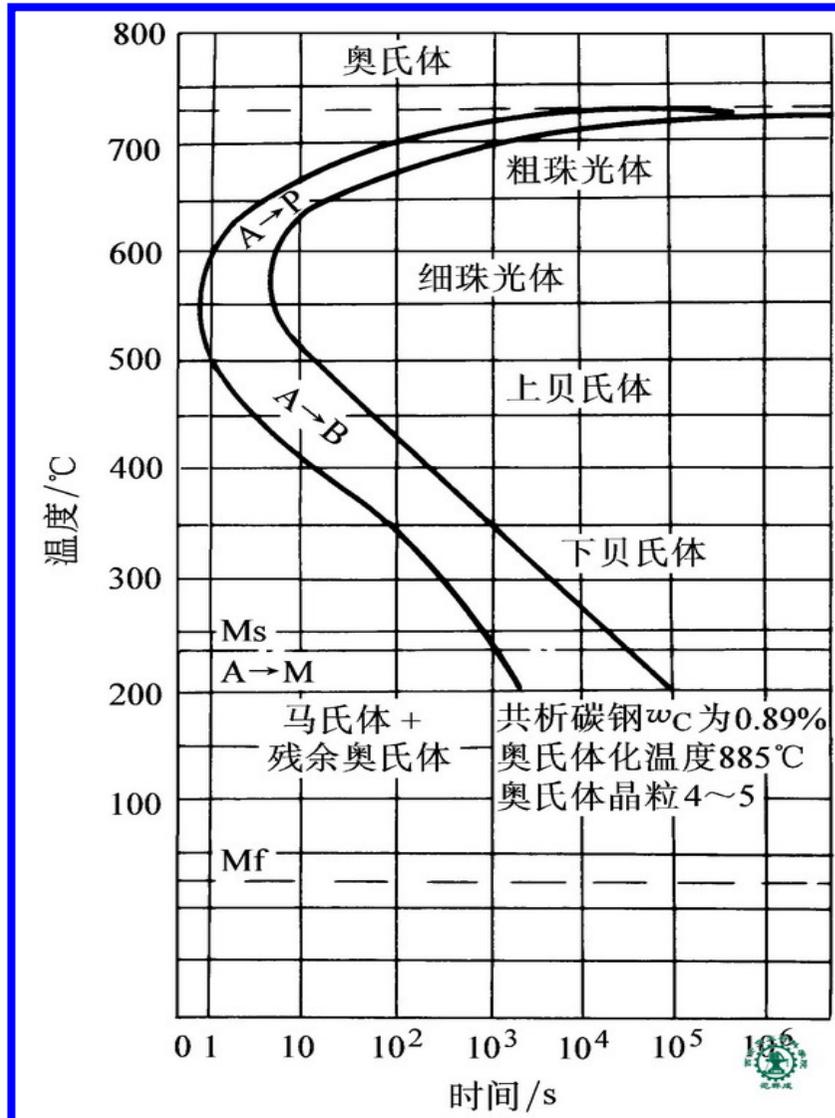


Diagram of measurement principle of C curve of eutectoid steel

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2. Analysis of isothermal transformation diagram of austenite



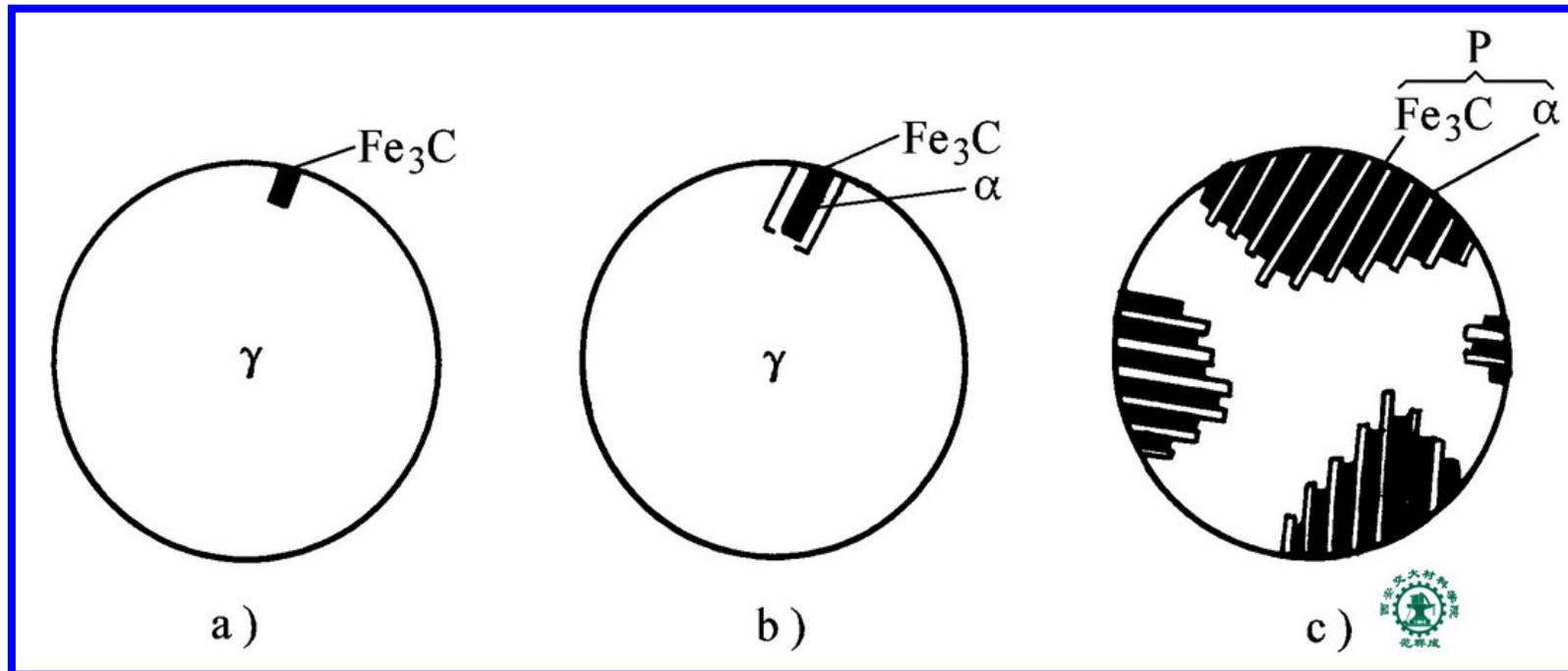
Isothermal transformation diagram of austenite for eutectoid steel

THE END

3. The process and products of isothermal transformation for super-cooling austenite

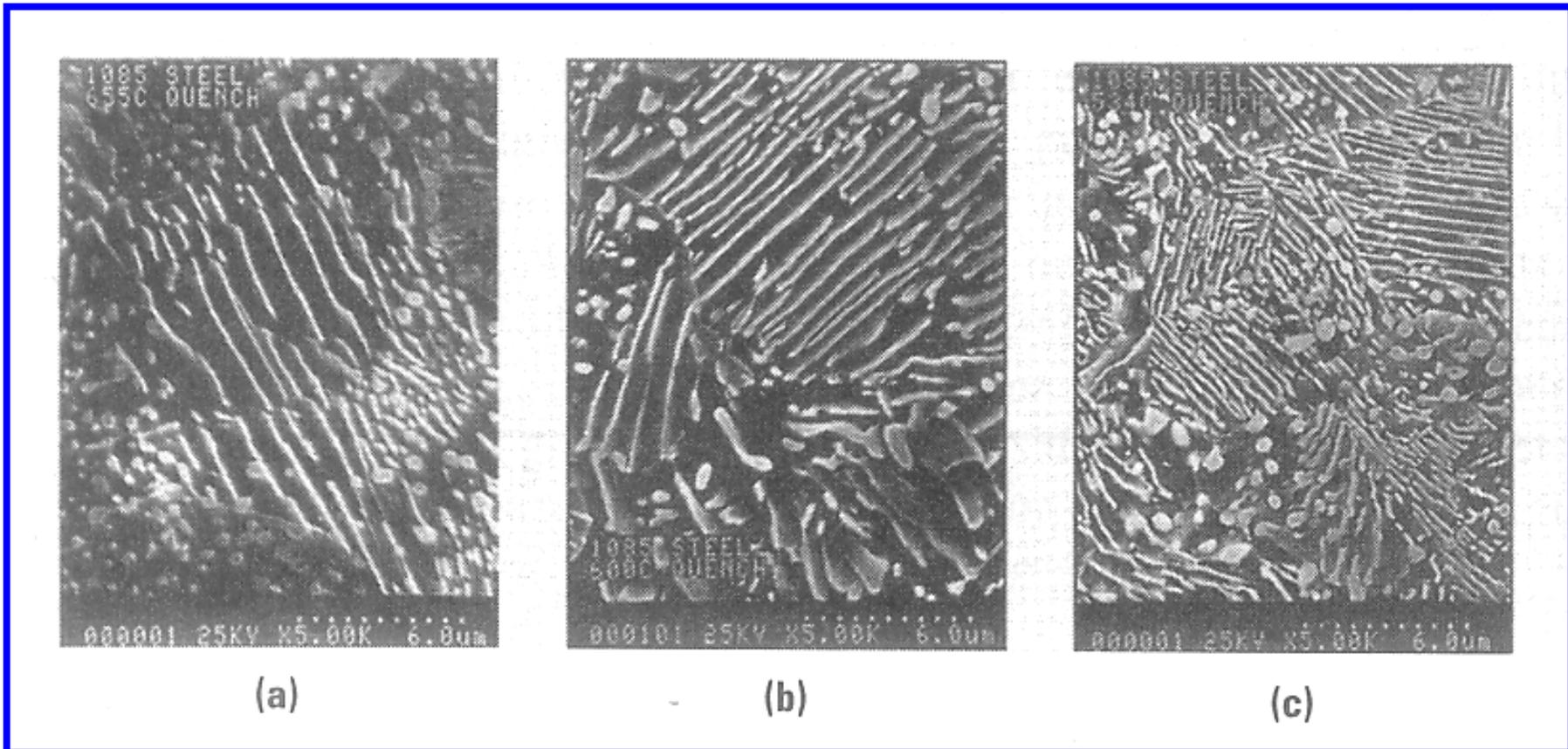
- What is the super-cooling austenite

1) Pearlitic transformation



Schematic of pearlitic forming

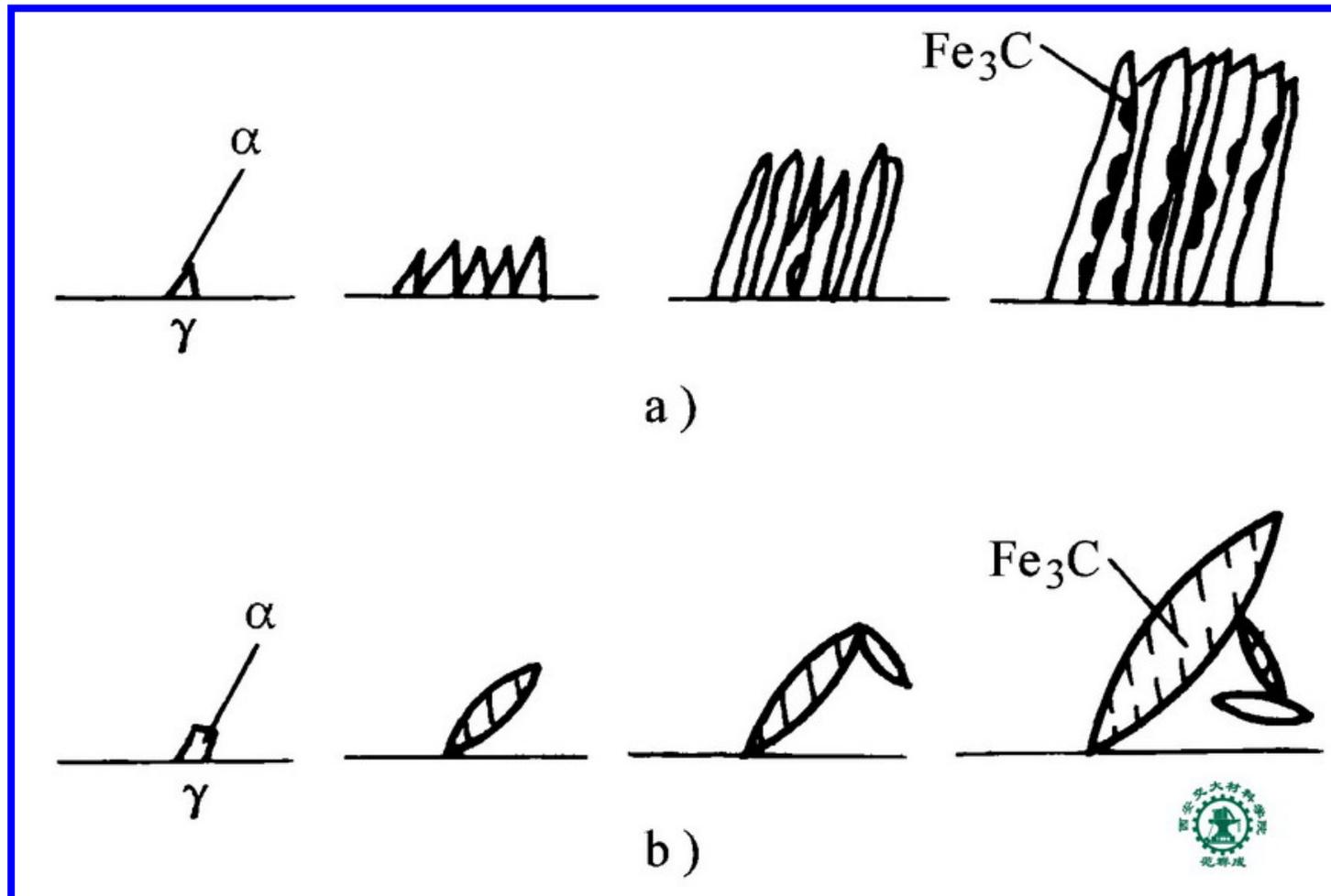
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Microstructures of pearlite formed at different isothermal hold temperature (a) 655°C, (b) 600°C, and (c) 534°C

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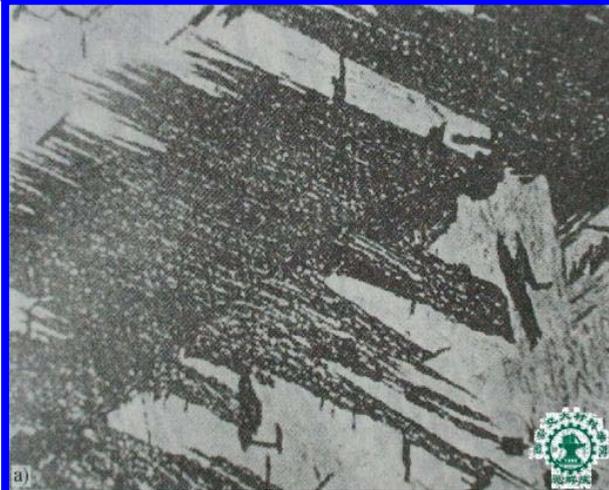
2) Bainitic transformation



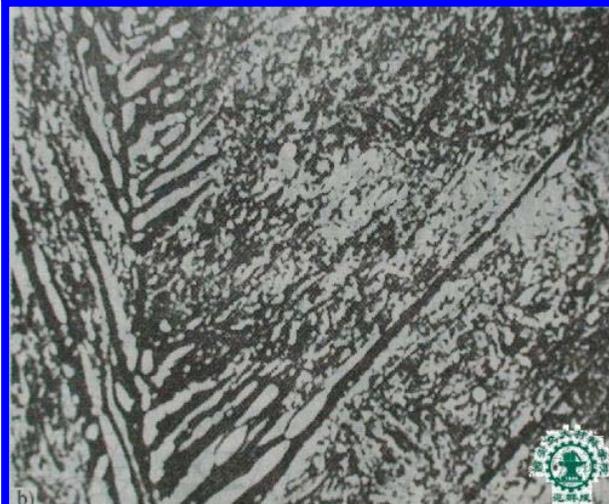
Schematic of bainitic forming

a) upper-bainite b) down-bainite

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a) $\times 500$



b) $\times 10000$



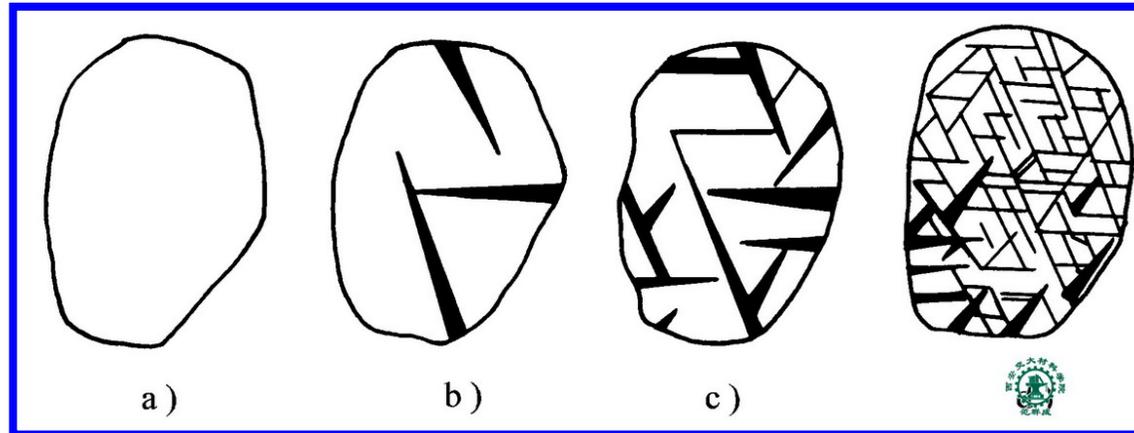
a) $\times 500$



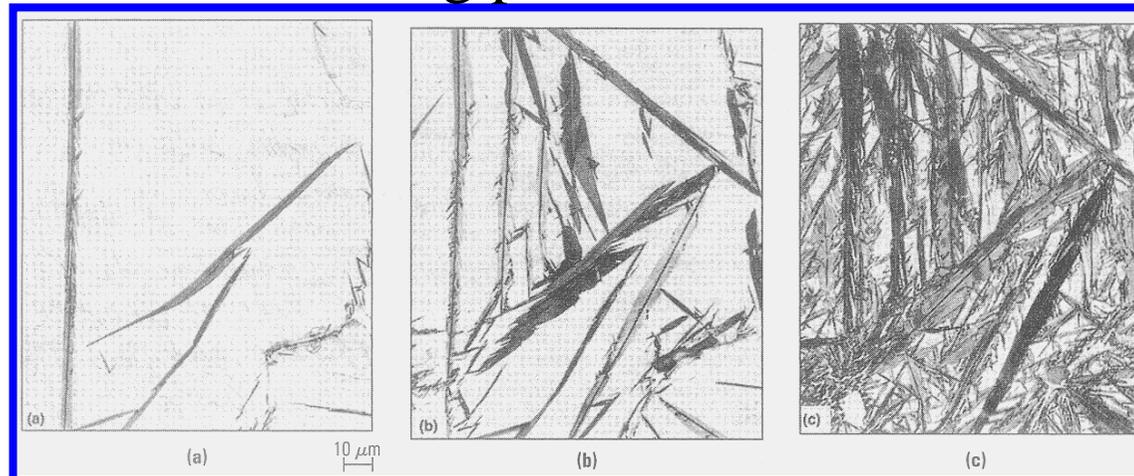
b) $\times 10000$

Microstructure of upper-bainite Microstructure of down-bainite

3) Martensitic transformation



Schematic of forming process for needlelike martensite



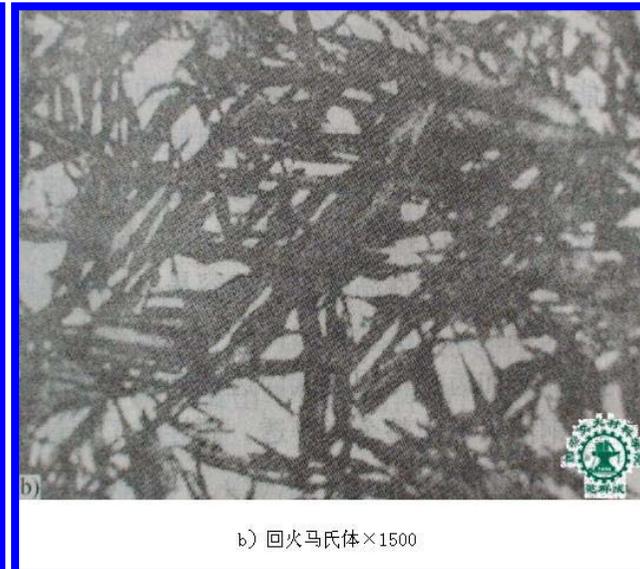
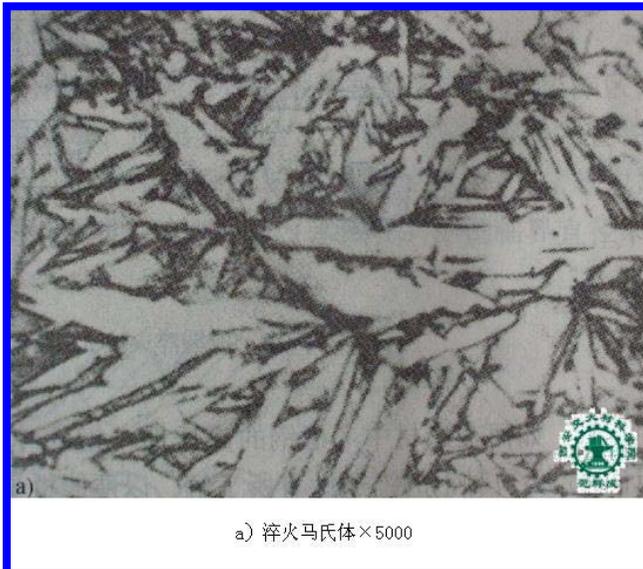
Progress of athermal martensitic transformation in an Fe-1.8 wt. %

THE END

C alloy cooling to (a) 24 °C, (b) -60 °C, and (c) -100 °C



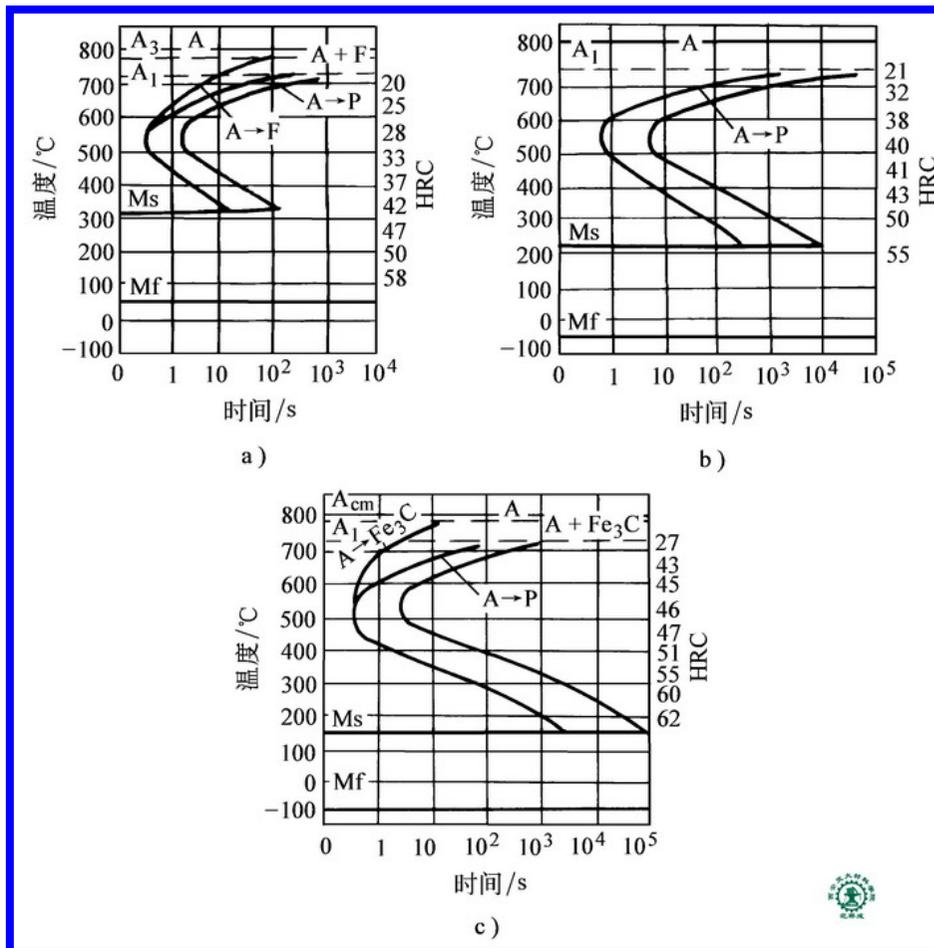
Micrograph of low carbon martensite



Micrograph of high carbon martensite a) quenched b) tempered

4. The main factors affecting isothermal transformation diagram of austenite

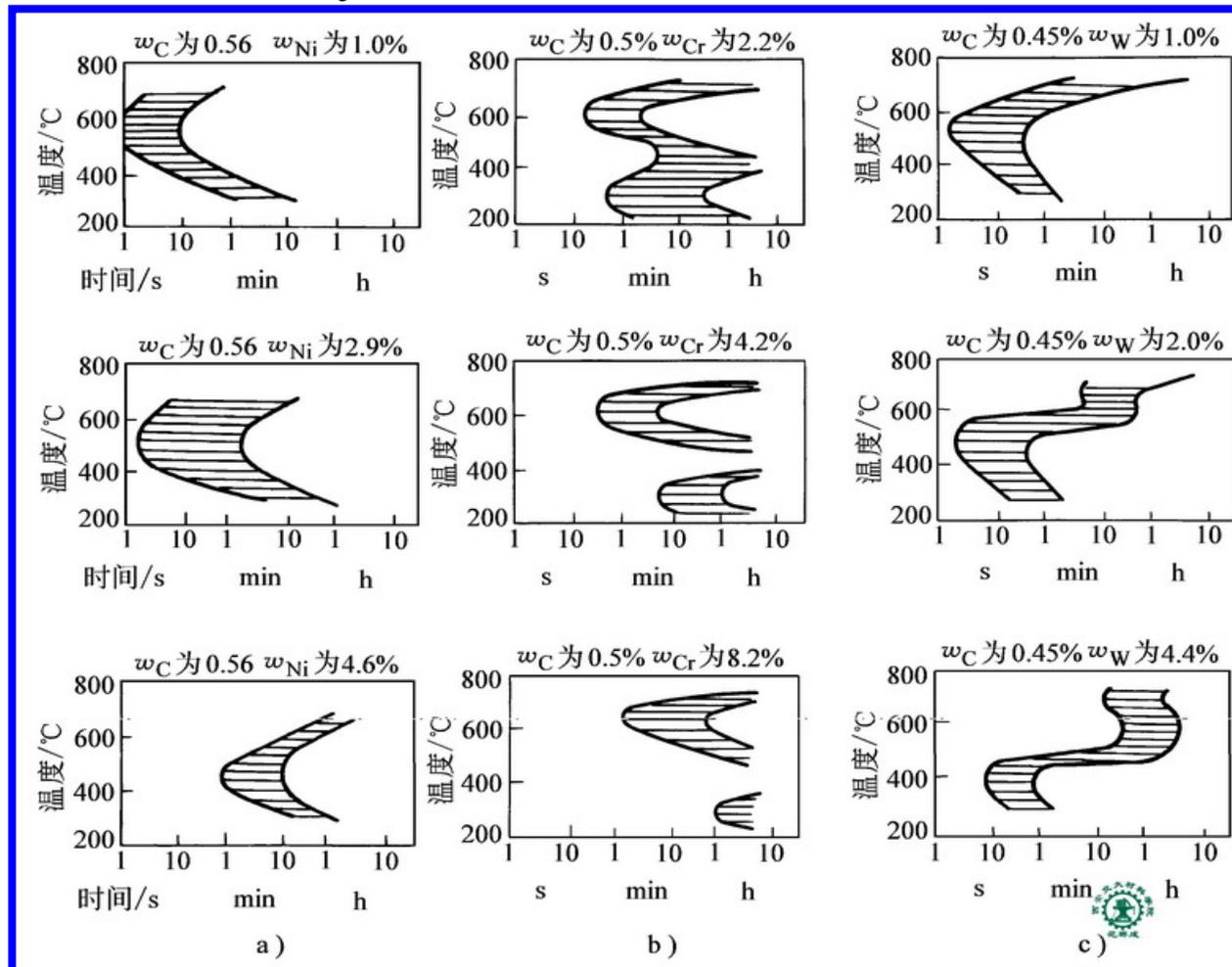
1) Effect of carbon content



Comparison among the isothermal transformation diagrams of (a) hypoeutectoid steel and (b) eutectoid steel and (c) hypereutectoid steel

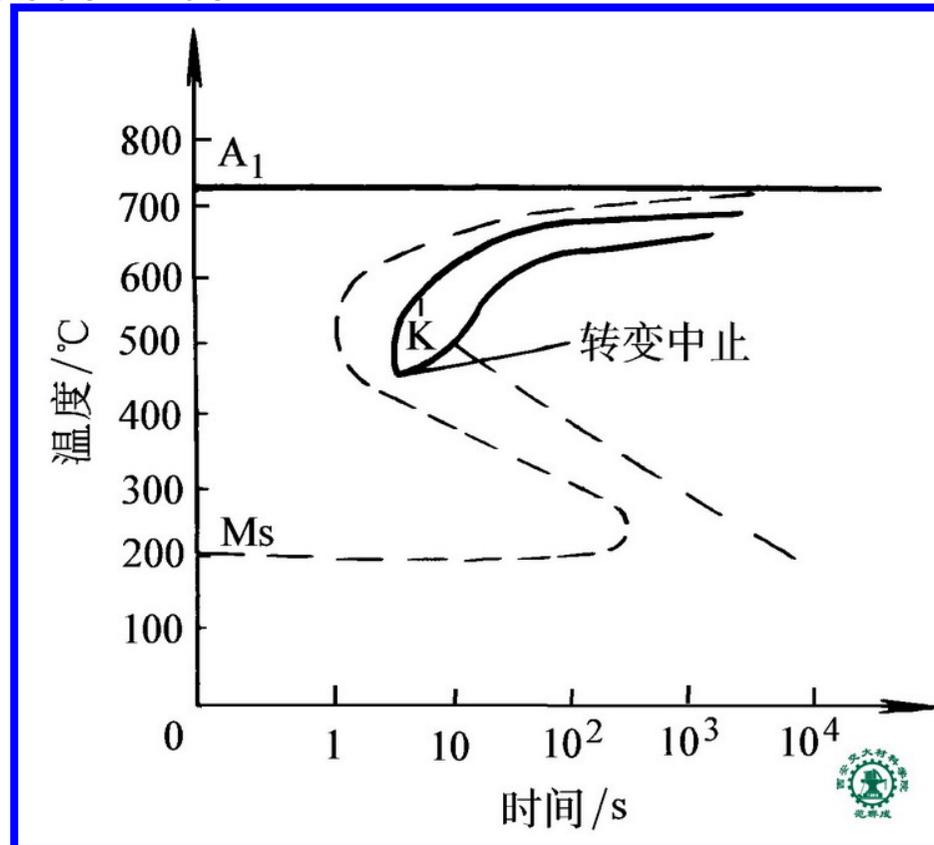
THE END

2) Effect of alloy elements



The effects of alloy elements on the isothermal transformation diagram of austenite, (a) effect of Ni, (b) effect of Cr, (c) effect of W

3.2.2 Continue cooling transformation diagram of austenite



Comparison between the continue cooling transformation diagram (continue line) and the isothermal transformation diagram (dashed line) of austenite for eutectoid carbon steel

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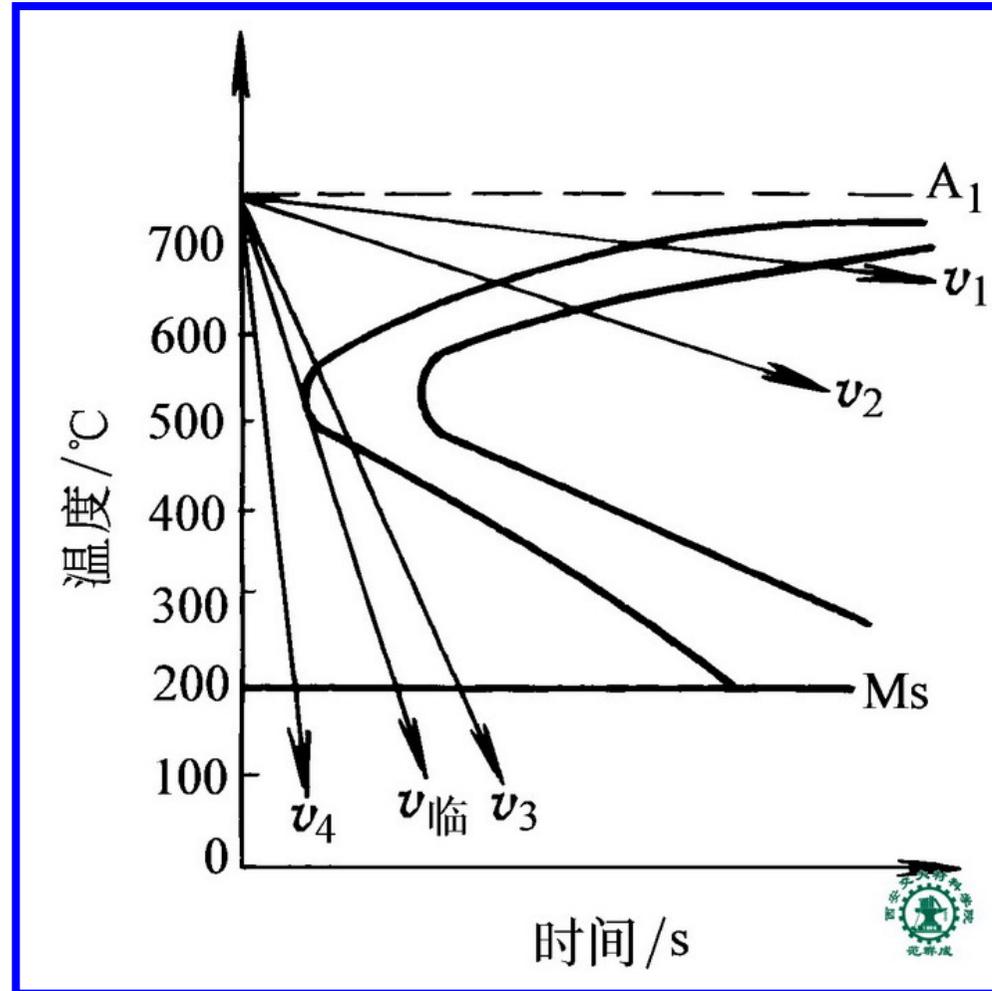
v_1 — P

v_2 — S

v_3 — T + M + A'

v_4 — M + A'

v_C — M + A'



Schematic of application of the isothermal transformation diagram of austenite for eutectoid steel as continuous cooling

THE END

§ 3-3 Common heat treatment of steel

3.3.1 Annealing of steel

1. Complete annealing
2. Spheroidizing annealing
3. Relief annealing

THE END



THE END

Complete annealing of 40 steel

3.3.2 Normalizing of steel



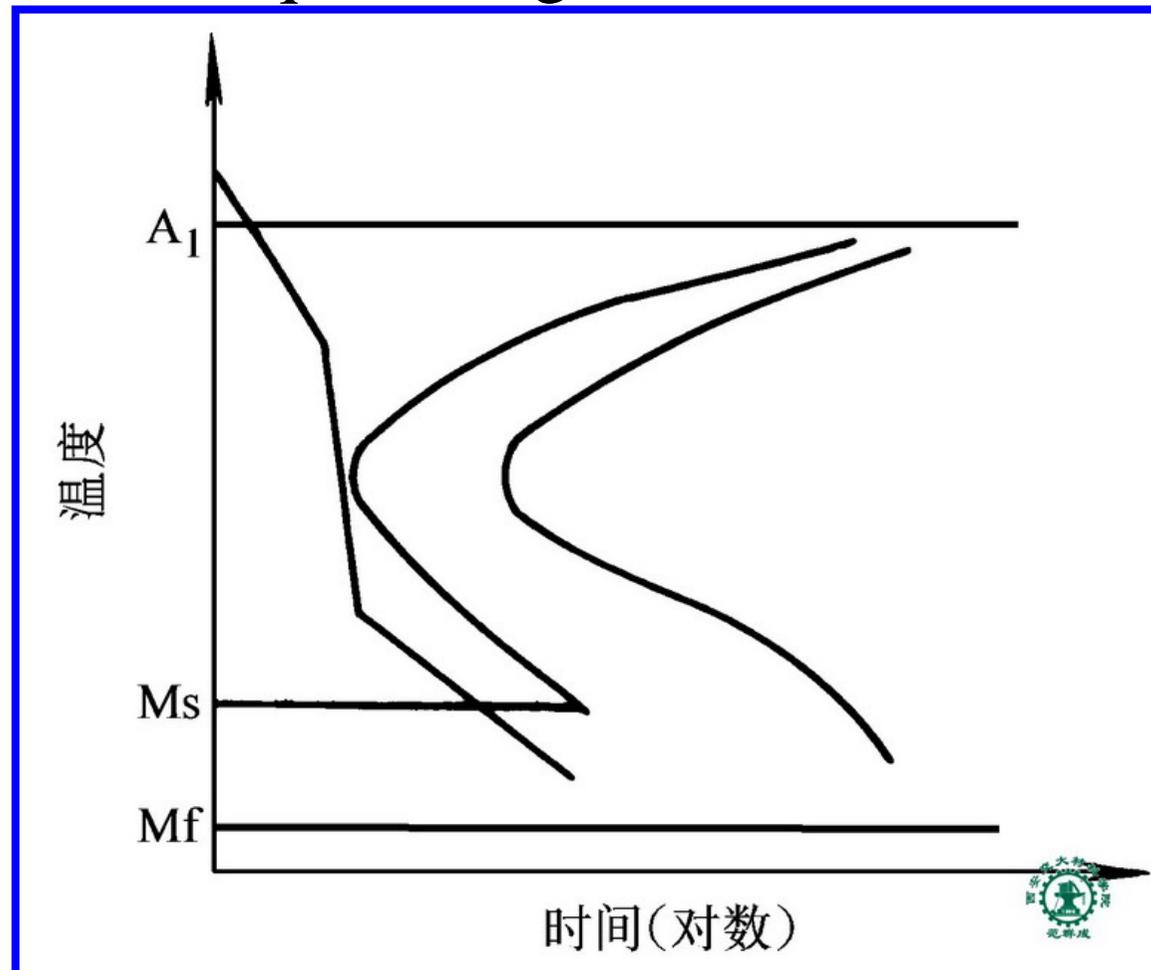
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3.3.3 Quenching of steel



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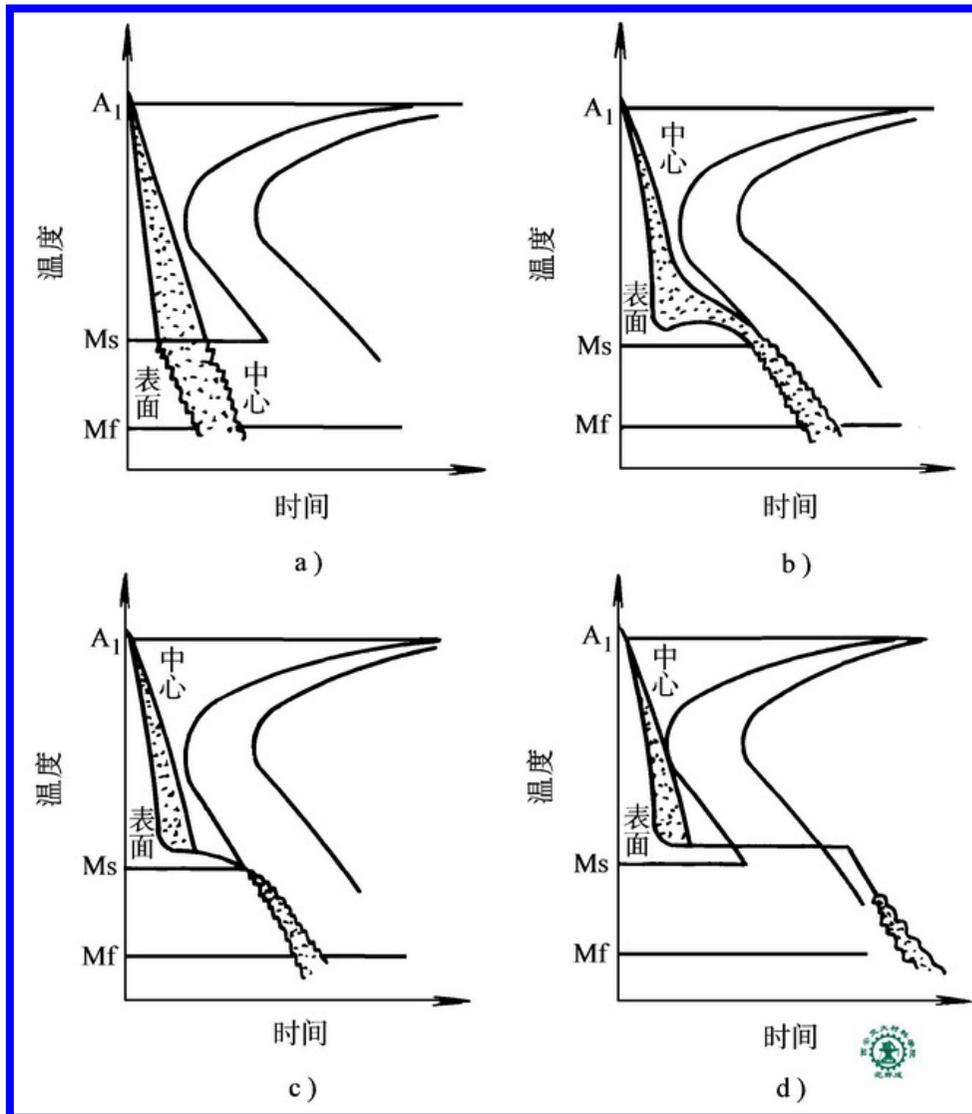
1. Purpose of quenching
2. Medium of quenching



Perfect cooling velocity for quenching of steel

THE END

3. Common methods of quenching



Schematic of common methods of quenching

(a) single-stage quenching

(b) double quenching

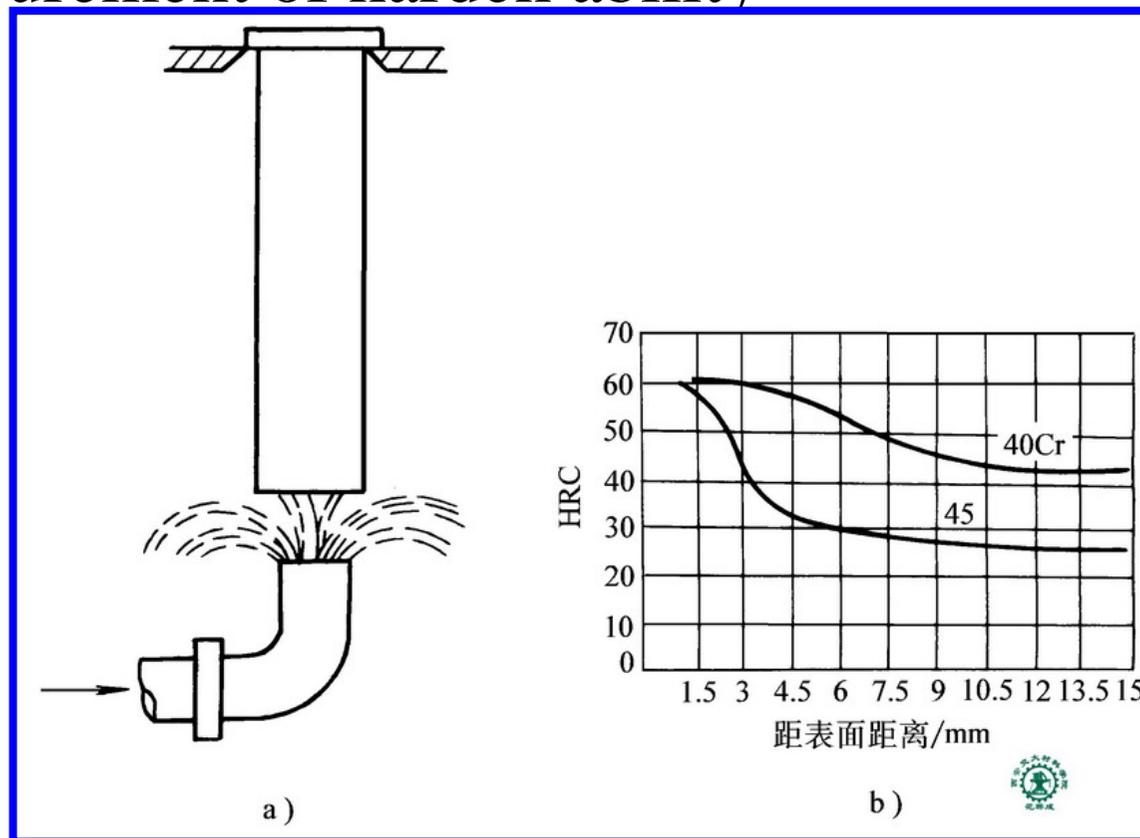
(c) step quenching

(d) isothermal quenching

THE END

4. Harden ability of steel

- 1) What is the harden ability of steel
- 2) Measurement of harden ability



Top-quenching method a) and the curve of harden ability

THE END

- 3) Main factors effecting the harden ability of steel
 - The essence effecting the harden ability of steel — incubation period of super-cooling austenite in the C curve of the syeel
 - The content of carbon in steel
 - The alloy element in steel
- 4) How to consider the harden ability of steels as selecting materials

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3.3.4 Tempering of steel

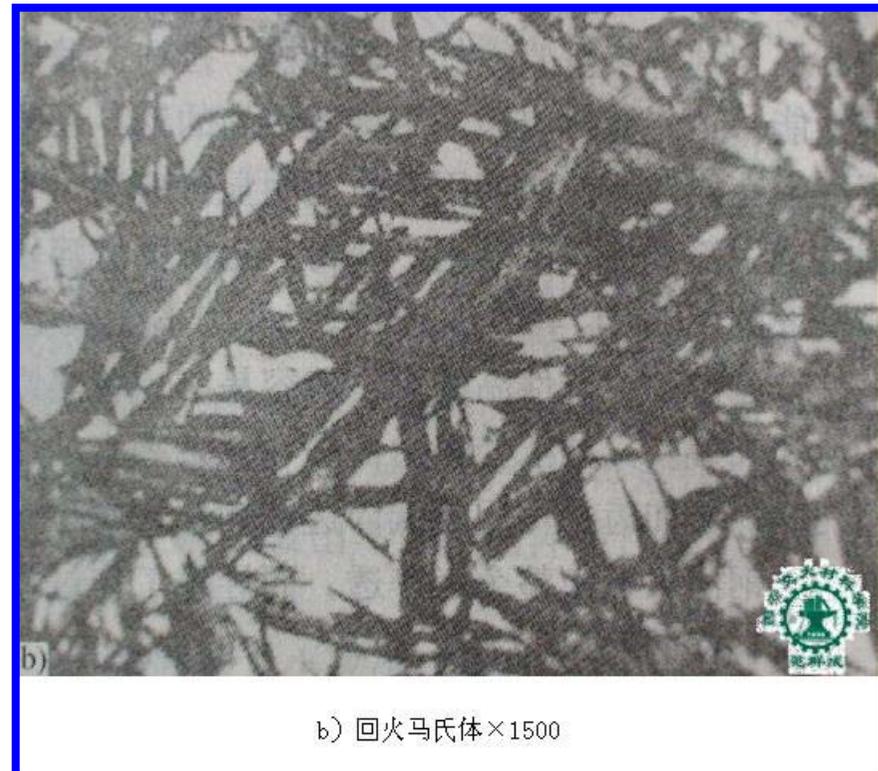
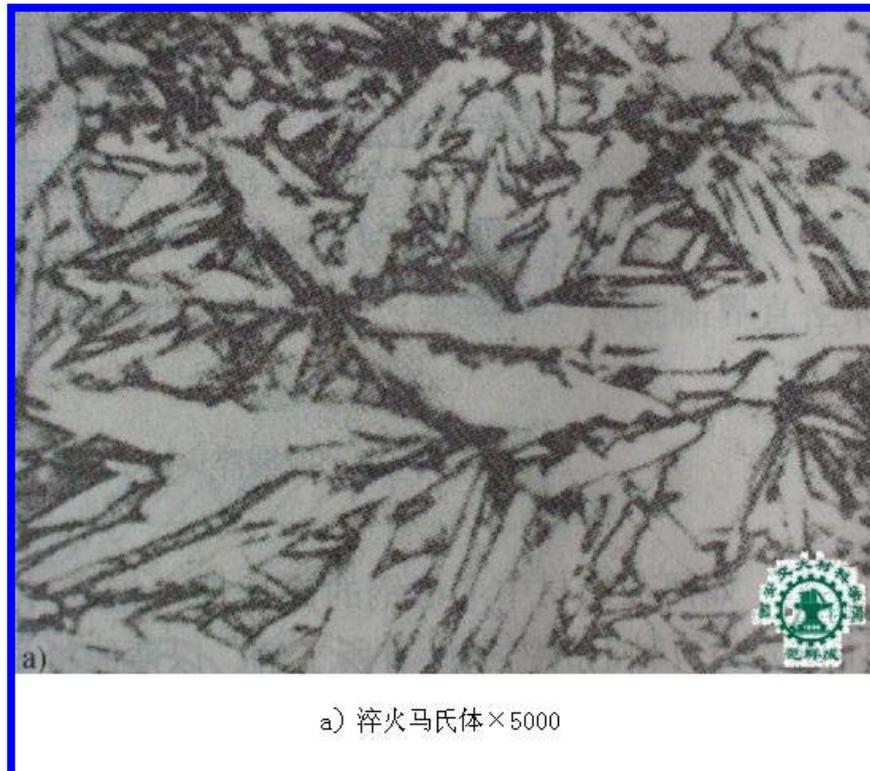
1. What is the tempering of steel



THE END

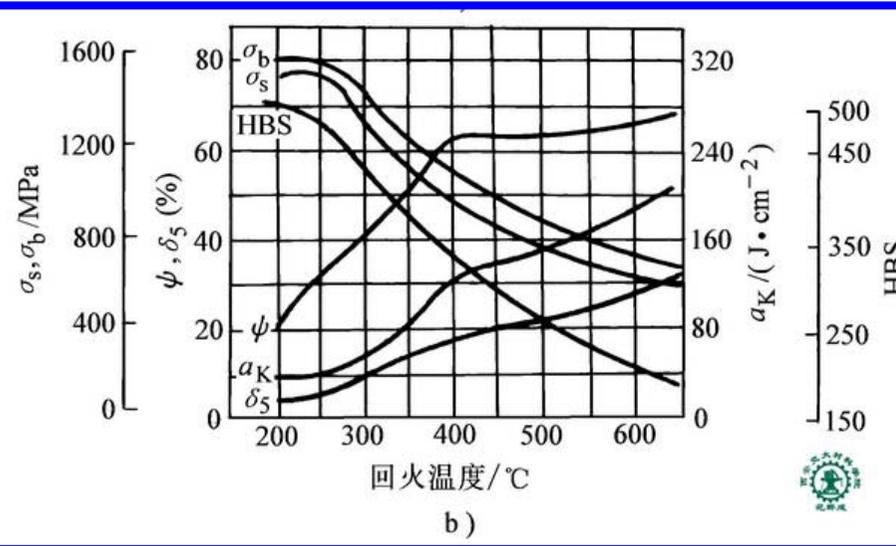
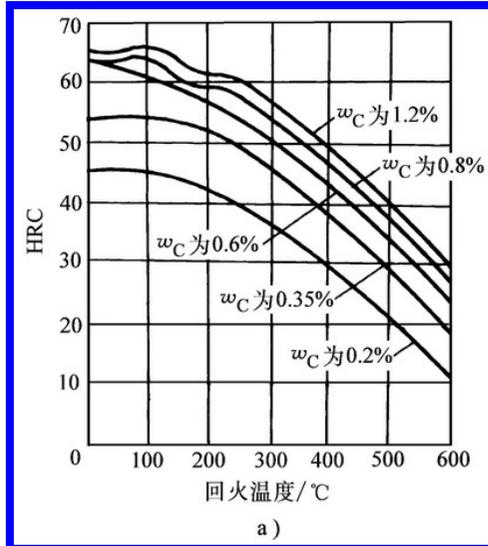
2. Purpose of tempering

3. The changes in structure and property of quenched steel as being tempered



Microstructures of quenched martensite a) and tempered martensite b)

THE END



Changes in mechanical properties of quenched steel with tempering temperature a) change in hardness of steel with different carbon content b) changes in various of mechanical properties of 35 steel

4. Class and application of tempering

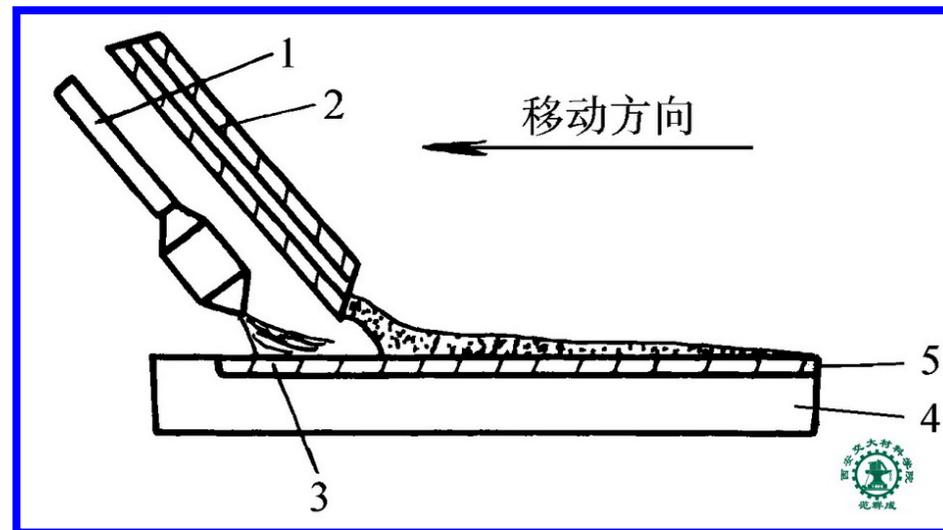
- 1) Low tempering $150 \sim 250^\circ\text{C}$
- 2) Average tempering $350 \sim 500^\circ\text{C}$
- 3) High tempering $500 \sim 650^\circ\text{C}$

THE END

§ 3-4 Surface heat treatment of steel

3.4.1 Surface quenching

- Purpose of surface quenching
 - Steel applying to surface quenching
 - Common methods of surface quenching
1. Surface quenching by flame heating



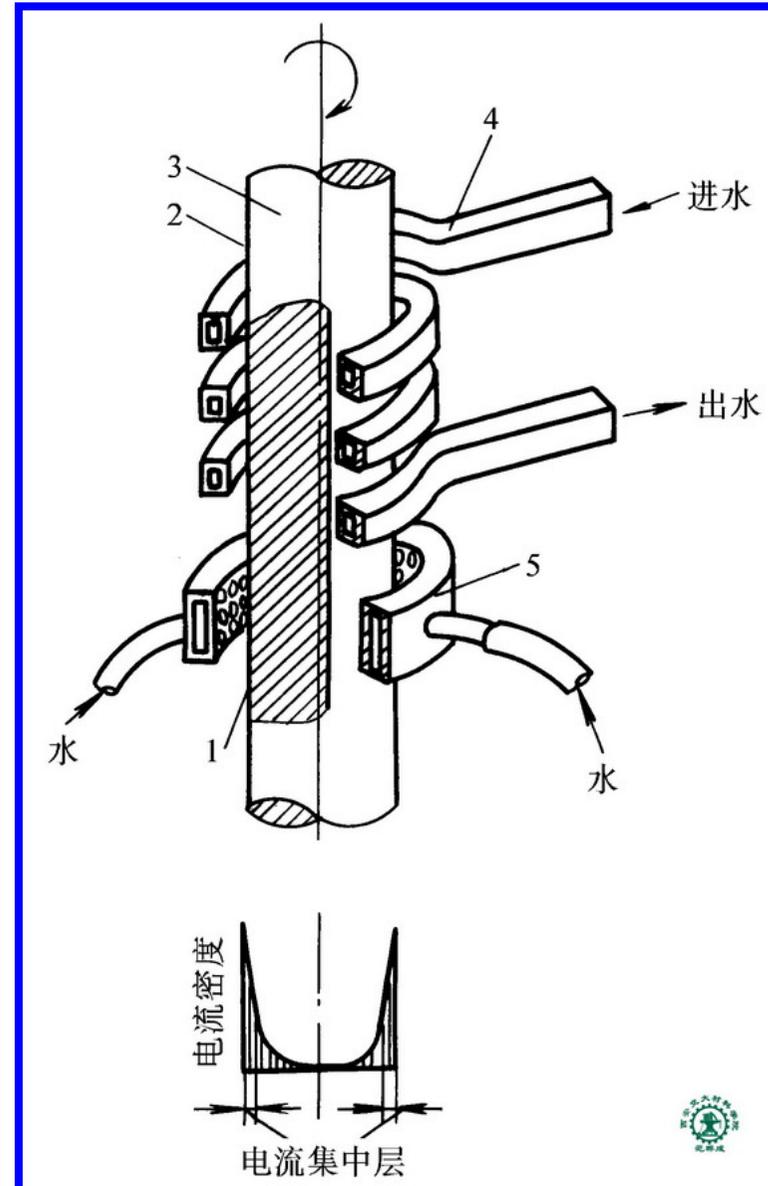
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Schematic of surface quenching by flame heating

2. Surface quenching by induction heating

- 1) Fundamental principle
- 2) Induction frequency
- 3) Pretreatment
- 4) Post treatment
- 5) Final structure

Schematic of surface quenching by induction heating



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Arrangement of hardened layer of a surface-quenched gear by induction heating

THE END

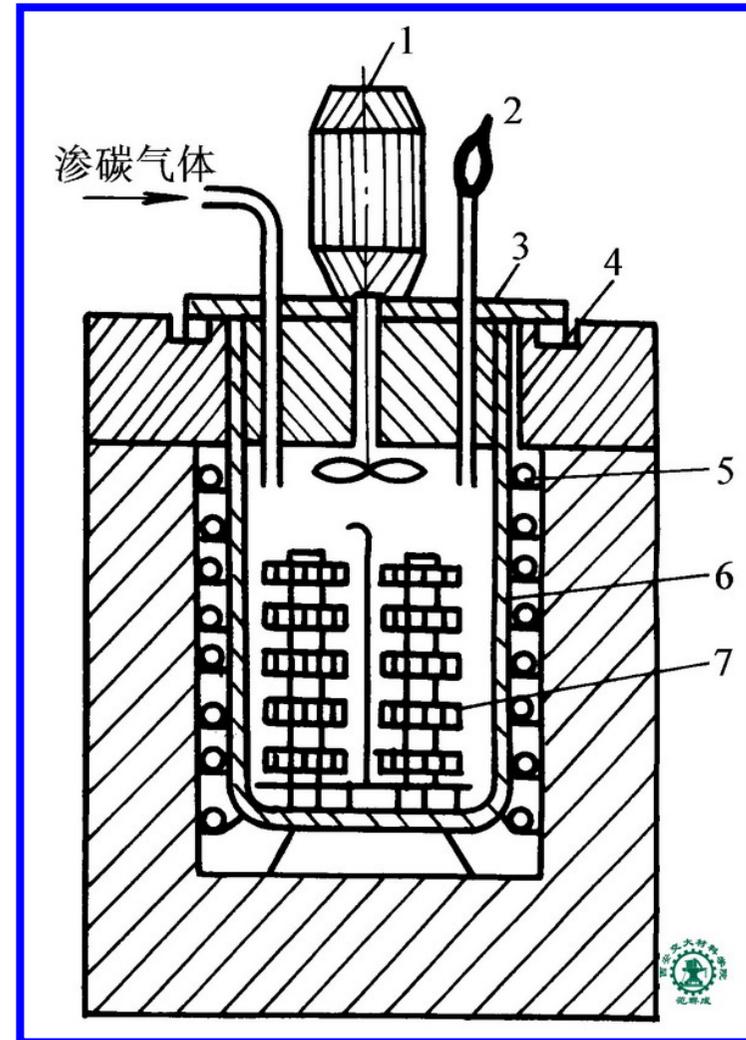


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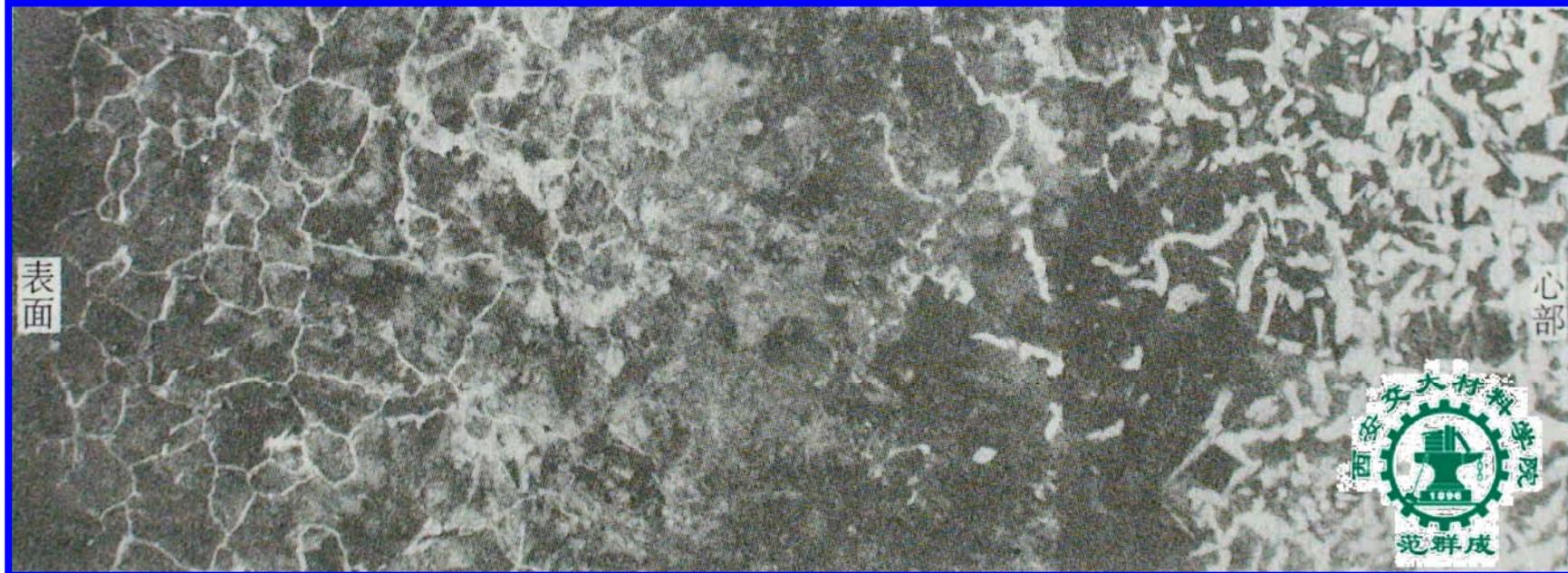
A cylinder liner Surface-quenched by laser heating

3.4.2 Surface chemical heat treatment

1. Purpose
2. Common methods
3. Gas-carburizing of steel
 - 1) Fundamental principle
 - 2) Steel applying to carburizing
 - 3) Temperature for carburizing
 - 4) Post treatment
 - 5) Final structure



Schematic of gas-carburizing method



Structure of low carbon steel as slow cooling after being carburized

THE END



THE END

A carburized gear