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# The Technology of Mould Steel for Online Pre-hardening

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**Abstract**

This article describes a production method of mould steel pre-hardening, and focus on the advantage of this method, The technical core of method is the variable frequency and variable amplitude pulse uniform high-precision temperature control, which achieved by using strong-medium-weak water cooling, gas-water cooling and gas mist cooling composite cooling control technology. Optimizing the cooling rate path is a good method of optimizing quenched organization and structure.



Keywords: mould steel; pre-hardening; the variable frequency and variable amplitude pulse temperature control; quenching; cooling rate change path

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## 1. Introduction

The online pre-hardening production line of mould steel, jointly developed by School of Mechanical Engineering, School of Automation and Electrical Engineering, School of Materials Science and Engineering of University of Science and Technology Beijing, Dongbei Special Steel Group and Beijing Anxin Zhongyuan Technology Development Co. Ltd was successfully put into production in November 2011(fig.1).

Fig.1. The variable frequency and variable amplitude pulse control online pre-hardening production line of mould steel

The production line has the following characteristics:

- The pre-hardening production line is located behind the mould steel mill, using remainder heat quenching on mould steel. It can omit many processes in the traditional production of mould steel, e.g. steel off-lining, cooling, reheating and quenching. Therefore, it has significant energy saving effect and 3 million kWh can be saved per 10 thousand tons plate production, which greatly reduced production costs.

- The variable frequency and variable amplitude pulse uniform high-precision target temperature control technology can greatly improve production quality. And it was put into production only 3 months, for thickness of 20mm-150mm and width of 850mm mould steel, the whole plate tempering hardness difference does not exceed 3 HRC and basically no less than 1.5HRC.

- The using of a variety combinations of control means, such as water-cooling nozzles, gas-water nozzles and gas mist nozzles and so on, making the production line has a wide range of cooling continuously adjustable. This facilitates the development of new production, and has successfully developed P20, 718, P20M, P20H, 4Cr13H and so on many kinds of pre-hardening flat and military steel, which were put into production only in 3 months.

- The combination of model pre-set, the model self-learning, online quality judgement and many kinds of modern control technologies and controlled cooling methods is conducive to the mould steel organizational structure control.

- The mould steel controlled rolling combined online quenching technology, effectively ensuring the organization and the temperature of the mould steel before quenching.

The variable frequency and variable amplitude pulse uniform high-precision target temperature control technology of the mould steel

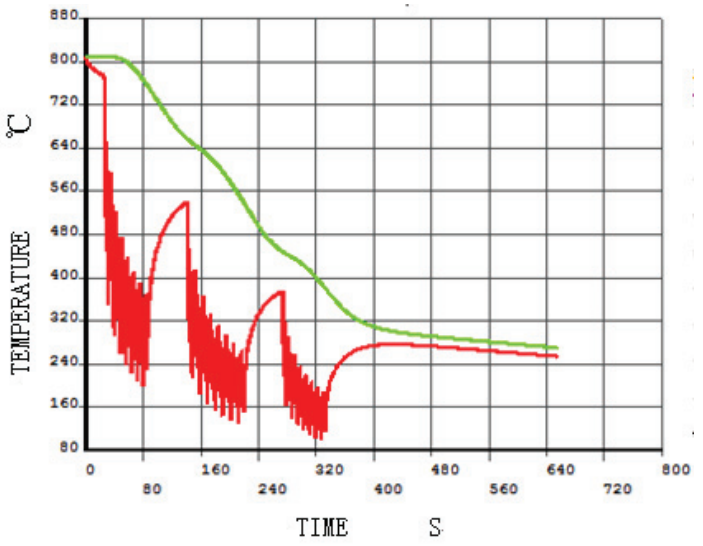



Fig.2. The variable frequency and variable amplitude pluse uniform high-precision target temperature control technology principle

For most mould steel, e.g. P20, 718 H, if quenched organization is martensite, the tempered organization will be uniform and fine; if quenched organization is bainite, the tempered organization will be coarse, and polishability will be worse than the former. Therefore, in the case of possible, quenching process model strived for martensite. But in order to obtain martensite, quenching process is required to have a higher cooling rate. This will result in a large temperature difference between the quenching mould steel surface and core, in addition to the large martensitic transformation volume expansion, crack easily produced. The better method of solve this contradiction is to make the whole workpiece martensite gradually, that is to say, when the workpiece is rapidly cooled to soon reach the martensite transformation temperature, immediately stopped cooling and return temperature, and so forth, until the entire workpiece organization is martensite. This rapid variable cycle and variable temperature amplitude and the martensite transformation temperature for the goal method are called the variable frequency and variable amplitude pulse target temperature control. This technology (fig.2) is the key of this quenching line.

## 2. Cooling Control technology characteristics

In order to complete the variable frequency and variable amplitude pluse uniform high-precision target temperature control technology, using strong-medium-weak water cooling, gas-water cooling and gas mist cooling composite cooling control technology on the production line.

### 2.1. The cooling rate control technology

The key of the above composite cooling control is the cooling rate control. Different cooling method has different heat transfer coefficient and different cooling rate. Fig.3.a is heat transfer coefficient under different water quality. Fig.3.b is heat transfer coefficient change curves under different air volume fraction.

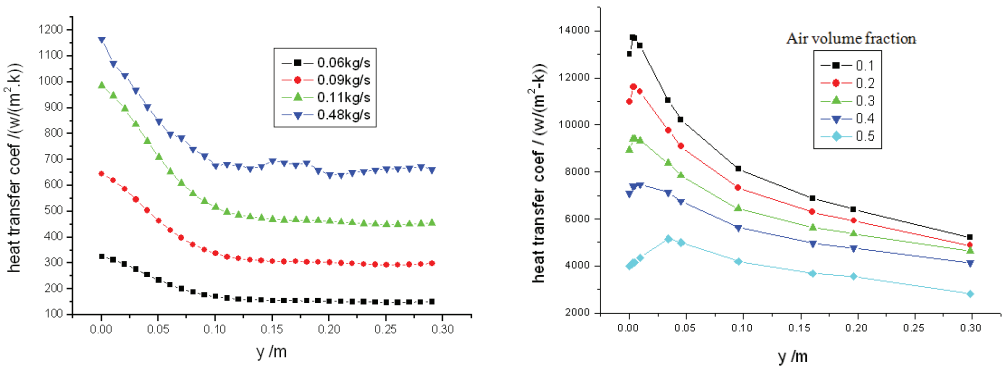



Fig.3.(a) heat transfer coefficient under different water quality;(b) heat transfer coefficient change curves under different air volume fraction

### 3.2. Uniform controlled cooling technology

- Variable frequency regulation technology

The cooling water system must be stable on production line, so using variable frequency regulation technology to ensure stable cooling water pressure.

- Uniformly distribute gas-water technology for nozzle

Each nozzle tank has many small nozzles. Using the uniform damping design can obtain nozzle water evenly distribute.

- Strong adaptation lateral cooling technology

In cooling lateral steel plate plane, as the middle location of transverse plate is cooled slowly and plate edge is cooled quickly. To ensure the plate lateral cooling uniform, the cooling intensity of nozzle must be strong at middle location and weak at plate edge. Due to the different thickness and width plate has different optimized lateral cooling curve, according to optimization, we find a curve can meet requirements of different thickness and width of the transverse uniform cooling plate, namely adaptation lateral cooling curves.

### 3.3. Control technology of the whole plate cooling target temperature

It must have a comprehensive control pre-set model that control the full range of the variable frequency and variable amplitude pluse target temperature control to ensure the whole board evenly hardening. Fig.4 is the program diagram of online pre-hardening mould steel.

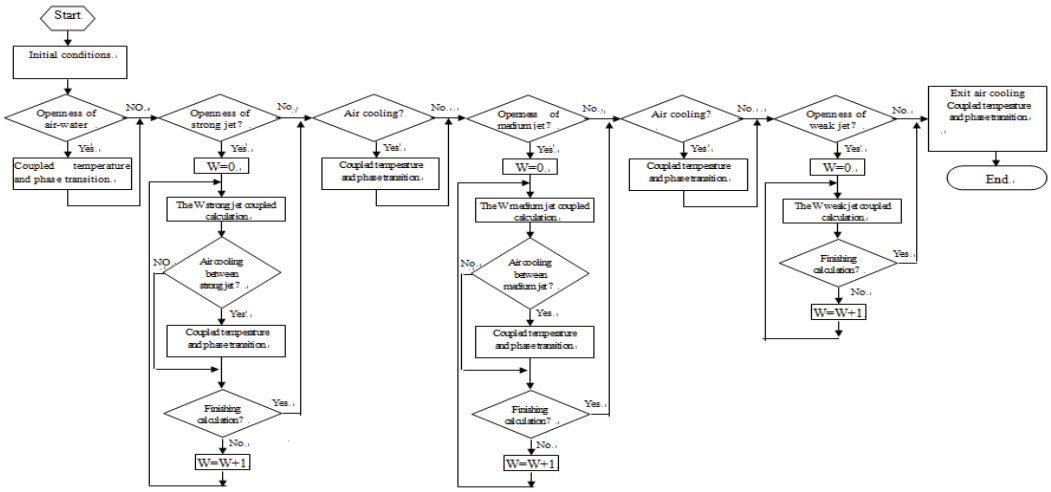
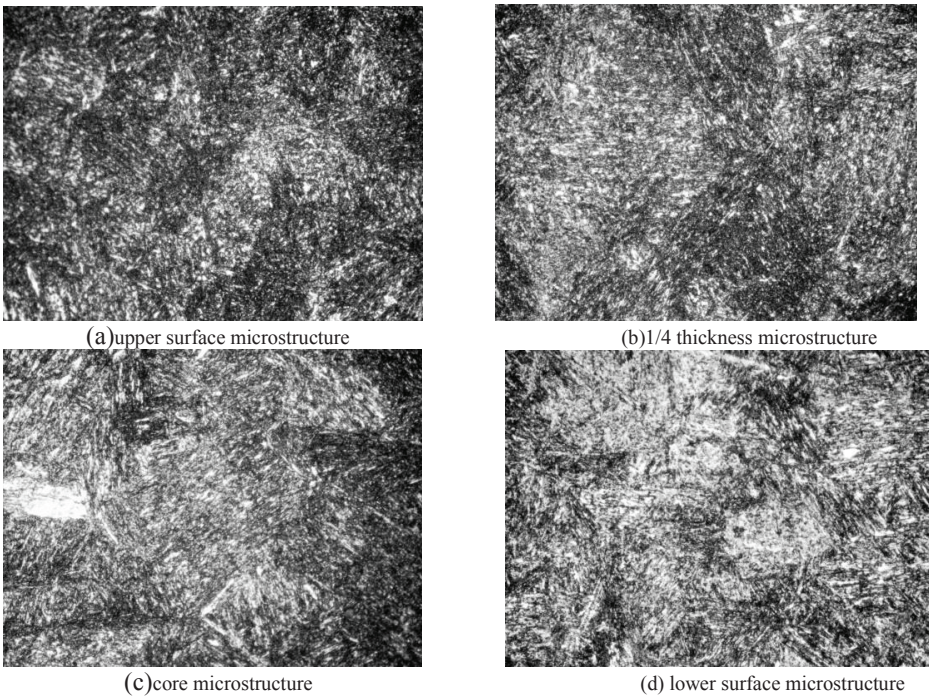



Fig.4. the whole plate cooling target temperature control of the mould steel online pre-hardening

## 4. Control technology of quenched organization and structure

*4.1. According to the mould steel dynamic CCT curve, taking obtaining martensite of the plate core as the goal, we developed the change path of cooling rate technology*



(a)upper surface microstructure (b)1/4 thickness microstructure

(c)core microstructure (d) lower surface microstructure

fig.5.(a) upper surface microstructure;(b) 1/4 thickness microstructure;
(c) core microstructure;(d) lower surface microstructure

Such as P20 mould steel, when the cooling rate is 0.5-1℃/s，the austenite is transformed to martensite and bainite. When the cooling rate is faster than 2℃/s, the transformation product of austenite is mainly martensite. After the processes of quenching, returning temperature, then quenching, and then returning temperature, the organization of surface and core is martensite.

For 718H mould steel, according to its dynamic CCT curve, when the cooling rate is faster than 0.2℃/s, the austenite is transformed to martensite.

By controlling cooling rate and optimizing cooling path, the mould steel can obtain more martensite. Fig.5.a—fig.5.d are the microstructure of the 718H mould steel (thickness 90mm) after quenching in upper surface, 1/4 thickness, core, and lower surface.

### *4.2. Different reduction rate of flat mill lead to different coarseness of martensite lath*

Generally speaking, the more large reduction rate of mill is, the more small martensite lath after quenching is fine. This is mainly because the austenite generated in a large number of dislocation and deformation zone, as the rolling reduction increases, hindering the growth of the martensite lath. Thus the martensite lath becomes small , and also increases the hardness of the mould steel.

## 5. Conclusion

- The online pre-hardening technology of mould steel is a good method of mould steel production.
- The variable frequency and variable amplitude pulse uniform high-precision target temperature control technology is a good technology of the online pre-hardening technology of mould steel.
- Strong-medium-weak water cooling, gas-water cooling and gas mist cooling composite cooling control technology is a good method for implementing the variable frequency and variable amplitude pulse uniform high-precision target temperature control technology.
- Optimizing the change path of cooling rate is a good method of optimizing quenched organization and structure.

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