Analysis on Key Production Control of High Carbon Wire Rod for Automotive Bead Wire

Cao Shuwei, Yang Xiaoqi, Du Yawei, Chen Zhanjie

Anyang Iron and Steel Group Co., Ltd., Anyang, Henan, China

Abstract—SWRH72A high carbon steel wire rod is an important raw material for producing automotive bead wire, hose steel wire and steel wire-robe. Based on design of chemical composition, reasonable adjustment and optimization of smelting and continuous casting process, reheating process, rolling process and cooling process etc., Anyang Iron And Steel StockCo., Ltd. produced successfully Φ 5.5 mm and Φ 6.5 mm high carbon steel wire rod grade SWRH72A by its 100t Converter-High Speed Wire Rod Mill. The results showed that the chemical composition control was narrowrange, centerline segregation was low, production process of trial steel was reasonable. The wire rod was in good mechanical performance with the range of tensile strength deviation of less than 50 MPa for same heat, same nominal diameter and same rolling system, the sorbitic metallographic structure of wire rod reached more than 90%. The performance indexes met the requirements of the bead wire users.

1. Introduction

The drawn product of high carbon steel wire rod is one of the main materials for manufacture of bead wire, hose wire and steel cord for radial tire. With the development of automobile industry in our country, the demand of bead wire is increasing year by year [1]. The high carbon steel wire rod with high quality is an important raw material for the manufacture of steel wire rope, pre-stressed steel wire, bead wire, spring wire and steel cord, etc. which is a high value-added product and has a wide market. SWRH72A high carbon steel wire rod is mainly used for the manufacture of cold drawing or cold rolling products as well as the framework material of rubber products, such as tire, conveyor belt and high pressure hose. The steel wire must has the excellent comprehensive mechanical properties of high strength, good toughness, antifatigue and impact resistance, and it is the high strength steel wire rod for deep processing of wire drawing [2]. Angang Group, as the main steel wire rod manufacturer in China, has the advantages of large-scaled and modernized equipment, its process control can completely satisfy the needs of the development of high grade variety of steel wire rod. For exploring the domestic and overseas markets, increasing the market competitiveness, improving the quality of products, promoting the upgrade of products and realizing the fine-product strategy, it carried on the R&D and trial production of SWRH72A high carbon steel wire rod.

2. Production process

2.1 Process flow

SWRH72A high carbon steel wire rod adopts the following production process:

BF hot metal → 100t convertor melting → LF secondary refining → 150mm×150mm billet
continuous casting →walking beam furnace reheating→high pressure water descaling→high speed wire rod mill rolling→laying→Stelmorcooling→reformtube→P/F line conveying→finishing, testing→packing→warehousing.

2.2 Composition design
SWRH72A high carbon steel wire rod are mainly used for manufacturing bead wire and other deep drawing products, whose technical quality requirements are stricter than normal high carbon pre-stressed wire. It requires narrow control range of chemical composition, small centerline segregation, pure steel and low content of hazard elements. Combining with the condition of process equipment, the chemical composition design of trial steel is given in Table 1.

| C       | Si | Mn    | P   | S   | Cr | Ni | Cu |
|---------|----|-------|-----|-----|----|----|----|
| 0.70~0.74 | 0.15~0.30 | 0.40~0.60 | 0.020 | 0.015 | 0.10 | 0.10 | 0.10 |

2.3 Steelmaking process

2.3.1. Melting process
It adopts high carbon melting process. In the process of melting, the key points are controlling C, Mn and Si of steel in a narrow range, and controlling lower content of P, S and residual elements in steel. To reduce the content of residual elements, the high quality scrap or self-produced scrap is used, the tapping temperature is required to more than 1600°C, the tapping top slag charges lime and fluorite, pre-deoxidation and alloying prefer to use Mn-Si alloy and a small amount of Fe-Si, end-deoxidation uses Calcium carbide, silicon carbide. Secondary slag-stopping is taken and slag carrying over is strictly prohibited for nozzle and tapping hole. The refining time of LF furnace is not less than 50 minutes, the retention time of white slag is not less than 15 minutes, and the weak stirring time is not less than 10 minutes.

2.3.2. Continuous casting process
The quality of continuous casting billet has a big effect on the property of final product. The inner core area of billet should be dense (loose and shrink hole should be small), the centerline segregation of billet should be small [3]. Especially for manufacturing high quality steel wire, centerline segregation and composition fluctuation will cause nonuniformity of wire rod performance and wire broken easily. The centerline segregation of SWRH72A wire rod of Angang Group is required not more than level 3. To ensure obtain the good solidification of billet, the full protection is used for continuous casting to guarantee Ar sealing of long nozzle. The long nozzle sealing gasket is used for good sealing of submerged nozzle to ensure the submerged nozzle centerline in mould. By using electromagnetic stirring in mould and double layers of casting powder in tundish, the lower layer is neutral covering agent, and the upper layer is carbonated rice husk. It requires the low target overheat and steady casting speed.

2.4 Steel rolling process

2.4.1. Reheating process
Reheating furnace is side-in and side-out walking beam type. The maximum heating capacity is 140t/h. From the charging side to discharging side, along the length direction, the furnace are divided into preheating section, heating section and soaking section, and their lengths are 6250mm, 7750mm and 6700mm respectively. For flexibly adjusting the temperature of each section and adapting the heating requirement of easy decarburized steel, the screwdown structure was installed at the top of soaking section and heating section. The control system network is 2-level structures with total of 6 automatic
temperature control sections, which can realize the calculation and control of optimized combustion digital model and guarantee the heating quality of billet.

2.4.2. Controlled rolling process
This production line adopts fully continuous non-twisted arrangement with 30 rolling stands. The mill is consist of 5 groups that are 6 roughing stands, 8 intermediate rolling stands, 4 pre-finishing stands, 8 finishing stands and 4 reducing/sizing stands. Cooling water tanks are arranged behind pre-finishing stand, finishing stand and reducing/sizing stand, which ensures the accurate temperature control to rolled piece in the process.

High precision geometry, uniform rod size, and smooth and non-defect surface are the development characteristics of high speed steel wire rod and the requirements of excellent drawing performance [4]. It uses the latest patented mill technology “8+4”of Morgan, that is adding 4 reducing/sizing stands after cooling section of finishing stand. This process has the following advantages: ① it can realize precision rolling, ensure size accuracy and make the precision of all product specifications reach±0.10 mm; ② it can simplify pass system, the finished rolling of the products of all specifications is completed by reducing/sizing mill, so roller change is reduced, and the operating rate is improved; ③ it can realize free rolling of certain specifications, increase product specifications; ④ it can reduce the rapid temperature rising due to deformation of rolled piece in high speed area, realize the temperature controlled rolling of low temperature high speed, thus ensure the metallurgical quality of the product, especially of the high quality high carbon wire rod.

2.4.3. Controlled cooling process
It adopts Stelmor conveyer with “Optiflex” plenums of large air volume, high air pressure and retarded cooling device developed by Morgan. The length of bulk cooling conveying line is 103.8m. The conveyer cover is 81m long, conveying speed is 0.1-2m/s, and the cooling speed is 0.3-20℃/s. For most of the steel grades, heat treatment process can be completed on-line to improve the metallurgical quality and uniform performance of products. Especially for steel cord, bead wire and pre-stressed wire, the obtaining performance can close to the index of lead bath quenching, and can reduce the diameter of Φ5.5mm wire to Φ1.2mm within one drawing pass, also can control scale forming. This not only omits the heat treatment before drawing, but also reduces the difficulty of surface cleaning for the next process, and finally get the products of excellent quality in all respects.

3. Trial result
3.1. Composition control
To ensure the smooth drawing and stranding, it requires the uniform and stable chemical composition, low content of hazardous element. The actual composition control of SWRH72A trial steel was given in Table 2. It can be seen that the fluctuation of composition is small, and especially the carbon control is very strict.

| Item     | C   | Si  | Mn  | P   | S   | Cr  | Ni  | Cu |
|----------|-----|-----|-----|-----|-----|-----|-----|----|
| Maximum  | 0.73| 0.23| 0.53| 0.014| 0.006| 0.03 | 0.012| 0.02|
| Minimum  | 0.71| 0.21| 0.51| 0.004| 0.006| 0.03 | 0.012| 0.01|

3.2. The control of centerline segregation
The centerline segregation of high carbon steel is one of the important factors that cause wire broken when drawing bead wire. Too high segregation degree will bring adverse effects on structure control in rolling process, and make the distribution of inclusion in steel non-uniform, easily to cause wire broken. The centerline segregation of high carbon steel is mainly generated by columnar crystal, and the casting temperature is the important factor to affect crystal growth [5]. During the trial production, when
strictly controlled the overheat of liquid steel and casting speed, used weak secondary cooling, the centerline segregation was improved obviously. The centerline segregation of wire rod is less than level 2, see Fig. 1 and Fig. 2.

![Fig.1 Macrostructure of steel billet](image1)

![Fig.2 Macrostructure of wire rod section](image2)

### 3.3. The structure control of wire rod

For structure of tested material is sorbite (the main) + pearlite + ferrite after controlled rolling and controlled cooling, please see Fig. 3. After hot rolling, the proportion of sorbite reaches 90~95% (area fraction) in the matrix, the higher content of sorbite structure ensures the good mechanical property and drawing performance of hot rolled wire rod.

![Fig.3 Microstructure of wire rod](image3)

### 3.4. Mechanical property control of wire rod

The reasonable controlled rolling and controlled cooling process makes the high proportion of sorbite in metallurgical structure of wire rod, thus obtained the ideal mechanical property. The mechanical property control is given in Table 3.

| Item         | Tensile strength Rm, MPa | Elongation A, % | Reduction of area Z, % |
|--------------|--------------------------|-----------------|------------------------|
| Maximum      | 1070                     | 22              | 59                     |
| Minimum      | 1020                     | 16              | 46                     |
| Average      | 1050                     | 18              | 52                     |

It can be seen from the table 3, the trial steel are rolled to the wire rod of Φ6.5mm, the fluctuation range of its tensile strength is not more than 50MPa, this completely reaches the requirement that the fluctuation range of the tensile strength of wire rod with same furnace number, same nominal diameter, and same rolling schedule is not more than 170MPa specified in the relevant standard of the state.

### 4. Application of wire rod

This batch of Φ6.5mmSWRH72A hot rolled wire rod for bead wire, produced by Angang Group, was supplied to a well-known domestic bead wire enterprise of China for test use. Its production process of wire drawing is: wire rod → inspection → paying-off → mechanical descaling → steam blowing → cold water rinsing → electrolytic pickling → borax → drying → rough drawing → lead bath heat treatment → fine drawing → tempering, copper plating → water rinsing → surface treatment → coating → drying → taking up. Practice showed that all performance data of SWRH72A hot rolled wire rods for bead wire, produced by Angang Group, can meet the requirement of bead wire industry.
5. Conclusion
SWRH72A high carbon steel wire rod for bead wire, developed by Angang Group, has the narrow control range of chemical composition, pure steel and lower hazardous element content. The process control of continuous casting is reasonable, the overheat control of liquid steel is strict, the casting speed is stable, the centerline segregation of billet is lighter, and the centerline segregation of wire rod is less than level 2. Through application by users it showed that the wire rod has the good surface quality, less decarburization, high proportion of sorbitestructure, good uniformity of mechanical performance, suitable strength and better use effect. It can completely meet the requirement of users, and lay the foundation for Angang Group to develop new grade of wire rod for steel cord.

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