Quality Improvement & Applications of Steel for Manufacturing Pneumatic Screwdriver Bits

氣動起子頭用鋼品質改善與應用

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1. Foreword

The steel used in manufacturing high-quality pneumatic screwdriver bits is mainly S2 type, which is an alloy steel that is highly impact resistant. As pneumatic screwdriver bits made from this type of steel feature high hardness and torque values favored by hand tool manufacturers, hand tool manufacturers always show a great affection for this type of steel that helps create very nice profit margins and dub it a “cash cow”.

However, the S2 type steel is with a high silicon content and hardenability, so when it is being rolled, it is susceptible to superficial cracking or surface defects of bar steel or wire coil resulting in sequential trimming or scrap, which not only reduces production, but also leads to disturbances like re-trimming, re-sampling, or even shipment delay. As a result, how to improve the problems of wire cracking and surface defects has been a very important task for the time being.

2. Production of Wire Coil and Manufacturing Procedures of Hand Tool Manufacturers

A. Manufacturing Procedures of Steel Plants

The detailed procedures for manufacturing S2 steel are as below:

1. The raw steel billet is produced with a casting machine and is later treated with heating, rust removing, preliminary rolling, and fine rolling. Then, it is cut into smaller steel billet, and is tested, grinded for removing superficial defects, before it is shipped to a wire factory and processed into steel bar or wire coil.
2. Smaller steel billet produced in a factory is delivered into various heating furnaces of each rolling factory at proper temperatures and duration settings, which are for ensuring even temperatures of steel billet and smooth rolling. After heat treatment and being cleansed by high-pressure water for rust removing, the wire is finally delivered to a factory for spheroidizing.

B. Manufacturing Procedures of Hand Tool Manufacturers

The detailed procedures of manufacturing pneumatic screwdriver bits made from S2 steel with extremely high hardness and torque values are as below:

Spheroidizing S2 wire coil→acid pickling→cold drawing hexagonal line→machining & milling→grinding semi-finished products→marking→quenching & tempering→fine grinding of finished products→surface treatment (electroplating or blackening)→finished pneumatic screwdriver bits

3. Problems Analyses and Improvement Solutions

A. Problems Analyses

As S2 steel is with high alloy content, when it is being rolled, it is susceptible to wire cracking and surface defects. With the increasing number of orders year after year, many people have started to take such a problem into serious consideration. Below is the explanation:

1. In a metallographic observation of S2 steel, if the spheroidized wire is found to show non-standard compliant cracking or surface defects, it then has to be retrimmed or removed as scrap in order to ensure product quality.
2. As reprocessing wire is time- and labor- consuming, how to improve wire cracking and surface defects in order to ensure product quality and lead times has currently been the most important work of all.

B. Improvement Solutions

In the metallographic observation of S2 steel, phenomena like wire cracks, surface defects and rough surface are oftentimes observed to exist at the same time. Fig. 1 shows decarburization and Fig. 2 shows the metallography of wire after being spheroidized and annealed. As cracks and surface defects can be both found in as-rolled metallography and after spheroidizing and annealing, we can conclude that the problem is not caused by the abnormality of wire spheroidizing.

Using magnetic powder to detect damages on steel, we noticed lots of bright lines (see Fig. 3). Then, we continued the wire sampling test, and we found that defects appeared discontinuously.

Exploring the causes of wire cracks and surface defects on S2 steel, we found that the roughness of rollers is the main cause which influences the surface quality of S2 steel. Below are the explanations:

1. The S2 is a type of steel with high silicon and alloy content and is rolled at low temperatures. When being rolled, the S2 seems to wear down the roller a little faster. As a result, if too much S2 steel has to be rolled, the worn and rough surface of the roller may cause wire cracks and surface defects.
2. Improvement solutions: In order to ensure surface quality, the time for replacing rollers used to process S2 must be determined.

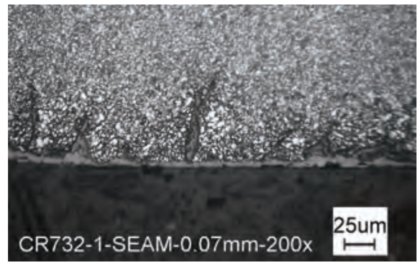

Fig. 1. "As-rolled" defective metallography

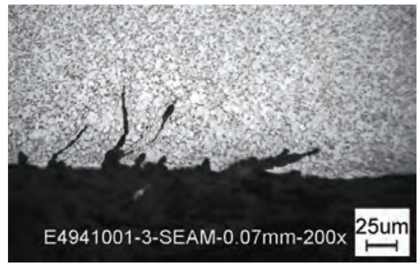

Fig. 2. Defective metallography after being spheroidized

4. Superficial Defects and Improvement Test

Although determining the frequency for replacing rollers used to process S2 can help ensure surface quality, it may influence the rolling capacity and increase the cost for roller replacement. If we would like to maintain both quality and cost, we have to again double check the metallography of wire cracks and surface defects, and carry out the following test:

A. Double checking the metallography of wire cracks and surface defects

When we rolled the previous batch of 9254 steel, the resulted quality was good; however, when we rolled the S2 steel later, wire cracks and surface defects were observed immediately. Fig. 4 shows wire cracks and surface defects (0.06mm in depth).

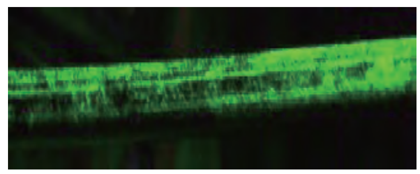

Fig. 3. Using magnetic powder to detect damages and found several bright lines

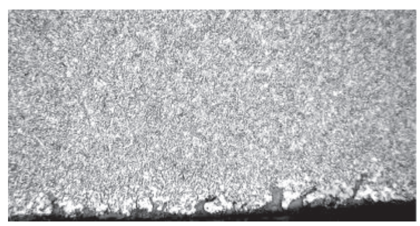

Fig. 4. Lots of wire cracks and surface defects

B. Analyzing the cross-sectional shrinkage of S2 steel at high temperatures and wire cracks/surface defects

Fig. 5 shows the cross sectional shrinkage of S2 steel at high temperatures. The cross sectional shrinkage increased when the temperature increased. At 880-920℃, the cross sectional shrinkage was greatly impacted by the furnace temperature. As a result, we estimate that when the steel is moved out of the furnace and the sequential temperature for rolling is at 880-920℃, the more significant variance of the cross sectional shrinkage is more likely to cause wire cracks and surface defects in fine rolling.

To generalize the above analyses, we know that if the temperature S2 is being fine rolled is at 900℃, wire cracks are very likely to occur. So, the solution is: increasing the temperature of fine rolling to prevent the variance of the cross sectional shrinkage from getting more significant when S2 is being rolled, which will result in wire cracks in sequential fine rolling.

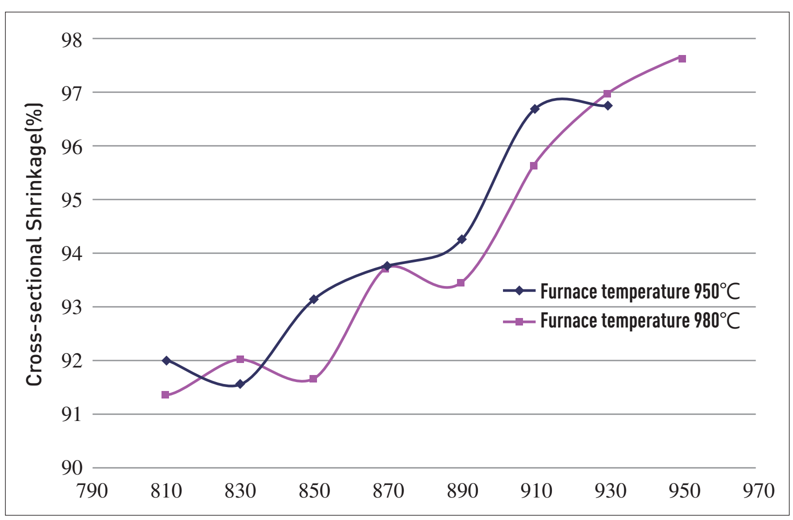

Fig. 5. The cross sectional shrinkage of S2 at high temperature

Table 1. The number distribution at different fine rolling temperatures and the depths of wire cracks/surface defects on S2

Wire cracks/surface depth(mm)	0		0.01		0.02		0.03		More than 0.04		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Fine rolling temperature at 900℃	4	50.0	0	0.0	1	12.5	2	25.0	1	12.5	8	100
Fine rolling temperature at 940℃	7	87.5	0	0.0	1	12.5	0	0.0	0	0.0	8	100

C. The test to further improve wire cracks and surface defects on S2

The test is illustrated as below:

In order to observe if the problems of wire cracks and surface defects can be improved after increasing the fine rolling temperature, the test is carried out at two respective temperatures. One is at 940℃ and the other is at 900℃.

1. Fine rolling at 940℃ shows a better result: 87.5% of defects observed are 0mm in depth and the remaining defects observed are in the depth of ≦0.03mm.
2. Fine rolling at 900℃ shows a worse result: only 50% of defects observed are 0mm in depth and 12.5% of defects observed are in the depth of more than 0.04mm. See **Table 1**.
3. Generally speaking, setting the fine rolling temperature at 940℃ can effectively reduce the ratio of defects observed in the depth of≦0.03mm.

D. Reduce the final rolling speed to improve wire cracks/surface defects on S2

Below is the illustration of rolling ϕ8mm S2 steel at a lower speed.

Rolling at a higher temperature and lowering the final rolling speed can reduce the strain rate, thus reducing the occurrence of superficial cracking. So, if we increase the fine rolling temperature to 940℃ and lower the final rolling speed, the ratio of wire cracks and surface defects observed in the depth of≦0.03mm can be also greatly reduced.

5. Improvements and Applications

Through the tests above, the problems of wire cracks and surface defects on the S2 steel with high silicon content and hardenability have been effectively controlled.

A hand tool kit includes products in various sizes. In the past, manufacturing a hexagonal bar required the use of ψ8.0mm spheroidized wire, 5 times of wire drawing and 4 times of spheroidizing. However, with the improved rolling capability, the same specification of a hexagonal bar can be currently made with the ψ5.5mm spheroidized wire and requires only 3 times wire drawing and 2 times spheroidizing, which helps save energy, reduce carbon emission, shorten lead times, lower costs, reduce processing fees and times of manufacturing procedures, and prevent abnormal surface quality from happening. Many hand tools manufacturers are very satisfied with the improved performance and do get much more orders due to the improvements.

6. Conclusions

1. The S2 steel is with high silicon content and hardenability, so when it is being rolled, it is susceptible to wire cracks and surface defects, which may result in further re-trimming and scrap. The result will not only reduce production, but will also cause disturbances such as the unnecessary retrimming and re-sampling and shipment delay. So, it is really important at this moment to improve the problems of wire cracks and surface defects on S2.
2. After increasing the rolling temperature, lowering the final rolling speed, and setting the period of replacing rollers with new ones, the ratio of wire cracks and surface defects observed in the depth of≦0.03mm can be also greatly reduced and effectively controlled. As a result, the quality of steel used to manufacture pneumatic screwdrivers can satisfy the needs of hand tool manufacturers and help them develop new markets and increase the competitive edge of their products.