Steel Development and Application for High Torque Pneumatic Fastening Tools

高扭力氣動鎖緊工具用鋼開發與應用

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Introduction

Pneumatic fastening tool, such as pneumatic screwdriver, is a screwdriver that is driven by compressed air. The tightening torque of screws can be controlled as long as the pressure of compressed air is well-adjusted, which is easy and convenient. Therefore, it is commonly used in factory assembling lines. Steel used to manufacture pneumatic fastening tools, such as S2 steel, is an impact resistant alloy steel, which can be used to produce the heads of pneumatic screwdrivers, screwdrivers and so on. Its most important property requirements are hardness and torque value. The higher the hardness and torque values, the more popular they are to consumers.

In the past, when some domestic hand tools manufacturers were producing screwdrivers (bits) with higher grades, they mainly used S2-1M2 steel. In recent years, as the price of steel has been skyrocketing, many hand tools manufacturers, while considering cost, will use 9254 steel as a replacement. However, screwdrivers (bits) made from these two types of steel cannot meet the standards of high hardness and high torque value at the same time. Even if manufacturers adjust and change tempering heat treatment conditions, improving the hardness, its torque value degrades. On the other hand, when a higher torque value is to be maintained, the hardness cannot meet the hand tool manufacturers' requirement for HRC60 or above.

The Steel Development for High Torque Pneumatic Fastening Tools

Since the industry is hoping to develop pneumatic screwdrivers or bits with torque values higher than S2-1M2 steel, its process and property must include: hardness of screwdrivers (bits) ≧ HRC60 and torque value at 230~250 kgf-cm, which enable them to develop new markets and stay away from the competition from China.

The following will introduce the previous steel development technology and the new steel development goals:

The Previous Steel Development Technology

After being heat treated, steel materials with high hardness usually show decreased toughness. When being wrenched too much, steel materials will fracture, causing accidental eye damages due to splashing metallic scrap. Hence, manufacturers should lower the hardness lest screwdrivers break into pieces.

The most commonly seen screwdriver in the market is made of SAE 6150 Cr-V steel, with its hardness at about HRC52±2, torque value at about 180~190 kgf-cm; besides, the best steel for screwdrivers - S2, though with the hardness as high as HRC60±2, will fracture easily when the hardness is too high. Therefore, the usual hardness is about HRC58~59 and the torque value is about 210~230 kgf-cm after heat treatment. In addition, some hand tool manufacturers use spring steel with high tenacity to produce in order to increase the torque value of products. Among all, screwdrivers made of SAE 9254 steel have the hardness at about HRC56~57 and torque value at about 220~240kgf-cm. No matter if the screwdriver is made of S2 or SAE 9254, both can meet the demand of manual operation. However, with the demand for better product performance, better steel material features that allow products to get into the international market and get rid of the competition from China will be needed. Therefore, this article will explore the steel development of high torque fastening tools and see how the advantages of S2 and SAE 9254 can be combined to improve product properties.

The Target of Development

The steel development for high torque fastening tools is to use the steel material of newly designed steel type, and then go through the process of heat treatment, so that the product can have hardness higher than HRC60 and torque value up to 230~250 kgf-cm. Furthermore, when being wrenched to break, it will show a ductile section, making it a screwdriver with excellent wear resistance. The key to successful development lies in not only grasping the key element of ingredient design, significantly modifying the component of S2 steel, but also working together with the industry to develop new products.

Element Composition, Process and Quality Features

Steel composition, processing accuracy, heat treatment are the three key factors influencing the features of screwdrivers. In order to give the material higher hardness and torque value, steel type on alloy component design has higher influence.

Previous Steel Components

The usual steel components for screwdrivers, SAE 6150 and S2-1M2, as shown in Table 1, are the most common steel types in the hardware market. 55CrV is the transitional product of SAE 6150 and SAE 9254.

Table 1. The Commonly Used Steel Components for Screwdrivers

Steel Type	C	Si	Mn	P	S	Ni	Cr	Mo	V
SAE 6150	0.50	0.25	0.80	<0.02	<0.01	-	0.90	-	0.20
55CrV	0.55	0.25	0.80	<0.02	<0.01	-	0.90	-	0.20
SAE 9254	0.54	1.40	0.70	<0.02	<0.01	-	0.70	-	-
S2-1M2	0.66	1.10	0.50	<0.02	<0.01	0.16	0.20	0.40	0.17

Previous Manufacturing Process and Quality Features

The previous main manufacturing process of screwdriver shafts was: coiling→spheroidization→wire drawing→processing→heat treatment→sand blasting. After heat treatment was finished, the measurement of hardness and torque value was started. Table 2 is the hardness and torque value of a screwdriver shaft made within the specifications “Ph.2,1/4”Hex. L:100mm.” The hardness cannot be too high in order to prevent splashing metallic scrap from damaging eyes.

Table2. The Hardness and Torque Value of Different Steel Types of Screwdriver Shafts

Steel Type	Hardness (HRC)	Torque Value (kgf-cm)
SAE6150	52~54	180~190
55CrV	54~55	190~200
SAE9254	56~57	220~240
S2-1M2	58~60	210~220

New Steel Component Design

When adjusting the proportions of alloy elements, the functions of certain elements in steel should be taken into consideration. For instance, the influence of carbon, silicon, nickel, chromium, molybdenum, vanadium in S2-1M2 on hardness and torque value of screwdrivers (bits) after tempering heat treatment will be taken into account and the element proportion must be discussed. While taking cost into consideration, developers must lower or eliminate the element content that decreases hardness and torque value and seek other alloy elements that increase favorable hardness and torque value.

(1) Carbon: Carbon is the main element that affects the hardness of steel materials. When the carbon content is at 0.66%, the quenching hardness will reach its highest value. When the carbon content is higher, not only does the quenching hardness has little increase, but its toughness will reduce and the increasing Austenite content will affect the torque value. For instance, S2 steel has higher carbon content, which leads to poorer toughness. Despite the fact that the hardness can easily reach higher than HCR60 after tempering heat treatment, brittle fracture can easily happen, causing accidental metallic scrap splashing. Hence, the tempering heat treatment of S2 steel is mainly about HRC58-59, which can prevent brittle fracture from happening.

(2) Silicon: Silicon is a solid solution element. It has an apparent anti-loosening function in spring steel. Also, it can improve the anti-plastic deformation ability and anti-torsional ability.

(3)Nickel: The purpose of adding nickel is to improve the toughness of steel. It can restrain the brittleness from happening in high-hardness steel.

(4)Chromium: Chromium is a strong carbide formed element and its price is cheaper than molybdenum. When carbide is formed, it has the wearable and tough feature. When combined with molybdenum, it has better wear resistance.

(5) Molybdenum: Molybdenum can improve the hardness and wearable feature of steel, and yet the alloy price is high; therefore, the industry is working hard on reducing use of this material.

(6)Vanadium: Vanadium can restrain the forming of grains during the process of Austenitization and improve the toughness and hardness of steel. However, excessive vanadium without refinement, if melting in steel, will easily cause distorted lattice and increase base strength, which relatively decreases the toughness of the base. Because the price of vanadium is also high, the industry will combine vanadium with niobium as a replacement.

(7) Niobium: Compared to vanadium, niobium is even harder to melt and also has the purpose of grain refinement. Its price is cheap and when a small amount of niobium is combined with vanadium, it can refine grain and improve the toughness of materials.

To sum up, for manufacturing high hardness, high torque value and wearable screwdrivers (making the hardness of material higher than HRC60 with high toughness), the content of each element used must be more than 0.65% of carbon, more than 0.25% of nickel and more than 1.7% of silicon, which can help increase the torque value of screwdrivers, expand the tempering temperature range, and make the product quality more stable after quenching and tempering heat treatment.

Table 3. The Elements of New Steel Type BT9865V

Steel Type	C	Si	Mn	P	S	Ni	Cr	Mo	V	Nb
BT9865V	0.66	1.80	0.55	<0.02	<0.01	0.26	0.65	0.30	<0.10	<0.024

Application of New Steel Type

1. Table 3 shows the elements of new steel type BT9865V. Among all, SAE 6150 and S2-1M2 are the commonly used steel types in the domestic hardware market. 55CrvV is the transitional products of SAE 6150 and SAE 9254.

2. Picture 1 shows the screwdrivers with high hardness, high torque value and wearable feature made of the new steel type BT9865V. This type of screwdriver has the hardness of above HRC60 and still shows enough toughness. The product within the specifications of "Ph.2 ,1/4"Hex., L:100 mm" under the torque test shows the torque value up to 230~250 kgf-cm; with such high hardness, it still shows ductile section when breaking into pieces, thus preventing from damaging eyes caused by splashing metallic scrap.

Picture1. Screwdrivers with high hardness, high torque value and wearable features

Conclusion

1. BT9865V is the best steel type. After being processed and heat treated, it can be used to make wearable screwdrivers with the hardness higher than HRC60 and torque value at 230~250kgf-cm. Not only can its hardness reach the level of S2 steel, its torque value also surpasses SAE 9254, and the wearable feature is even better than S2, which can be regarded as the best product with its extraordinary hardness, torque value and wearable features.

2. With the successful development of this new steel type BT9685V and the practical tests by foreign hardware factories, this new steel type has been proven to show higher wearable feature and toughness than S2. For those domestic hand tools OEM companies, they can be worldly admired with the outstanding features of their products, which can also increase their competitiveness in the industry.