The gap between China's self-produced fastener materials and those of developed countries is relatively large, so it is necessary to formulate cold-forged steel wire rod dedicated to automotive fasteners and upgrade the technical level of cold-forged steel wire rod, to meet the demand for raw materials for high-strength fasteners for automobiles in a targeted manner and regulate the technical quality level of Chinese fastener products. This article briefly introduces the technical progress of "cold-forged steel wire rod for auto fasteners", which is marked by adding the specific letter of "Q" from Chinese phonetic transcription to the first letter of the grade. With reference to the current national standard GB/T 6478 for cold forged steel wire coil, there are 5 types of cold forged steel wire rod: Type 1 non-heat-treated steel wire rod with 11 categories; Type 2 case hardened steel wire rod with 4 categories; Type 3 tempered steel wire rod with 23 categories; Type 4 boron-containing tempered steel wire rod with 19 categories; Type 5 non-tempered steel wire rod with 3 categories. 7 new categories are added to the item of tempered steel wire rod; 10 new categories are added to the item of boron-containing tempered steel wire rod.

Technical Progress of "Cold-Forged Steel Wire Rod for Automotive Fasteners"

《汽车扣件用冷镦钢盘元》的技术进展

1. Overview

In the environment of rapid development of the automotive industry, with the increasingly fierce competition in the market, coupled with the continuous improvement in the quality of automotive fasteners, such as light-weighting, environmental protection, long service life and other requirements, the technology and equipment of automotive fastener enterprises will continue to innovate. The market space for automotive fasteners is huge. As one of the key components of automobile manufacturing industry, the variety and quality of fasteners have an important impact on the quality of cars. **China is a large automobile manufacturing country, but for a long period of time the U.S., German, Japanese, and other countries' joint ventures with manufacturers in China have had to rely upon imports of critical auto parts, such as grades 10.9 and 12.9 engine fasteners made of steel supplied by (Japan) Kobe, (Japan) Nippon Steel, (S. Korea) POSCO, and other steelmakers.**

In an automobile engine, connecting rod bolts, cylinder head bolts, crankshaft pulley bolts, flywheel bolts and crankshaft bearing cover bolts are called the five critical bolts. In addition, components related to chassis, driving, and steering also use high-strength fasteners, all of which account for over 60% of the number of fasteners used in a car and are of the strength above Grade 10.9 with the category being alloy cold-forged steel requiring heat treating. For this reason, production of high-strength fasteners for automobiles has stricter requirements for fatigue strength, plasticity and toughness, content of impurities, surface quality, metallography, and cold forgeability of raw materials. To ensure a certain clamping force, the assembly in production

basically uses the torque and angle control method. The connecting rod bolts as the key engine bolts will be tightened to the yield state. The connecting rod bolts in the operating engine must withstand the inertia and centrifugal forces of the piston connecting rod generated from reciprocal motion, and in the cylinder compression and burst stroke, it also has to withstand the impact of thousands of times per minute. The fracture is usually called fatigue fracture.

Throughout the continuous progress of China's steel production technology, the self-production of steel for high-end automobile fasteners has been gradually advanced. At present, **Baosteel, Xingtai Iron & Steel, Jiangsu Yonggang, Jinan Iron & Steel, Magang, Xingcheng Specil Steel, Xiangtan Iron & Steel and other enterprises can produce high strength fastening steel, and some of their products have been certified by car manufacturers and are used in critical parts of high-end automobiles. Up to now, the common grades of steel for high-strength fasteners are: SWRCH35K, 10B21, 10B28 steel for Gr. 8.8 fasteners; 10B33, 35CrMo, 40Cr steel for Gr. 10.9 fasteners; 35CrMo, 42CrMo, SCM435 steel for Gr. 12.9 fasteners, etc.**

2. Presentation of Problems

Under the trend of more stringent requirements for high strength, long service life and light-weighting of automobile fasteners, bolt materials are urgently required to have better performance and more stable quality, to meet the advanced design concepts and methods and promote the development and progress of fastener manufacturing level in Chinese automobile fastener industry. Due to the late start of research on automobile fasteners in China, the research and development of materials lags behind developed countries such as Europe, the United States and Japan, and there is relatively few research on basic materials in China, such as actual fatigue characteristics and R&D of new materials. At present, the materials in China are mainly made by the European Union, the United States and Japan. There is a big gap between Chinese fastener materials and the developed countries, which is mainly manifested in high impurities and uniformity of domestic steel, and the high oxygen content and non-metallic impurities. Steel hardenability fluctuates, high temperature & high performance steel, low temperature impact resistant steel, economical and high strength fasteners for mass production lack raw materials.

With the successive development of cold forged steel for automobiles by various enterprises, the basic technical indexes of GB/T 6478 and GB/T28906 (the existing national standard for cold forged steel), cannot meet the latest quality demand of cold forged steel for automobiles, and in addition, raw materials for high strength fasteners have high requirements and higher cost than ordinary cold forged steel. Since there is no national or industrial standard for these special cold forged steel in China, many enterprises have formulated their own standards. Since 2018, in order to improve their technical level, enterprises have begun to formulate their own standards based on GB/T 6478. The main purpose of these corporate and group standards is to improve the standard technical indicators for reference of automotive fasteners manufacturers. However, due to the differences in the starting point, technical level and standard drafting level of the standard-setting units or institutes, the quality and technical index requirements of the final industrial standards for cold forged steel for automobiles vary, it is not favorable to the standardization and unification of the standard quality requirements and it is also not favorable to the use of users and standardization of fasteners. **YB metallurgical industrial standards "Cold Forged Steel Wire Rod for Automobile Fasteners" will be undertaken by the Secretariat of Technical Sub-committee for Steel Wire Coil and Rod Standards of China National Steel Standard Committee, standard formulation by Jiangsu Yonggang to formulate standards for cold forged steel wire rod for automotive fasteners,** which will upgrade the technical level of cold forged steel wire rod. Due to high requirements for composition, purity, cold forging and surface quality, the cold forged steel wire rod for automotive use can meet the demand of high strength automotive fasteners and improve the technical quality of fastening products in China. China can also make use of the export of fastening products to advance the process of self-production of high-strength steel for automotive fasteners. In addition, the standards are used as a guide to lead the quality level of cold forged steel for automobiles in China, with the goal of improving the quality of cold forged steel throughout China and reducing the import volume of high-end automotive fasteners.

3. Process of Steel Wire Rod

The basic production process of cold forged steel wire rod for automotive fasteners is as follows: KR → BOF → LF → RH/VD → Continuous bloom casting → cogging → grinding→ flaw detection→ grinding → rolling. Steelmaking process control focuses on impurities, segregation, grain size, composition uniformity and consistency, and oxygen/ nitrogen/ hydrogen content, etc. The rolling process focuses on surface quality (avoiding scratches and cracks), decarburization layer, dimensional accuracy, oxidation, head and tail trimming, microstructure (avoiding Weiss), cold forging performance, etc. Critical fasteners have high requirements for hydrogen embrittlement. For example, the commonly used material is SCM435 steel, and China mostly uses materials from Japanese Kobe and Japanese Nippon Steel.

The process for this material is PASAIP, which focuses on blank size selection, spheroidizing, decarburization, phosphate coating, surface quality, etc. To meet the requirements of cold forged automobile fasteners, the control of surface quality (in addition to reasonable spheroidizing) is very critical. For this reason, the appearance of the material is required to be free of defects such as scratches, indentations, bent areas, oxide residue and rust spots.

4. Revision of Standards

4.1 Citation of Standards

"Cold Forged Steel Wire Rod for Automotive Fasteners" combines the development of domestic steel enterprises, optimization of production process and progress of technology and equipment as well as needs of the fastener industry, refers to relevant standards outside China, and is formulated based on GB/T 6478-2015. **The main domestic and overseas standards for reference are: (1) GB/T 28906 "cold forged steel hot rolled wire rod"; (2) ISO 4954-2018 "cold forged and extruded**

steel"; (3) EN 10263-1-4:2017 "cold forged and extruded steel wire rod, bars and wires including part 1: general technical conditions of delivery, part 2: non-heat treating conditions, part 3: technical conditions of delivery for case hardened steel, and part 4: technical conditions of delivery for tempered steel"; (4) JISG 3507-1:2010 "carbon steel for cold forging including part 1: wire rod", JIS G 3508-1:2010 "boron-containing steel for cold forging Part 1: wire", JISG 4053:2016 "alloy steel for machine manufacturing".(5) ASTM A29/A29M-16 "carbon and alloy steel bars for hot forging and cold processing"; ASTM A510/A510M-18 "general requirements for carbon steel wire and rough drawn round steel wire", etc.

4.2 Categories and Chemical Composition

In order to ensure the stability of material properties and consider the properties of cold forging and extrusion, the range of carbon and impurity content of each category has been tightened, i.e., **the general classifications of carbon content has been adjusted to 5 and the impurity contents (P and S) has been reduced to 0.020%.** To facilitate the distinction between cold forged steel wire rod for automobile fasteners and existing categories, **the category follows the way in GB/T 6478 and is preceded by a letter "Q (a phonetic transcription of "automotive" in Chinese) for identification. For Grades 13.9 and 14.9 fasteners, as the development of their corresponding steel hasn't been mature and are not used often, so they're not included in the category.** As non-tempered cold forged steel features considerable advantages in new energy vehicles, and its current development progress goes smooth, it'll be continuously included in the standard.

According to the current national standard GB/T 6478-2015 for cold forged steel, there are 5 types of cold forged steel wire rod, including 11 categories of type 1 non-heat treated steel wire rod, 4 categories of type 2 case hardened steel wire rod, 23 categories of type 3 tempered steel wire rod, 19 categories of type 4 boron-containing tempered steel wire rod, and 3 categories of type 5 non-tempered steel wire rod.

8 new categories are added to tempered steel wire rod: QML38, QML40Mn and QML50, respectively corresponding to SWRCH38K, SWRCH41K and SWRCH50K of JIS 3507-2010, QML15CrMo and QML42CrMo, respectively corresponding to SCM415 and SCM440 of JIS G 4053-2016; and QML41CrMoV, QML35CrMoV, and QML21CrMoV for heat resistant steel for automotive fasteners; ASTM A29/A29M is also referenced .

10 new categories are added to boron-containing tempered steel wire rod: QML23B corresponding to 10B23 in ASTM A29-16, QML28B corresponding to 28B2 in ISO 4954: 2018, QML33B, QML38B, and QML45B respectively corresponding to 10B33, 10B38, and 10B45 in ASTM A29-16; QML20CrB corresponding to 51B20 in ASTM A29-16. Categories that can improve hardenability and mechanical properties are added and the addition of Cr is required.

4.3 Others

4.3.1 Cold Forging - according to the technical requirements of ISO 4954-2018, the requirements for cold forging property of steel have been revised, removing the option of normal level (1/2 cold forging) and adding the option of 1/5 cold forging for users' own choice. The plastic cracking problem will occur if wire rod is processed by 1/4 or 1/5 cold forging without annealing; as a result, the step of annealing before 1/4 or 1/5 cold forging should be added.

4.3.2 Decarburized Layer - Referring to ISO 4954-2018 and EN10263.1-2017 the requirements for the decarburized layer have been revised: tempered steel (incl. boron-containing steel) and non-tempered steel should be examined in accordance with GB/T 224 and section 7.3 for decarburized layers, and the depth of the decarburization layer should be in accordance with the provisions of **Table 1**. If users have special needs, they should be stated clearly in contracts.

Table 1. Decarburized Layers of Tempered Steel (Incl. Boron-Containing Steel) and Non-Tempered Steel (Unit: mm)

Nominal Diameter (D)	Completely Decarburized Layer	Total Decarburization Layer Depth
D≤10	Not allowed	≤0.07
10<D		≤0.007D

4.3.3 Grain Size - Referring to relevant standards, the austenitic grain sizes of non-heat treated, case hardened, and tempered (incl. boron-containing steel) steel are required to be no coarser than the requirements of Gr. 6.0.

4.3.4 Non-metallic Impurities - The requirements for impurities have been revised with reference to ISO 4954-2018 and the requirements of the automotive fastener industry. To accommodate different needs, two impurities levels have been proposed to cover different grades of fastener requirements (**See Table 2**).

Table 2. Requirements for Non-Metallic Impurities

Group	A		B		C		D		DS
	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	
I	≤2.0	≤1.5	≤2.0	≤1.5	≤1.0	≤1.0	≤1.5	≤1.5	≤1.5
II	≤1.5	≤1.0	≤1.0	≤1.0	≤0.5	≤0.5	≤1.0	≤1.0	≤1.0

5. Conclusions

Under certain conditions, the quality of raw materials will affect the selection of production process parameters of fasteners, which will also directly affect the comprehensive mechanical properties and safety of high-strength automotive fasteners. In the process of automobile assembly, the development and application of high-strength automotive fasteners are still faced with challenges from suppliers and manufacturing. Selecting the right materials for use in right locations is the best way to meet the requirements of car manufacturing. Due to the increasing demand for high precision and high strength fasteners, the demand for high purity, high performance and high-quality cold forged steel has also become more urgent. Through the formulation and implementation of standards, the quality of fasteners and the development of the industry will be both promoted.