Application and Development Trend of Advanced High-Tensile Steel in Modern Automobile

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Abstract. As the largest country to product and sale the automobile, China is facing the problem of oil shortages. As an important measure to save energy and reduce emission, Automobile lightweight is of great urgency. At the sometime, automobile lightweight also has a significant effect on the improve of automobile safety and comfort and decline of manufacturing costs. This paper introduces the advanced high strength steels and analyses the considerable role that advanced high strength steels in automobile lightweight by listing data. With the rise of new energy vehicles, advanced high strength steel will still play an irreplaceable role in the future automobile market. This paper offers some instruction and references for the application of advanced high strength steel in modern automobile market.

Keywords: automobile lightweight · advanced high-tensile steels · new energy vehicles · market application

1 Introduction

Automobile lightweight is one of the most effective measures to reduce energy consumption and pollutant emission. In recent years, with the continuous increase of automobile production and ownership, as shown in Fig. 1, the three major problems that China facing of energy consumption, safety and environmental protection have become gradually salient. In order to promote the sustainable development of the automobile industry, improve the fuel economy of automobiles and reduce greenhouse gas emissions, China has treated automobile lightweight as an important way of energy conservation and emission reduction at a strategic height.

Automobile lightweight is an inevitable choice. The research shows that about 75% of the fuel consumption is related to the weight of vehicle. When the vehicle weight decreases by 10%, the fuel consumption decreases by 8% and the emission decreases by 4% [1]. The competition of automobile materials is increasingly fierce. In recent years, in order to pursue automobile lightweight, the competition between aluminum alloy, magnesium alloy, plastic and composite materials and automobile steel has become increasingly fierce, and the consumption of aluminum magnesium alloy and composite materials in automobiles has been increasing. This competition has effectively promoted

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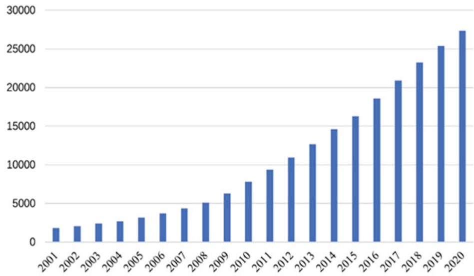

Fig. 1. Civilian car ownership in China (million)

the development and application technology of automobile high-tensile and ultra-high tensile steel. Automobile lightweight is to reduce the vehicle weight as much as possible on the premise of ensuring the vehicle strength and safety, then improve the power, safety and other comprehensive performance of the vehicle, therefore to achieve the purpose of energy conservation and emission reduction. Moreover, automobile lightweight can also improve the driving performance and safety performance of the vehicle.

This paper introduces the advanced high-tensile steels (AHSS) and analyses the considerable role that advanced high-tensile steels in automobile lightweight by listing data. With the rise of new energy vehicles, advanced high-tensile steel will still play an irreplaceable role in the future automobile market. This paper offers some instructions and references for the application of advanced high-tensile steel in modern automobile market.

2 Introduction to Common Advanced High-Tensile Steels

In terms of actual car body manufacturing, the application of high-tensile steel (HSS) has been continuously improved in recent years. As shown in Fig. 2, the proportion of advanced high -tensile steel in 2020 is far higher than that of traditional high-tensile steel. The types and characteristics of advanced high-tensile steel has been continuously studied at home and abroad. In the third edition of the international iron and Steel Association (IISI) application guide for advanced high-tensile steel, high-tensile steel is divided into conventional HSS and AHSS [2].

Traditional high-tensile steels mainly include carbon manganese (C-Mn) steel, bake hardening (BH) steel, high-tensile interstitial free (HSS-IF) steel and high-tensile low alloy (HSLA) steel; as shown in Fig. 3, advanced high-tensile steel (AHSS) mainly includes dual phase (DP) steel, transformation induced plasticity (TRIP) steel, martensitic grade (M) steel, complex (CP) steel, hot forming (HF) steel and twin induced plasticity (TWIP) steel. Traditional high-strength steels are mainly strengthened by means of solid solution, precipitation and grain refinement, while AHSS refers to a kind of Steel Strengthened by transformation. The structure contains martensite, bainite and/or residual austenite, including DP steel, TRIP steel, CP steel and M steel [3, 4]. Advanced high-tensile steel for automobile is divided into hot rolled, cold rolled and hot galvanized products, and its process characteristics are all strengthened through phase transformation. Advanced high-tensile steel has higher tensile (500~1500MPa) than ordinary

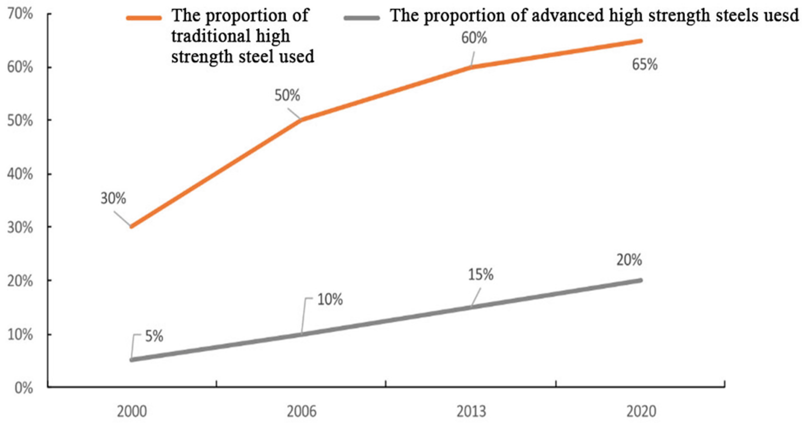

Fig. 2. Proportion of traditional high-tensile steel and advanced high-tensile steel used in recent 20 years

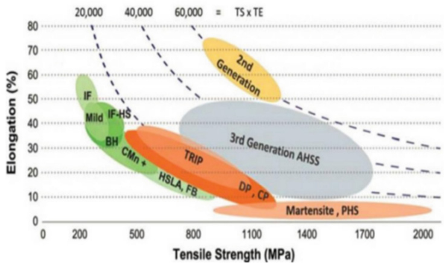

Fig. 3. Advanced high-tensile steel family for automobile

high-tensile steel. It also has high-tensile and good formability, especially high work hardening index, which is beneficial to improving the energy absorption in the collision process. The appearance of advanced high-tensile steel has consolidated the leading position of steel in the field of materials to a great extent. As the current price of auto parts has an absolute impact on sales, advanced high-tensile steel has become the preferred material for automobile companies to reduce the weight of ordinary automobiles, and has been widely used in the automotive industry [5].

2.1 Dual Phase Steel (DP)

Dual phase (DP) steel is a new kind of steel developed in the 1970s, and it is also an advanced high-tensile steel developed earlier for automobiles. DP steel is composed of ferrite and island like second phase martensite distributed in the ferrite matrix, and its schematic diagram is shown in Fig. 4.

Martensite content (volume fraction) is generally 5%~30%, the strength can be increased by increasing the proportion of martensite phase. DP steel is produced by controlling the cooling of austenite phase or the cooling of two zones (ferrite + austenite),

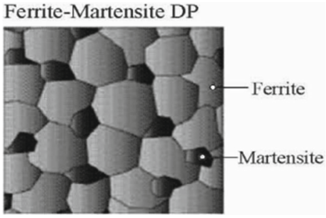

Fig. 4. Schematic diagram of islanding martensitic DP steel distributed in ferrite matrix

so that part of austenite is transformed into ferrite and residual austenite into martensite. Ferrite and other soft and ductile phases provide good formability for the steel plate, while martensite and other strengthening phases ensure the high tensile of the material. At present, DP590 and DP780 are widely used.

2.2 Martensitic (M) Steel

Martensitic (M) steel is a kind of steel with strip martensitic structure, which is obtained by rapid quenching and cooling of high-temperature austenite structure through continuous annealing after hot rolling, cold rolling or annealing after forming. It is the highest tensile grade of high-tensile steel used in commercial fields at present. Martensitic steels are usually tempered after quenching to improve their ductility. The addition of carbon is used to increase hardenability and strengthen martensite. Manganese, silicon, molybdenum, boron and nickel can also enhance hardenability.

2.3 Transformation Induced Plasticity (TRIP) Steel

TRIP steel is a new kind of steel developed to better improve the formability and crashworthiness of steel plate and meet the requirements of forming, weight reduction and safety of automobile parts with complex shapes. The microstructure is shown in Fig. 5, which is composed of ferrite, bainite and retained austenite. The reason that it called TRIP phenomenon is that the transformation induced plastic effect, which means the stable retained austenite in the steel is transformed into martensite during deformation, which makes it have special advantages compared with other high-tensile steels, especially suitable for bulging forming. At present, the commonly used tensile grades of this steel are TRIP 590 and TRIP 780. Great progress has been made in the research and development of a new type of TRIP steel.

2.4 Twin Induced Plasticity (TWIP) Steel

TWIP Steel usually has a high content of Mn (15%~30%), Si (2%~4%), Al (2%~4%), so that it can maintain full austenite at room temperature. When there is no external load, its room temperature structure is stable retained austenite. When subjected to external load, mechanical twins will be generated under the induction of strain. Its "twin induced plastic effect" will make the material show excellent mechanical properties. It has extremely high tensile and formability, making TWIP Steel available for stamping parts with complex shapes.

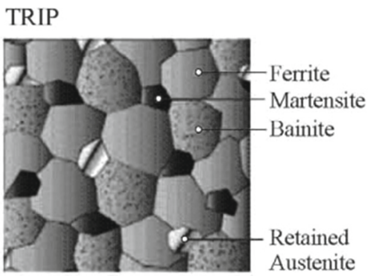

Fig. 5. Schematic diagram of microstructure of TRIP steel

Table 1. The proportion of advanced high-tensile steel

Material type	Baking harden steel (BH)	High strength low alloy steel (HSLA)	Dual phase steel (DP)	High strength steel (HSS)
Percentage/%	10	1	74	4
Material type	Martensite steel (M)	Transformation induced plasticity steel (TRIP)	Complex phase steel	Others
Percentage/%	4	3	1	3

3 Application of Advanced High-Tensile Steel in Car Body

It is found that when the steel plate thickness is reduced by 0.05mm, 0.1mm and 0.15mm respectively, the body weight is reduced by about 6%, 12% and 18% respectively, indicating that reducing the plate thickness is an important method to realize the automobile lightweight [6]. By using high-tensile steel plate, the thickness of the plate can be reduced and the safety performance can be improved. After years of technical cooperation between the steel industry and the automotive industry in steel lightweight body, especially the research and development project of ultra-light body concept car project (ULSAB-AVC) organized by the international iron and Steel Association, it has been proved that steel is still the leading material for automotive use in the future. As shown in Table 1, the proportion of advanced high-tensile steel accounts for more than 80%, while the proportion of dual phase steel (DP) is as high as 74%.

At present, the mainstream application varieties, tensile grades and the maximum tensile of commercial supply of advanced high-tensile steels for automobiles are shown in Fig. 6. Among them, DP steel is widely used in automobile body and automobile parts, such as wheels, bumpers, suspension systems and stiffeners, because its manufacturing process and method are relatively easy and its product series are relatively complete. It has become one of the first choices for automobile structural parts [7, 8]. Martensitic (M) steel is mainly used in the manufacture of quenched parts after hot forming, and will be increasingly used in ultra-high tensile parts and anti-collision parts in automobiles. With the development of automobile industry, the application of TRIP steel in car body has been paid more attention. At present, the commonly used -tensile levels are TRIP 590

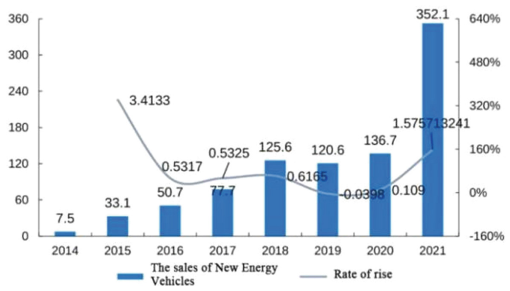

Fig. 6. Sales statistics and growth of new energy vehicles in China from 2014 to 2021

and TRIP 780, which are widely used to make automobile baffle, chassis components, wheel rims, door impact beams and so on [9].

At present, China's automobile market is undergoing a transformation from traditional power vehicles to new energy vehicles. In 2016, China produces a total of 517,000 new energy vehicles, accounting for about 50% of the global output; The cumulative promotion volume has exceeded 1million vehicles, accounting for more than 50% of the global market [10]. A number of excellent new energy enterprises have emerged, such as BYD, JAC, SAIC, Chery, Greely and BAIC. At the same time, BYD has taken the lead in completing the product layout of traditional fuel vehicles and new energy vehicles. The rapid development and large-scale application of new energy vehicles, on the one hand, have improved the comparative advantages of steel materials over aluminum alloys and modified plastics, on the other hand, have also raised the threshold for steel mills to serve the manufacturing of new energy vehicles. Because new energy vehicles use batteries as power, in order to increase their mileage and improve the durability and safety of the body, it is an inevitable way to reduce the weight of the vehicle. At the same time, as an effective energy-saving means, vehicle lightweight technology has become one of the important directions of the development of China's new energy vehicle industry, which is also the basic technology for the development of new energy vehicles. Table 2 shows the proportion of materials used for several new energy vehicles. It can be seen that advanced high-tensile steel accounts for a significant proportion.

4 Conclusion

The research results of the automobile lightweight project show that the application of advanced high-tensile steel plate can reduce the thickness of plate components and reduce the quality of components to make the automobile lightweight on the premise that the required performance is unchanged or slightly improved; the application of advanced high-tensile steel in automobile ultra-light steel body, ultra-light steel body and advanced concept vehicle shows a good application prospect and good competitiveness in terms of weight reduction, energy saving, safety improvement and emission reduction. With the rise of new energy vehicles, the rapid growth of new energy vehicle consumption market will lead the development demand trend of high-tensile automotive steel, especially the application of high-tensile steel with tensile grade of about 1000 MPa. Therefore,

Table 2. Proportion of materials for several new energy vehicles

Materials	Electric Ford Mustang	Mazada MX-30 BEV	Jaguar I-PACE	Nio ES6	Tesla Model 3	Bomag ix3
Common Steels	22.20%	36.10%	1.30%	0.60%	27%	21.90%
High Strength Steels	26.30%	26.10%	0.20%	4%	24%	38.70%
Strength Steels*	11.60%	9.30%	0.20%		11%	8.70%
Ultra High Strength Steels	7.70%	19.50%	3%		6.80%	0.20%
Thermoformed Steels 24.90%	24.9%	9%			8.70%	14.80%
Aluminum Alloy	4.80%		84%	88%	19%	9.70%
Others	2.50%		11.30%	7.40%	3.50%	6%

advanced high-tensile steel will have a very broad market prospect in China's automotive industry in the future. This paper offers some instruction and reference for the application of advanced high tensile steel in modern automobile market.

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