

# Research on microstructure and properties of automobile body steel and its development trend

Yan Liu<sup>1,\*</sup>, Haiqing Ye<sup>2</sup>, Yu Yao<sup>2</sup> and Luxin Zhang<sup>2</sup>

<sup>1</sup>The Liaoning Provincial Key Laboratory of Advanced Materials & Preparation Technology, Shenyang University, Shenyang, 110044, China

<sup>2</sup>School of Mechanical Engineering, Shenyang University, Shenyang 110044, China

\*Corresponding author e-mail: liuyanue@163.com

**Abstract.** With the promotion of green sustainable economic development, the study on automobile lightweight to reduce greenhouse gas emissions is one of the important means for reducing air pollution. At present, the most valuable research direction is how to reduce the car's self-weight in the performance of the safety and comfort of automobiles, so as to achieve the goal of energy saving and emission reduction. Based on the brief introduction of the microstructure and properties of automobile steel from the first generation to the third generation, the paper analyzes the future research and development trend of automobile steel. Compared with the first and second generation automobile steel, the third generation automobile steel has better strength and economic performance, can better meet the current needs of people and is more suitable for a large number of production and application. At present, with the continuous progress of the process (such as hot forming process), the third generation automobile steel has great development research value in reducing the weight of automobile.

## 1. Introduction

As the world economy enters the era of rapid development, the environmental problems are becoming more and more serious, especially in the aspect of air pollution. Cars bring convenience to people's life, at the same time, they also bring a very serious environmental problem. The auto industry's focus has shifted from initial formability, corrosion resistance and safety to the current problem of reducing greenhouse gas emissions [1,2]. Reducing exhaust emissions from automobiles depends not only on the development of new clean energy sources, but also on the development of automotive lightweight [3]. Automobile lightweight in the structural optimization has been difficult to further progress, but there is still a lot of research space in the body weight. The body weight is reduced by 10wt%, the oil saving amount is about 6wt%-8wt% and the exhaust emission reduction is about 5g/km. This paper describes the microstructure and properties of automobile steel from the first generation to the third generation and analyses the future research and development trend of automotive steel.

## 2. Application of automotive materials

Now a lot of automobile production will use the aluminum alloy and magnesium alloy to replace the steel plate. The comprehensive performance of aluminum and magnesium alloy is good, but due to the cost problem, they will only appear in some high-end automotive products, which is also a key factor restricting the development of magnesium alloy and aluminum alloy. In the future steel vehicle (FSV) project, the research results show that if 97wt% of the car body uses high strength and ultra-high



strength steel, automobile body's overall mass can be lowered by 39wt%, about 188 kg, which is the same quality as the aluminum body. There is a large amount of savings under the condition of constant production cost. So at present, the main production materials of the automobile are mainly steel, and the proportion of steel in the car body will remain between 60wt% and 70wt% for a long time in the future [4,5].

The rapid development of the auto industry makes people's demand for cars higher and higher. Now people's attention to the car is more focused on the safety and comfort, so the sheet used in automobile manufacturing is also being developed and updated in a generation, as shown in figure 1 [6,7]. The first generation automotive steel is typical of the interstitial-free (IF) steel, dual-phase (DP) steel, phase transformation induced plasticity (TRIP) steel. The second generation automobile steel, which is typically represented by the twin induced plasticity (TWIP) steel, is developed on the basis of increasing the strength and obtaining higher plasticity. Because of the more alloying elements, it is difficult to refine the second generation automobile steel and the production cost is also very high. So on this basis, researchers develop the martensite (Q&P) steel with TRIP effect, high strength and plastic (toughness) as the representative of the third generation automotive steel, which uses a small number of alloy elements, reduces the production cost and refining difficulty, has the high strength and good plastic performance and more and more meets people's needs.

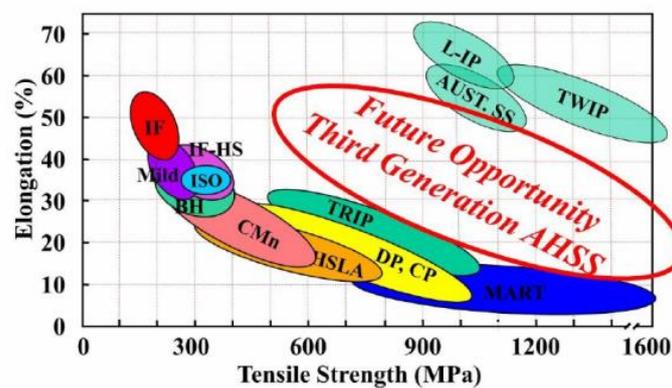
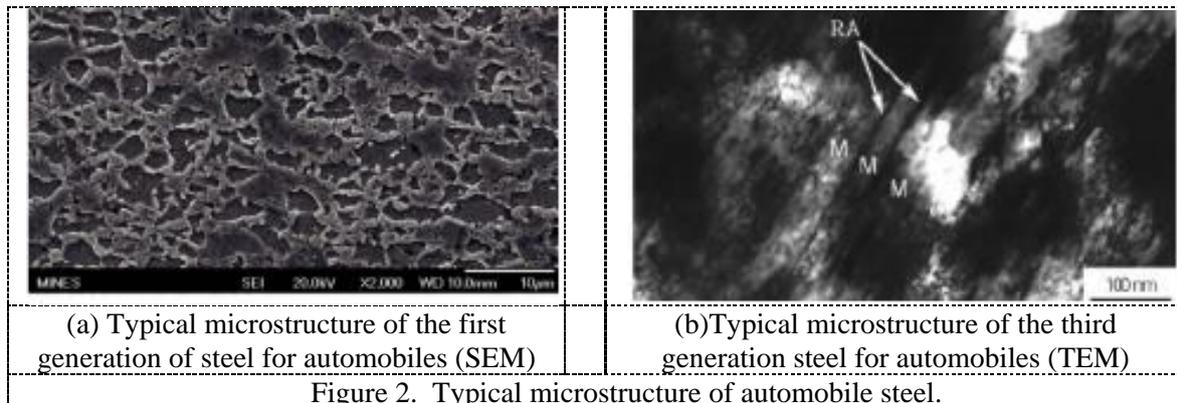


Figure 1. Schematic diagram of automobile steel for 3 generations.

### 3. Study on the microstructure and properties of automobile steel

#### 3.1. Study on the microstructure of automobile steel

Figure 2 is the typical microstructure of automobile steel. The main microstructure of the first generation automobile steel is ferrite and martensite, as shown in figure 2 (a) [8]. The main microstructure of the second generation automobile steel is ferrite and residual austenite, which is similar to that of the third generation automobile steel, but has more alloying elements in the chemical composition, as shown in figure 2 (b) [9]. Because of the existence of the residual austenite, the third generation of automobile steel in strength is no less than the first generation of automotive steel, and has a better formability. Although the main microstructure of the second generation automobile steel is the same as that of the third generation steel, it is very expensive and difficult to use widely because of the addition of a large number of alloy elements in the second generation of steel. The less alloy composition makes the third generation automobile steel has the advantage of mass production, which is not available for the second generation of automobile steel, as shown in table 1.



### 3.2. Study on the properties of automobile steel

Depending on the composition of the steel, there will also be different properties, as shown in table 1 [10]. The first generation of automotive steel is mainly ferrite and martensite, so it has good strength. The second and third generation of automotive steel also contain the residual austenite, so they have better plastic properties, and the strong plastic product is higher than the first generation.

Table 1. Comparison of main microstructure and properties of typical automotive steels.

Generation	Typical steel	Main microstructure	Performance	Strong plastic product (Gpa·%)
The first generation automobile steel	DP steel	Ferrite, martensite	High-strength, good formability	10-20
	TRIP steel	Ferrite, bainite, residual austenite, martensite	High elongation, good plasticity	
	Multiphase steel	Fine ferrite, high proportion of hard phase (martensite, bainite)	High absorption capacity and reaming performance	
	Martensitic steel	Lath martensite	High-strength, low formability	
The second generation automobile steel	TWIP steel	Ferrite, residual austenite, martensite	Excellent plasticity	50-70
The third generation automobile steel	Q&P steel	Ferrite, residual austenite, martensite	Ultra high strength, high formability	>30

Table 2 [11,12] lists the basic mechanical properties of each generation of automotive steels. The tensile strength of the third generation automobile steel is between the first generation and the second generation automobile steel and it has the good economic performance, therefore which will be vigorous research and development and the widespread application.

Because different parts of the car have different functions, it is necessary to choose the steel of each part according to the properties of the materials, such reasonable selection of material design will make the car more optimized in manufacturing [13]. According to table 3 [14], the car's cover is more suitable for the selection of DP steel, TWIP steel and Q&P steel. The structural parts are more suitable for TRIP steel, TWIP Steel and Q&P steel. The reinforced parts are more suitable for the selection of martensite steel, TWIP Steel and Q&P steel. Q&P steel performance can be applied to a variety of body parts and the strength is higher than the first generation of automotive steel, the economy is better than the second generation of automotive steel, so the third generation of automotive steel is the direction of the future development and application.

Table 2. Performance analysis of typical automotive steels for 3 generations.

Generation	Typical steel	Yield strength (MPa)	Tensile strength (MPa)	Elongation rate (%)
The first generation automobile steel	IF steel	201	393	41
	DP steel	400	700	19-25
	TRIP steel	450	800	26-32
The second generation automobile steel	TWIP steel	-	600-1400	30-64
The third generation automobile Steel	Q&P steel	1087	1225	-

Table 3. Characteristics of automobile components and selection of steel elements.

Part type	Part name	Feature requirements	Control factors of main steel
Covering parts	Door outside board, floor, etc.	Formability, rigidity, sag resistance, corrosion resistance	Tensile resistance, rigidity, sag resistance
Structural parts	Components, engine silos	Formability, rigidity, impact energy absorption, fatigue strength, corrosion resistance, weldability	Component rigidity, impact energy absorption, fatigue strength
Walking parts	Lower bracket, wheel, etc.	Formability, rigidity, fatigue strength, corrosion resistance	Component rigidity, fatigue strength, weldability
Enhanced parts	Front and rear anti-collision beam	Formability, weldability, impact energy absorption	Impact energy absorption

#### 4. Research and development trend of automobile steel

Steel is more economical than aluminum and magnesium alloys, steel will be used as the main materials for most cars in the future. Developing a new type of steel which can be mass production, can make the properties of steel more conform to the car's development direction of lightweight, comfort and safety, and the manufacturing technology of the new steel will be also developed, which is the next issue we should focus on.

The third generation automobile steel has better strength and plasticity than the first generation. Compared with the second generation automobile steel, it reduces the alloy composition and the production cost and is more economical. It can be applied to the machining of different parts of body and realize their performances. In view of the different functions of different parts of the car, different characteristics of steel are used to make the materials reach the most reasonable application.

The third generation automobile steel contains the advantages of the first and the second generation automobile steel. However, its forming performance under normal temperature condition is poor, it is easy to generate springback, the stamping pressure is high, the die service life is short, and the hot forming process of new research solves this problem well [15]. Therefore, it is necessary to develop new processing technology as well as the new steel. With the continuous progress of the process, the application of the third generation automobile steel in the car will be gradually improved. Only in this way we can more reasonably complete the automotive lightweight.

## 5. Conclusions

On the basis of comparing the microstructure, properties and processing technology of automobile steel from the first generation to the third generation, the paper analyses the future research and development trend of automobile steel and obtains the following conclusions.

(1) Compared with the third generation automobile steel, the strength and plasticity of the first generation automobile steel can't obviously meet the current demand of people.

(2) Compared with the third generation automobile steel, the metallurgical manufacturing process of the second generation automobile steel is difficult and expensive, which is not suitable for a large number of production and application.

(3) With the continuous research and development of technology, the third generation of automotive steel can have more excellent performance. The emphasis of the future automobile lightweight should research how to gradually replace the first and second generation automobile steel with the third generation of automobile steel in the direction of developing new processing technology (such as hot forming process), so that the weight of the car can be further reduced.

## Acknowledgments

This work was financially supported by the Liaoning Province Natural Science Fund Project (No. 20170540643) and the Open Subject Fund of the Liaoning Provincial Key Laboratory of Advanced Materials & Preparation Technology (No. 201601).

## References

- [1] Luo Y 2018 Research and development of automotive steel *World Metals* **B11** 1-4
- [2] Luo Z X, Rong J, Yang K, Liu G J, Qi W, Yu T and Xu H 2015 The development of high strength automotive steel and the research of the third generation high strength automobile steel *AT & M Field of Vision* **4** 1-5
- [3] Shi C F 2015 Development of the third generation automotive steel *Shanxi Metal*. **1** 1-3
- [4] Ren H M 2014 Application status and development trend of automotive body materials *Electronic World* **10** 411
- [5] Kang Y L and Zhu G M 2014 The development trend of automobile in china and the opportunities and challenges faced by automobile *Iron steel* **49** 1-7
- [6] Buo X T 2013 A new generation of automotive steel *Heat Treat.* **28** 64
- [7] Kang H W 2015 Analysis on characteristics and development trend of modern automobile steel *Shandong Metal*.**37** 22-24
- [8] Li W, Speer John G and Wang L 2016 Microstructure and mechanical properties of an ultrahigh strength dual phase steel developed by intercritical annealing *ICAS & HMnS 2016* 394-397
- [9] Chen M M 2013 An integrated process of thermal deformation and Q&P treatment *Shanghai: Shanghai Jiao Tong University*.
- [10] Han Z Y, Zhang M D, Xu H F, Dong H and Cao W Q 2016 Characteristics of microstructure and properties of high performance automotive steel and its future research and development direction *Iron steel* **51** 1-9
- [11] Su K, Yu J X and Xu J B 2006 Application status and development trend of new type high strength steel for automobile *Iron Steel Van. Tit.* **27** 53-57
- [12] Jiang H T, Tang H and Mi Z L 2007 Development and application of advanced high strength steel for automobile *J. Iron Steel Res.* **19** 1-6
- [13] Lin Z G 2016 Research progress and technical application status of advanced high strength automotive steel plate *Hebei Metal*. **1** 1-7
- [14] Wang J 2014 Present situation of automobile steel and its development in Handan iron and steel company *Hebei Metal*. **9** 67-71
- [15] Tu M A and Hu S 2016 Development and application of body thermoforming parts *Shanghai Auto*. **3** 58-62