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Advanced Steels

The Recent Scenario in Steel Science and Technology

Metallurgical Industry Press
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Preface

At present, Steel is one of the most common material widely used in the world, both for structural and functional applications. Steel has been the basic material for weaponry, agriculture, construction, etc. in the human society since the beginning of iron age, and now it is still playing very important roles in the world. It is generally believed that steel is really a kind of advanced materials due to its advantages during processing, fabrication, applications, and also recycling. People cannot image what the world would be if there be no steel around us.

Steels have been widely using for construction, automobile, machinery, energy, transportation, daily life, etc. in this special occasion that people take much more care with the climate change and global warming. Will steels still play an important role to our society in the future? Yes, it will be. More advanced steel products with the characteristics of high performance, low cost, easy fabrication, low tolerance, and environment benign have been developed to meet the demands from both market and environment protection. It seems there is no stop of this advancing trend.

The development of steel products is dependent on the steel knowledge we have. Although there have been a good accumulation of steel knowledge since the massive production of liquid steel, the new phenomena and roles in steels have still been investigated in recent years. Now people involved in steel research, steel processing and steel applications are concerned more and more with the progresses of steel science and technology than ever before, and have made great contributions to steel knowledge. This is one of the reasons why steel products change year by year. In order to illustrate the current status of steels, the editors of this book decided to ask outstanding professors and researchers all of the world to write a review on their research fields on the occasion of ICAS 2010.

The First International Conference on Advanced Steels was held at Guilin, China, November 8–11, 2010. The International Conference on Advanced Steels (ICAS) is the merging of two international series conferences: "International Symposium on Ultrafine Grained Structures (ISUGS)" and "International Conference on Advanced Structural Steels (ICASS)". Over 270 papers have been presented in the Conference. It was really a platform for people all over the world to share their contributed works in steels with their colleagues effectively. ICAS 2010 will cover almost every aspect of steels: physical metallurgy, steel grades, processing and fabrication, simulation, properties and applications, etc. It is a comprehensive conference on steel products and technologies. Plenary and keynote speakers are very active in the relative steel fields, and are invited to illustrate their works in this specific proceedings in detail.

The aim of this book is to introduce steel researchers and technologists to the understanding of present status of different kinds of steels and relative technologies. It covers general review on steel industry, physical metallurgy, HSLA steel, automobile

steel, specialty steel, processing and fabrications. It is the summary of steels over past decades and also the forecast of advanced steels into the future. I believe physically that this specific book would help people to have the progresses of steels in hand.

Beijing, China Rang Cai

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Part I
General Review

Advanced Steel and Our Society: Better Steel, Better World (Opening Address and the Introduction of the Specific Proceedings)

Yong Gan

Abstract

It has been generally believed that steel is a kind of advanced materials, presenting characteristics to meet a variety of requirements. They could be applied to the circumstances subject to the elevated temperature up to 650°C and cryogenic temperature down to −196°C, to the applied stresses from 100 up to 5,000 MPa, to the corrosion of atmosphere, acid, alkali, salt, etc. Steels has been widely used for construction, automobile, rails, shipbuilding, petrochemistry, machinery, weaponry, daily life, etc.

Keywords

Steels • Low alloy steels • Iron bridge

1 The Importance of Steels

It has been generally believed that steel is a kind of advanced materials, presenting characteristics to meet a variety of requirements. They could be applied to the circumstances subject to the elevated temperature up to 650°C and cryogenic temperature down to −196°C, to the applied stresses from 100 up to 5,000 MPa, to the corrosion of atmosphere, acid, alkali, salt, etc. Steels has been widely used for construction, automobile, rails, shipbuilding, petrochemistry, machinery, weaponry, daily life, etc. (Fig. 1). Thanks to the heaven that there have existed a vast resources of iron ores and human beings have accumulated the experiences to produce and to use steels, which have changed our world remarkably.

Steel industry is the basic link in the economic chain. It provides raw materials to the downstream sectors, such as machinery, automotive, shipbuilding, appliance, and construction (Fig. 2). And it also draws upstream sectors, such as coal mine, electricity, transportation, mineral ores, ferro-alloys, machinery, etc., through the consumption of their products. Steel industry is actually an index to evaluate the industrialization of a country and the comprehensive national power. Generally speaking, the major developed countries are almost stronger at steel industry. Thanks to the advantages of steel, they play very important roles in economy, sustainable society, public finance and tax, defense, and employment.

2 Historic Review of Steels

In the year of 1333 BC, Tutabkhamun's sarcophagus had both a gold and a steel dagger upon it (Fig. 3), signifying the importance of both metals. It was believed to be made from meteorites in Hittite, now Syria. In 1867, the essayist Thomas Carlyle declared: "the nation that gains control of iron soon gains control of gold." At least, it was really true from the beginning of iron age to the end of World War II.

It is obliging to illustrate the two sites of UNESCO World's Heritage to you for the evidence of steels for Industrial Revolution.

Volklingen Ironworks in Germany was an integrated ironworks that was built and equipped in the nineteenth and twentieth centuries and has remained intact (Fig. 4).

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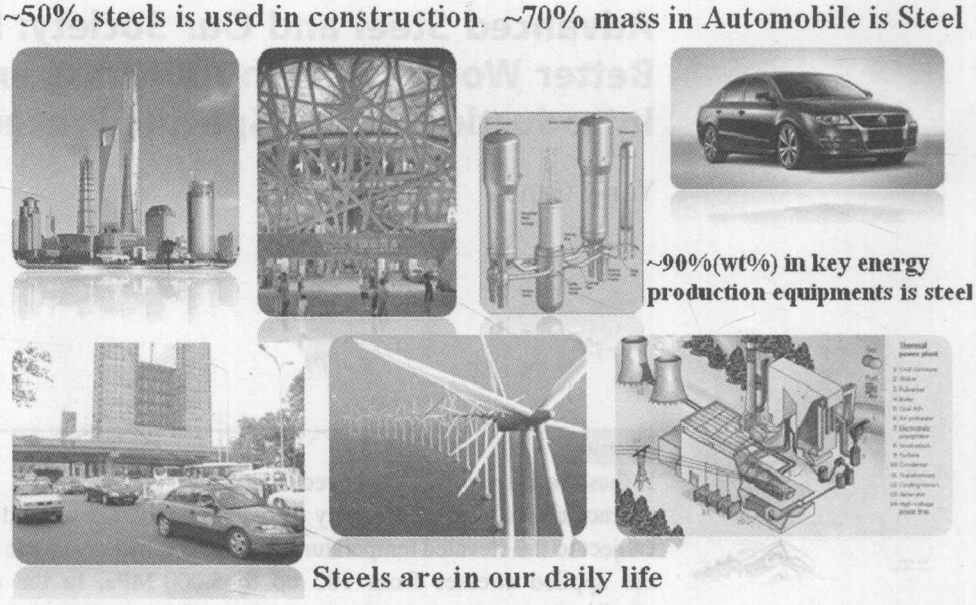

Fig. 1 Steels accompany with us in every aspects

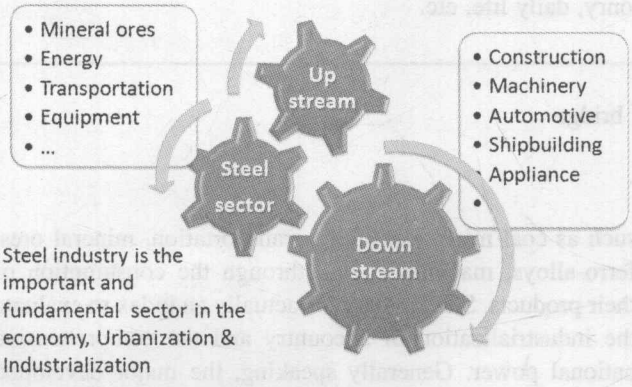

Fig. 2 The roles of steel industry in the economy

The ironworks, which cover some 6 ha, dominate the city of Völklingen. Although it has recently gone out of production, it is the only intact example, in the whole of western Europe and North America, of an integrated ironworks that was built and equipped in the nineteenth and twentieth centuries and has remained intact. And due to the production of steel in the history, it was listed as the site of UNESCO World's Heritage (http://whc.unesco.org/en/list/687/gallery/).

The world's first cast iron bridge was built over the River Severn at Coalbrookdale in 1779 (Fig. 5). Ironbridge Gorge in UK, the site of the world's first cast iron bridge, is known throughout the world as the symbol of the Industrial Revolution. Not only iron founders and industrial spies flocked to see this wondrous bridge, but also artists and travelers. The bridge had a far reaching impact: on local society and the economy, on bridge design and on the use of cast iron in building. The story of the bridge's conservation begins in 1784 with reports of cracks in the southern abutments, and is brought up to date with the English Heritage sponsored work of 1999 (http://www.ironbridge.org.uk/about_us/the_iron_bridge/index.asp).

Ironbridge is known throughout the world as the symbol of the Industrial Revolution. It contains all the elements of progress that contributed to the rapid development of this industrial region in the eighteenth century, from the mines themselves to the railway lines. Nearby, the blast furnace of Coalbrookdale, built in 1708, is a reminder of the discovery of coke. The bridge at Ironbridge, the world's first bridge constructed of iron, had a considerable influence on developments in the fields of technology and architecture (http://whc.unesco.org/en/list/371).

And a modern integrated steel plant, Caofeidian, has been constructed as one of the example of steel technology innovation in China (Fig. 6). Steels play a very important role in the urbanization and industrialization. There are strong demands for steel products not only in quantity but also quality, even for environment benign. For Caofeidian, the steel plant has been established to possess three fundamental roles, steel production, energy conversion, and waste treatment. It may as the model for newly constructed steel plants.

Low alloy steels are as approximately 30% of total steel products. The efforts on the increase of both strength and toughness (ductility) have not stopped over past 50 years. Although Q345 steel is widely produced and applied, higher strength steels are now preferred to construct high rise and large span building, long span bridges, high pressure large diameter pipelines, light weight vehicles, large ships, e.g. Q420 and Q460 steel plates used to construct of "Bird Nest", "Water Cube" and CCTV Station Building for Beijing Olympic Games (Fig. 7); Q420 steel plates for the construction of Dashengguan Bridge over Yangtze

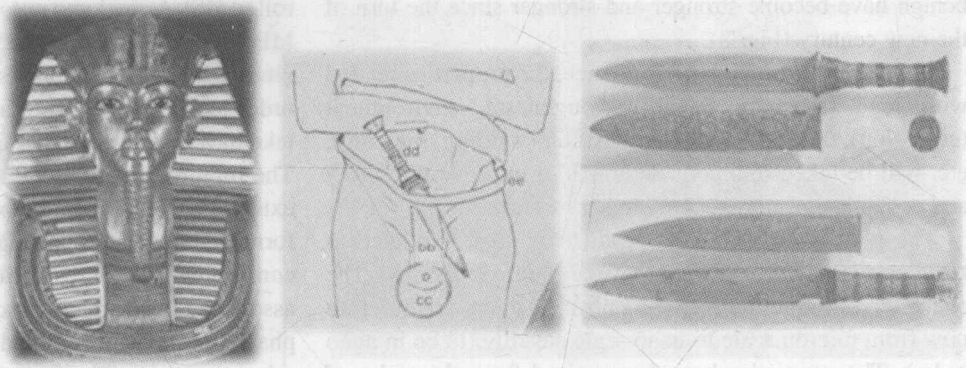

Fig. 3 Tutabkhamun's steel dagger in ancient Egypt over 3000 years

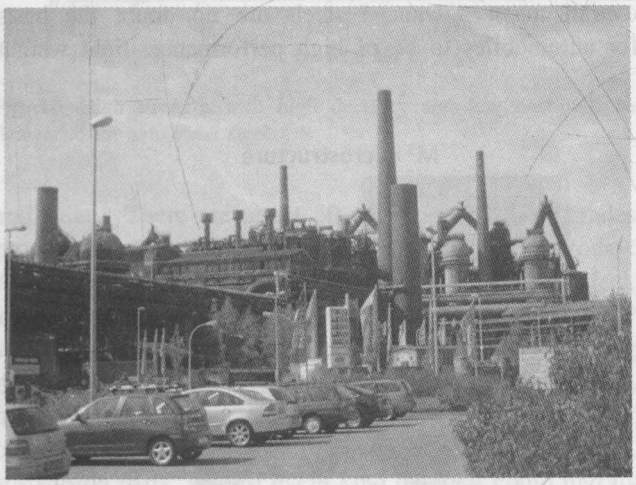

Fig. 4 The intact Volklingen Ironworks in Germany

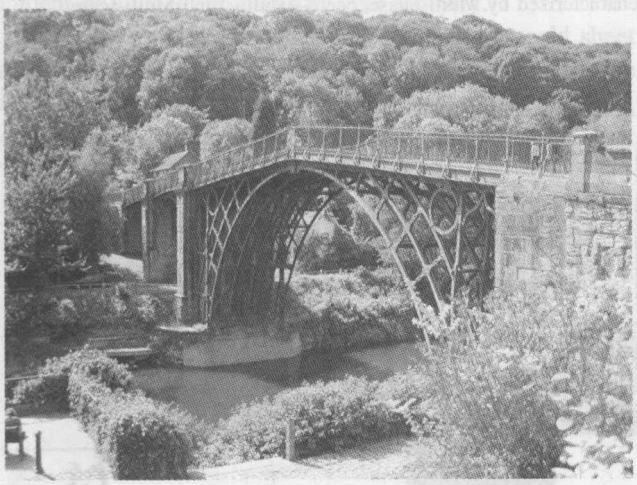

Fig. 5 Ironbridge Gorge in UK, the site of the world's first cast iron bridge, is known throughout the world as the symbol of the Industrial Revolution

River of high speed railway from Beijing to Shanghai, X80 steel plates for west to east oil pipeline construction, 590 MPa steel plate to reduce the weight of vehicles, FH40, DH40 and EH40 steel plates for large ship building, etc.

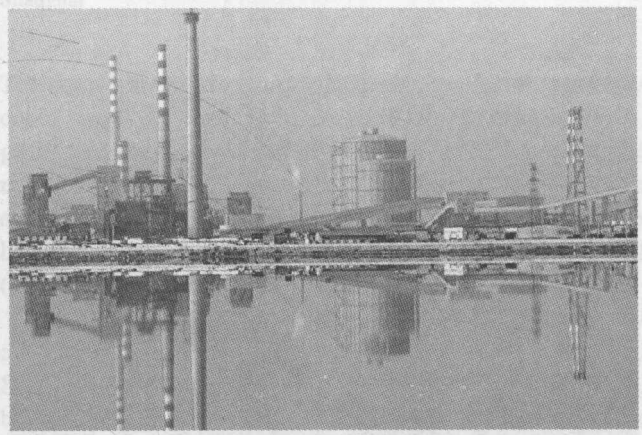

Fig. 6 Caifeidian, a newly constructed steel plant in China, possesses three fundamental roles: steel production, energy conversion, and waste treatment

3 Future Perspective of Steels

Steel is the basic material for almost every sector such as construction, machinery, transportation, energy, utensil, etc. From ancient time to now, steel has been playing a very important role in the civilization of human beings. Our world has been changed significantly since the application of steel. Steel will lead us to be higher, faster, and stronger. The main topic of the first International Conference on Advanced Steel is: Better Steel, Better World.

There is no doubt that steel will still be the dominant material in the foreseeable future. Steel is really a type of advanced materials that changes day by day. This change is mainly due to the contribution of physical and chemical metallurgy, steel processing and facilities, market requirements, etc. The new constraints of environment protection and resource saving should be borne in mind in the development of steels in the future. It is noticeable that the requirements for steel products to be of high performance, low cost, easy fabrication, low tolerance, and environmentally

benign have become stronger and stronger since the turn of the new century (Fig. 8).

Concerning with high performance, the properties related with load (strength, ductility, toughness), environment (corrosion), time (duration), fabrication (welding, drawing), etc. will be taken into considerations to improve the safety and reliability of components made of steels.

The performance of steel products is closely related to the constitutes and morphology of microstructures. The characterization and effective control of microstructure are now from micron scale to nano scale steadily (to be in nano order). The properties have been raised from the order of 10^6 to 10^9 unit (to be in Giga order). The strength of hot rolled HSLA steel and auto sheet steel has been raised from MPa order to GPa order. The fatigue strength limit of ultrahigh strength steel has been also improved from MPa order to GPa order. The fatigue cycles for steels to undertake have been demanded from Mega cycles to Giga cycles. The rupture time for steel at elevated temperature has been extended from Mega seconds to Giga seconds. The performances of steels in Giga scale are related to precisely controlling of microstructure in nano scale, and closely associated with microstructure characterized with Multi-phase, Meta-stability, and Multi-scale (so-called as M^3 microstructure) (Fig. 9).

Steel makes up approximately 70% of an automobile's overall mass. Advanced steels are no doubt the basis for automobiles to be of high performance, light weight

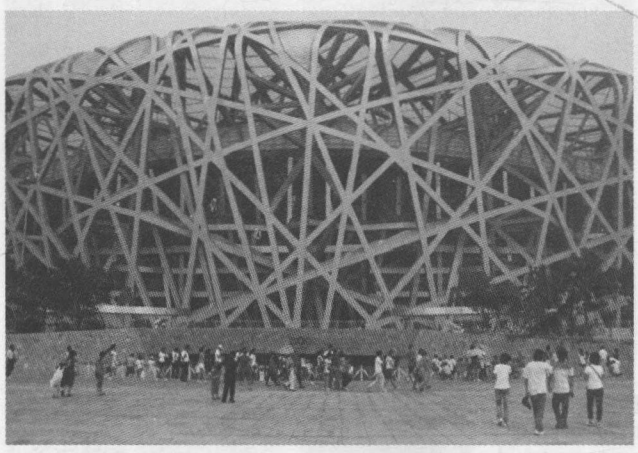

Fig. 7 The "Bird Nest" for 2008 Olympic Game was made of HSLA steels, Q420 and Q460

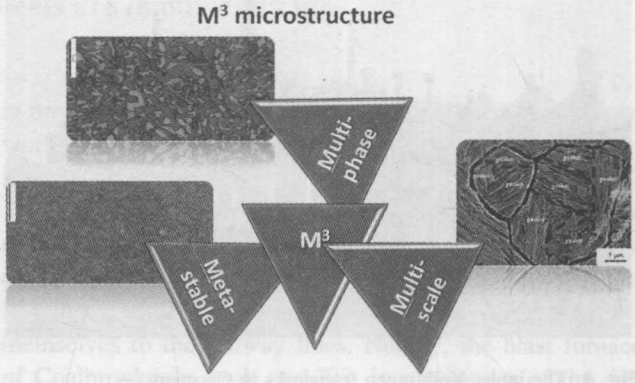

Fig. 9 The performances of steels are associated with microstructure characterized by Multi-phase, Meta-stability, and Multi-scale

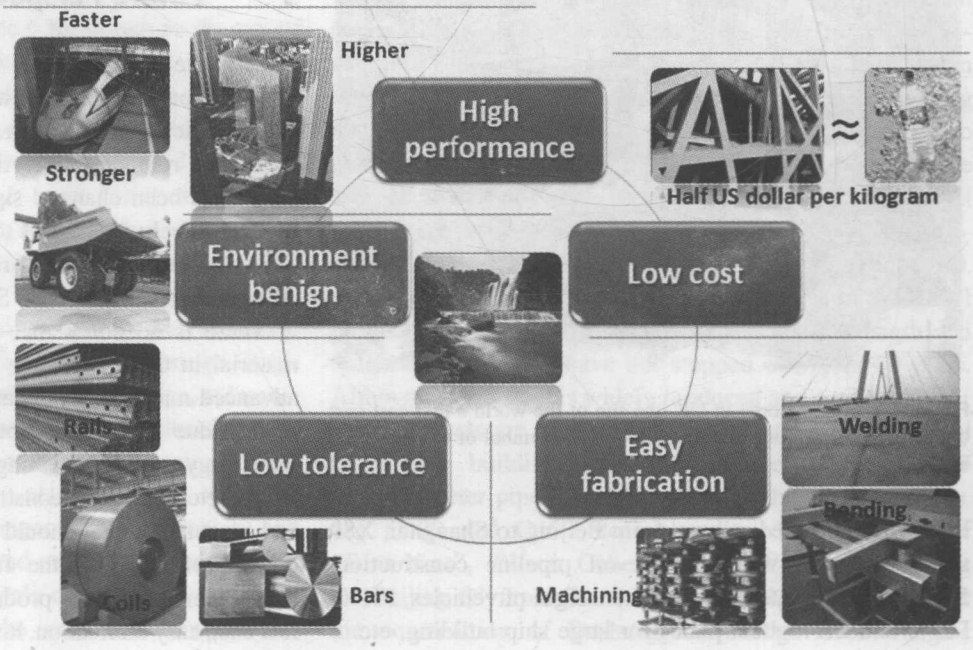

Fig. 8 Advanced steels to be of high performance, low cost, easy fabrication, low tolerance, and environmentally benign

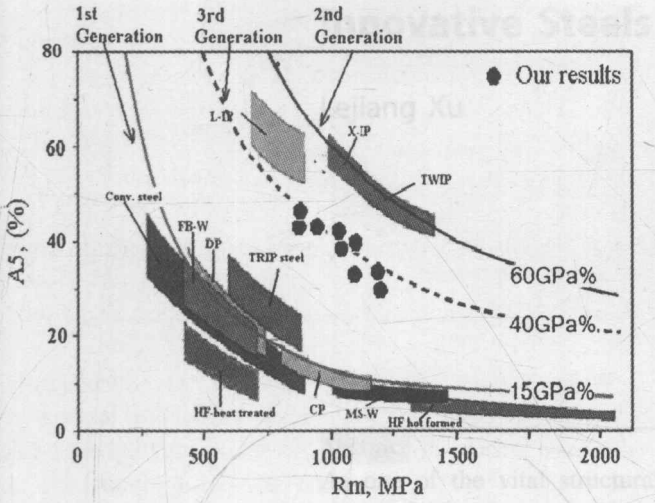

Fig. 10 High strength with high ductility and low cost will be demanded for auto sheet steel

and safety. There are about 30 categories of steel grades produced and used in automobiles or in fabrication today: Al-killed steel, IF steel, BH steel, IS steel, CMn steel, HSLA steel, DP steel, CP steel, martensitic steel, TRIP steel, TWIP steel, austenitic stainless steel, hot stamping martensitic steel, engineering steel, ferritic stainless steel, heat resistance alloy, etc. They are used to manufacture car body and enclosure, engine, transmission system, chassis, suspension parts. Almost every kind of steels could find its way in the manufacture of automobiles, which means that the automobile steels are also very important to the development of all steel products in steel industry.

Nowadays, there are increasing demands for cold sheet steel and coated sheet steel to be in high strength to reduce weight, better ductility to improve formability and safety, low alloy addition and easy fabrication to reduce cost.

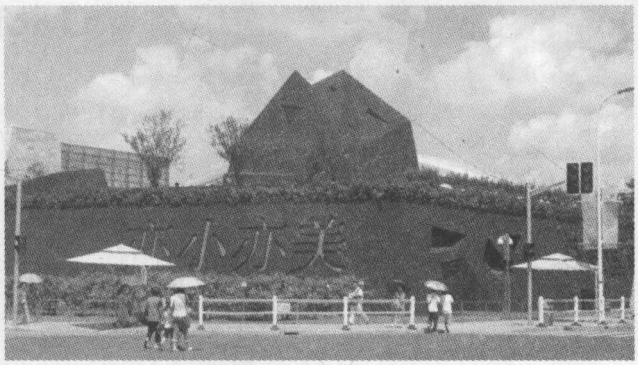

Fig. 11 Luxemburg Pavilion made of weathering steel in Expo 2010, Shanghai

The development of automobile steels is so fast that nobody could image the future progress precisely. In the last 1990s, people focused their efforts in IF steel and BH steel. And now, DP steel, TRIP steel and hot stamping martensitic steel are being widely used in automobiles, and even to begin with the research of the third-generation sheet steel (Fig. 10).

One of the main disadvantages of steels with low alloying elements is easy to be corrosive in the atmosphere. Stainless steel is one of the ways to overcome this problem, but cost a lot. Another way is to adapt weathering steels for infrastructures and buildings to be of longer duration (Fig. 11). Longer duration will need to pay more attention, not only to resist corrosion, but also to resist heat, cycling load, hydrogen embrittlement, wearing, etc. As a result, the components made of steel will be more effective, and the steel consumption will be reduced.

It is confidently believed that steel will become much better, and eventually leads to a much better world for human beings in the future.