# Innovative Vehicle — the "A-train"

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*OVERVIEW: The "A-train" structure of a train-carbody brings many advantages including a much quieter interior, improved rigidity, and better crashworthiness. In addition, the use of friction stir welding (FSW) to replace fusion welding produces less distortion, so a train-carbody fabricated from an "A-train" structure is sleeker than conventional bodies. The "A-train" structure is a modular concept that enables lead times to be reduced and makes refurbishment easier with better residual value. Moreover, it is superior in terms of recyclability because it is made of aluminum and is a "module-to-mounting" rail structure. The use of FSW to replace fusion welding technology is one of the recommendations of the Uff/Cullen Report on the Ladbroke Grove Inquiry, and this technology is attracting considerable attention all over the world.*

## INTRODUCTION

IT is widely recognized that a reliable railway system is a key to achieving sustainable economic growth and the prosperity of society. For the past 85 years, Hitachi has been constructing reliable railway networks in Japan and other countries. Hitachi, Ltd. has radically enhanced the structure and manufacturing methods of the railway rolling stock to help customers achieve their goals by providing quiet, reliable, comfortable, and safe trains that have a shorter lead time and cause less damage to the environment. The "A-train" (see Fig. 1) is the next-generation aluminum rolling stock that enables reducing the life-cycle cost and damage to the environment. It has already proven effective in various types of services, i.e. commuter, suburban, and express.

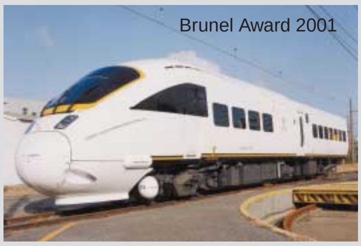
The following manufacturing methods and components have been incorporated in the design of "A-train":

• Friction stir welding (FSW), an innovative welding method that enables producing a high-precision and high-quality aluminum double-skin carbody structure


**815-Series Commuter EMU for Kyushu Railway Company**

**20000-Series Commuter EMU for SEIBU Railway Co., Ltd.**

**683-Series Express EMU for West Japan Railway Company**




**885-Series Tilting EMU for Kyushu Railway Company**

*Fig. 1— The "A-train" Family of Trains.*
*To meet the requirements for various types of rolling stock, a next-generation, aluminum carbody system—which incorporates several new concepts and ideas—called the "A-train" structure is being developed.*

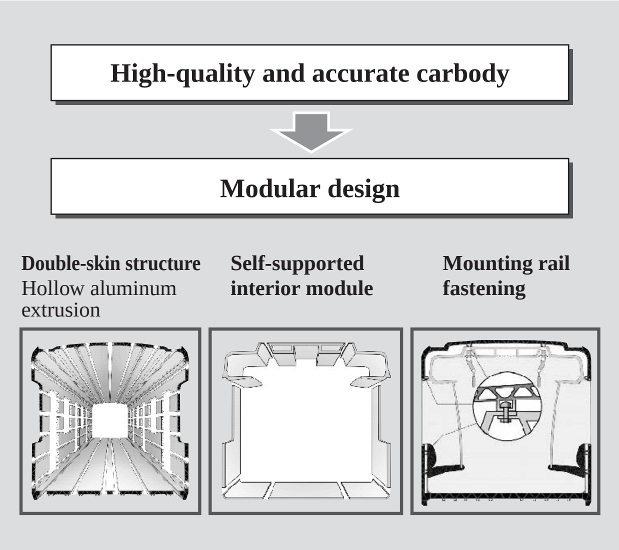



*Fig. 2— The Basic Concept of the "A-train" Structure.*
*The combination of a double-skin structure and a self-supporting interior-panel module revolutionizes the carbody structure and production method.*

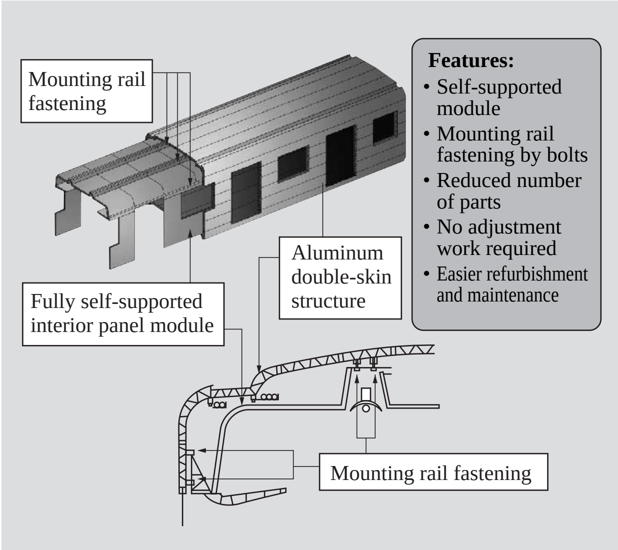



*Fig. 3— The Basic Configuration of the "A-train."*
*The mounting rail integrated with the aluminum double-skin structure can be easily fitted with the self-supporting interior-panel module using a minimum number of bolts.*

• A fully self-supported interior module
• A mounting rail with an extrusion structure to form a single unit, enabling a much simpler fastening of the module to the mounting rail

Combined with the FSW technology, the characteristics of the "A-train" carbody structure provide many advantages including a much quieter interior, improved rigidity, and a safer crashworthy structure. Moreover, FSW, with its distortion reducing process, has also contributed to the design of a sleek body of the "A-train."

A modular concept approach has enabled a shorter lead time and easier refurbishment with better residual value. "A-train" is superior to conventional trains in terms of recyclability due to the use of aluminium and its module-to-mounting rail structure. The use of FSW to replace fusion welding is one of the recommendations of the Uff/Cullen Report on the Ladbroke Grove Inquiry, and this technology is attracting considerable attention all over the world.

## THE "A-TRAIN," THE NEXT-GENERATION ALUMINUM VEHICLE

### Concept and Basic Structure

The "A-train" has been effective in reducing the life-cycle cost and environmental damage. The "A-train" features a number of improvements;
• The carbody structure has been simplified by greatly reducing the number of components
• Most adjustment processes in the interior panel fitting have been eliminated
• The modular concepts have facilitated more efficient production by enhancing the opportunity for outsourcing

The basic concept of the "A-train" is illustrated in Fig. 2 and its the basic configuration is shown in Fig. 3.

### Advantages of the "A-train"

#### Economy

The modular nature of the "A-train" structure based on the FSW technology, which enables creating a high-precision double-skin carbody, significantly reduces the life-cycle cost. This is achieved by simplifying the refurbishment and maintenance of the train.

#### Less environmental damage

The structure of the "A-train" enables easy dismantling of modules and separation of materials giving excellent recyclability. The aluminium alloy can be recycled with energy consumption as low as 3% for new metal production.

#### Precision/Quality

A combination of the aluminium double skin and FSW technology resulted in the creation of a sleek body of the "A-train." The use of extruded aluminium provides greater flexibility in the choice of cross section of the body.

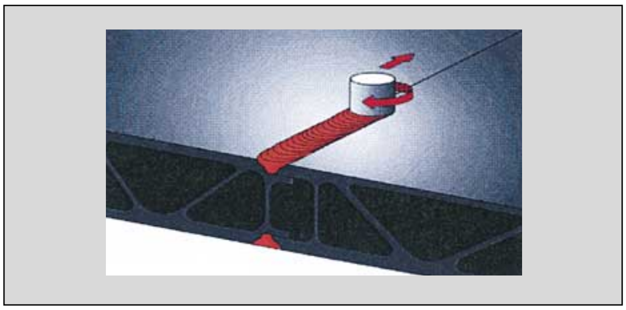


*Fig. 4— The Principle of FSW.*
*As it moves along the weld line, a revolving metallic tool generates frictional heat that melts the aluminum and forms the welded joint.*

## FSW, INNOVATIVE WELDING TECHNOLOGY

### History and Principles of FSW

TWI, a British welding research institute, developed friction stir welding in 1991. Hitachi, Ltd., as a member of the research and development team, worked on the practical applications of the technology, developing a device for the welding of 25-m aluminium material by FSW. The principle is shown in Fig. 4. A revolving metal tool progresses along the welding line, where the aluminium alloy is softened and welded by frictional heat.

### The Advantages of FSW

FSW has five main advantages:
(1) There is hardly any distortion or contraction resulting from welding.
(2) There is hardly any discoloration of the welded sections.
(3) Welding rods and shielding gas are not required.
(4) There is no spatter, no fumes, no ultraviolet rays.
(5) There are no flaws (blowholes, cracks).

### Characteristics of Joints Welded by FSW

(1) Temperature and amount of distortion of welded joints

The maximum temperature that FSW welds at is 480°C, far lower than the 660°C temperature of MIG (metal inert gas) welding. The amount of distortion is only one-twelfth of that in MIG welding. A comparison of the amount of distortion and contraction for the two welding methods is shown in Fig. 5.

(2) Strength and reliability

FSW welds were shown to be equal to or better than MIG welds on tensile strength tests. All ruptures were in sections affected by the heat. FSW has better mechanical features than MIG welding because the welding temperature is lower, there is less distortion, and there are no flaws.

(3) Impact strength

The results of Charpy impact tests carried out at room temperature show that the impact strength of joints welded by FSW is 1.7 times greater than that of the parent metal, and 2.4 times stronger than that of

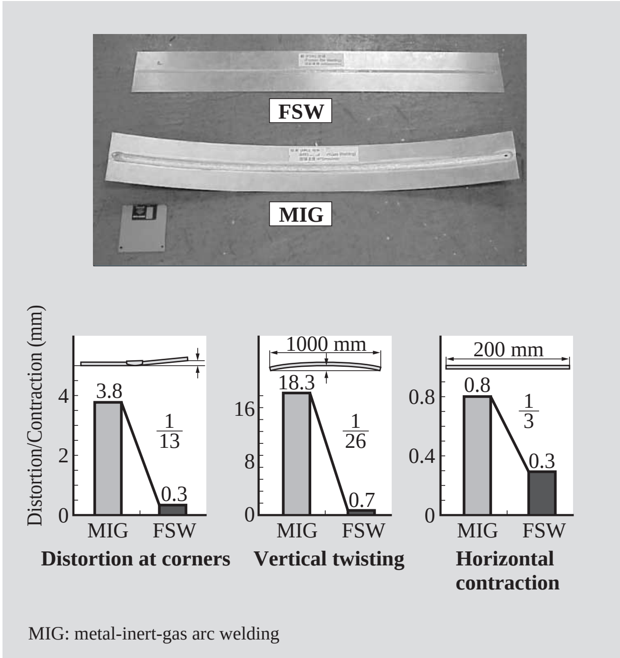



*Fig. 5— The Amount of Distortion/Contraction in FSW and MIG Welding.*
*Since FSW is based on the low-temperature-plastic-flow characteristics of aluminum, the required heat input is also low; consequently, the welding distortion and contraction are low.*

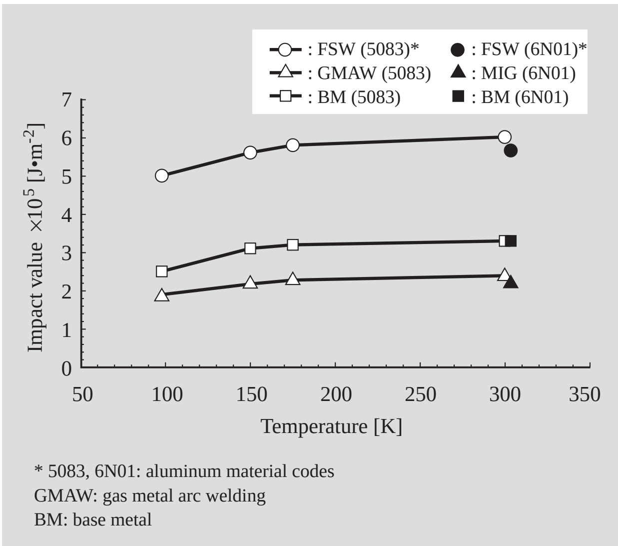



*Fig. 6— Impact Strength of FSW and MIG Welds.*
*Impact strength of joints welded by FSW is 1.7 times greater than that of the parent metal, and 2.4 times stronger than that of joints welded by MIG.*

joints welded by MIG. The ‘stirring’ of the aluminium alloy during FSW gives it a finer micro-structure, which improves its resistance to impact. In contrast, MIG welds have a coarse columnar crystalline structure, and in the post-extrusion parent material, a rougher micro-structure is formed as a result of re-crystallization and its columnar crystalline structure. The results of the Charpy impact tests are shown in Fig. 6.

## CONCLUSIONS

The “A-train” has already proven to be fully operational as new rolling stock. Because of its modular concept and the FSW technology, the “A-train” will be a solution to building tomorrow’s reliable railway networks.

## ABOUT THE AUTHORS

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