

# Development of Aluminum Frame for Heavy-Duty Trucks

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## Abstract

Aluminum was successfully used as the material for the chassis frame, a main structural member of heavy-duty trucks, to significantly reduce the truck weight and so allow the payload to be increased. A variable-section extrusion technology was used to mold the side rails of the aluminum frame (the first of its kind in the world). The shape and configuration of the aluminum frame design were optimized while maintaining strength and rigidity equivalent to those of a standard steel frame by using computer-aided-engineering analysis. Using the aluminum frame thus developed, a super-lightweight bulk truck was developed and exhibited at the 2002 Tokyo Motor Show.

*Key words:* Aluminum Frame, Load Efficiency Improvement

## 1. Introduction

With a view to meeting market demands for lower truck weights, Mitsubishi Fuso Truck & Bus Corporation has been working on development of an aluminum chassis frame for heavy-duty trucks since 1995 in collaboration with Mitsubishi Materials Corporation and Mitsubishi Aluminum Co., Ltd. Following the resolution of various technical obstacles, the development program has advanced to the point at which the goal – commercial production of aluminum frames – is in sight. This report describes the development targets and technical features of a recently produced prototype aluminum frame. It also gives an overview of a recently built super-lightweight bulk truck that has a cab-and-chassis configuration incorporating an aluminum frame and is fitted with an aluminum tank that was made by Mitsubishi Materials Corporation and has a class-largest capacity of 17 m<sup>3</sup>.

## 2. Targets of development

The aluminum frame was developed for application to high-rigidity and fixed-payload vehicles such as tank lorries, which are subject to keen demand for weight reduction. Weight-reduction targets aimed at higher fuel economy and loading efficiency were set both for the frame and for the overall vehicle. Rigidity and strength comparable with those of a current steel frame were also targeted. The strategy employed for their achievement was optimization of the overall vehicle design.

### (1) Weight reduction targets

- Aluminum frame: at least 300 kg lighter than steel frame
- Super-lightweight bulk truck: at least 1500 kg lighter than steel-frame truck



Fig. 1 Aluminum frame

## 3. Major specifications

The major specifications and appearance of the aluminum frame are shown in Fig. 1. The major specifications of the super-lightweight bulk truck are shown in Table 1, and the appearance of the truck is shown in Fig. 2.

## 4. Technical features

### 4.1 Reduced weight and improved fuel consumption

Weight reductions were implemented in chassis components that accounted for 65 % of cab-and-chassis weight and in the bulk tank mounted on the chassis. Also, super-single tires (Fig. 3), whose rolling resistance is 10 % lower than that of conventional tires, were specified for improved fuel consumption.

[Main weight-reduction items]

- (1) Adoption of aluminum chassis frame (weight reduction achieved: 320 kg)
- (2) Adoption of super-single tires with aluminum wheels (Fig. 3) as well as other aluminum parts including fuel tank (weight reduction achieved: 200 kg)

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**Table 1 Major specifications of super-lightweight bulk truck**

Overall length x overall width x overall height	(mm)	11270 x 2490 x 3430
Wheelbase	(mm)	7040
Gross vehicle weight	(kg)	24930
Bulk tank capacity	(m <sup>3</sup> )	17
Maximum payload	(kg)	15800
Crew		2
Engine		6M70 (T2)
Piston displacement	(cc)	12882
Maximum output	(kW/min <sup>-1</sup> )	257/2200
Maximum torque	(Nm/min <sup>-1</sup> )	1520/1200
Transmission		M130S7D
Tires	Front	295/70R22.5
	Rear	435/45R22.5 (super single)



**Fig. 2 Super-lightweight bulk truck, SUPER GREAT FU (exhibited at 2002 Tokyo Motor Show)**



**Fig. 3 Super-single tires**

(3) Adoption of aluminum bulk tank: (weight reduction achieved: 1000 kg)  
 These measures reduced weight by approximately 1.5 tons in total, allowing the payload to be increased by the same amount and concurrently realizing a 3 % improvement in fuel consumption.

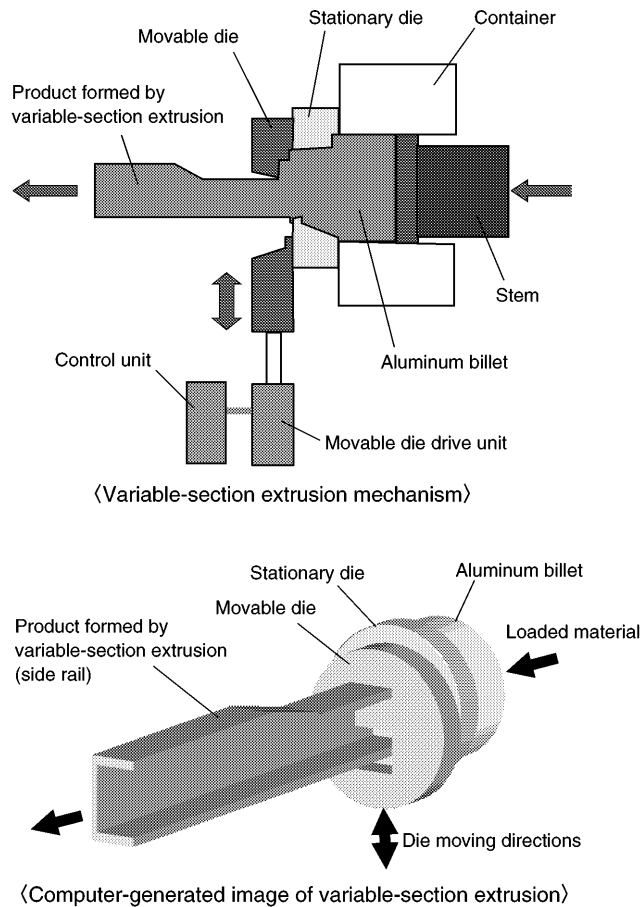
**4.2 Variable-section extrusion**

Variable-section extrusion technology was adopted to form the side rails, which constitute major parts of the aluminum frame. This technology was originally developed by Mitsubishi Aluminum Co., Ltd.

Unlike standard extrusion technology, which forms products of a uniform section using only stationary dies, the variable-section extrusion technology uses movable dies in addition to stationary dies as shown in Fig. 4. The variable-section extrusion system changes the positions of the movable dies using a drive unit, thus varying the section of the product as the material passes through the dies.

This technology is suitable for side rails, whose sectional shape needs to differ from area to area. Its single-piece forming capability eliminates the need for welding and thus ensures increased accuracy and rigidity in the frame.

Extrusion-formed, high-rigidity channel-section beams and box-section beams were adopted as the



**Fig. 4 Variable-section extrusion**

crossmembers connecting the left- and right-hand rails. Mitsubishi Materials Corporation assembled the side rails and crossmembers, successfully producing a frame with dimensional accuracy as high as that of a steel frame.

**4.3 Rigidity**

Each heavy-duty truck shipped from the factory in cab-and-chassis form is completed by a body builder in accordance with the customer's order. The truck's frame must be sufficiently strong and rigid to bear the load of the body constructed on it and to thus assure a vehicle service life over a million kilometers. Any significant deficiency in the frame's rigidity can detract

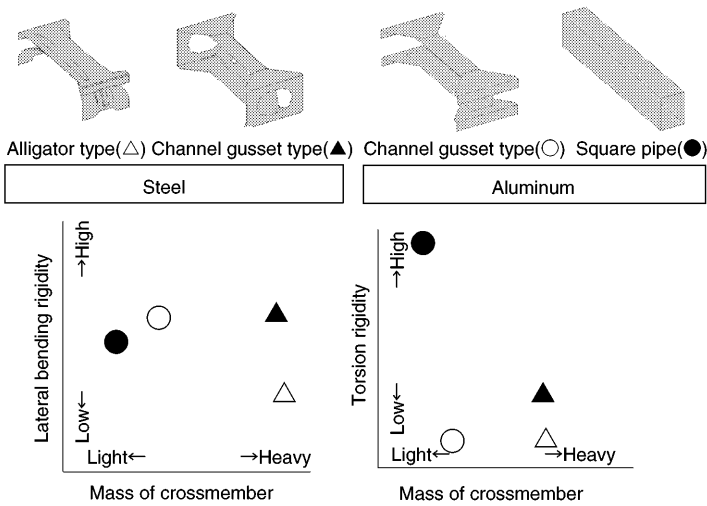


Fig. 5 Rigidity of crossmember



Fig. 6 Stiffness test of aluminum frame

from the vehicle's handling stability and cause the body structure to be subjected to concomitantly increased input loads, resulting in premature wear of body components. The rigidity of the aluminum frame was assured by the following features:

- Rigidity of vertical bending: The thicknesses of the side rails' flanges and webs were optimized taking advantage of the variable-extrusion method.
- Rigidity of lateral bending and torsion: Aluminum channel-section crossmembers that are highly resistant to lateral bending were combined with extrusion-formed box-section crossmembers that are highly resistant to torsion (Fig. 5).

The results of rigidity tests (Fig. 6) conducted on the aluminum frame indicated rigidity comparable with that of the current, time-proven steel frame.

In addition, computer-aided-engineering (CAE) analysis was conducted using the model shown in Fig. 7 for optimal matching of the frame and tank, resulting in overall vehicle rigidity equivalent to that of the current steel-frame bulk truck (Fig. 8).

4.4 Strength and durability

The adoption of aluminum in place of steel as a

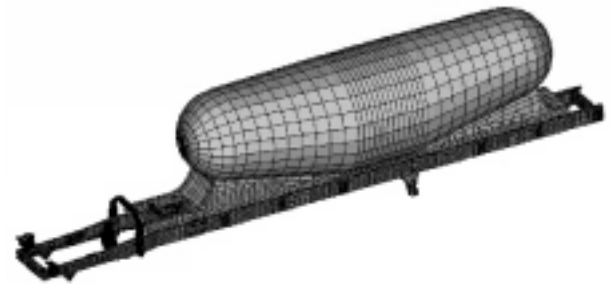


Fig. 7 Analysis model of aluminum frame with tank

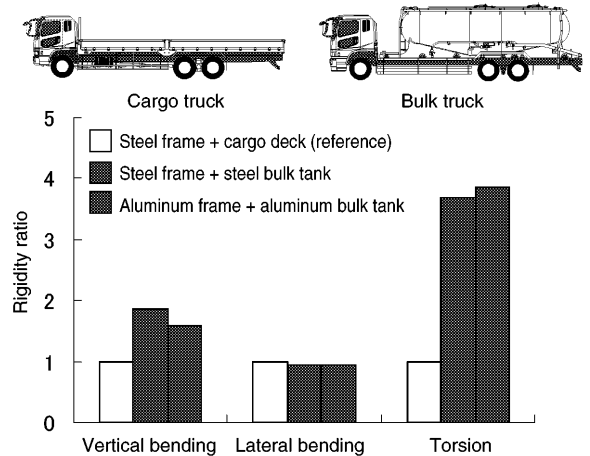


Fig. 8 Rigidity of entire vehicle

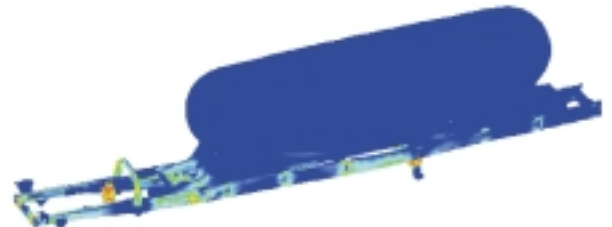


Fig. 9 Stress distribution during vehicle-turning

truck-frame material necessitated various strength-related studies since it resulted in a reduction of about one half in tensile strength and a reduction of about one thirds in vertical modulus of elasticity.

To ensure adequate strength in the aluminum frame and aluminum bulk tank mountings, CAE analysis of the entire vehicle was conducted with assumed conditions corresponding to harsh inputs caused by steering maneuvers. The analysis results were reflected in the aluminum frame design, resulting in strength equivalent to that of a steel frame (Fig. 9).

The aluminum frame was also subjected to a bench test (Fig. 10), which proved that the frame was sufficiently strong and durable to resist large, local load inputs in the vicinity of the rear suspension.

To compensate for inferior local strength in fastener areas, the unit surface pressure of each nut was reduced using a large washer (which also helped to prevent the



Fig. 10 Strength test of aluminum frame

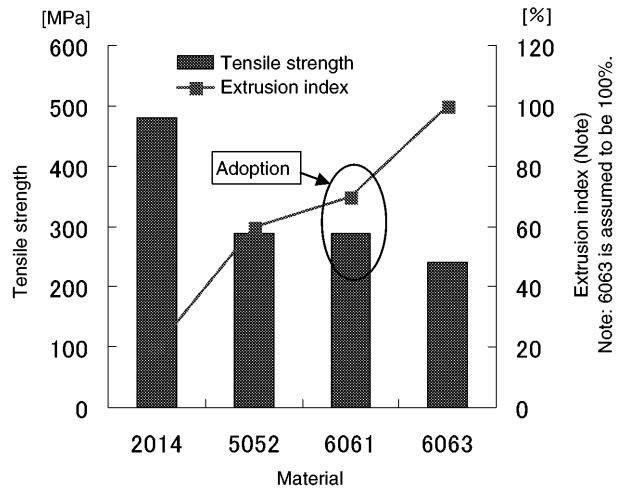


Fig. 12 Tensile strength and extrusion index of aluminum material

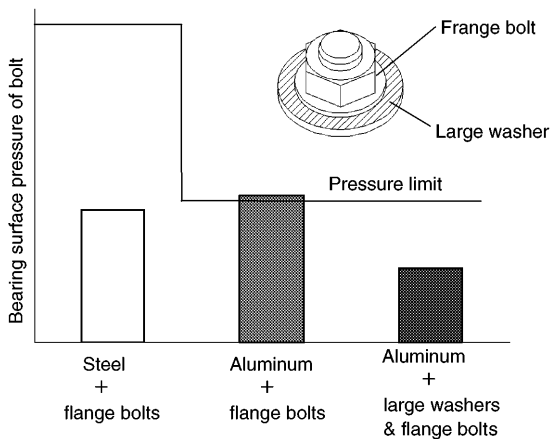


Fig. 11 Strength of bolting locations

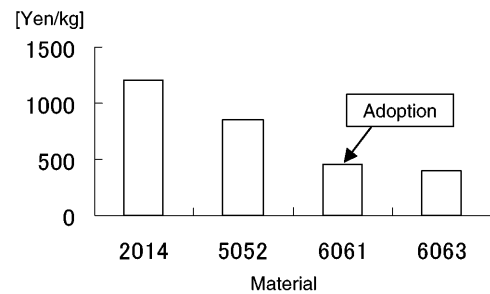


Fig. 13 Costs of aluminum materials

bolt from coming loose) (Fig. 11). These fasteners were dacrotized to prevent contact corrosion.

#### 4.5 Material

The material selected for the frame is 6061-T6, which is well balanced in terms of extrusion formability, strength, and cost (Figs. 12 and 13). This material has been used for the crossmembers of certain heavy-duty trucks since 1998.

#### 5. Summary

Collaborative development with Mitsubishi Materials Corporation and Mitsubishi Aluminum Co., Ltd. yielded an aluminum frame that satisfies the weight-reduction target and has sufficient strength and rigidity. Remaining technical issues will be addressed to enable commercial adoption of the aluminum frame. Finally, the authors wish to express their gratitude to all of the people inside and outside the company who gave valuable suggestions and assistance.

#### References

- (1) Japan Light Metal Association: Aluminum Handbook
- (2) Akira Yamamoto: Theory and Calculation of Screw Fastening



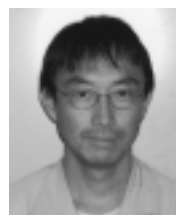
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