

# Development of Magnet Compound Type Seat-Suspension

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## Abstract

Small trucks have severely limited freedom of layout in the cab interior, so the space for the suspension to be installed under the seat is also limited. As the conventional seat suspension utilizing coil springs and torsion bars does not have a sufficient working stroke, the setting has been rather hard with a high spring constant. Recently, we have successfully developed a new seat suspension that offers softer, better riding comfort, yet it occupies even less space than the conventional type suspension. This was achieved by utilizing the combination of a magnetized coil spring with non-linear spring characteristics and a torsion bar with linear spring characteristics. This paper introduces the new seat suspension.

**Key words:** Truck, Seat, Riding Comfort, Magnet

## 1. Introduction

As anyone who has played with magnets as a child is aware, unlike poles attract each other and like poles repel each other, the attraction or repulsion becoming stronger as the poles are brought closer together. The attraction and repulsion between poles is fundamental to devices that work using magnetism.

The performance available from permanent magnets was dramatically increased in 1984 with the development of a magnetic material made from neodymium (Nd), iron (Fe), and boron (B). Since then, Nd-Fe-B permanent magnets have been used for an increasingly wide range of purposes in electrical appliances, medical equipment, automobile engines, and other products (Fig. 1<sup>(1)</sup>).

Permanent magnets also have possibilities for seat-suspension. Vibration-absorption arrangements for seat-suspension conventionally employ either compressed air or metal springs. Air-suspension generally allows a low spring constant, and it allows easy compensation for weight differences between users by means of adjustment of the pressure in the air-suspension chamber. On the downside, air-suspension is costly and requires considerable space for installation. And with light-duty trucks, which generally lack on-board compressed-air supplies, it cannot be used unless a dedicated source of compressed air is also provided.

Seat-suspension employing metal springs (typically coil springs and/or torsion bars) also has shortcomings: Since the spring characteristics are linear, a location that does not provide space for an adequate stroke generally necessitates a high spring rate, resulting in a relatively hard ride.

Mitsubishi Fuso Truck & Bus Corporation avoided these limitations with the magnetic spring arrangement

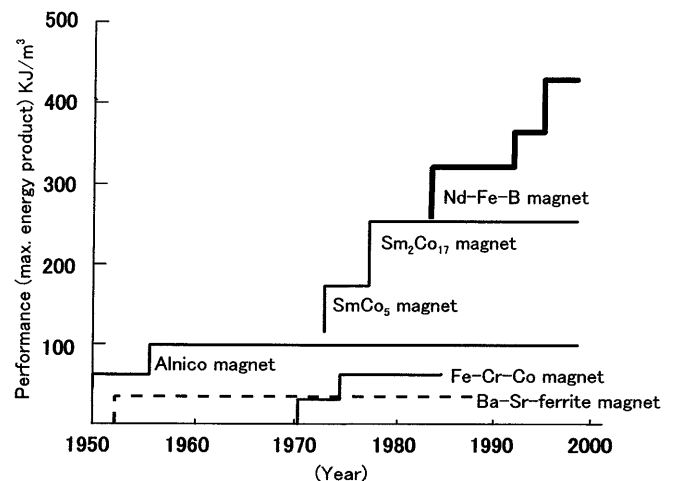


Fig. 1 Development of permanent magnet

that it recently developed for seat-suspension: Non-linear characteristics provided by the magnetic spring are combined with the linear characteristics of auxiliary metal springs, permitting a low spring rate that yields a comfortable ride despite a short stroke.

## 2. Development goals

For maximal headroom in the new Mitsubishi CANTER, the hip point was set 15 mm lower than in previous models. Since the space available under the seat was reduced as a result, it was not possible to achieve a comfortable ride by using a conventional coil-spring seat-suspension system. A magnetic seat-suspension system whose non-linear spring characteristics permit both compact dimensions and superior ride comfort was thus developed.

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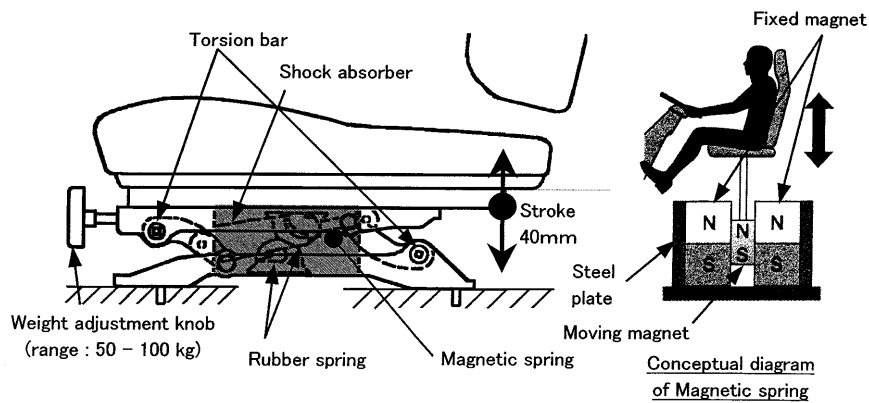


Fig. 2 Structural outline

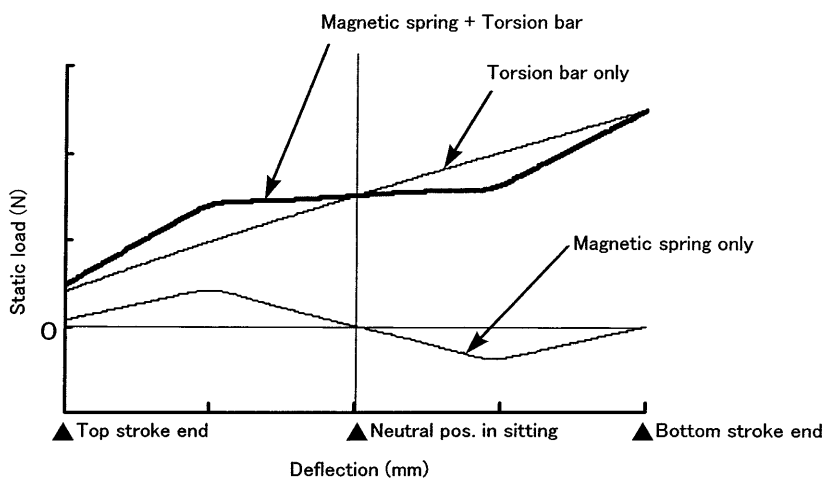


Fig. 3 Static load - deflection characteristic

Table 1 Specification comparison

|   | Magnetic suspension                            | Coil-spring suspension                     |
|---|--|--|
| Method of vibration absorption & damping    | Magnetic spring + Torsion bar + Shock absorber | Coil spring + Torsion bar + Shock absorber |
| Spring constant (N/mm)                      | 7.8 - 8.8                                      | 14.8 - 15.8                                |
| Overall stroke (mm)                         | 40   | 60   |
| Downward stroke (mm)                        | 25   | 40   |
| Damping force of shock absorber (N/0.3 m/s) | Extension: 686<br>Compression: 1372            | Extension: 1029<br>Compression: 1764       |
| Weight adjustable range (kg)                | 50 - 100                                       | 50 - 90                                    |
| Mass of unit (kg)                           | 10.0   | 9.5  |

### 3. Structure and characteristics

A magnet attached to the seat (moving magnet) moves up and down between left- and right-hand floor-mounted magnets (fixed magnets), producing spring forces of particular non-linear characteristics (Fig. 2).

Magnetic forces balance when the seat occupied by the driver is at the neutral point. At a seat position higher or lower than the neutral point, the magnetic spring produces an upward or downward non-linear force,

respectively. The magnetic spring is combined with two torsion bars (auxiliary springs) to enable a low spring constant (and a concomitantly soft ride) when the seat is occupied (Fig. 3).

To soften the shock caused by bottoming at the end of the stroke, rubber springs are located on the left- and right-hand links (one upper rubber spring and one lower rubber spring on each side). The torsion bars permit stepless adjustment for driver-weight variations in a range from 50 kg to 100 kg.

The specifications of the magnetic seat-suspension system and the specifications of a conventional coil-spring seat-suspension system are compared in Table 1. As shown, the spring constant in the vicinity of the neutral point is approximately 50 % lower, i.e., softer, with the magnetic system.

### 4. Results of evaluation

#### 4.1 Results of bench tests

For a ride-comfort comparison, the magnetic seat-suspension system and a conventional coil-spring seat-suspension system for light-duty trucks were each set on a bench-mounted shaker and subjected to displacement inputs corresponding to vehicle operation at 70 km/h on Metropolitan Expressway in Japan.

As shown in Fig. 4, the magnetic system yielded both lower resonant frequency (see ① in Fig. 4) and lower peak transmissibility (see ② in Fig. 4) than the coil-spring system. The magnetic system also comprehensively suppressed transmissibility in the 3 - 15 Hz range (see ③ in Fig. 4). (Vibration in this frequency range is particularly easy to feel.)

The two seat-suspension systems were also subjected to displacement inputs corresponding to vehicle

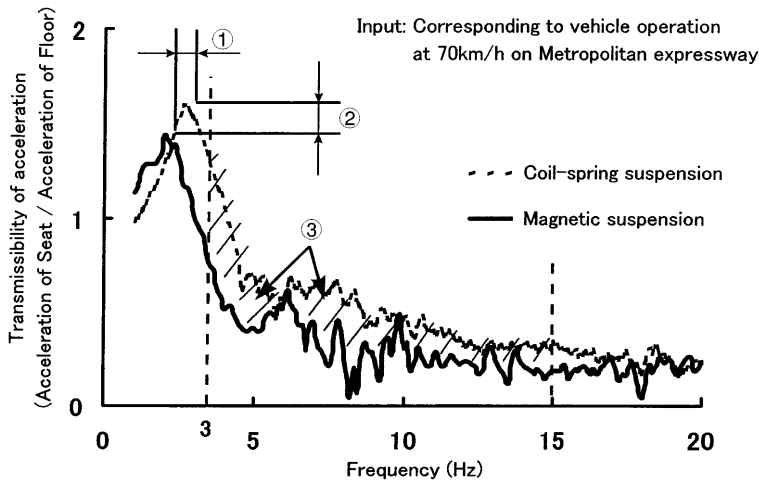


Fig. 4 Bench test of riding comfort (1)

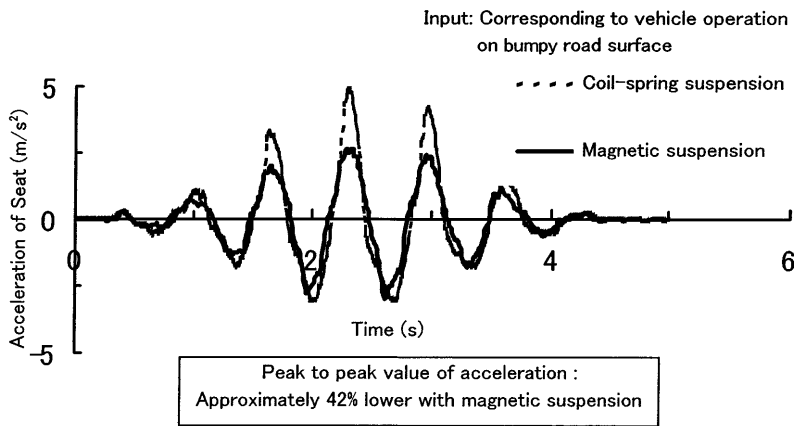


Fig. 5 Bench test of riding comfort (2)

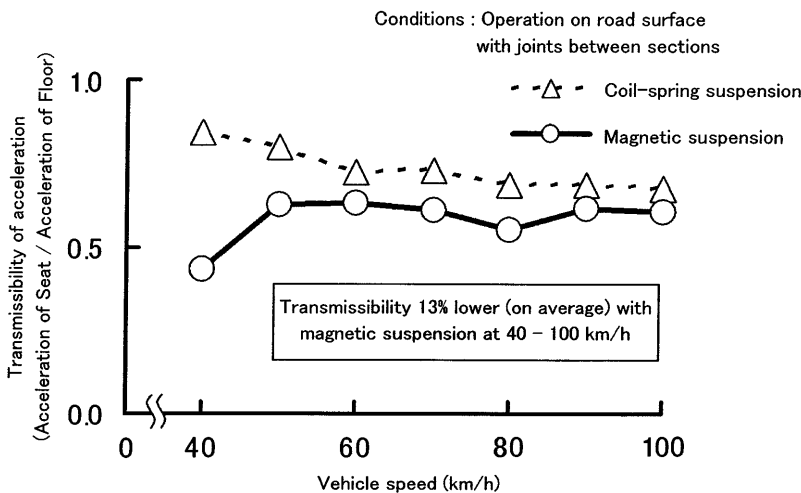


Fig. 6 Vehicle test of riding comfort

operation on bumpy road surfaces, and compared in terms of acceleration. As shown in Fig. 5, peak-to-peak values were approximately 42 % lower with the magnetic system and there was no deterioration in damp-

ing.

With regard to durability, magnetic spring and related links, torsion bars, and shock absorbers in the magnetic system remained free of abnormalities after 500000-cycle vibration tests.

#### 4.2 Results of vehicle tests

The acceleration transmissibility at every vehicle speed was measured with each suspension system on a road surface with joints between sections (the kind of surface found on elevated roads), and the results were compared. As shown in Fig. 6, the average acceleration transmissibility of the magnetic system at speeds in the 40 – 100 km/h range was 13 % lower than that of the coil-spring system.

The results of evaluation of ride feeling during actual vehicle operation can be summarized as follows: ① On a smooth road surface, the magnetic system gave a sense of smooth movement over the entire stroke by lower spring constant and lower friction, resulting in superior ride comfort. ② On a road surface with joints between sections, the magnetic system's seat acceleration was lower, resulting in superior ride comfort. ③ On a bumpy road surface, bottoming could occasionally be felt toward the end of the magnetic system's stroke, but damping was good and there was no abrupt shock. Overall, the magnetic system's ride feeling was always comparable to or better than that of the coil-spring system.

#### 5. Resolution of concerns

The use of permanent magnets gave rise to concern about leakage of magnetic flux, so the extent of leakage was verified.

The magnetic spring is constructed such that the permanent magnets are covered by steel plating. Magnetic flux flows within the plating, so the plating effectively forms a shield that minimizes leakage. As shown in Table 2, it was confirmed that leaking magnetic force did not exceed 0.33 mT (3.3 gauss) (well below the reference value of 0.5 mT (5 gauss) for cardiac pacemakers<sup>(2)</sup>). It was thus confirmed that leakage had no health effects.

It was also confirmed that tools, bolts, nuts, and other metallic items did not stick to the magnetic spring. Not even a paper clip weighing approximately 0.3 g was attracted strongly enough to stick. Further, a cover

**Table 2** Measured value and reference value of magnetic force

|   | Location of measurement      | Result                      |
|---|------------------------------|-----------------------------|
| Measured leakage of magnetic flux                 | Upper surface of Cushion pad | Max. 0.13 mT (1.3G)         |
|   | Front surface of Suspension  | Max. 0.27 mT (2.7G)         |
|   | Side surface of Suspension   | Max. 0.33 mT (3.3G)         |
| (Reference data)<br>Devices affected by magnetism | Devices                      | Reference value             |
|   | Bank card, Wristwatch        | Not more than 2.0 mT (20 G) |
|   | Magnetic tape, CPU           | Not more than 1.0 mT (10 G) |
|   | Cardiac pacemaker            | Not more than 0.5 mT (5 G)  |

mT: millitesla; G: gauss

made of non-woven fabric was fitted over the entire magnetic spring to keep foreign objects out.

With regard to deterioration of the permanent magnets over time, measurements taken by the magnet manufacturer showed that the demagnetization coefficient after 10 years was no greater than 1 %. It was thus confirmed that deterioration in magnetic-spring performance was not an issue. Further, a nickel coating was applied to the magnets to prevent rust from forming on them. After 500 hours of salt-spray testing, it was confirmed that no rust had formed and that no change in magnetic force had occurred.

## 6. Summary

A magnetic seat-suspension system for trucks (the first such system) was developed and was adopted in the new Mitsubishi CANTER. The system is standard equipment in some models, and it has received a generally favourable evaluation at dealer presentations, press test drives, and other events. In accordance with customers response, we intend to enhance the system and pursue reductions in size, weight, and cost.

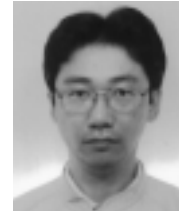
In closing, we wish to express our gratitude to the staff of the departments and companies that co-operated in the development program.

### References

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