15T Traction Machines for High-Speed Elevators

Traction machine, Elevator, PM motor, Sheave, Dual braking system

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Abstract

The expansion of the elevator market is remarkable worldwide. Due to urbanization into the big cities, demand for higher-speed and larger-capacity elevators is increasing. Responding to this, we developed and released a 15T traction machine with a load capacity of 2000kg and speed of 240m/min to fit high-speed elevator demand. Conventionally with high-speed elevators, the bearing stands are located on both sides of the sheave and use a both-ends construction that distributes the load of the sheave. However, our elevator facilitates exchange of the sheave by using one-end sheave construction. In addition, the optimization of the traction machine construction resulted in a 10% reduction of mass compared with the former machine.

Following the amendment of the Japanese Building Standard Law effective since 30 September 2009, any elevator traction machine is required to take actions for redundancy of braking system and bearing oil leakage protection. This new product was designed to meet the new elevator safety standard requirements.

1. Preface

In the elevator industry, compact and slim design, simple installation and adjustment, and minimal maintenance time are key requirements. To meet the recent rising energy-conservation needs, traction machines changed from induction motors with reduction gears to a gearless design with Permanent Magnet (PM) type synchronous motors. The full stream drive unit is now an Insulated Gate Bipolar Transistor (IGBT) inverter. Further a common approach is to use the regenerative converter to make the best use of the regenerative power.

For more than 30 years, we have been undergoing product developments for electrical components for elevators. In particular, our recent focus has been on the development of PM motors and traction machines. This paper introduces high-speed traction machines and their features.

2. Scope of Application

Fig. 1 shows application scope of our electrical components for elevators. The speed range of 105m/min or below is categorized into medium and low speeds. The high-speed range covers speeds from 120 to 240m/min. We developed and put into production the traction machines for the 15t class sheave shaft load to fit the above-mentioned high-speed range.

3. Specifications

Fig. 2 shows construction of a high-speed elevator. The traction machine is installed in the machine room

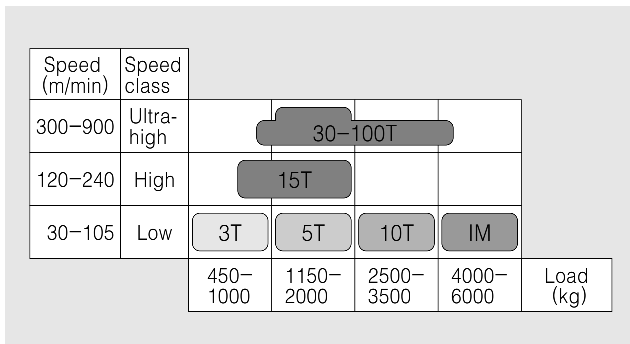

Fig. 1 Application Scope of Electrical Components for Elevators

The relationship is shown between loads and speeds applicable to Meiden electrical appliances for elevators.

of the highest floor. The sheave is rotated by the driving motor to move the cable and further to drive the cage and its counter weight. In order to support the mass of cable, cage, and counter weight, a heavy load is exerted on the sheave shaft of the traction machine. In the case of a low-speed elevator, one-end sheave construction is mainly utilized where the load is supported on the motor output shaft. For the high-speed elevator, on the other hand, the stroke becomes longer and the cable mass becomes large. Therefore, generally in high-speed elevators bearing stands are allocated on both sides of the sheave. This is both-ends construction to secure strength of structural pieces against the sheave shaft load and also to ensure bearing life. In the case of this construction, however, the sheave cannot be installed or removed

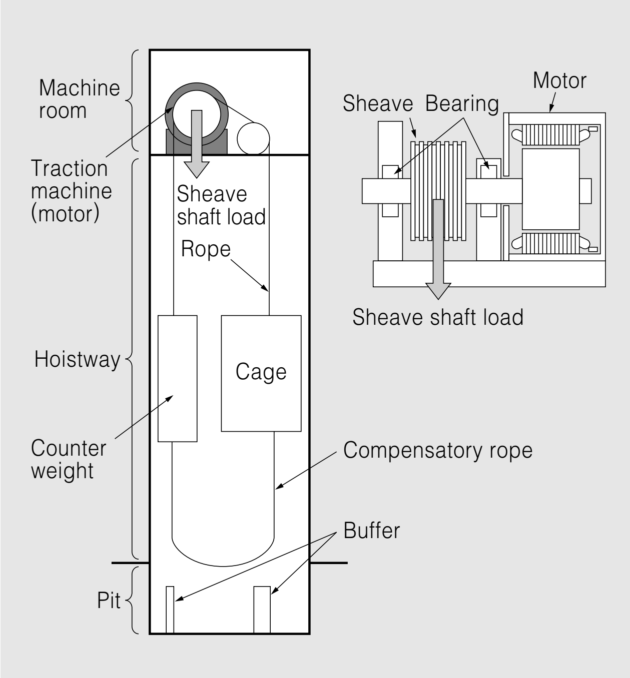

Fig. 2 Construction of High-Speed Elevator
This figure shows an internal construction of a high-speed elevator generally used in office buildings.

Table 1 Basic Specifications
Compared with conventional both-ends construction, external dimensions have been reduced by 15% in volumetric ratio.

Item	Specifications
Load	2000kg
Speed	240m/min
Rated output	50kW
No. of poles	24P
Rated revolution	255min^{-1}
Sheave shaft load	147,000N
Sheave diameter	600mm
Brake torque	3377N・m
Dimensions	W1012 × H1030 × L1127mm

unless the bearing stands are disassembled. This point had been a problem that replacement of the sheave cannot be accomplished easily.

To solve this current problem and challenges relating to high-speed elevators, our traction machine offers the following features:

(1) A single ended construction is used. This is our first experience to use this construction for traction machines in high-speed elevators. As a result, the sheave can be replaced easily and maintenance work became easier.

(2) Characteristics of low torque ripples and smooth riding comfort were attained by fully using electromagnetic field analysis and through effective magnet shape design.

(3) Low-speed and high-torque characteristics are realized to obtain gearless features.

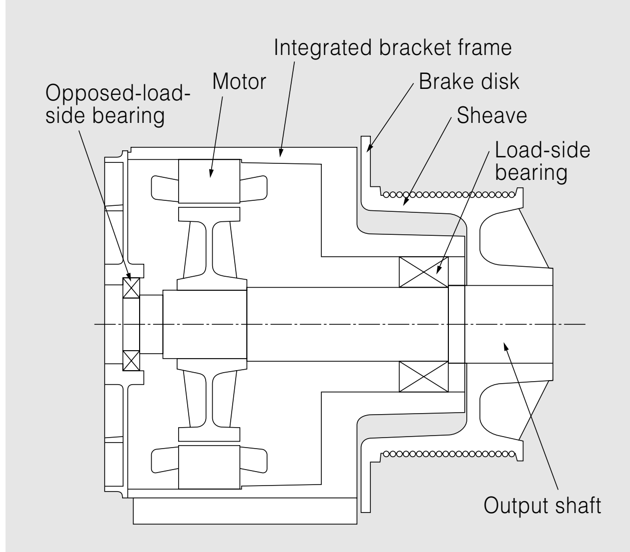

Fig. 3 One-End Sheave Construction
This construction is devised to insert the load-side bearing in the sheave inside. Smaller size can be expected compared with a former both ends sheave supporting construction.

Table 1 shows the basic specifications of our traction machine for elevators.

4. Discussions on 15T Traction Machine

4.1 Realization of One-End Sheave Construction

It is necessary to largely reduce load bearing on a sheave to lower the volume and mass in comparison with a both-ends construction in the motor output shaft that supports the load of a sheave with one end construction.

As shown in Fig. 3, this traction machine has a construction where the load-side bearing is positioned inside of the sheave. Since the frame and load-side bracket and the sheave and brake disk are unified respectively, the following points could be realized:

(1) Reduction of the bending moment of motor output shaft load by selecting the shortest overhung distance between the load-side bearing and the center of sheave load

(2) Reduction of shaft deflection

(3) Reduction of sheave leaning

(4) Fulfilling a life of the bearing

4.2 Light and Compact Design

Frame strength was analyzed by the CAE analysis method. In particular, a best shape was determined to avoid concentration of stresses. Specifically, in the corner in which large stress often appears, raising the radius of curvature disperses stress to avoid stress concentration. Fig. 4 shows the result of CAE analysis for the frame. In the parts where stresses are small, the wall thickness was reduced to obtain lighter mass. By adopting a construction where the bearing is inside the sheave, the life of bearing becomes longer and axial direction length is reduced. Since the sheave and the brake disk are integrated, a compact design is possi-

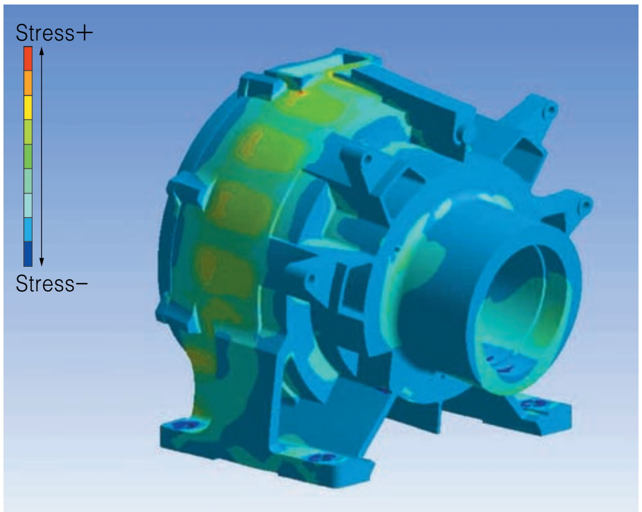

Fig. 4 Result of CAE Analysis
In the construction where a bearing is inserted inside the sheave, stresses are dispersed to secure strength.

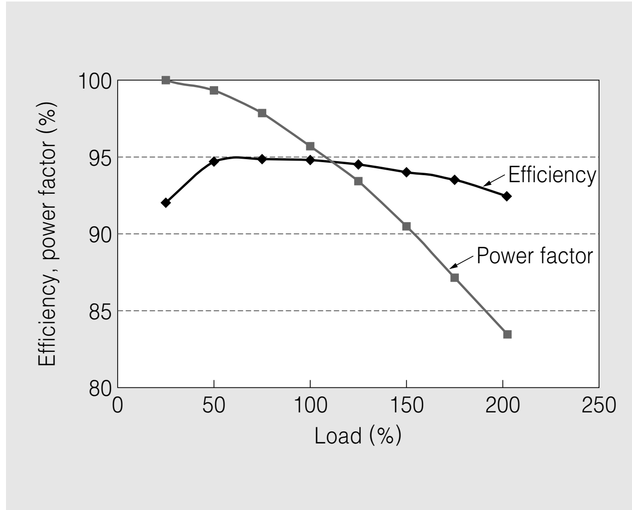

Fig. 5 Efficiencies and Power Factors in Motor Load Test
Efficiencies and power factors at the rated output were obtained from measurements. It showed the result of high efficiency.

ble. As a result, compared with conventional both-ends, there was a 10% reduction in terms of mass, and a 15% reduction in terms of volume.

4.3 Low Torque Ripples and High Efficiencies

Fractional Slot Windings and Slot Skew configuration was adopted for the stator. The effective magnet shapes was made through electromagnetic field analysis. As a result, we realized low torque ripples and high efficiencies that are characteristics preferable in elevators.

4.4 Meeting New Safety Standards of Japan

Following the amendment of Japanese Building Standards Law effective since 30 September 2009, the two additional requirements specified below were applied in regard to safety of traction machines for elevators. Our newly developed traction machine incorporated the requirements under the new safety standards.

(1) Braking system redundancy

Following the new safety standards, two sets of brake units have to be installed. One brake is required to make sure it can stop and hold the 100% rated load and it has such braking performance. Our traction machine is equipped with two magnetic clampers and large-scale brake disks to satisfy the above-mentioned conditions. Since the sheave and the brake disk are integrated into a united body, disk's ring strength is increased and displacement of brake disk is reduced.

(2) Protection against oil leakage from bearing section

The new safety standards require the construction to avoid oil contamination in a place affecting braking force. The other structural requirements are that oil leakage shall be examined from the outside at the time of maintenance and inspection.

As a countermeasure against oil leakage, the oil seal and labyrinth seal for our traction machine is of the double seal type. In the case of oil leakage caused as a result of oil seal deterioration, you can check the oil leakage from a drain hole located under the motor.

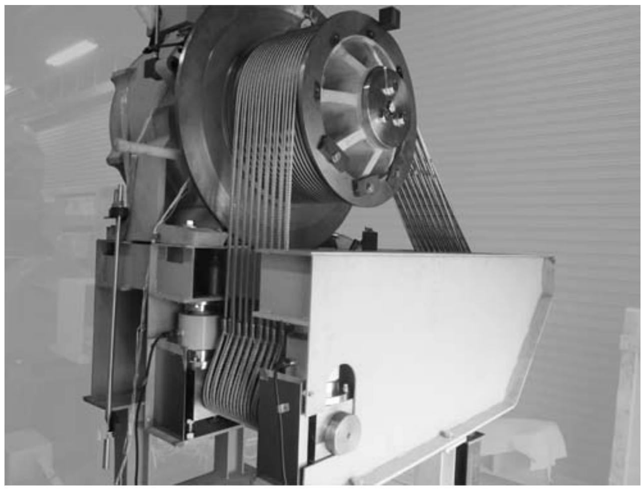

Fig. 6 Sheave Shaft Load Tester
Resting configuration is shown for sheave shaft load testing. The photo shows a test facility of stresses and frame strength.

5. Verification Test on Actual Machine

5.1 Motor Load Test

Fig. 5 shows the graphs of efficiencies and power factors of this motor. At the rated output, efficiency of 94% or above and a power factor of 95% or above were attained. This result confirms that the motor sufficiently meets the recent needs of energy conservation.

5.2 Shaft Load Test

Shaft load testing was carried out for the comparison of analytical values of stresses exerted on the frame and confirmation of frame strength. Fig. 6 shows the sheave shaft load tester. According to the result of this testing, we confirmed that the measured stress values in concentration areas reasonably coincide with the analytical values and that it has a sufficient strength against the sheave shaft load.

5.3 Measurement of Displacement in the Brake Disk

We carried out analysis and actual measurements to confirm that the brake disk displacement is kept at a sufficient level so that the brake disk does not come in contact with the brake pad when a maximum sheave shaft load (147,000N) is applied. The brake disk displacement at the time of maximum sheave shaft load still shows ample allowance in regard to the brake gap length. This value is found to coincide with the analytical value very well.

5.4 Oil Leakage Test

Through the oil leakage test, we examined the construction against oil leakage. Oil is always discharged from the oil drain and no oil leakage is observed from any sections other than the oil drain. We confirmed that oil does not reach the braking contact surface.

6. Postscript

This paper introduced features of our 15T traction machine for high-speed elevators. Going forward, we anticipate that the market needs for higher performance and safety will be there. We will make our best effort in our R&D to meet these requirements.