Linear-Motor-Driven Full-Active Mass Damper

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1. Motive for Development

In the field of civil engineering and construction, as large and high-rise structures are increasingly created, the number of cases where there is concern over structural motion due to strong winds is growing. For example, in the field of construction, a mass damper has been employed as a measure to address a phenomenon causing a tall building motion induced by strong winds such as typhoon, making people in the building "building sick," which is something akin to seasickness. Recently, there is also an increasing momentum for the adoption of mass dampers as a measure against the after-shaking of tall buildings due to long-period ground motion. The prolonged after-shaking of high-rise buildings in Tokyo due to the Great East Japan Earthquake of March 11, 2011 is still fresh in our memory.

To meet this social need, mass dampers, mainly the "passive type," in which the moving mass is supported by a spring mechanism using a pendulum or coil spring, and the "hybrid type," in which an actuator is incorporated into a passive type device, have conventionally been used. Although these devices have been used widely as mass dampers for large structures, such devices are huge due to the limited stroke of the moving mass, seriously affecting installation space, etc. in structures (the performance of a mass damper is the product of the amount of stroke and the moving mass). Another issue in these conventional devices is high maintenance costs due to special components used.

We have been committed to addressing the issues stated above with a focus on the research and development of a "full-active type" mass damper that does not include a passive mechanism. Consequently, we have developed a linear-motor-driven full-active mass damper ("the linear-motor-driven mass damper") shown in Figure 1.

2. Features

(1) Longer Stroke

The ultimate concept of the linear-motor-driven mass damper is "to have a long stroke that can suppress long-period ground motion." Conventional full-active mass dampers use a mechanical drive system, in which the rotational motion of a ballscrew, etc. is converted into a translational motion, to drive the moving mass. However, they have a disadvantage that the stroke is limited to about ±0.5 to ±1.5 m depending on the workmanship or limitations of the strength of the ballscrew. On the other hand, with stators (permanent magnets) placed in a row, the linear-motor-driven mass damper provides a stroke approximately two to three times longer compared with a damper using a ballscrew. This is an effective measure for a long-period ground motion of ultra-high-rise buildings over 200 meters tall.

The benefits of long-stroke design can also be extended to the lighter weight of the damper. Since the performance of a mass damper is the product of the amount of stroke and the moving mass, by extending the stroke up to the limit of the installation space and reducing the weight of the moving mass, the reinforcement required for the structure to install the damper can be reduced. Figure 2 shows a comparison of the dimensions of our mass damper products with equivalent performance. The height of the linear-motor-driven mass damper is about one-fourth of a conventional hybrid type model and about half of a ballscrew-driven type model.

(2) Unit-based Design

The linear-motor-driven mass damper does not use special components and consists of shared general-purpose components only. This has resulted in the following advantages.

- Improved design efficiency thanks to the construction composed of a combination of standard general-purpose components instead of special components
- Ease of upgrade and maintenance of components by using general-purpose items
- Ease of additional damper installations in existing buildings thanks to the significantly reduced parts count and separable components

(3) Use of Capacitor Bank

When the moving mass of a mass damper generates an inertial force through repeated accelerations and decelerations, regenerative electric power is generated. As shown in Figure 3, this system employs a technology for saving energy by reusing the regenerative electric power with a capacitor bank. The power supplied from the power source is consumed only as loss in the system, which makes the reduction of the power supply capacity to approximately one-third the current capacity possible. With this system, the power loss during AC-DC conversion can also be reduced, successfully reducing the power load of the structure and the running costs.

3. Application Record

The mass damper has a wide range of application and can be applied to ships and marine structures, as well as civil engineering and construction. Since 2011, when the development was completed, the mass damper has been adopted by a total of 12 projects (32 units), including 10 completed projects and two ongoing projects, as of 2016.

4. Conclusion

The mass damper has characteristics including compact size and wide scope of application that are not found in other conventional devices, thanks to the use of a linear motor as part of the full-active mass damper. We consider that the mass damper can be expected to be used for a range of applications as part of disaster prevention and mitigation technologies for safe and secure society.

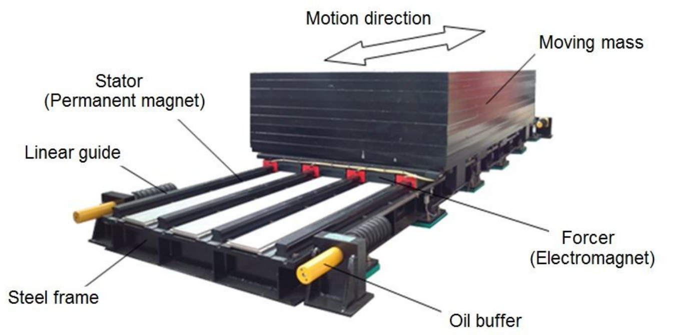
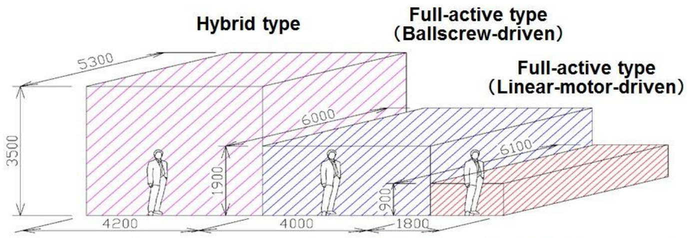


Figure 1. Exterior View of Linear-Motor-Driven Mass Damper



	Hybrid type	Full-active type (Ballscrew-driven)	Full-active type (Linear-motor-driven)
Moving mass weight	110 ton	50 ton	20 ton
Stroke	±0.3 m	±0.6 m	±1.0 m
Total mass	140 ton	60 ton	25 ton

Figure 2. Comparison of Product Dimensions

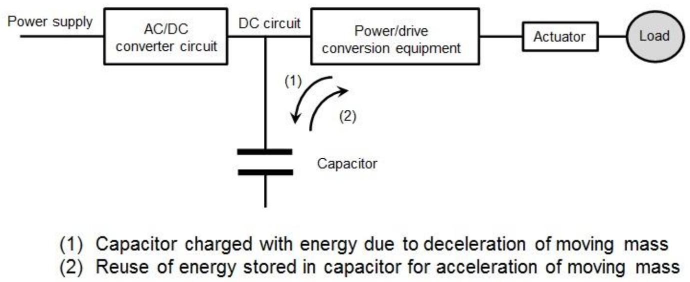


Figure 3. Conceptual Diagram of Regeneration System