Study on Friction Damper as a Seismic Support

T. Nomura, N. Kojima
Mitsubishi Heavy Industries, Ltd., Kobe, Japan
N. Katayama
Sumitomo Metal Industries, Ltd., Osaka, Japan
K. Fujita, T. Ito
Mitsubishi Heavy Industries, Ltd., Takasago, Japan
T. Nakatogawa, Y. Takayama
Mitsubishi Atomic Power Industries, Inc., Tokyo, Japan

ABSTRACT

This study aims to clarify the fundamental characteristics of the refined friction damper for the nuclear plant piping support. This damper was originally used in the railway carriage shock absorber and the highrise building seismic energy absorber. The loading test and tests under high temperature and high humidity were carried out. As a result of the tests, the characteristics of the damper under these conditions were clarified and it was understood that the damper showed constant reaction force under the design condition of the nuclear power plant. It was demonstrated that the application of the friction damper to actual nuclear pipings is feasible.

INTRODUCTION

Application of energy absorbing elements to actual plants is the most realistic method to rationalize seismic design of components and piping systems in the nuclear power plant. Last year, many technologies were brought into practical use to either control or reduce the effects of earthquakes upon bulding structures. Many types of seismic control dampers were developed as a result of this research. Some of them, for example, the friction damper / 1 / and the visco-elastic material damper, have already been brought into practical use in highrised buldings as effective seismic energy absorbers as devices for reducing input energy. This report describes the fundamental dynamic characteristics and effect of the friction damper which has been modified as a supporting device to be applied to components and piping systems in nuclear power plants.

Mechanism of the Friction Damper and the Test Method

1) Mechanism of the friction damper

Fig. 1 shows the outline of the friction damper. The damper was modified to be smaller and have higher durability, but was mostly comformed to the design of the damper for buildings. The damper consists of an outer cylinder, a rod, a nut, cup springs in which the rod is inserted, inner wedges, and cotter outer wedges. The inner surface of the outer cylinder is chrominum plated to stabilize the friction force.

The friction is generated between the outer cylinder and the friction parts. The cup spring presses the inner wedges against each side of the connector, so that the wedging effect is used to generate a compression force between the outer cylinder and the outer wedges divided into three parts around their circumference. The value of this compressive force can be controlled by tightening the torque of the nut.

A piece of copper alloy is used as a friction part in the portion of the outer wedges in contact with the outer cylinder. Lubricant (graphite) is included in the alloy to provide a stable friction and to eliminate noise when the friction producing surfaces slip. The mechanism is therefore oil-less and maintenance-free.

2) The method of the test

<u>The test method</u>

Fig. 2 shows the testing method. The outer cylinder was supported through a pin joint and the cyclic displacement was applied from the rod side by control of the hydraulic servo actuator. The measured items were the damper's friction force by means of the wire strain guage or the load cell, the friction part's displacement by means of a dial gauge or a cantilever gauge and the outer cylinder's surface temperature by means of a thermocouple.

For the case of the test under high temperature condition, the heater was attached around the damper outer cylinder. The set temperature (150°C) was held for more than 5 minutes before the measurement. For the case of the test under high temperature and high humidity condition, the damper was covered with a box, then saturated steam in shop was put in the box.

The test was implemented after approximately 200 cyclic excitations were applied under the condition : amplitude : 40 mm, frequency : 0.3 Hz.
Cyclic displacement was applied as shown in Table 1 to study the effect of the increasing velocity, cyclic number, surface temperature of the outer cylinder and humidity in which the test was conducted. The humidity test was performed after steaming for 5 minutes, and then the excitation was applied while steaming continued throughout.

<u>Test damper</u>

In the test, the damper with a friction force of 490N (50 kgf) was used to determine the dynamic characteristics. The main parts (the outer cylinder, the rod, the wedges etc.) of the damper are made of carbon steel. A damper whose main parts are made of stainless steel was also used in order to compare it with the damper of carbon steel.

Test Result

The dynamic characteristics were evaluated by load-deflection curves. A slight drop in the friction force was observed when the moving part began to slide, but this is thought to be a transient phenomenon occurring when static friction changes to dynamic friction.

1) Effect of the increasing velocity

Fig. 3 and 4 show the effect of the exciting velocity on reaction force characteristics (hysteresis loop). In Fig. 3, maximum displacement was varied keeping the vibration frequency constant (0.33 Hz). In Fig. 4, the exciting frequency was varied keeping maximum displacement constant (10 mm). It is evident that, in both conditions the friction force was constant and independent of the increasing velocity. It is obvious that, therefore, the absorbed energy per cycle is nearly proportional to the maximum displacement and it is not affected by the increasing velocity.

2) Effect of the surface temperature of the outer cylinder

Fig. 5 shows the effect of the surface temperature of the outer cylinder on the hysteresis loops when the 3000 cyclic displacement (frequency : 2 Hz, maximum displacement : 10 mm) was applied. It is evident that, as the surface temperature rises, the friction force tends to decrease slightly. This might be caused by the difference of thermal expansion coefficients. The decreasing rate of the friction force at the surface temperature T = 82°C is about 6% of that at 22°C. The tendency of the absorbed energy is similar to that of the friction force.

After a large number of excitations were applied, the friction part was inspected, but no harmful wear was observed. The friction damper seems to have sufficient durability under practical seismic conditions.

3) Effect of saturated steam (high humidity)

Fig. 6 shows the effect of high humidity on the hysteresis loops. Compared with the condition of room temperature, the change in the friction force under the high humidity condition was small. The change in the friction force under the condition of both high humidity and high temperature (150°C) was about 20%.

4) Effect of the material

The above tests were carried out by using the damper whose main parts (the outer cylinder, the rod, the wedges) were made of carbon steel. The damper of stainless steel, which is more anti-corrosive than carbon steel, was also tested.

Fig. 7 shows the effect of the surface temperature of the outer cylinder on the hysteresis loops in the case of stainless steel damper. When the temperature rises, the friction force tends to increase slightly. The friction force increase at the temperature T = 150°C is about 15% of that at room temperature (T = 20°C). The change in the friction force seems to be small. This indicates that the difference of the dynamic characteristics between the two dampers is very small.

CONCLUSION

The conclusions are as follows.

1) The dissipated energy per cycle of this friction damper which was developed for a nuclear plant piping support is almost constant regardless of the exciting velocity and cycles. It is nearly proportional to the maximum displacement.

2) The influence of the surface temperature of the outer cylinder and high humidity on the dissipated energy of the damper is very small. Therefore the damper is applicable to the actual plant.

3) The dynamic characteristics of the damper of stainless steel is almost the same as that of the carbon steel damper.

4) According to these results, it is demonstrated that application of the friction damper to actual nuclear piping systems is feasible.

REFERENCE

T. Teramoto et al. "Application of Friction Damper to Highrise Buildings", 13th Congress prereport, Helsinki, International Association for Bridge and Structural Engineering (IABSE), June 1988.

Table 1 Items of Vibration Test

Amplitude δ : mm	Frequency f : Hz	Increasing Velocity V : cm/sec	Room Temperature		150°C
			No Steamed	Steamed	Steamed
2	10	12.6	O	O	O
5	0.33	1.0	O		
5	5	15.7	O	O	O
10	0.33	2.1	O		
10	2	12.6	O	O	O
30	0.33	6.2	O		
40	0.1	2.5	O		
40	0.33	8.3	O		

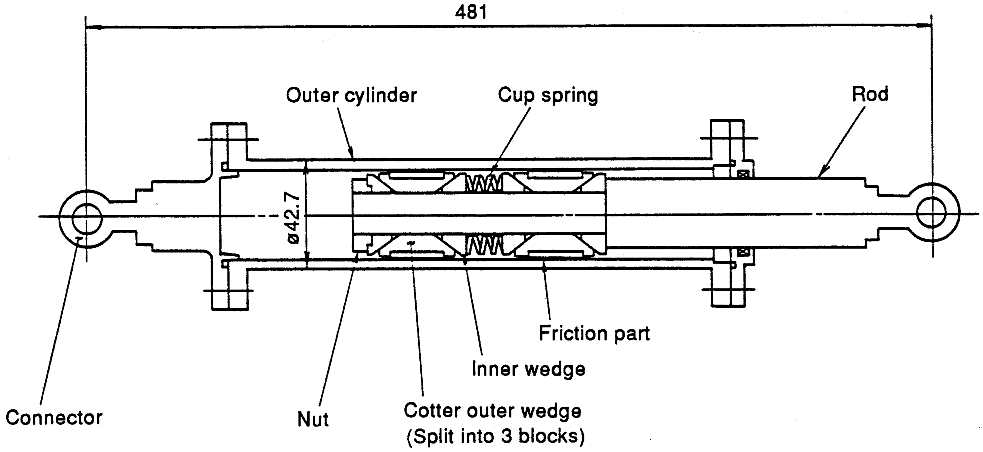

Fig. 1 Friction Damper's Mechanism

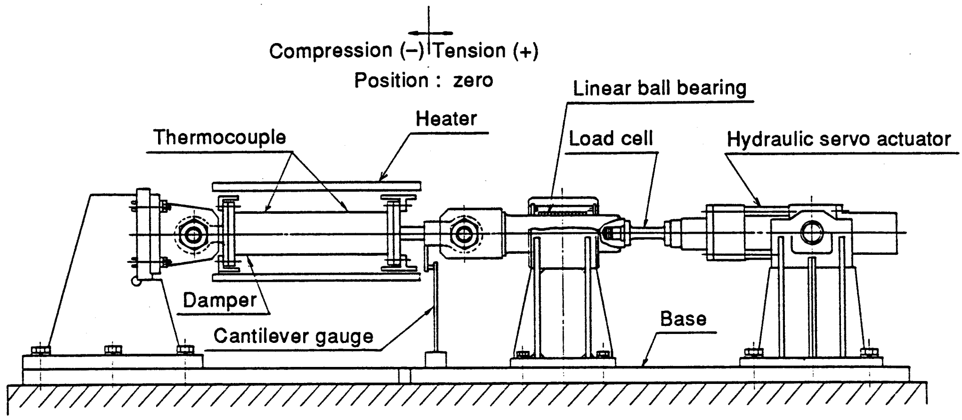

Fig. 2 Testing Device and Measurements

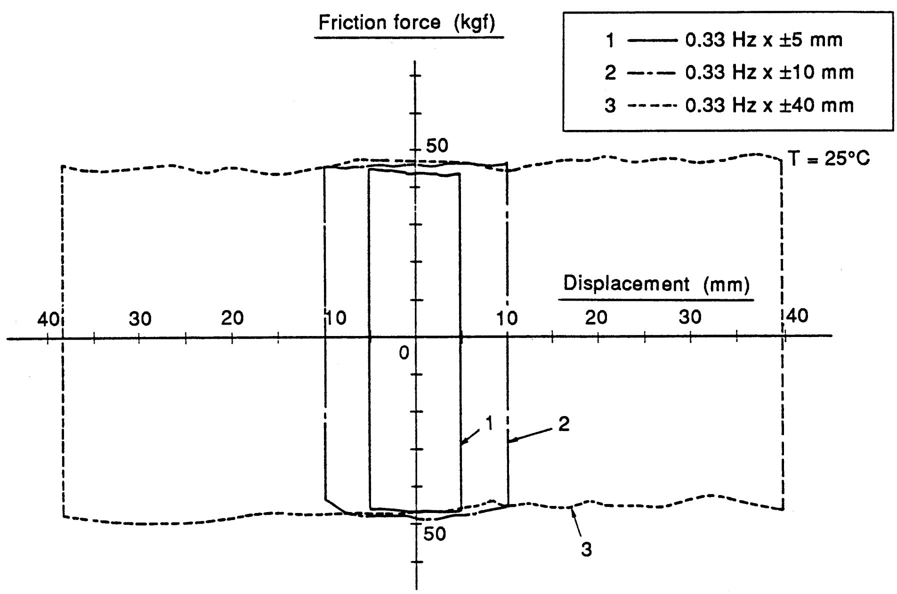

Fig. 3 Effect of the Exciting Velocity (Frequency : 0.33 Hz)

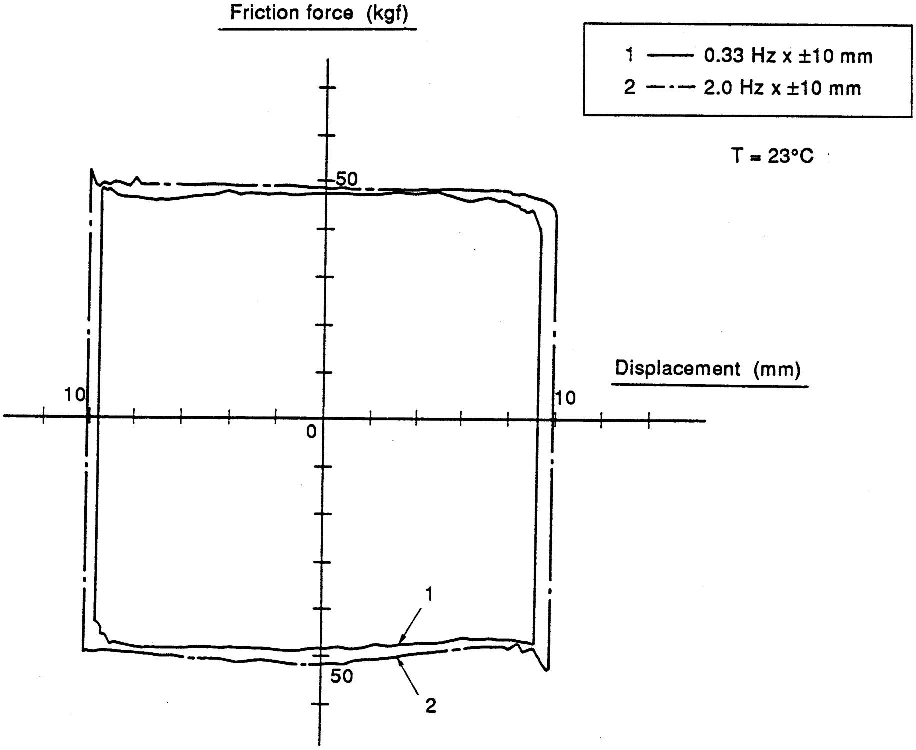

Fig. 4 Effect of the Exciting Velocity (Maximum displacement : 10 mm)

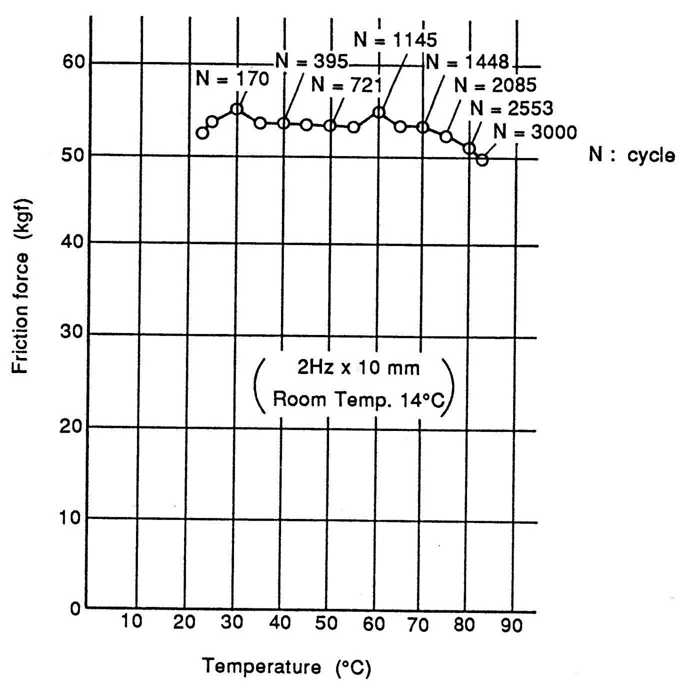

Fig. 5 Effect of the Surface Temperature of the outer Cylinder

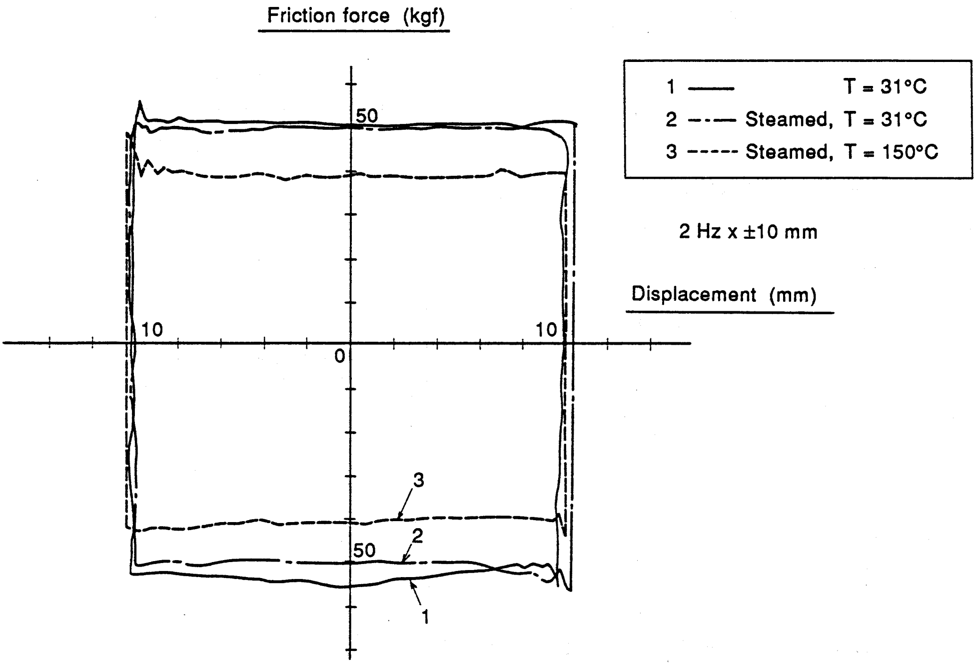

Fig. 6 Effect of the Saturated Steam

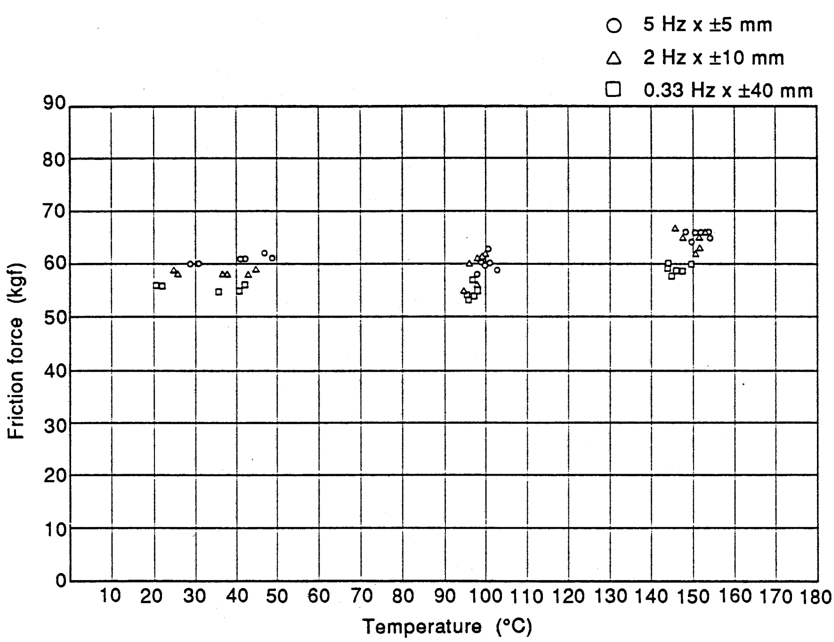

Fig. 7 Characteristics of Stainless Steel Damper