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Case study of tuned mass damper and modeling of gyroscopic damper for corresponding effect

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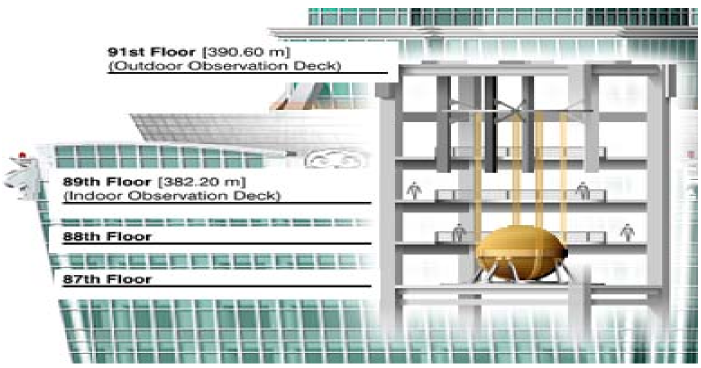
Abstract
As published in the previous paper regarding the concept of gyroscopic vibration damper, this paper continuation and validation for such hypothesis. By analyzing a case study of a tuned mass damper and calculating the energy and momentum ranges of working of the previously designed and adopted dampers, this paper focuses on possibilities of making a working prototype replacement of damper [proposed by the hypothesis.

Keywords: Wind Load, Wind Vibrations, Vibration Damping, Gyroscopic Damping, Fly wheels, Tuned Mass Dampers.

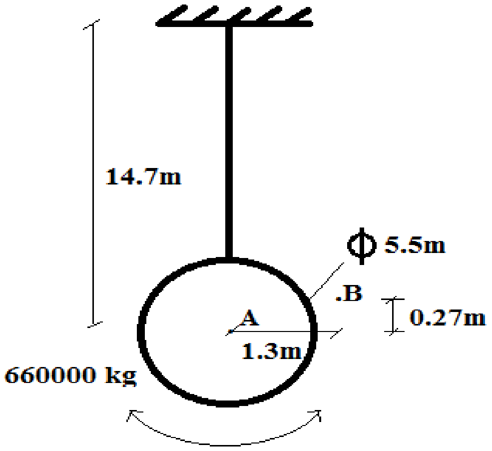
1. Introduction
Concept of tuned mass damper has been in the field of engineering from a quite short period, but the fast improvement and adaption of this technology has made possible for engineers to use this giant dampers in skyscrapers. Such a mass dampers is already adopted in a tall skyscraper *Taipei 101*, with such a great height and high amplitude wind and earthquake vibrations it was necessary to adopt for vibration damping solutions. A tuned mass damper is adopted for damping such vibrations, with a heavy mass hanging from the roof of top floors by suspension cables to make a pendulum system. It gas limitations for less space efficiency a restrictions for little range of vibration amplitudes.

2. Case Study Analysis
Taipei 101 is an iconic skyscraper located in the city of Taipei, in Taiwan. It rises to 509 meters and consist of exactly 101 floors. At the time of its construction in 2004, it was the tallest building in the world – a title it held on to until the Burj Khalifa came into being in 2010. Sitting just 660 ft. from a major fault line, Taipei 101 is prone to earthquakes and fierce winds common in its area of the Asia-Pacific. The engineers had to design a structure that could withstand gale winds up to 216 km/h and the strongest earthquakes. Typically skyscraper must be flexible in strong winds yet remain rigid enough to prevent large sideways movement. Flexibility prevents structural damage while resistance ensures comfort for the occupants and protection of glass, curtain walls and other features. Most designs achieve the necessary strength by enlarging critical structural elements such as bracing, but the height of Taipei 101 combined with the demands of its environment called for additional innovations.



3. Energy Conservation Analogy

With a string length of 14.7 m and a mass of 660,000 kg hanging from 90th floor to the 87th floor to provide a offset of movement of about 1.3 m.



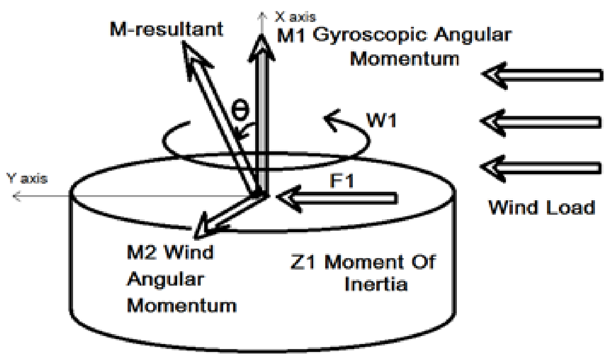
The energy gained by the pendulum in raising its center of mass to a height of 0.27 m is purely gravitational potential energy. The gyroscopic damper should have an equivalent energy range and capacity to store such energy to compensate for the energy transferred to the building.

Potential energy gained = mgh
m = 660,000 kg
$g = 9.81\ m/s^2$
h = 0.27m

Maximum Energy Transfered by the Vibrations = Potential energy gained by the Damper Mass

Potential energy gained = mgh
= 1764.3 kJ

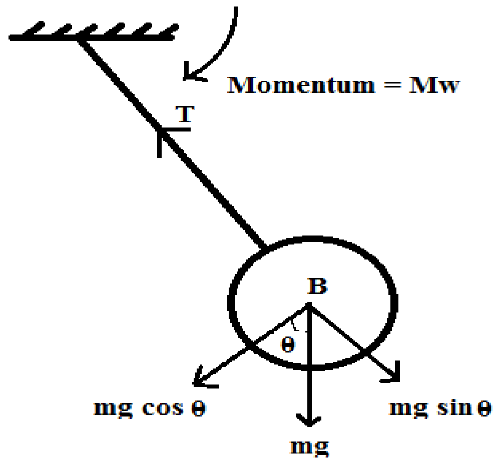
Rotational Energy = Rw



Above figure shows a gyroscope subjected to high wind loads. The M1 represents the flywheel angular momentum, while M2 represents the wind angular momentum by the Wind Load-F1. The resultant caused by these two combination is inclined at an angle from the vertical axis. Z1 represents the moment of inertia of the flywheel. W1 is the anticlockwise angular velocity of the flywheel. Due to rotation kinetic energy an angular momentum M1 is induced in the gyroscope. This axis of rotation is now with an extra inertia or resistance towards any external force. With Rw as rotational energy stored.

Rw = 1764.3 kJ

4. Momentum Conservation Analogy



The swinging of pendulum causes the gain of potential energy and is acted upon by the force of gravity at its most peak position which results in generation of a restoring angular momentum. This restoring momentum cases the damping effect of wind vibrations and increases the stability of the structure against such vibrations.

m = 660,000 kg
$g = 9.81\ m/s^2$
$\theta = 78.8^0$

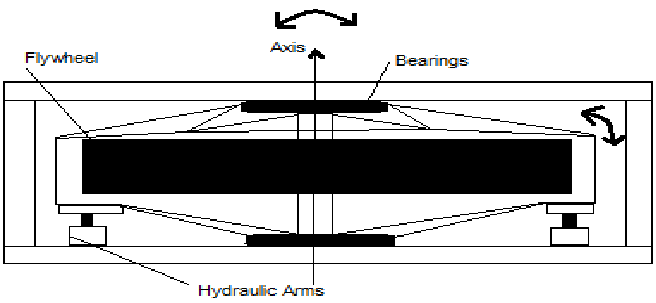
Maximum angular momentum = Maximum Restoring angular momentum

Maximum angular momentum = $mg \cos\theta \times L$
= 1248 kNm

Mw = 1248 kNm

5. Working Specifications

Gyroscopes will be made up of high density carbon steel prefabricated detachable components. It will be mounted on a free axel with smooth bearings. The axis of the flywheel will be powered by an electromechanically operated motor transmitting sufficient power by a gear chain. The axis of rotation is controllable using hydraulics jacks supporting four supports of the flywheel. These units will be able to control the direction of the angular momentum caused by thee gyroscopes. Suitable configuration processed by computes will be adopted on regarding the given vibration characteristics.



Flywheel is rotated with a predefined angular speed to cause an energy equivalent analogy as well as an angular momentum analogy. The calculations for the size of the dampers purely depends upon the incoming wind vibrations and the amplitude causes on the structure. The above calculations are only for the case studied tuned mass damper adopted in an existing building. With rotating flywheel any energy requirement can be achieved and a similar angular momentum can be generated.

6. Acknowledgment
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