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Composite C Springs for Anti-Seismic Building Suspension: Positioning Virtual Center of Pendulation above Gravity Center

Max Sardou*, Patricia Sardou and Thomas Berg

Department of Mechanics, University of Bordeaux, Bordeaux, France

Abstract

Now that weight saving is mandatory, composite springs invented by SARDOU SA are the best choice for automotive suspensions, compared to steel. A Joint Venture called Sara was created in order to mass produce composite coils springs, with start of production in 2014 for AUDI. This has demonstrated that the viability of producing composite coil springs. This paper describes the benefits of composite 'C' springs and 'S' springs for high performance vehicle suspensions, spacecraft stage separation, and satellite orbital launching. Developing spacecraft stage separation for CNES (Centre National d'Etudes Spatiales) used the concept of 'line of action'. Two springs are inclined in such a way that the resultant line of action cross at a virtual center well above the springs. This virtual center is above the top stage which provides stable and straight guidance. This spacecraft technology can be transferred to buildings by creating a 'virtual center' of pendulation positioned above the building center of gravity. This is achieved by using tilted composite springs oriented in such a way that their line of action converges creating this 'virtual center'. Thanks to the 'virtual center' position, the building behaves as a pendulum, hanging from above. When an earthquake happens, the building will oscillate around its 'virtual center' and will go back safely to equilibrium after the tremor. 'C' springs, offering anti rust, anti-settlement, fail safe suspension with a virtual center is a must for long lasting protection of buildings against earthquakes.

Keywords: Anti-seismic building suspension • Base isolation • Composite "C" springs • Earthquake • Virtual center of pendulation

Introduction

Center of gravity is an imaginary balancing point where the body. Weight can be assumed to be concentrated and equally distributed. Its symbol is COG or CG. It is the point of exact center, around which the body may rotate freely in all directions. It can also be called center of mass. Anatomically; this point can be represented by the point of intersection of the three cardinal body planes (capital, frontal and transverse). The center of gravity can be located within or outside the body depending on the body's configuration and position; it is inside an object when the object is uniform and outside the object when it is not uniform [1].

A simple pendulum is a string with a mass at the end which is free to swing is called pendulum. To and fro motion means the ball moves to and fro. It rises to extreme positions on both sides and reverses its motion oscillations gradually die down compound pendulum. The compound pendulum, which is also known as the physical pendulum, is an extension of the simple pendulum. The physical pendulum is any rigid body that is pivoted so that it can oscillate freely.

The compound pendulum has a point called the center of oscillation. This is placed at a distance L from the pivot where L is given by L=I/m R; here, m is the mass of the pendulum, I is the moment of inertia over the pivot and R is the distance to the center of mass from the pivot. Periodic time of the simple pendulum called the time taken to complete one oscillation is called the periodic time of the simple pendulum. It is sometimes also called its period and is denoted by T [2].

A simple pendulum has a small bob linked to the end of the string. In a simple pendulum, the length of the string is large compared to the measurements of the bob. In this type of condition, the mass of the bob is concentrated at the center of gravity. When the dimension of the bob is not negligible compared to the distance from the axis of suspension to the center of gravity, then the pendulum is called the compound

***Address for Correspondence:** Max Sardou, Department of Mechanics, University of Bordeaux, Bordeaux, France; E-mail: max.sardou@sardou.net*

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pendulum. Every object falls freely when dropped, with the uniform acceleration, if the opposition due to air is negligible. The gravitational attraction of a body towards the center of the earth results in the same acceleration for all bodies at a particular location, regardless of their mass, shape or material and such acceleration is known as acceleration due to gravity, g. This g value varies from place to place, being highest at the poles and the lowest at the equator. But, direct measurement of the acceleration due to gravity is very hard. Therefore, the acceleration due to gravity is often found by indirect methods, for example, using a simple pendulum or a compound pendulum. If we define g using a simple pendulum, the result is not very accurate because an ideal simple pendulum cannot be understood under laboratory conditions. Hence, a compound pendulum is used to define the acceleration due to gravity [3].

Literature Review

SARDOU SAS has developed highly stressed composite parts for 38 years, starting with SARDOU torsion springs

Torsion spring "proof of concept" was completed in 1983., Development started in 1986 which led to development of the composite torsion beam structure as well as the test benches. The torsion beam is a fairly straightforward design. It teaches us that we can reach incredibly high strains in glass fibers in tension, if the fibers are perfectly oriented and in line with the stress. The key was how to introduce heavy torque in a small beam. This was achieved using an optimized topknot design, reaching a very high torque of 28 KN-m from a 60 mm beam. Torsion angle is 1 degree for 1 centimeter of beam. On the picture we see the torque wheel on the left and inclinometer pendulums on the beam in order to measure accurately the local torsion (Figure 1) [4].

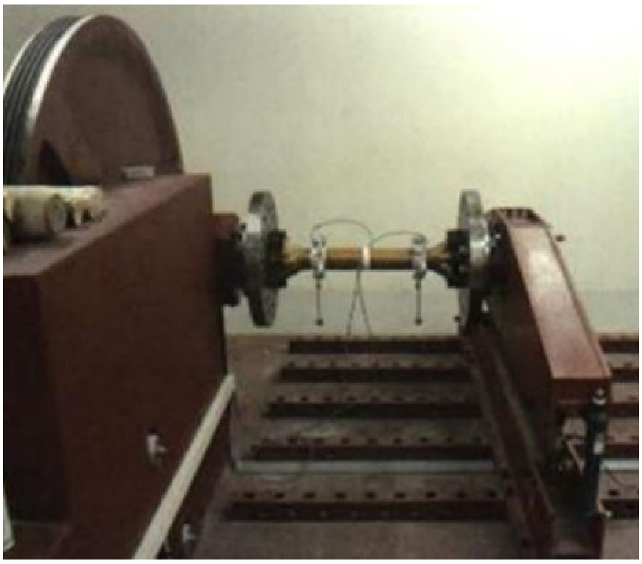

Figure 1. Torsion beam under test on test bench., spring is reaching 280 KN.m of torque for a 60 mm beam diameter.

SARDOU "C" springs

Composite "C" springs were invented and patented in 1993 (Figures 2 and 3).

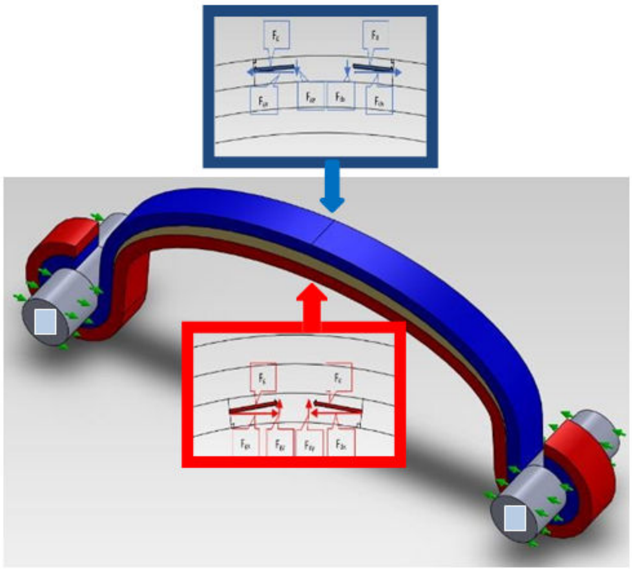

Figure 2. "C" spring is a unique self-stacking structure.

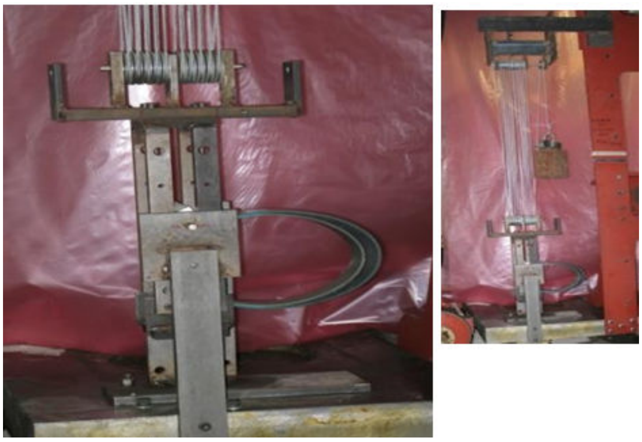

Figure 3. "C" spring is a unique long-lasting structure. It has 20 years under load without creep. One spring is shown under gravity loading.

Composite "C" springs are a unique and advanced design:

A load is applied to both ends of the "C" spring. The central core (gray color) is designed in such a way that strain in both upper and lower composite layers is maintained equal for about 90% of the length. The fibers making up the composite layers go from the end of the right loop to the end of the left loop, perfectly straight. When a load is applied on the "A" loading point, toward "B" loading point, the same fiber is loaded in "A" and unloaded in "B". There is absolutely no-load transfer in the spring structure. The fibers can be elongated up to their theoretical limit. As the fibers are elongated to their limit, the matrix plays a role controlling:

- The sheer stress between top (tension) and bottom (compression) tapes, especially close to loop regions.

- The differential strain between the top tape, contracting on the tension side and expanding on the compression side, because of the Poisson effect.

These features explain why:

- "C" springs can be designed that reach up to 1500 Joule per kilogram energy density, compared to 300 J/kg-350 J/kg for steel coils springs.
- Springs have been tested for millions of cycles with success, up to 6 million cycles for some samples.
- The ability to withstand, without settlement, heavy loads for many years. Below is a photo of a spring loaded successfully for 20 years with absolutely no creep (Figure 4) [5].

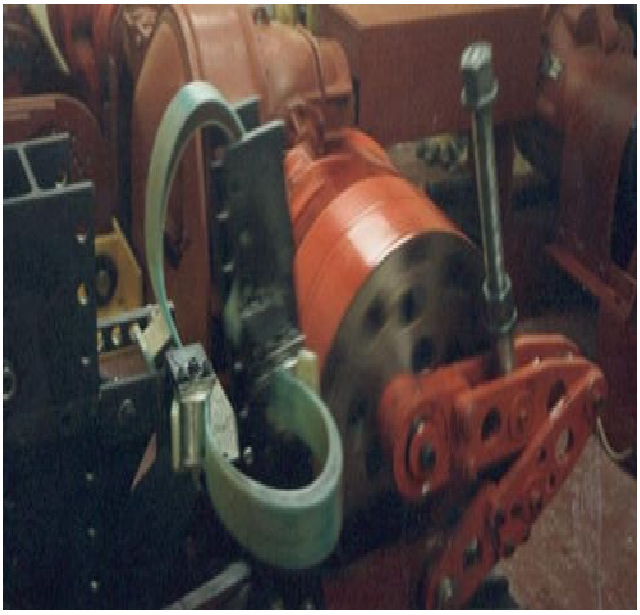

Figure 4. "C" spring is a unique long-lasting structure under fatigue. On the picture we see 2 springs under sinusoidal cycling.

Figure 5 shows "mule" of cars fitted with composite "C" springs. Clients have successfully tested their cars, on proving ground and open road, for up to 90,000 km. We are at TRL 9 on cars now. "C" springs offer improved performance for vehicles suspension, for spacecraft stage separation, for satellite orbital launching and for long lasting, base isolation of buildings against earthquakes.

The "C" spring can be the preferred solution for some cars designs and long trucks with long travel suspension (Figure 5) [6].

Figure 5. "C" spring integrated in two SUV.

Discussion

SARDOU coils springs

Composite coils springs are derived directly from our original torsion spring concept. Despite their huge advantage, platform managers did not use "C" springs because there was no easy "way back" to use steel coil springs. So, in 2002 we designed a composite coils spring to fit the same space as a steel coil spring. All technology has been developed in house. Composite coils springs offer an energy density up to 800 J/kg and have proven to be a very good choice for automotive suspensions compared to steel. To produce composite coil springs, a joint venture called SARA was created [7].

Production of composite coil springs for AUDI started in 2014. This has demonstrated the viability of producing composite coil springs. And it also has helped develop interest in mass production of composite "C" springs. In order to achieve the targeted fatigue life, a high-performance epoxy called EPOSIL® was developed. Thanks to EPOSIL®, the life expectancy has been increased by more than ten times compared to the coils springs. In addition, EPOSIL® provides protection against humidity aging (Figure 6).

Figure 6. Composite coil springs integrated in cars.

Anti-seismic base isolation application

Studying potential spacecraft stage separation applications with CNES, the test set up shown in Figure 7 was produced. If two springs are properly inclined, and if the “line of action” is a line from one loop of a “C” spring to the other loop of the same spring, where the lines of action cross there is a “virtual center” which behaves as if both springs where pulling from that point.

The red arrow in Figure 7 is the resulting pulling force, since the lateral black and brown forces cancel each other. We have demonstrated these properties on a six components compression machine also shown in Figure 7.

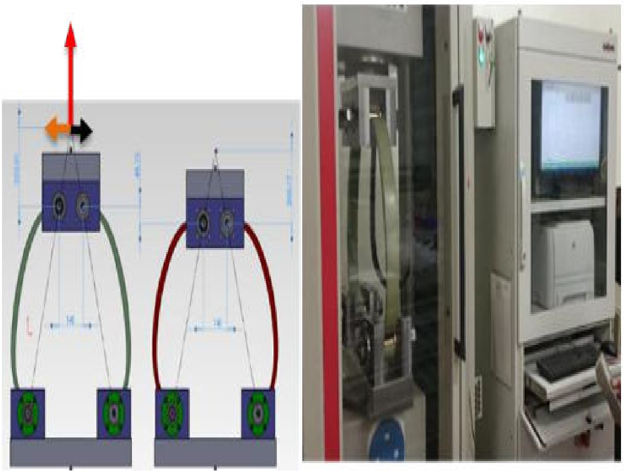

Figure 7. ”C” springs creating a virtual center of pulling in red.

Mr. Gurtuna, OLIN epoxy marketing manager, asked if our technology could be applied to seismic base isolation for buildings. This was a straight-forward application for SARDOU! [8].

Similar to the spacecraft stage separation application, a "virtual center" of pendulation is located right above the building center of gravity. This is achieved by orienting tilted composite springs so that their line of action converges at the "virtual center".

Thanks to the location of the "virtual center", the building behaves as a pendulum. When an earthquake happens, the building will oscillate around its "virtual center” and will go back safely to equilibrium after the tremor (Figures 8-10) [9].

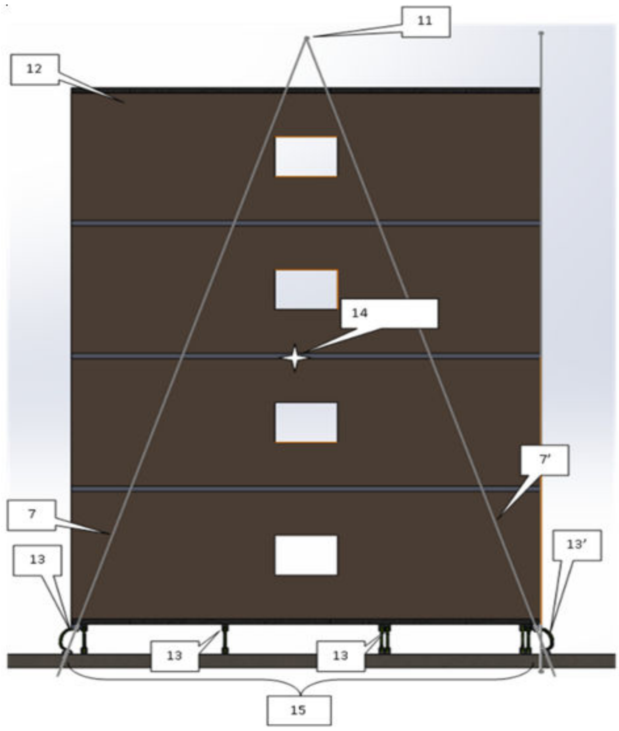

Figure 8. ”C” springs are creating a virtual center (11) above the gravity center. The building behaves as a pendulum oscillating around that point (11).

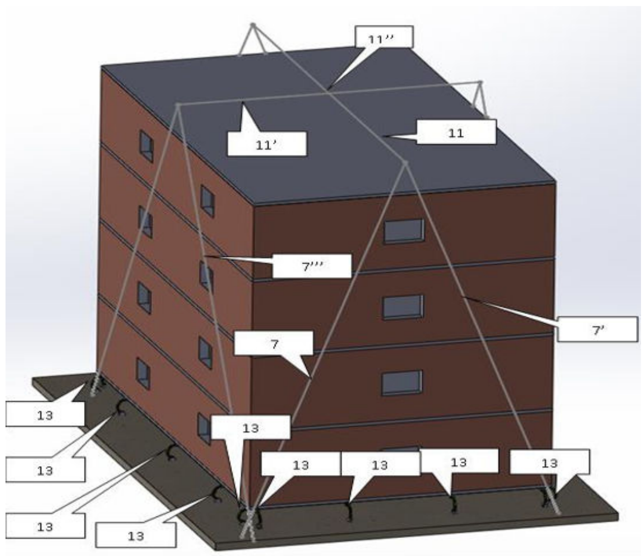

Figure 9. In 3 dimensions,” C” springs are creating a virtual center above the gravity center and building behave as a pendulum oscillating around point.

Figure 10. In 3 dimensions, C springs are creating a virtual center of pulling above the gravity center and building behave as a pendulum oscillating around point its virtual center [10].

Conclusion

Due to their unique design and their lightweight properties, composite “C” springs offer advantages for:

- Automotive suspension
- Spacecraft stage separation
- Satellite orbital launching

Due to their unique design and their long-life, composite “C” springs will be an advantage for:

- Anti-seismic base isolation building suspensions
- Anti-seismic base isolation bridge suspensions
- Anti-vibration base isolation for delicate structures

References

1. Ouakka, Slimane, Olivier Verlinden, and Georges Kouroussis. "Railway Ground Vibration and Mitigation Measures: Benchmarking of Best Practices." *Railw Eng Sci* 30 (2022): 1-22.
2. Oliveira, Carlos Sousa. "The Main Developments of Seismology and Earthquake Engineering Since the Early 1700s and the New Challenges for a Sustainable Society." *Bull Earthq Eng* 20 (2022): 4697-4863.
3. Abbas, Mohsin, Khalid Elbaz, Shui-Long Shen, and Jun Chen. "Earthquake Effects on Civil Engineering Structures and Perspective Mitigation Solutions: A Review." *Arab J Geosci* 14 (2021): 1-17.
4. Whitcomb, Stanley E. "Ground-Based Gravitational-Wave Detection: Now and Future." *Class Quantum Gravity* 25(2008): 114013.
5. Sobczyk, Martin, Sebastian Wiesenhutter, Jorg Rainer Noennig, and Thomas Wallmersperger. "Smart Materials in Architecture for Actuator and Sensor Applications: A Review." *J Intell Mater Syst Struct* 33 (2022): 379-399.
6. Liu, Yuxin, and Zhitao Lu. "Seismic Performance and Storey-Based Stability of Suspended Buildings." *Adv Struct Eng* 17 (2014): 1531-1550.
7. Landolfo, Raffaele. "Lightweight Steel Framed Systems in Seismic Areas: Current Achievements and Future Challenges." *Thin-Walled Struct* 140 (2019): 114-131.
8. Yang, Jianjin, Shengyang Zhu, Wanming Zhai and Georges Kouroussis, et al. "Prediction and Mitigation of Train-Induced Vibrations of Large-Scale Building Constructed on Subway Tunnel." *Sci Total Environ* 668(2019): 485-499.
9. Ribeiro, Tiago, Luis Bernardo, Ricardo Carrazedo and Dario de Domenico. "Seismic Design of Bolted Connections in Steel Structures-A Critical Assessment of Practice and Research." *Buildings* 12 (2022): 32.
10. Medel-Vera, Carlos, and Tianjian Ji. "Seismic Protection Technology for Nuclear Power Plants: A Systematic Review." *J Nucl Sci Technol* 52 (2015): 607-632.

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