Magnetic compliant suspension concept for space robotics

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Supplemental Material

Poster

Space Robotics Lab
School of Systems Engineering

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Magnetic Compliant Suspension Concept for Space Robotics

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Novel approach to suspension systems for a medium sized rover

This paper proposes a Dual-Magnet Magnetic Compliance Unit (DMCU) for use in medium sized space rover platforms to enhance terrain handling capabilities and speed of traversal. An explanation of magnetic compliance and how it can be applied to space robotics is shown, along with an initial mathematical model for this system. A design for the DMCU is proposed including a 4-legged DMCU Testing Rig.

Magnetic Compliance

Magnetic compliance exploits the non-linear repulsive forces between two magnets which have been placed in opposition – opposing magnetic poles facing each other – to offer a novel suspension mechanism for robots [1]. We propose that this suspension mechanism can be applied to a space robotic rover to decouple it from the surface that it is traversing, so that impacts experienced do not damage the system.

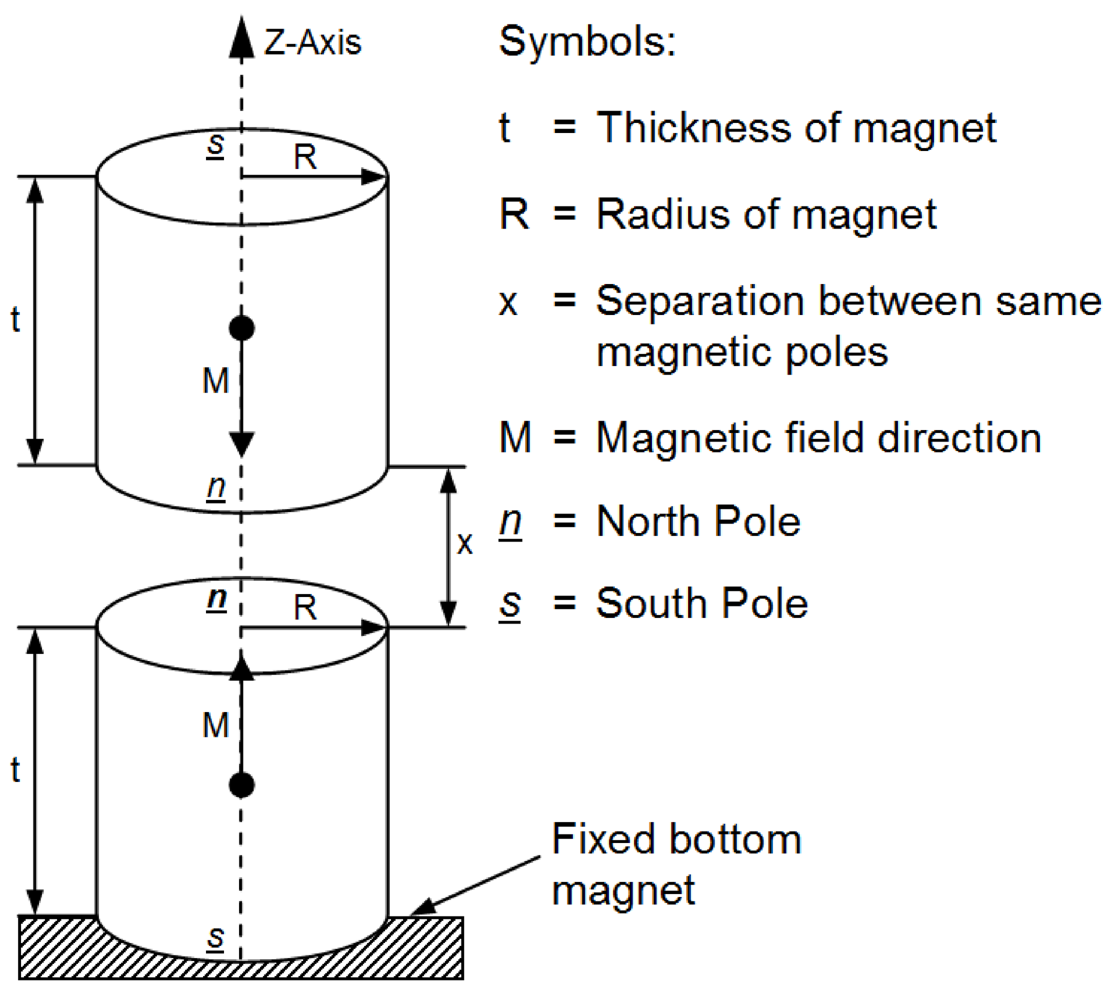

Figure 1: The compliance model showing variables

Figure 1 shows the experimental setup for the DMCU using two cylindrical magnets. All magnets used in our experiments are constructed from N42 Grade Neodymium which is considered an extremely hard magnetic material.

This consideration does not take into account de-magnetisation forces which the magnets exert on each other when compressed together. The motion of the magnets is constrained to the Z-Axis.

DMCU Mathematical Model

The equation below was used to model the DMCU shown in the previous figure. This model was used to determine the resting state of the DMCU when under no load, which was then used in the physical design of the DMCU.

$$F = \frac{\pi \mu_0}{4} M^2 R^4 \left[\frac{1}{x^2} + \frac{1}{(x+2t)^2} - \frac{2}{(x+t)^2} \right]$$

The equation uses the same variables as the figure in the previous column, with *M* defined as the magnetic flux density divided by the permeability of the intervening medium μ_0, in this case free space.

This model considers that the magnets are 'perfect' and very magnetically hard, but in reality the magnets have imperfections, allowing de-magnetisation forces to affect the magnetic field strength. This effect can be clearly seen on the graph below.

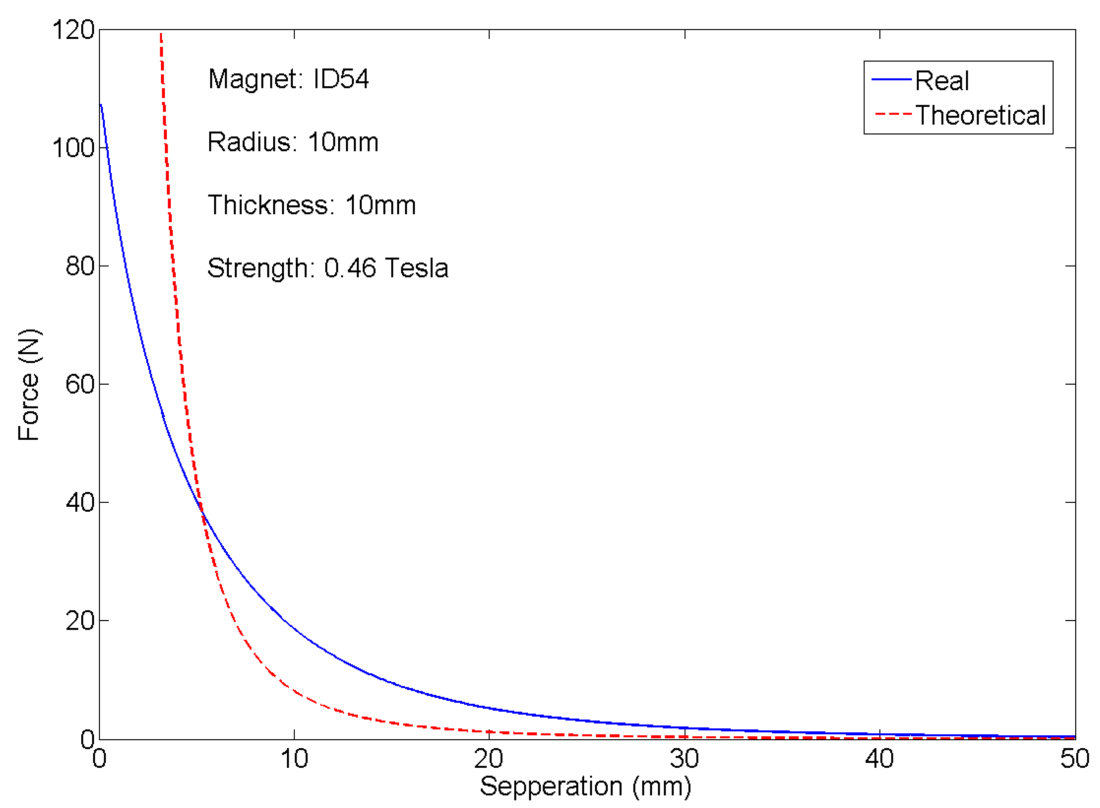

Figure 2: Theoretical and Real-World Results

This data was recorded by recreating the system model in a load cell which could perform static load testing. This system allowed the testing of many different magnets, which lead to a revision of the equation above. This revision of the equation states that the model is approximately true when the separation between the magnets is grater than the thickness of the magnets (*when* $x > t$).

Prototype Dual-Magnet Compliance Unit

The prototype design uses two N42 Grade Neodymium magnets with a radius and thickness of 10mm. These magnets were chosen as they had a resting separation of 50mm whilst still being able to support a maximum load of 10kg. The materials used for construction of the DMCU are clear acrylic plastic and Delrin, as these materials satisfied all the design constraints whilst not affecting the magnetic fields of the two magnets housed within the DMCU. The prototype DMCU is shown in Figure 3.

Figure 3: Prototype DMCU assembled

DMCU Robot Test Rig

A simple 4-wheeled test rig incorporating 4 compliance units was also designed to use 4 of the DMCU modules. The test rig allows each leg to be adjusted so that the angle of attack is locked between ±45° from vertical and is made from the same materials as the DMCU. Figure 4 shows the test rig including 4 DMCU modules, without the wheels mounted. This test rig will be used for future testing, and is currently having the measurement electronics installed. These measurement devices will help evaluate the model.

Figure 4: DMCU Robot Test Rig with 4 DMCU modules

Conclusions

The speed a rover can traverse difficult terrain is currently an important research area.

Our initial observation is that magnetic compliance can enhance the versatility of space robotic rovers.

Further research will investigate enhancements to the mathematical model and will experimentally evaluate the DMCU.

References

[1] R. McElligott and G. McKee, "Magnetic Compliance in Legged Robots", Proceedings of the 9th International Conference on Climbing and Walking Robots (CLAWAR), pp. 104-108, 2006

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