Experimental study on controlled stiffness gripping’s suitability for overhead cranes

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Abstract.

Writing briefly and in an interesting way here what was studied and what was learned in order for the reader to learn if this can be used as a reference for further scientific research.

Introduction

Cranes have made their way to every industry where heavy objects need to be lifted. The technology around lifting heavy objects has always relied on strong hooks and some manual labour to attach the target object in various ways to the hook. Conventionally, in overhead crane lifting the object to be lifted are attached to the hook via chains or ropes. This system, having two mass nodes attached via ropes is prone to double pendulum dynamics (Kim, D. and Singhose, W., 2010). Also, this system requires workers to constantly work around the dangerous environment around the hook. In order to achieve more efficient and safer crane lifting, a universal gripper could be implemented.

Gripping technology in robotics has taken lots of big steps recently. Gripping technologies can be divided naturally in to 3 different categories; actuation, controlled stiffness and adhesion [soft gripping paper]. Actuation basically covers all of the traditional gripping technologies such as different rigid jaw grippers. It also covers the compliant materials that deform during the gripping process and thus dividing the pressure evenly. (Check soft gripping paper chapter 3 to add more stuff about gripping by actuation. It is in articles folder in Drive)

The idea behind controlled stiffness is that the gripper can be deformed in it’s soft configuration to surround the target object. After the gripper has surrounded the target object, the gripper is then stiffened and thus it forms a grip around the target object. One example of this is granular jamming where there is a tight and air-sealed pouch filled with granular material. When the pouch is at its soft configuration, it can deform easily and it’s contents can be considered as fluidic in macro-scale. After the air between the granular mass has been sucked out, the granular contents get jammed and the pouch stiffens to its deformed shape around the target object. Stiffness can be controlled also in alloys that change their phase in depending on the temperature. There are also some fluids that respond to electric and magnetic fields by changing their viscosity. (Short review on shape memory materials chapter 4.4. and the adhesion review to be added. These are also in soft gripping paper that is in Drive)

Universal gripper could save a lot of time for crane operators. Currently crane operators have to use a lot of time for attaching their target object somehow to another object that can be lifted with a hook. Thus a lot of time could be saved with a universal gripper. Universal grippers are such that can lift objects with variable shapes [5]. Development in the robotics industry has led to promising results in lifting with granular jamming. For example, Empire Robotics has successfully lifted objects with a mass of around 10 kg with a 16.5-cm-diameter-gripper. Thus, this paper documents experimentation on different granular jamming -based techniques aiming to lift heavy objects.

Add theory around granular jamming and talk about possibility of increased strength in grip if air between granular mass is replaced with fluid. Add Sven's comment on the stiffness' dependence on the stiffness of granules, also add his hypotheses that the granule size scales too as the membrane scales.

Methods

This section will have the following order. Firstly, the system and all the material parameters will be briefly described. Secondly, the testing environment will be described.

System description

In order to gain some knowledge on granule size parameter's effect on the gripping force, wooden pellets were chosen as one material. The wooden pellets could be grounded to smaller granule sizes relatively easily. Also wooden pellets used had relatively high stiffness compared to its lightness. The other granular materials used for the study were Polyoxymethylene granules, which have even smaller density and higher stiffness, and sand, which has very high stiffness and very high density.

Granule material	Granule size	Density	Stiffness
Wooden pellets [L]	Dia = 6mm+-0.2mm Length = 15.6mm+-5mm	Lighter than water	Can't be squeezed with fingers
Wooden pellets [S]	Dia 6mm+-0.2mm Length 5mm +-2.5mm	Lighter than water	Can't be squeezed with fingers
Polyoxymethylene granules [POM]	Unknown	Lighter than water	Slightly higher than wooden pellets
Sand	Unknows	Very high	Very high

Table 1. Granular material parameters

The sheer weight of the granular material inside the gripper's pouch can cause great stresses to the surface material. Thus, a custom solution was developed. Two balls were made with different strengthening mid layers. The first ball was chosen to have carbon fiber and the other glass fiber. Both balls were sealed airtight with silicon coating on the inner and outer surface of the ball.

reference	materials	Tensile strength	elasticity	thickness
Exercise ball	latex	Unknown	High	<1mm
Custom ball 1	Silicon coating, glass fiber layer	Unknown	Unknown	<1mm
Custom ball 2	Silicon coating, carbon fiber layer	Unknown	Unknown	<1mm

Table 2. Pouch surface material parameters

The rest of the system includes a custom metallic structure connecting the pouch with the cranes hook. Also a suction system was connected to the metallic structure in order to create a pressure difference between the contents of the membrane and environment. The vacuum machine used was General Electrics model 5k H35 using AC motor and oil suction system.

Testing environment

The testing was done with multiple different combinations of granular and membrane surface materials. The combinations are listed below in table 3. Every material combination was put through the same sequence of lifting tasks. First task was to lift a 1kg weighing box to for making sure the setup is working correctly. Second task was to lift three different shaped objects roughly weighing 5-10 kg: a chair, a sealed box, a training ball. The last lifting task was to lift 30 kg weighing sealed box. All lifting tasks were rated either as a success or a failure. A task was a success if the membrane could lift the object from the ground and keep it up for 30 seconds.

Combination	Granular material	Pouch surface
1	Wooden pellets [L]	Exercise ball
2	Wooden pellets [S]	Exercise ball
3	Wooden pellets [S]	Custom ball 1
4	POM	Exercise ball
5	POM	Custom ball 1
6	Sand	Custom ball 2

Table 3. Tested material parameter combinations

References

1. **Amend, J. (2016). Soft Robotics Commercialization: Jamming Grippers from Research to Product. *Soft Robotics, 3*(4), pp. 213-222. https://doi.org/10.1089/soro.2016.0021.**

2. **Lanni, C., & Ceccarelli, M. (2009). An optimization problem algorithm for kinematic design of mechanisms for two-finger grippers. *Open Mechanical Engineering Journal*, *3*, 49-62.**

3. **Felip, J., & Morales, A. (2009, October). Robust sensor-based grasp primitive for a three-finger robot hand. In *Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on* (pp. 1811-1816). IEEE.**

4. **Manti, M., Hassan, T., Passetti, G., D'Elia, N., Laschi, C., & Cianchetti, M. (2015). A bioinspired soft robotic gripper for adaptable and effective grasping. *Soft Robotics*, *2*(3), 107-116.**

5. **Pham, D.T., Yeo, S.H. (1991). Strategies for gripper design and selection in robotic assembly. International Journal of Production Research. Feb1991,Vol.29 Issue 2, pp. 303-317p.**

6. **Schmidt, I. (1978). Flexible moulding jaws for grippers. Industrial Robot: An International Journal, Vol. 5 Issue 1, pp.24-26. https://doi.org/10.1108/eb004491.**

7. **Brown, E., Rodenberg, N., Amend, J., Mozeika, A., Steltz, E., Zakin, M., Lipson, H., Jaeger, H. (2010). Universal robotic gripper based on the jamming of granular material. Proceedings of the National Academy of Sciences. Nov 2, 2010 107(44) pp.18809-18814. https://doi.org/10.1073/pnas.1003250107.**

8. **Nishida, T., Okatani, Y., & Tadakuma, K. (2016). Development of Universal Robot Gripper Using MR α Fluid. *International Journal of Humanoid Robotics, 13*(04), 1650017.**

9. Amend, J., Brown, E., Rodenberg, N., Jaeger, H., Lipson, H. A Positive Pressure Universal Gripper Based on the Jamming of Granular Material. *IEEE Transactions on Robotics*, vol. 28, no. 2, pp. 341-350, April 2012. https://doi.org/10.1109/TRO.2011.2171093.

10. Alkaabi, A., Alkaabi, M., Alnaqbi, M., Alnaqbi, R., Alnaqbi, S., Alsakarneh, A., Tabaza, T. (2018). Experimental analysis of the holding-force of the jamming grippers. *Advances in Science and Engineering Technology International Conferences (ASET)*, Abu Dhabi, 2018, pp. 1-3. https://doi.org/10.1109/ICASET.2018.8376880

11. Shintake, J., Cacucciolo, V., Floreano, D., Shea, H. Soft Robotic Grippers. (2018). Advanced Materials, Volume 30 Issue29 July 19, 2018. https://doi.org/10.1002/adma.201707035.

12. KIM, D. and SINGHOSE, W., 2010. Performance studies of human operators driving double-pendulum bridge cranes. Control Engineering Practice, Vol 18 Issue 6, June 2010, pp. 567-576. https://doi.org/10.1016/j.conengprac.2010.01.011.