Granular jamming based gripper for heavy objects

Patrick Frilund[1, a *], Iiro Vuorinen[2,b] and Jesse Miettinen[3,c]

[1]Full address of first author, including country

[2]Full address of second author, including country

[3]List all distinct addresses in the same way

[a]email, [b]email, [c]email

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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

The technology around lifting heavy objects has always relied on strong hooks and some manual labour for attaching the target object in various ways to the hook. Conventionally in overhead crane lifting, the objects 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.

Universal gripper could save a lot of time for crane operators. 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. This study was conducted to show if granular jamming will be a viable option for heavy lifting in the future.

Methods

System description

The system consisted of a custom made metallic body, a vacuum suction machine and the pouch. The body acted as a medium between the hook and the pouch. The connection between the hook and the pouch was air-sealed. The vacuum machine was attached on top of the body and it was able to suck the air out through the body. The vacuum machine used was Robinair single stage vacuum pump. (General Electrics model 5k H35) using AC motor and oil suction system).

Picture 1. Gripper with exercise ball and Wooden pellets L combination

In order to gain some knowledge on granule size -parameters 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 the wooden pellets that were used had relatively high stiffness-lightness ratio. 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	< 997kg/m^3	< 50 MPa
Wooden pellets [S]	Dia 6mm+-0.2mm Length 5mm +-2.5mm	< 997kg/m^3	< 50 MPa
Polyoxymethylene granules [POM]	2.5mm	< 1400kg/m3	< 2 GPa
Sand	0.5mm - 1.5mm	2700kg/m^3	< 70 GPa

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

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
4	POM	Exercise ball
5	POM	Custom ball
6	Sand	Custom ball

Table 3. Tested material parameter combinations

Results

Combination	1kg box	Chair	10kg box	Training ball	30kg box
1	Yes				
2					
3					
4					
5					
6					

Table 4. Successes and failures

Discussion

This study was conducted for learning if the granular jamming might be viable technology for heavy lifting in the future. From the table 4 we can clearly see that…

By comparing the results between combinations 1 and 2, it can be deduced that smaller granule size [raised/lowered/had none effect on] the gripping force.

The limiting factor in this experiment was the pressure difference between the environment and the insides of the pouch. With a more powerful vacuum machine or underwater environment, this technology could lift objects in the range of such and such kilograms.

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