Introduction

1. Industrial Robots
   - Numerous robots are located in the industrial site. In particular, due to its nature of the electronics production process, it requires simple repetition with delicate hand technology
   - Since industrial robots repeatedly and continuously move, based on coded activities, they operate only in a safety cage and are difficult to use in the same space as humans.

2. Application of Co-bot
   - Cooperative robots can physically interact with people while working in the same space as people are.
   - Robots are responsible for simple and repetitive manual tasks while people respond flexibly to emergencies.
   - Therefore, efficiency of the work can go up.

3. Touch and emotional discomfort
   - Unexpected contact or collision with cooperative robot can cause worker injuries or discomfort during collision.
   - Collisions between robots and humans frequently occur, and this lead to human injury or death.
   - Therefore, our goal is to prevent any type of collision between workers and cooperative robots by preventing such a collision, but most of the robots currently in use are not equipped with such collision system.
   - Therefore, our goal is to prevent any type of collision between workers and cooperative robots by reducing any discomfort through softening effects on industrial cooperative robots and solve the urgent problem; to achieve goal of FREEGOS.
   - Since the sense of discomfort when in contact, varies from person to person, criteria for generalization is necessary.
   - The criteria was selected by gender and age of around 24 years old.

Objectives

1. Manufacture Soft Robot skin based on evaluation of polymer material properties and emotional evaluation
   - Selection of materials suitable for robot skin production.
   - Conduct preference survey according to age and gender.
   - Adhesion measurement through contact angle test.
   - Measure elasticity of material through compressive creep test.

Materials selection & preparation

5. Materials selection
   - Requirement
   - Homogenous
   - Stretchable material for skin absorption.
   - Material that does not react strongly.

5. Procedure for materials preparation
   - Dry for 24 hours at room temperature after mixing.
   - Cure: 8%.

6. Physical property measurement
   - Contact angle test
   - Determining the relationship between the angle of contact and the surface.
   - The larger the strain, the softer the sample.

7. Physical property measurement Result
   - Contact angle of Ecoflex skin, Ecoflex and PDMS are 102.8, 107.2 and 107.7 degrees respectively.
   - The largest contact angle sample is PDMS while the smallest contact angle sample is Dragon skin.
   - For this result, the most sticky sample is Dragon skin while the least sticky sample is PDMS.

8. Physical property measurement Result
   - Compressive Creep test was kept under the condition where retention strength is kept 100 N for 30 minutes, while the resilience is 15 minutes.
   - The largest deformed sample is Ecoflex and the least deformed sample is PDMS.
   - For this result, we can know that the stiffer sample is PDMS and the least stiff sample is Ecoflex.

9. Physical property measurement Result
   - The table is the result of the preference survey based on male and female, age and physical properties.
   - According to the results of physical property measurement and survey results, the most preferred substances by gender/age group were as well.
   - Based on the analysis of the survey, people tend to prefer materials which are less sticky and softer.

Experimental Details

5. Preference Survey
   - Sample: Tactile feedback for sample contact angle test.
   - Survey details:
     - Male: 50, Female: 45
     - The preference was conducted for total 232 people, whose ages range from 18 to 32 years old.
     - The criteria was selected by gender and age of around 24 years old.

5. Preference Survey Result
   - Tendency of preference regarding physical property
     - Shoulder:
       - Male: 6 mm Dragon Skin, 8 mm Dragon Skin
       - Female: 6 mm Dragon Skin, 8 mm Dragon Skin
     - Elbow:
       - Male: 6 mm Dragon Skin, 8 mm Dragon Skin
       - Female: 6 mm Dragon Skin, 8 mm Dragon Skin

6. Preferred materials by gender & age
   - Shoulder:
     - Male: 6 mm Dragon Skin, 8 mm Dragon Skin
     - Female: 6 mm Dragon Skin, 8 mm Dragon Skin
   - Elbow:
     - Male: 6 mm Dragon Skin, 8 mm Dragon Skin
     - Female: 6 mm Dragon Skin, 8 mm Dragon Skin

7. Survey details:
   - The preference survey was conducted for total 232 people, whose ages range from 18 to 32 years old.
   - The criteria was selected by gender and age of around 24 years old.
   - Therefore, efficiency of the work can go up.

8. Survey details:
   - The larger the strain, the softer the sample.
   - Standard:
     - Male (125)
     - Female (105)

9. Preference score based on point of body contact only
   - The red number indicates the highest preference score while the blue number indicates the lowest preference score.
   - Therefore, we need to reduce variables to figure out the most appropriate materials to be applied in real industrial environments.
   - Depending on preference score only in point of body contact, contact of shoulder using 10 mm Ecoflex showed the highest preference score while the contact at elbow using 10 mm Ecoflex showed the highest preference score.
   - For the mixed samples of Ecoflex and PDMS, with varying ratios of 35, 70, 75, 77, 80, 90, 95, 99% to PDMS, the most suitable with good stiffness while minimum thickness is observed.

10. Mixed materials
   - Ecoflex + PDMS
     - 100% Ecoflex is too soft and sticky so that it is difficult to attach Ecoflex on the robot.
     - The most preferred material is 10 mm PDMS sample.
     - The mixed sample of Ecoflex and PDMS shows the most suitable with good stiffness while minimum thickness is observed.

Future work

- Plan to fabricate mixture of ECOFLEX/PDMS with its ratio of 5:5 with its thickness of 10 mm and come up with idea on how to wrap this materials around robot arm.

Summary & Conclusion

- To prepare for 4th industry revolution, the soft robot skin should be developed in consideration of the gender, age, and working environment of workers in the same space.
- The material should be harmless to the human and should not have unbearable smell in use. We have selected the following 6 materials according to those requirement explained above: Dragon skin, Ecoflex, Sylgard, EP73, Ecoflex, PDMS.
- As a result of preference survey, both males and females preferred 10 mm Ecoflex when in contact with the robot using shoulder while 10 mm Ecoflex was preferred when in contact with the robot through elbows.
- Since it is difficult to wrap PDMS alone on the curved surface due to its high stiffness, Ecoflex was invented to indicate the properties to be able to wrap on the curved surface.
- As a result of the measurement, it can be concluded that the mixed sample of Ecoflex which is corneal flexible, while adhesion and stiffness do not deviate much from our desired standards, was determined to be the most suitable material.