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1 Introduction

1.1 Purpose of this document

The purpose of this document is to demonstrate the iHand assist/prevent glove. The iHand assist/prevent glove system is based on the same technology as the iHand rehab glove but with entirely different specifications when it comes to speed and force levels. The iHand assist/prevent glove is intended to be used by healthy individuals who are at risk of developing musculoskeletal disorders (MSDs) or who need extra strength and endurance in the grasp.

2 Demonstrator

2.1 Overview of the system

The iHand assist/prevent glove is a modular system that consist of a five-finger glove, a power pack, and two armstraps. The system mimics the user's grasp movements and gives extra strength and endurance to the grasp. This relieves the muscles and conservers the energy of the operator.

The iHand assist/prevent glove is not intended to replace the operator's normal protective gloves, rather, it serves as a compliment to the protective gloves. The assist/prevent glove is intended to be worn underneath a normal protective working glove. The protective working glove serves both to protect the operator from his or her normal risks as well as protecting the assist/prevent glove from the environment.

2.1.1 System when worn by an operator

The illustration and table below show all parts of the system.

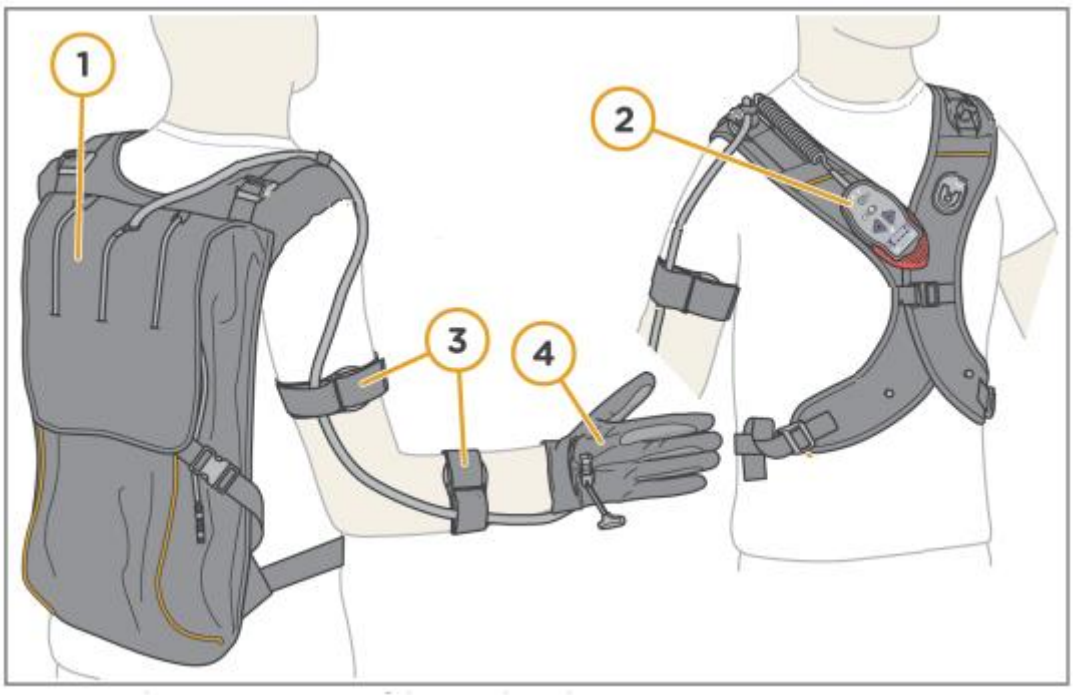

Figure 1 Overview of the iHand assist/prevent system

Item	Name	Function
1	Backpack containing the power pack	Protects the power pack
2	Remote control	Operator control interface
3	Arm straps	Keeps the cable attached the operator's arm
4	Glove	Provides grasp force

The glove is connected to a power pack via a cord. The power pack is worn on the users back in a backpack and consists of motors, linear actuators, electronics and a battery. The cord is held close the operator's arm using arm straps.

2.1.2 Power pack

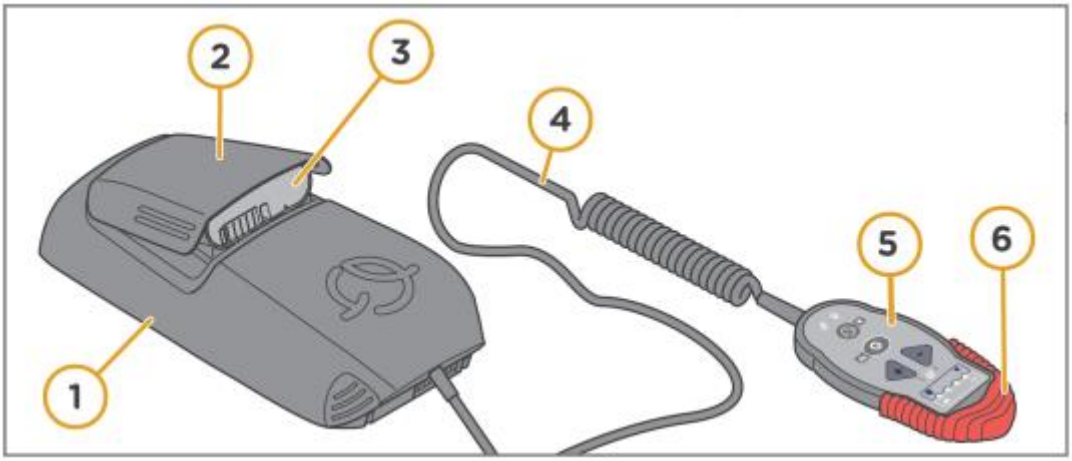

Figure 2 The power pack

Item	Name	Function
1	Power pack	Controls and powers the assist/prevent glove
2	Battery compartment	Holds the battery
3	Battery	Power source of the power pack
4	Cord	Transmits commands and power between the power pack and the remote control
5	Remote control	Operator control interface
6	Quick stop	Shuts down the system quickly

2.1.3 Glove

The glove uses Bioservo's patented SEM™ (Soft Extra Muscle) technology. The glove mimics the hand's own anatomy using

- artificial tendons that transfers force to the finger in a similar way as the finger tendons;
- finger sensors that senses contact force between the fingers and the grasped object;
- electric motors that pull the artificial tendons and act like muscles;

- intelligent intention detection algorithms that ensures that the support is given when the user intends to grasp an object and releases the support when the user wants to release the grasp.

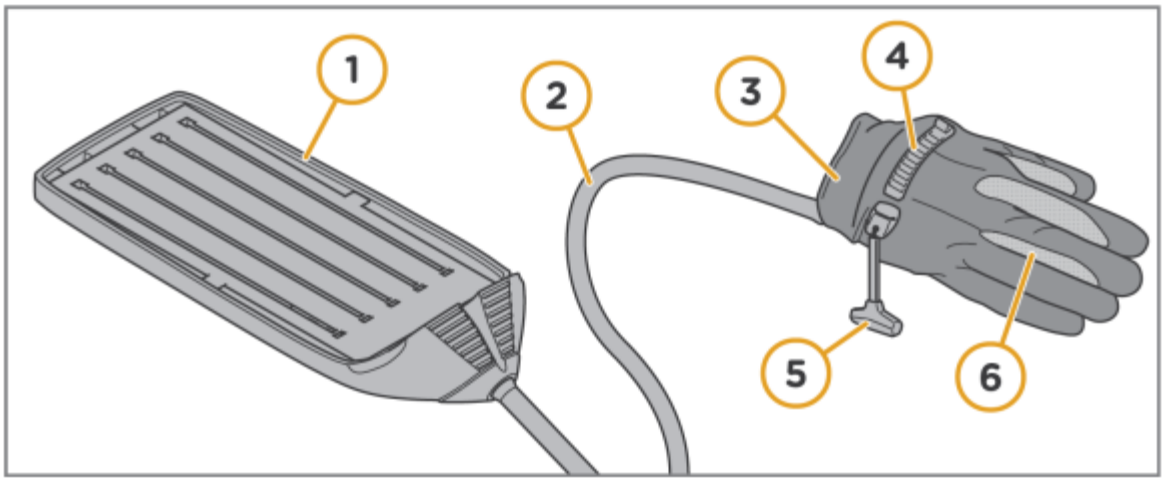

Figure 3 The glove

Item	Name	Function
1	Connector	Connects the glove to the power pack
2	Cord	Transmits sensory data and force
3	Glove	Provides grasp force
4	Wrist brace	Secures the glove on the hand
5	Release handle	Loosens the wrist brace
6	Mesh	Provides ventilation for the hand

2.1.4 User interface

The user interface in the iHand assist/prevent glove is a remote control worn on the backpack's shoulder strap,

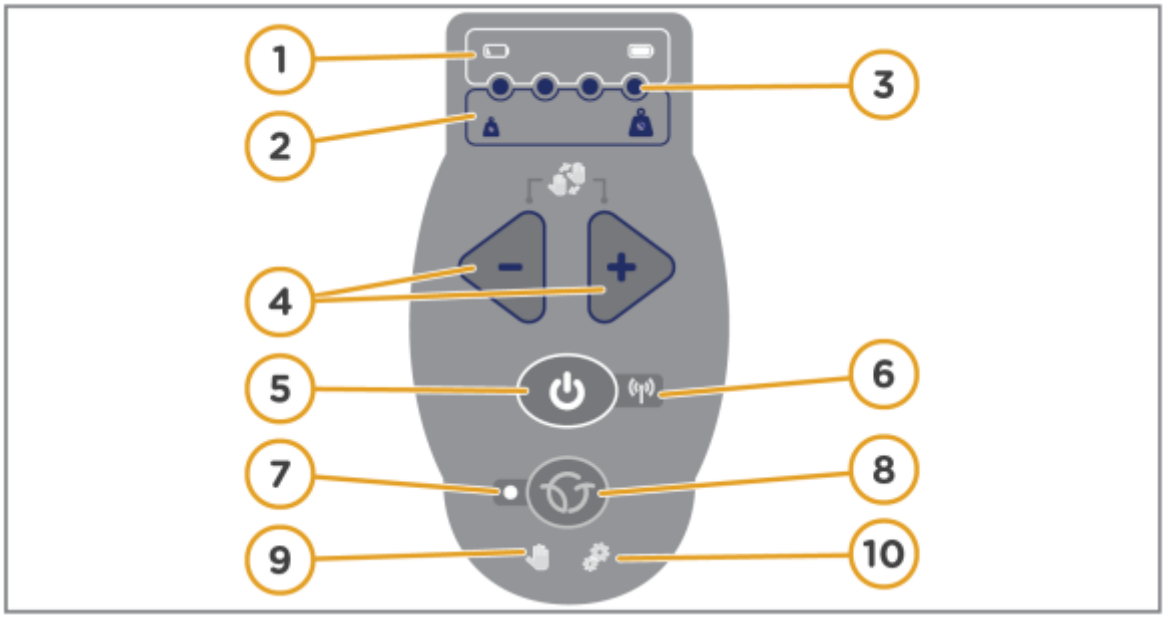

Figure 4 The remote control

Item	Name	Function
1	Battery Indicator	Shows remaining battery level
2	Force level indicator	Shows chosen force level
3	LEDs	White – battery level, blue – force level
4	Force adjustment	Press to adjust the force level
5	On/off button	Hold for approximately 1s to turn the system on or off. Double click to enable wi-fi
6	Wi-fi indicator	Blinking = wi-fi is turned on, steady = connected to wi-fi.
7	Profile selection indicator	Off = primary profile, on = secondary profile
8	Profile selection button	Press to select profile
9	Glove status indicator	Indicates glove errors
10	Power pack status indicator	Indicates power pack errors

2.2 User Group

The iHand assist/prevent glove is suitable for anyone with a grasp intensive work situation. It is intended to be used as either an assistive device for people with reduced hand functionality or as a preventive device, preventing people in hand intensive work situation from getting strain injuries.

2.3 Technical development

2.3.1 Technical overview

The iHand assist/prevent glove system is based on the same technology as the iHand rehab glove system, but the technical specifications are different to better suit healthy individuals in a professional environment. For healthy people using the robotic glove in an industrial environment the activation speed and force levels are of more importance than when comparing to people using the rehab glove. If a professional robotic glove system is too slow, it will hinder the operator in his or her work making the product less useful. To give better support in the grasp, the assist/prevent glove is a five-finger glove with activation on each of the five fingers.

The glove is considered a personal device and is not shared between different operators. The power pack, on the other hand, is not considered personal and can be shared between operators.

2.3.2 Force transfer

2.3.2.1 Actuators

When compared to the rehab glove the assist/prevent glove is five times faster and around three times stronger. This is accomplished by supplying the system with a higher voltage and using motors that have higher output power rating. Since the iHand assist/prevent system is a five-finger device the power pack has five actuators, one connected to each finger. The actuators developed for the iHand assist/prevent system are linear actuators that are geared with the motor characteristics in mind so that the output speed and force are correctly balanced to give a strong enough and fast

enough system. The stroke of the actuator has been increased compared to the rehab glove up to 150 mm to better support people with large hands.

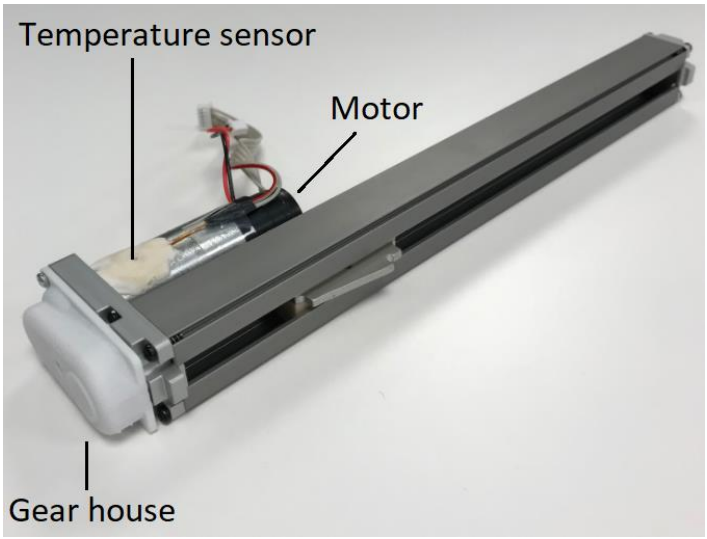

Figure 5 Linear actuator developed for the iHand assist/prevent system

2.3.2.2 High electrical powers

Both the voltage and the current output from the battery are higher than in the rehab glove. The electronics have been developed to support the higher power output from the battery. Since the power consumed by the motors are high, different temperatures needs to be monitored and controlled for the system not to risk overheating. Each motor has a temperature sensor mounted to it (see Figure 5) and the battery has an internal temperature sensor which is monitored by the firmware. The processor where the firmware program is running also has an internal temperature sensor which is monitored by the firmware. When either of these temperatures reaches a predefined upper limit, the motor current is limited by the firmware. This stops the temperature from rising further. The system can still be used but the output force will be limited to protect the system from overheating. This temperature control ensures that the system can be used continuously in any environment without risking overheating.

2.3.3 Carrying system

The drawback of the high-power performance of the iHand assist/prevent system is that the weight and size of the system is greater when comparing to the rehab glove. The assist/prevent system is therefore designed to be carried on the operators back in a backpack where the weight does not have a large impact. Two different backpacks have been designed, a two-system backpack and a single-system backpack.

2.3.3.1 Single-system back-pack

Most operators only need assistance on one of their hands. Most often it is their dominant hand that they use most extensively throughout the work day. A single-system backpack has been designed

with the goal to make it as slim and small as possible.

Figure 6 Single-system back pack

2.3.3.2 Two-system backpack

Some operators need assistance for both their hands and are therefore in need of a carrying system that can hold two systems. The drawback of the two-system backpack is that is larger than the single-system backpack and thus covering a larger portion of the operators back. Covering a large portion of a person's back can cause the operator to be warm when wearing the backpack for an extended period. That is the reason for developing a single-system backpack as a compliment to the two-system backpack.

Figure 7 Two-system backpack.

2.3.3.3 User interface

Since the system is worn on the operators back, a user interface not located on the power pack needed to be developed. A remote control that is attached to the shoulder straps has been developed, see Figure 4.

2.3.4 Electronics

2.3.4.1 Sensor circuitry

The electronics in the iHand assist/prevent system have been developed to support different sensor technologies. From firmware it is possible to adjust the electronics to change the amplification on the finger sensor measurement circuitry. This feature makes the assist/prevent glove future proof for using sensors with different force to resistance characteristics. A digital potentiometer is set from firmware to alter the resistance and thereby altering the bias voltage used in the circuitry.

2.3.4.2 EEPROM memory

The electronics feature an on-board EEPROM memory that is used to store data and parameters. The EEPROM is communicated with using the protocol SPI. The presence of an on-board EEPROM makes it possible to upgrade the firmware without the upgrade tool needing to handle customized parameters and statistics. This enables over the air firmware upgrade of the iHand assist/prevent system, which will be further described in D3.4.

2.3.5 Robustness of sensors

In a professional environment the demand for mechanically robust products are high. The mechanical stress that the assist/prevent system is put through is much greater than that of the rehab glove. The most exposed component is the finger force sensors used to activate the system. The sensors are positioned where the operator's finger and the object the operator is grasping meets. The forces in that point can be very high thus creating a less than ideal situation for the sensors. In lab tests and early field tests the sensors used in the rehab glove is determined to not be

robust enough after failing after only a few days of use. In order to solve this issue, a new finger sensor has been developed. In the graph below the results from a lab durability test comparing the two generations of sensors are presented.

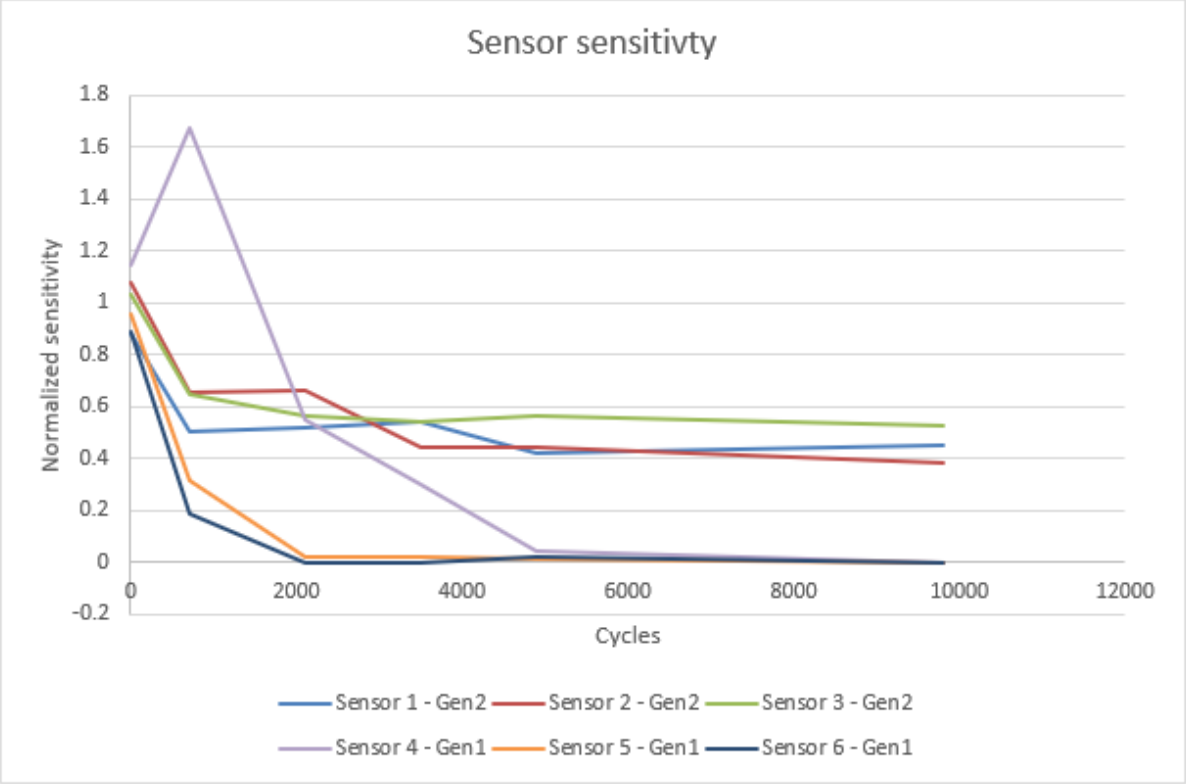

Figure 8 Sensor sensitivity as a function of number of test cycles in durability lab test.

In Figure 8 the difference between the two generation sensors can be seen clearly. The first-generation sensors used in the rehab glove (4, 5 and 6) quickly lose sensitivity. Sensor 5 and 6 are completely unresponsive after 2000 cycles whereas sensor 4 survives a bit longer. The second-generation sensors developed for the iHand assist/prevent glove (1, 2 and 3) follow a predictable pattern and level out to a constant level after 1000-3000 cycles.

2.3.6 Glove textile

The glove textile used in the assist/prevent glove is quite different from the textile used in the rehab glove. The rehab glove is a stand-alone glove whereas the assist/prevent glove is part of a two-layer system where the operator wears his or her normal protective glove on top of the iHand glove. Since a protective glove is intended to be worn on top of the iHand assist/prevent glove, the glove has been designed to be as thin as possible using breathable materials to reduce the warmth. Cost and making the glove easy to sew and assemble has been a major focus during development.

2.3.7 Making the glove washable

Since they glove will be used throughout the working day it is important that it can be washed to get it clean and hygienic to use. Making the glove washable is a greater challenge than to make the glove textile washable. All components seen in Figure 3 needs to be washed since it cannot be dissembled further. The plastic connector, electronics, cables and sensors all need to be washable. The sensors proved to be the hardest to make washable. Sensors of the FSR type needs to be able to have air

getting in and out from the small cavity in the sensor. The solution was to attach a ventilating membrane to a small hole used to let the sensor being ventilated.

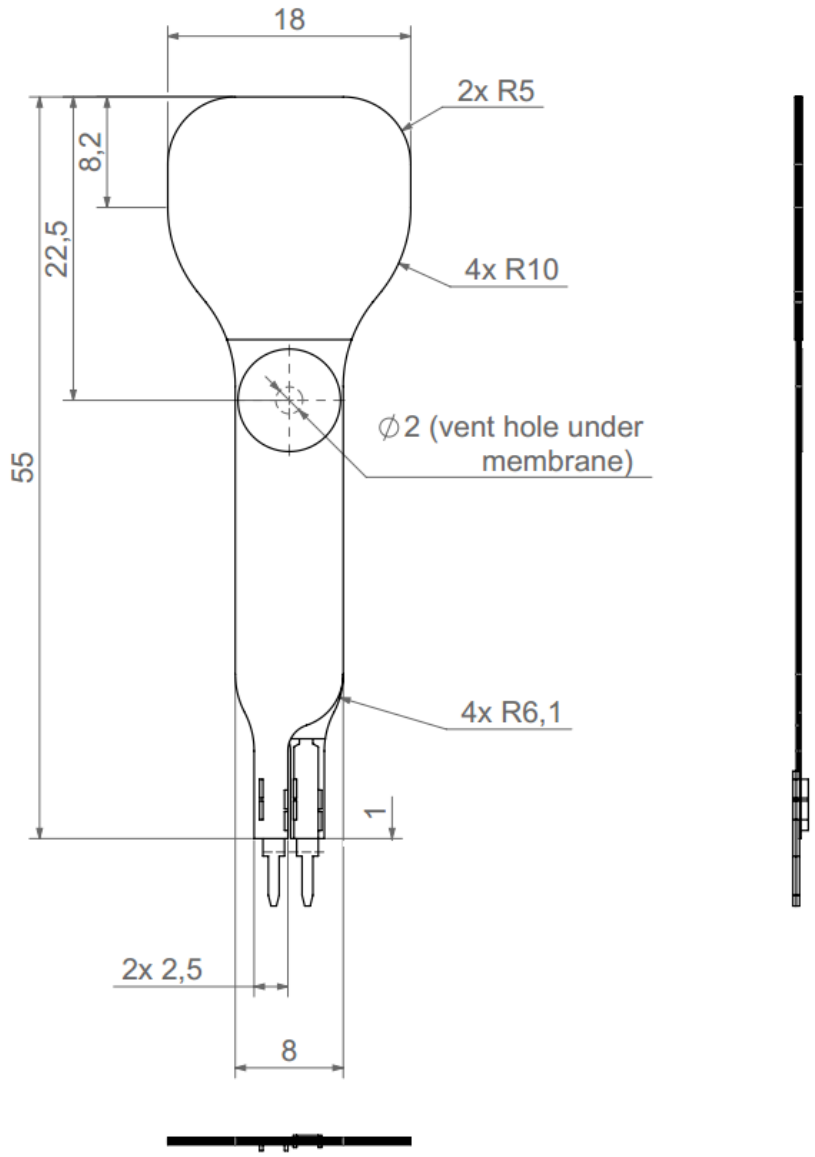

Figure 9 Force sensor with ventilating membrane

2.3.8 Data collection

The iHand assist/prevent system has extensive capabilities of recording, storing and uploading data to a server for further analysis. The data recorded by iHand is stored in the form of histograms that are stored on either the main PCB in the power pack or on an EEPROM memory locate on the glove hardware depending on the characteristics of the data. Operator data is stored on the glove since the glove is considered personal and technical operational statistics, such as diagnostics, are stored on the power pack.