OBJECTIVE EVALUATION OF CATHETER EYELETS

– FROM SUBJECTIVE JUDGMENT TO MEASURABLE DATA

Högskoleingenjörsutbildning i kemiteknik
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Sammanfattning

Urinvägskatetrar är vanligt förekommande medicintekniska produkter, där yt-defekter runt drängeringshålen, så kallade eyelets, kan orsaka smärta, irritation och ökad infektionsrisk. Idag baseras bedömningen av eyelets främst av manuell taktil inspektion, en metod som är snabb men subjektiv och beroende av operatörernas erfarenhet. Syftet med detta examensarbete var att utveckla och utvärdera mer objektiva metoder för att bedöma slätheten hos eyelets genom en kombination av optisk mikroskopi, taktil utvärdering och friktionsmätningar.

Studien visade att katetrar som genomgått mekanisk kompression uppvisade tydligare geometriska avvikelser och att dessa i hög grad sammanföll med lägre taktila betyg, där eyelets uppfattades som skarpare och mindre släta. Friktionsmätningarna visade dessutom större variation för mindre kateterstorlekar och för komprimerade eyelets, särskilt i områden där ojämnheter i ytan påverkade den mekaniska interaktionen mellan kateterytan och mothållets yta under friktionsmätningen

Resultaten visar att optisk mikroskopi och friktionstestning kan fungera som värdefulla komplement till den subjektiva *'Feel and Touch'* metoden genom att tillföra objektiva och reproducerbara mätdata. Metoderna har därmed potential att bidra till förbättrad kvalitetskontroll samt vidare utveckling av urinvägskatetrar.

Abstract

Urinary catheters are commonly used in medical devices, and surface defects around the drainage holes, known as eyelets, can cause pain, irritation and an increased risk of infection. Today, the evaluation of eyelets is mainly based on manual tactile inspection, a method that is quick but subjective and dependent on the operator's experience. The aim of this thesis was to develop and evaluate more objective methods for assessing the smoothness of eyelets by combining optical microscopy and friction measurements and correlate the results with results from tactile evaluation.

The study showed that catheters subjected to mechanical compression exhibited more pronounced geometric deviations, and that these largely coincided with lower tactile ratings, where the eyelets were perceived as sharper and less smooth. The friction measurements also demonstrated greater variation for smaller catheter sizes and for compressed eyelets, particularly in areas where irregularities in the surface affected the mechanical interaction between the catheter surface and the counter surface during friction measurements.

The results indicate that optical microscopy and friction testing can serve as valuable complements to the subjective Feel and Touch method by providing objective and reproducible measurement data. Combining these methods enables a more comprehensive and data-based evaluation of eyelet smoothness, thereby supporting improved quality control and further development of urinary catheters.

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1. INTRODUCTION

Urinary catheters are an important medical device and are among the most frequently used medical devices in healthcare. They play an important role for patients who cannot empty their bladder independently. They are commonly used after surgery, during illness or when the bladder muscle function is impaired (Flores-Mireles et al., 2015; Werneburg, 2022). A urinary catheter is a small and flexible tube that drains urine from the bladder into a collection bag or into the toilet. It may look like a simple product, but the design and surface of the catheter are very important for patient safety and comfort. One essential component of the catheter functionality is the small drainage holes called eyelets. These holes are near the tip of the catheter and let the urine flow out from the bladder to the collection bag. Because this section of the catheter is inserted first, the design and surface quality of the eyelets directly influence how the catheter feels during insertion. If the eyelet edges are not smooth enough, they may damage the urethral tissue and cause irritation or increase infection risk (Moore et al., 2023; Stensballe et al., 2005).

To improve patient safety, Wellspect Healthcare has developed a new drainage hole design for some of their product lines. The new drainage hole design has several smaller eyelets. Recent studies show that micro-hole drainage zones provide fewer flow interruptions, reduced mucosal suction and significantly lower mucosal microtrauma compared to traditional large eyelets (Landauro et al.,2023; Willumsen et al., 2024). A key challenge in the development of these products is how to reliably evaluate the smoothness of the eyelets to ensure consistent patient safety.

Wellspect HealthCare uses internal manual methods to check the surface quality of catheters. Two methods form the basis for the evaluation approach used in this project:

- **MB-5302** – *Manual test of smoothness*- catheter eyelets, used to test the tactile and visual smoothness of the drainage holes.
- **MB-5092** – *Manual evaluation of catheter coating during development* -Used to check the quality and consistency of the hydrophilic coating.

This project combines elements from both procedures to create a structured testing approach. The new version in this report will be called the '*Feel and Touch'* Method. It involves a human operator visually inspecting and touching the eyelets to judge the surface quality. The main limitation of this approach is its subjectivity, since different operators may feel and judge the same surface differently (Chen et al., 2023). The variation between the operators makes the method less reliable for quality control. Because of the limitations there is a need for a better objective and data-based method that can quantify eyelet smoothness. A method with higher repeatability and reduced operator influence could support safer and more comfortable catheter designs while lowering the risk of urethral irritation and infection (Flores-Mireles et al., 2015; Werneburg, 2022).

1.1 Background

Urinary catheters are medical devices used to drain the bladder when natural voiding is not possible. There are two main types of catheters (Moore et al., 2023):

- Indwelling catheter (Foley catheters): Catheter that remains inside the bladder for hours or several days.
- Intermittent catheter: Catheter that are inserted for a few minutes and removed immediately after bladder emptying.

Wellspect HealthCare manufactures only intermittent catheters.

Indwelling catheters are well documented as a major risk factor for urinary tract infections (UTIs). In hospital settings, 70-75% of all hospital-acquired UTIs are associated with catheter use, and most occur in patients with indwelling catheters (Flores-Mireles et al., 2015; Werneburg, 2022). A specific subtype of UTI is catheter-associated urinary tract infection (CAUTI), which refers to UTIs that arise because of catheterization. This diagnosis is primarily linked to indwelling catheters, where the device remains inside the bladder long enough for bacteria to attach to the catheter surface and form biofilm. Werneburg (2022) reports that CAUTI incidence varies depending on catheter material and clinical conditions.

One of the main reasons for these infections is bacterial growth on the catheter surface. Biofilm can form on catheter surfaces with small irregularities. A biofilm is a thin, sticky layer made up of bacteria and the substances they produce to protect themselves. Once the bacteria attach to the surface, they begin to multiply and build this protective layer. When the biofilm has developed, bacteria become much harder to remove because the layer shields them from both cleaning and antibiotic treatment (Flores-Mireles et al, 2015) However, biofilm formation is primarily a concern for indwelling catheters that remain in the body for extended periods. Wellspects catheters are intermittent, meaning they are inserted only briefly and removed immediately after use, giving bacteria little time to attach or form biofilm (Neumeier et al., 2023). Although intermittent catheters do not often develop biofilm-related infections, the surface quality of eyelets is considered important. Traditional eyelets have relatively larger openings that will create mucosal suction with possible microdamage to the urothelium. This can result in pain, discomfort and higher infection rates (Landauro et al. in 2023; Willumsen et al. in 2024). Some studies show that new materials and antimicrobial coatings can reduce how much bacteria stick to the catheter. This shows again that the tiny structure of the surface is important to control (Kanti et al., 2022). Currently, the smoothness of catheter eyelets is tested manually. Trained operators inspect surface quality by using tactile feedback. Although this approach is simple and fast, it relies heavily on individual experience. Different operators might give different judgments for the same sample and subtle irregularities that may affect product quality and safety cannot be easily detected by manual inspection alone (Chen et al., 2023). Wellspect HealthCare has conducted several internal investigations into how manufacturing decisions influence eyelet smoothness. No objective or standardized method of evaluation has been developed for eyelet smoothness. A measurement-based approach with high repeatability could reduce operator variability and improve the safety and comfort of catheters while minimizing the risk of irritation or infection.

1.2 Purpose

The main purpose of this project is to develop an objective method to measure how smooth the eyelets of urinary catheters are. The method used is manual evaluation to judge the smoothness of the eyelet. It is a simple method, but it depends on each operator's judgement and can give inconsistent results. A more objective method based on measurements could make it easier to control quality and improve patient safety. This project is done together with Wellspect HealthCare. The goal is to find connections between how the surface feels and what can be measured using simple instruments like microscopes and friction testers. A reliable and objective method would not only improve production quality but also help ensure safer and more comfortable catheters for patients.

1.2.1 Scientific questions

1. What is the connection between manual evaluation results, specifically 'Feel and Touch' results and other measurable parameters, such as friction and eyelet dimension?
2. How can the size and shape of catheter eyelets be measured using an optical microscope?
3. What methods exist to measure friction on catheter materials, and are these methods suitable for eyelets?
4. Is it possible to suggest a standardized and objective method to evaluate the smoothness of the catheter eyelets?

2. THEORY

2.1 Surface roughness and how it is measured

Surface roughness defines the small irregularities on a surface making it less smooth, these variations can be so small that they cannot be detected by touch. The level of roughness is usually described by standardized parameters such as Ra (arithmetic average) or Rz (ten-point height). Ra refers to the arithmetic average of all the height deviations, for instance, peaks and valleys from the mean line within a measured area. It gives an overall result of the surface being rough or smooth because it averages all tiny ups and downs. Rz concentrate on the difference between the tallest peaks and the deepest valleys within a sampling length. Rz measures the distance between the five highest peaks and the five deepest valleys along the surface. Both Ra and Rz find applications in the development of medical devices for studying how the surface may behave after coming into contact with biological tissue (Hamzah et al., 2022). According to Shah et al. (2021), the importance of surface roughness for patient safety accounts for the fact that roughness can influence how safe and comfortable a medical device will feel. Because the urinary catheter goes into the body through a natural orifice and is in contact with the urethral mucosa, the surface must be as smooth as possible to avoid pain and infections.

Unlike other types of medical catheters, such as venous or surgical, urinary catheters are made from soft and flexible polymers-usually polyurethane, silicone or PVC. These materials are used because they are biocompatible and do not cause harmful reactions or irritation for the user. Their softness makes the surface roughness difficult to measure since a contact-based instrument may deform the catheter and give false results. Indeed, most of today's urinary catheters are designed with thin hydrophilic coatings that enhance comfort and safety. This coating absorbs water and becomes slippery, further complicating contact-based measurement methods.

One common device to measure roughness is the profilometer. It works by dragging a small stylus across the surface of interest to record height differences that can be used to calculate Ra and Rz values later. This method is reliable for hard materials, like metals or ceramics, but in soft polymers like PU or silicone, the stylus deforms the material and gives incorrect results (Evangelista et al., 2023). This limitation is highly relevant for this project because eyelets possess inner edges, curved surfaces and confined openings that make it impossible for the stylus to maintain stable contact and have any chance of getting reproducible data. That is why profilometers are used at Wellspect for catheter tubing, but this is unsuitable for eyelets. Due to the drawbacks of these methods, non-contact optical measurement techniques are favored for geometries that are small, soft or complex. Techniques such as white-light interferometry and confocal microscopy can capture high-resolution 3D surface information without touching the sample, thereby avoiding deformation and providing accurate measurements for hydrophilic-coated polymers (Jiao et al., 2022).

2.2 Optical microscopy and 3D imaging

Optical microscopy is an important tool for studying and evaluating the surface quality of soft polymers used for medical devices like catheters. These materials are flexible and biocompatible, but their softness also makes them easy to deform. Bending or stretching the soft material can cause micro-level deformations, and these small irregularities are not visible to the human eye and can allow bacteria to attach and increase the risk of infection (Evangelista et al., 2023). With optical microscopy, it is possible to see details on catheter eyelets, such as harsh edges, scratches or small variations in shape that can affect how the catheter interacts with the body.

Different optical or 3D imaging methods require certain conditions to work properly. Catheter materials have different optical properties, such as how much light they can reflect or absorb. Hydrophilic coatings can also scatter or weaken the light, which makes the image less clear. Because of this, the measurement setup often needs to be adjusted so that the material's optical properties do not disturb the collected images (Jiao et al., 2022). These factors are important to consider when choosing the right optical method for examining catheter components.

Techniques such as confocal microscopy, white-light interferometry and structured-light scanning can capture minor variations in edge shape and surface roughness that may not be visible by 2D inspection (Jiao et al., 2022). These techniques are highly relevant for catheter eyelets, since the geometry is small and curved and partially hidden. Advanced systems such as micro-CT or laser-based 3D scanning can detect extremely small defects and generate highly detailed 3D models of curved and complex shapes like catheter eyelets. However, these systems are expensive, time-consuming and impractical for routine production quality control. Their long measurement times and complex setups make them unsuitable for daily inspection of small components (Jiao et al., 2022).

The goal of this project is to measure the smoothness of catheter eyelets. The material being soft, coated and geometrically curved, contact instruments like profilometers cannot deliver reliable results due to deformation and unstable contact on the inner edges. Advanced 3D imaging techniques are available but are not practical for continuous inspection in an industrial setting. Therefore, a 2D optical microscopy measurement technique is used. It provides a sufficient level of detail that can detect surface irregularities across the edges of eyelets without deformation and optical disturbances that are expected with other measurement techniques.

2.3 Measuring friction and smoothness

Friction is one of the most common ways to evaluate how smooth the surface of a urinary catheter is. In urinary catheters, friction describes the resistance that occurs when the catheter moves against the urethral tissue. Lower friction makes the insertion more comfortable and reduces the risk of irritation or pain for the user. Because of this, friction measurements are important in catheter development in general and they are also used at Wellspect to evaluate how different materials, surface structures and coatings influence the catheter's smoothness and overall user comfort. Friction can be measured using a device called a tribometer, which records the force needed to move a weight along the sample surface (Kazmierska, Szwast & Ciach, 2007). The measured value is the coefficient of friction (COF), which provides a numerical indication of how slippery or resistant the surface is (Moore et al., 2023).

Hydrophilic coatings create a thin water-based lubricating layer that reduces friction during insertion, thus providing a smoother experience for the user. In various studies, hydrophilic-coated catheters have been found to have lower COF values and cause less tissue irritation than uncoated or silicone-coated catheters (Stensballe et al., 2005; Liao et al., 2022). Amphiphilic coatings were compared to traditional hydrophilic coatings (Burns et al. 2024). Results showed that this coating interacts both with water and lipids and gave lower friction values, maintaining its lubricating properties across a wide range of environmental conditions.

Surface texture plays an important role in how the catheter material responds during friction measurements. Small irregularities and higher roughness can increase friction when sliding against the tissue. Studies have shown that when the material is smooth, the contact area with the tissue is more even and less force is needed. Combining friction measurements with optical roughness data has proven that the surface strongly influences how the catheters perform during use (Evangelista, 2023).

3. METHOD

The study evaluated the smoothness and geometric quality of catheter eyelets using three complementary methods:

1. Optical microscopy
2. Feel and Touch
3. Friction testing

The methods target different aspects of surface performance, geometric precision, tactile perception and mechanical friction. Together they provide a comprehensive understanding of how eyelet design influences usability and comfort. Each method targeted different aspects of the surface performance and allowing validation between measurements, physical touch and mechanical behavior. All testing was conducted at Wellspect Healthcare, Mölndal, Sweden.

3.1 Optical microscopy

The purpose of the microscopy method was to objectively assess the geometry of catheter eyelets. The analysis focused on detecting small dimensional variations and visible defects such as burrs, scratches or asymmetry that could influence tactile smoothness or frictional behavior.

3.1.1 Equipment & materials

All measurements were performed using a digital microscope (EQ-Q2753) (Figure 1) equipped with variable magnification and adjustable LED illumination, which allowed dimensional measurements with high precision. A fixture EQ-Q-4592-(2) (Figure 2) held each catheter horizontal and stable under the microscope during the measurement. Before each measurement, every catheter was marked with an identification code on the tube for full traceability across all methods.

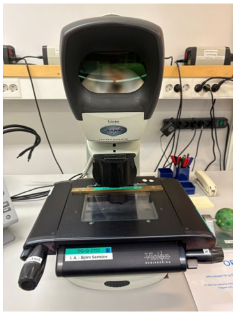

Figure 1: EQ-Q2753

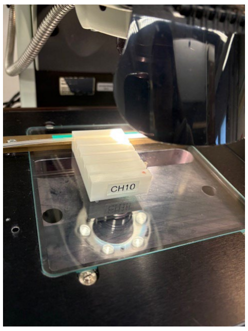

Figure 2: EQ-Q-4592(2)

Each catheter had three rows of eyelets, with four holes in each row. To make the analysis systematic, the holes are labeled as follows in figure 3. This numbering system ensured that every microscopic measurement corresponded to the same position across all methods. The samples used for microscopy are presented in Table 3 (see section 3.4).

- *Row 1: 1.1-1.4*
- *Row 2:2.1-2.4*
- *Row 3: 3.1-3.4*

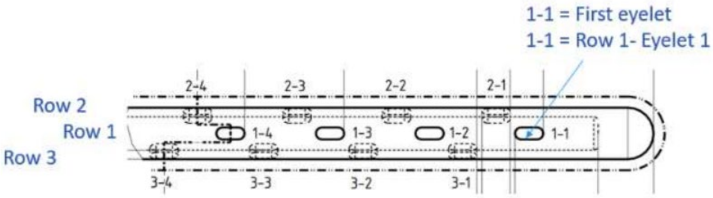

Figure 3: Row and eyelet numbering system

3.1.2 Measurement procedure

Each catheter was placed horizontally in the fixture EQ-Q-4592-(2) under the microscope and the three rows were analyzed in order (Row 1 → Row 2 → Row 3),

For every eyelet, four geometric parameters were analyzed:

- ***Outer X-dimension*** *(Outer width)*
- ***Outer Y-dimension*** *(outer length)*
- ***Inner X-dimension*** *(Inner width)*
- ***Inner Y-dimension*** *(Inner length)*

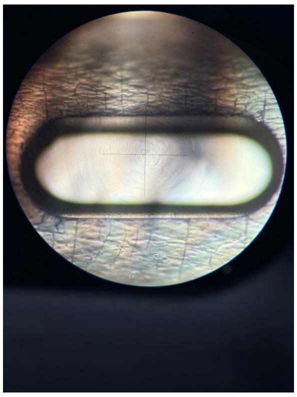

Figure 4: Eyelet in microscope

These parameters were used to capture both the external shape at the catheter surface and inner opening geometry towards the tube lumen. All measurements were recorded in the Excel sheet for calculations. The outer dimensions were used for later calculations, and the inner dimensions were collected as supplementary raw data but were not used for comparison or statistical calculations.

3.1.3 Calculations

For each row, the average and standard deviation (SD) values were calculated for the outer X and Y dimensions. A total SD was then calculated by combining all twelve eyelets from the same catheter. SD shows how large the variation is, where a higher SD means bigger differences between the eyelets. By comparing the total SD between the compression and non-compression versions, it was possible to see if the forming pressure created more variation in the eyelet geometry.

Shape Proportionality:

To assess proportionality, the Y/X-ratio was calculated for every eyelet using the following equations:

$$R_i = \frac{Y_i}{X_i}$$

$$\bar{R}_{Row} = \frac{1}{n}\sum_{i=1}^{n} R_i$$

$$\left|R_{dev,i}\right| = |R_i - \bar{R}_{Row}|$$

- *R_i =length to width ratio for each eyelet*
- *$\bar{R}_{Row}$=mean ratio for row*
- *$\left|R_{dev,i}\right|$= absolute deviation from the mean ratio*
- *n= 4 (since each row contains four eyelets)*

To identify disproportional eyelets, a deviation threshold of:

$$\left|R_{dev,i}\right| > 0.01$$

- *Was used. Eyelets exceeding this limit were flagged as non-proportional*

$$\%diff = \frac{|R_i - \bar{R}|}{\bar{R}} \cdot 100$$

- *%Δ R deviation calculation*

This absolute deviation was then used to quantify how much each eyelet differed from the proportionality of the row. In the results section, both the absolute deviation and the percentage deviation from the row mean are reported for clarity.

3.2 Feel and Touch

The *Feel and Touch* method was designed to systematically evaluate the tactile impression of each catheter eyelet. It measures how smooth or rough the eyelet feels it is inspected and touched. The method was inspired by the internal Wellspect tactile procedures (MB-5302 and MB-5092) but was further developed to include a five-point rating scale, descriptive tags and new handling rules focused on the eyelets to ensure consistency.

3.2.1 Material

The same catheters analyzed under the microscope were used for the tactile evaluation (see Table 3, section 3.4). All tests were performed under controlled laboratory conditions. The setup included a 1000 ml measuring cylinder filled with tap water, which was used to activate the dry surface coating before testing. A stopwatch was used to ensure precise timing, while a hanging rack allowed the catheters to air dry vertically without physical touch (Figure 5). All observations and ratings were documented directly in the Excel datasheet.

Figure 5: Materials for performing Feel and Touch

3.2.2 Procedure

Before starting the tactile test, the catheter identification codes were verified against the microscopy documentation to ensure traceability between the two methods.

Each catheter was first conditioned by immersion in the measuring cylinder with tap water for 10 seconds, followed by air drying for 3 minutes. After drying, the catheter was held horizontally, and the operator used the pad of the thumb to gently perform three strokes along the first row of eyelets. During these strokes, attention was focused on identifying roughness, bumpiness, harsh edges or asymmetrical shapes that could affect smoothness. All tactile impressions for row 1 were recorded immediately before continuing to Row 2 and Row 3 which were evaluated using the same procedure.

For data documentation, each row received a rating between 1 and 5, based on the smoothness scale. The average of the three rows rating scores was calculated to obtain the overall smoothness rating (R1-R5) for each catheter. Severity was documented for clarity, along with descriptive tags that explained the type of irregularity. All parameters of the evaluation are presented in Table 2. All ratings and descriptive tags were entered directly into the excel sheet for comparison with the microscopy measurements.

Parameter	***Description***	***Level***
Severity	*Indicates how critical or noticeable the irregularity was*	***Mild*** *– Barely noticeable, no risk* ***Clear -*** *Affects usability, risk for discomfort* ***Poor*** *– May cause discomfort or irritation, high risk*
Tags	*Type of irregularity detected*	***R*** *= rough* ***B*** *= bumpy* ***H*** *= harsh* ***A*** *= asymmetric/irregular shape*
Rating	*Row smoothness on a scale*	***1*** *– Poor – rough* ***2*** *– Problematic – clearly noticeable* ***3*** *– Acceptable* ***4*** *– Good – smooth* ***5*** *– Optimal – completely smooth*
Overall rating (R1-R5)	*Calculated mean value of all three rows*	***R1*** *(Poor) <1.0* ***R2*** *(Problematic) 1.0-2.49* ***R3****(Acceptable) 3-3.49* ***R4*** *(Good) 3.5-4.49* ***R5*** *(Optimal)>4.5*

Table 1: Parameters for Feel and Touch.

After the initial tactile evaluation was completed, the catheters were set aside and allowed to dry before a secondary verification test that was conducted by a different operator. The operator used the same procedure, with a 10 second wetting time but 1 minute air drying time, focusing on an overall assessment of smoothness. The results from the second operator were only analyzed within the Feel and Touch method to validate consistency of the first operator's observation. This validation step was performed to strengthen the reliability of the tactile data and confirm that the perceived differences were reproduced.

3.3 Friction

The purpose of the friction test was to evaluate how surface texture and compression influence friction behavior of catheter eyelets. The method simulates dynamic contact occurring between catheter surfaces and soft tissue during clinical use.

3.3.1 Equipment and materials

All friction measurements were performed on the Harland FTS6000 friction tester connected to a computer running the Harland interface software. A custom modified saddle was designed for this study, where a metal pin was horizontally taped to the right side of the fixture (*Figure 6*). Additional equipment included a stopwatch, ruler and graduated cylinder for preparing water for wetting catheters. The samples used for friction testing are presented in Table 4 (section 3.4).

Figure 6: Saddle design

3.3.2 Test procedure

Before the friction test, selected catheters were analyzed under the microscope to document eyelet geometry and identify potential surface irregularities. These pre-measurements were not part of the friction method itself but were performed to provide supporting data for later comparison. The samples analyzed with microscope are listed in Table 5. This step ensured that any observed difference in friction could later be related to variation in eyelet shape or compression. The microscopy data was later compared with the frictional result to assess if there was any correlation between the friction results and the geometry results.

To allow friction testing directly on the eyelets, a new method was developed. Each catheter was cut to a total length of 15 cm and stabilized by inserting a thin metal pin inside the catheter to prevent deformation during the test. The test region of each catheter was divided into three sections, corresponding to the same areas used in the microscopy and tactile method: Upper (row 1), middle (row 2), lower region (row 3).

Before each measurement, the catheter was immersed in tap water for 30 seconds and then allowed to air-dry for 90 seconds. These wetting and drying cycles ensured consistent hydration and were repeated for every test. The catheter was carefully positioned so that the side of the catheter with the first row of eyelets (row 1) was in contact with the metal pin on the modified saddle (see figure 7).

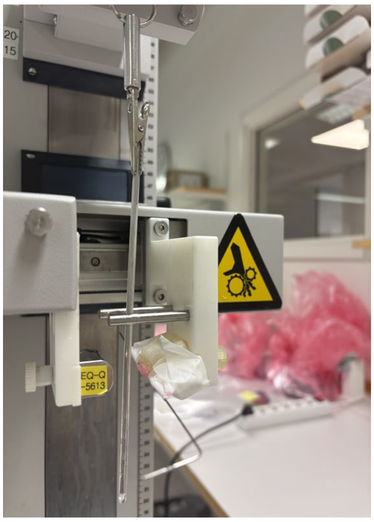

Figure 7: Catheter position

During the test, the pin applied controlled light pressure as the catheter was moved linearly under the pin on the modified saddle. The Harland system was operated through the software interface and each test had a constant speed of 1mm/s with an applied normal force of 200g. The test length was 5 cm, corresponding to the effective contact distance across the eyelets.

During the test, the tangential frictional force (F_t) and the normal force (F_n) were continuously recorded. The dynamic coefficient of friction (μ) was calculated automatically by the equipment software:

$$\mu = \frac{F_t}{F_n}$$

Harland calculation:

After completing the measurement for row 1 the catheter was carefully repositioned so that the next row (Row 2 and Row 3) was placed directly forced to the saddle with the metal pin. The same procedure for sample placement was repeated for all three rows.

Data storage:
Each test and each row were saved directly in the Harland Software using a consistent naming format:

CH, Compression, date from the batch, Test row
Example:(CH10, small-compression, 20250605, Test1, Row 1)

Parameters	Value	Description
Speed	*1 mm/s*	*Constant testing speed*
Force	*200 g*	*contact force*
Samples	*10 points/mm*	*500 data points per row*
Cycles	*1*	*One cycle per row*
Stroke length	*5 cm*	*Length of the catheter testing*

Table 2: Parameters for Harland.

The friction force recorded by the Harland system is expressed in grams (g). Since the instrument collects 10 measurement points per millimeter, each data series consists of approximately 500 force values per eyelet row. One gram corresponds to approximately 0.01 N, meaning the measured forces represent very small variations in friction sensitivity. This resolution makes it possible to detect subtle differences between compression levels, catheter sizes and individual eyelets.

3.3.3 Friction calculation

From every test result graph, two parameters were calculated: the slope (K) and the angle (θ). Together, these describe how quickly and strongly the friction force changes as the pin passes over an eyelet. Each friction curve shows small peaks and valleys. The distance between two peaks in the friction curves is approximately 90 sampled points, which fits well with the expected spacing between the eyelets. The width of each valley also agrees qualitatively with the eyelet lengths measured in microscopy. The valley becomes slightly wider than the geometric hole itself, since the pin needs more force to climb out of the eyelet than to move down into it.In the curves, the force starts to drop when the pin enters the eyelet, reaches a minimum while it is inside, and increases again when the pin leaves the eyelet and transitions back onto the coated surface. This interpretation matches the shape of all friction curves in the study (see Figure 8).

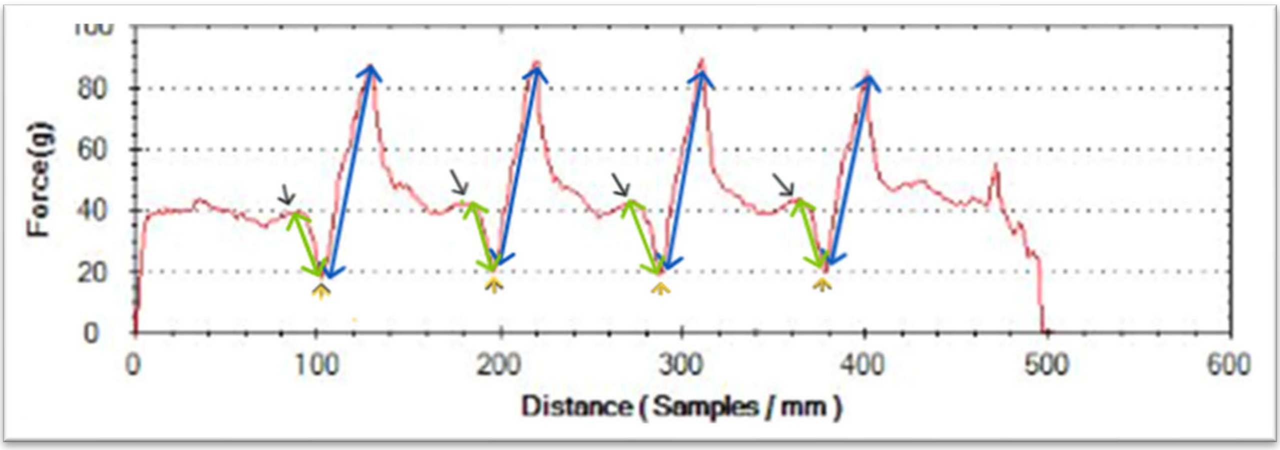

Figure 8: Example of a friction force curve recorded using the Harland FTS6000. The x-axis is shown in samples, but represents the distance along the catheter.

To analyze the curve in a consistent way, three points were defined:

- *The black arrows mark the entry points, located 10 data points before each minimum.*
- *The yellow arrows mark the minimum point.*

- *The green arrows show the segment from the entry point down to the minimum.*
- *The blue arrows show the segment from the minimum up to the following maximum.*

Since the Harland friction tester records ten points per millimeter, each point corresponds to 0.1 mm. By consistently using ten points before the minimum, all calculations start from the same baseline.
The slope K was calculated separately:

- *The entry of the hole (10 points before minimum -> minimum)*
- *The exit of the hole (minimum → maximum)*

$K_i = \frac{\Delta Y}{\Delta X}$

- *Y= Friction force (g)*
- *X =Distance (mm/10)*

To make the slope easier to compare visually, the angle θ was calculated:

$$\theta = arctan(K)$$

This converts the slope into degrees and gives a more intuitive view of the entry and exit regions in the friction curve.

Each catheter row contained four eyelets. For every row the mean average and standard deviation (σ) were calculated for both K and θ. The mean average shows the typical friction behavior for the row and SD shows how much variation there was between the four holes. To find out if any eyelets behaved differently from the others in the same row, a simple statistical rule was used. If a value was more than two standard deviations (±2* σ) away from the mean, it was flagged and classified as an outlier. These calculations were used for flagging the outliner:

$$\Delta K_i = |K_i - \bar{K}|$$

$$Flag = \text{'flag' if } |K_i - \bar{K}| > (\pm 2 * \sigma)$$

The same equations were applied for θ.
A flag means that the eyelet's friction behavior is statistically different from the others. The limit corresponds to a 95% confidence interval.

3.4 Samples and method integration

3.4.1 Sample overview

The catheters used in this study were made with two different punching tools from manufacturer A and B. Each manufacturer was tested in both compression and non-compression variants. This sample design was chosen to investigate how forming pressure influences eyelet geometry, how the surface feels during Feel and Touch evaluation and whether these differences affect frictional behavior.

3.4.2 Samples used for microscopy and Feel and Touch

A total of 12 catheters were used for optical microscopy and tactile testing. The samples covered manufacturer A and B samples in small compressed and non-compressed samples.

Type	Compression	Manufacturer	Samples
Type 1	Small-compression	A	3
Type 2	Non-compression	A	3
Type 3	Small-compression	B	3
Type 4	Non-compression	B	3

Table 3: Catheter samples used for microscopy and tactile testing, total twelve samples.

3.4.3 Samples friction and microscopy

The test was performed on catheters with non-compression, small and medium compression. The compression value describes the sample thickness during compression in the punching chamber. Six catheters were tested for each size, the sizes that were included were CH10, CH12, CH14 and CH16. CH stands for Charrière and describes the outer diameter of the catheter tube in millimeters times 3, i.e. CH12 is a catheter with outer diameter of 4,0 mm. The test was carried out on catheters with various compression levels and sizes to evaluate how geometry and compression influenced surface friction on the eyelets. In total, 24 catheters and 288 eyelets were tested.

Size	Compression	Manufacturer	Samples	Microscopy sample
CH10	Small-compression	B	3	2
CH10	Medium-compression	A	3	2
CH12	Small-compression	B	3	2
CH12	Medium-compression	A	3	2
CH14	Small-compression	B	3	1
CH14	Non-compression	B	3	1
CH16	Small-compression	B	3	1
CH16	Non-compression	B	3	1

Table 4: Catheter size, compression, manufacturer and microscopy samples.

3.4.5 Method integration

All methods used the same eyelet numbering system and the same sample identification codes. This made it possible to connect the results between the three methods:

- Microscopy measurements could be compared directly with Feel and Touch.
- Feel and Touch could be linked to changes in friction slope and angle.
- Friction peaks and statistically flagged values could be traced back to specific geometric deviations.

This unified sample structure enabled consistent row by row and eyelet by eyelet comparison across microscopy, tactile perception and frictional behavior. This integrated approach provides a deeper understanding of how catheter eyelet design influences both subjective smoothness and mechanical performance.

3.5 Objective testing of developmental products

In addition to the prototype samples described in sections 3.1-3.3, six samples from the developmental catheter product were included in this study. These samples were added to evaluate whether the objective microscopy and friction methods developed in this project were applicable under developmental product conditions. Since the Feel and Touch method is primarily intended for identifying harsh edges and surface irregularities during prototype evaluation, it was therefore not applied to the developmental samples.

Three microscopy measurements and three friction measurements were performed on the developmental product samples. The same procedure described in section 3.1 (optical microscopy) and 3.3 (friction testing) were followed. Since the Feel and Touch method is primarily intended for identifying harsh edges and surface irregularities during early-stage evaluation, it was not applied to these samples.

4. RESULT

This chapter presents the results from the microscopic measurements, shape proportionality analysis, Feel and Touch results and friction testing. The purpose was to investigate how mechanical compression influences eyelet geometry, shape balance, perceived smoothness, and frictional behavior. All raw data, graphs and detailed calculations are presented in Appendix A–J.

4.1 Microscopic measurements and Feel and Touch analysis

Microscopic measurements and tactile analysis were used to assess how mechanical compression influences eyelet geometry and surface feel. For each compression level, three test series were performed, each containing 12 eyelets. Results are presented for dimensional measurements (X and Y), shape proportionality (Y/X ratio) and Feel and Touch. Full datasets are provided in Appendix A– C.

4.1.1 Dimensional analysis

Microscopic measurements were performed according to the procedure described in section 3.1. The inner dimensions were collected as reference values but were not included in the calculations (Appendix B). The mean and standard deviation (SD) for all outer X and Y values are shown in Table 5 and Table 6.

Compression	***Test***	***Mean X (mm)***	***Mean Y (mm)***	***SD X***	***SD Y***
Small-compression	*Test 1*	2.676	1.125	0.0238	0.042
	Test 2	2.676	1.109	0.0245	0.018
	Test 3	2.663	1.111	0.0275	0.016
Non-compression	*Test 1*	2.696	1.085	0.0094	0.013
	Test 2	2.697	1.081	0.0239	0.027
	Test 3	2.672	1.075	0.0257	0.029

Table 5: Mean and SD of X and Y dimensions for manufacturer A catheters at different compression levels. (Full dataset available in Appendix A).

Based on the SD values in Table 5, both the small-compression and the non-compressed samples showed similar levels of variation in the X and Y dimensions. Some rows in each group had slightly higher or lower SD values, but the differences were small and not consistent across tests. Therefore, no clear or statistically supported difference in geometric variation can be concluded from these data.

Compression	***Test***	***Mean X (mm)***	***Mean Y (mm)***	***SD X***	***SD Y***
Small-compression	*Test 1*	2.352	1.184	0.028	0.043
	Test 2	2.350	1.175	0.033	0.015
	Test 3	2.328	1.183	0.030	0.031
Non-compression	*Test 1*	2.315	1.108	0.026	0.024
	Test 2	2.310	1.110	0.031	0.016
	Test 3	2.315	1.128	0.024	0.013

Table 6: Mean and SD of X and Y dimensions for manufacturer B catheters at different compression levels (Full data available in Appendix A).

The samples showed stable geometry across all tests. Compared to manufacturer A, the X-dimension was slightly smaller while the Y-dimension was slightly larger. The SD values for both forming levels were small and similar in magnitude, and no statistically significant difference in variation (SD X or SD Y) can be concluded from these data. These dimensional results form the basis for the proportionality assessment in the section 4.1.2

4.1.2 Geometric Proportionality Analysis

Table 7 summarizes all eyelets that were classified as disproportionate based on the Y/X- ratio method described in section 3.1.4. Eyelets with an absolute deviation greater than 0.01 from the row mean were flagged. For each eyelet, both the absolute deviation (ΔR) and the percentage deviation (%ΔR) are reported.

Manufacturer	***Compression***	***Test***	***Flagged points***	***ΔR (deviation)***	***%ΔR (deviation)***
A	*Small-compression*	*1*	1.1, 1.2, 3.4	1.1 = 0.036 1.2 = 0.038 3.4 = 0.012	+8.5% -9% +2.8%
		2	-		
		3	2.4,3.4	2.4 = 0.013 3.4 = 0.011	+3.19 % +2.58 %
A	*Non-compression*	*1*	-		
		2	2.2	2.2 = 0.012	+2.72 %
		3	-		
B	*Small-compression*	*1*	1.1,1.4,2.2,2.3,2.4	1.1 = 0.017 1.4 = 0.013 2.2 = 0.035 2.3 = 0.017 2.4 = 0.017	+3.35 % –2.59 % +7.01 % –3.26 % –3.36 %
		2	3.2	3.2 = 0.012	+2.30 %
		3	1.1,1.4,2.4	1.1 = 0.011 1.4 = 0.011 2.4 = 0.012	2.15 % 2.12 % 2.46 %
B	*Non-compression*	*1*	2.1,3.1	2.1 = 0.013 2.4 = 0.017	2.59 % 3.52 %
		2	-		
		3	-		

Table 7: Shape proportionality analysis summarized for manufacturer A and B (Full label data and graphs available in Appendix A).

The small-compression samples showed the highest number of flagged eyelets for both manufacturer A and B, indicating that compression introduces measurable geometric distortion. The most frequently flagged positions were 1.1, 2.2, and 3.4. Eyelet 1.1 being the most consistently disproportionate across both materials. In contrast, the non-compressed samples showed minimal or no flagged eyelets, indicating that the eyelet geometry remains stable and symmetric in the absence of mechanical loading.

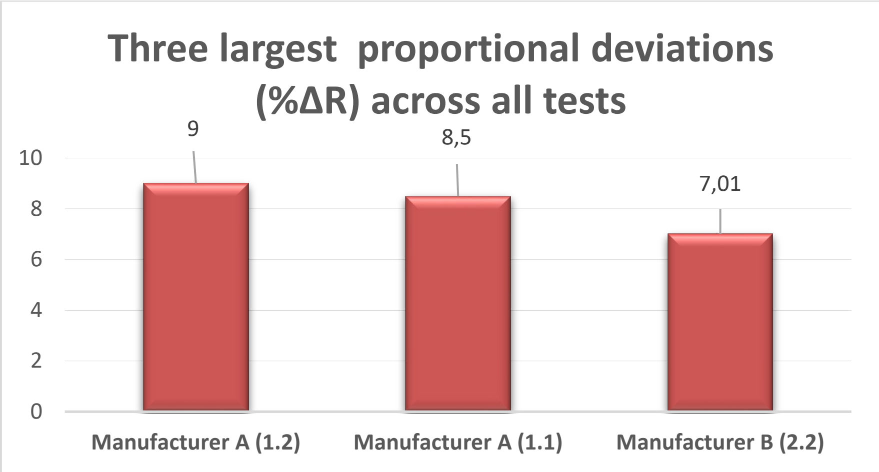

Figure 9: Top three proportional deviations observed across all tests.

The largest deviation was found in the small-compressed samples from Manufacturer A, at eyelet 1.2 (–9.0 %), followed by eyelet 1.1 (+8.5 %). The third-highest deviation occurred in small-compression sample from manufacturer B at eyelet 2.2 (+7.01 %). These results show that the small compression leads to noticeable geometric distortion, with manufacturer A displaying the largest single eyelet deviations and manufacturer B also showing elevated values under the same compression level.

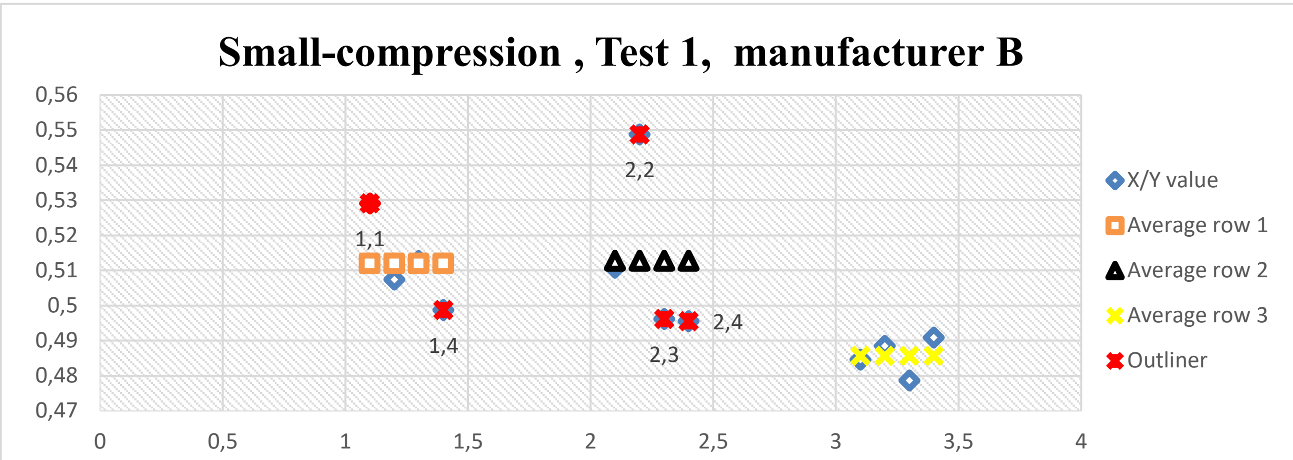

Figure 10: Outlier plot for manufacturer B, Small-compression, Test 1. The x-axis represents the eyelet positions (1.1,1.2,1.3,1.4,2.1, etc).

The small-compression samples from Manufacturer B (Test 1) showed the highest proportional deviation within the manufacturer B dataset and contained the largest number of flagged eyelets. The flagged positions included 1.1 (+3.35 %), 1.4 (–2.59 %), 2.2 (+7.01 %), 2.3 (–3.26 %), and 2.4 (–3.36 %). Although the small-compressed samples from manufacturer A exhibited the largest single-eyelet deviations overall, the Small-compressed sample from manufacturer B (Test 1) was also included among the top three deviations across all tests, with eyelet 2.2 representing the highest deviation within the manufacturer B group. An outlier plot for this test is included because it illustrates both one of the three largest deviations in the full dataset and the broadest spread of geometric distortions observed within a single test.

4.1.3 Feel and touch

The tactile evaluation was performed according to the procedure described in Section 3.2. Each row was assessed independently, and the overall smoothness rating (R1–R5) for each test was calculated as the mean value across all rows. A clear relationship was observed between the geometric proportionality results and the tactile assessments. Eyelet positions that frequently showed deviations from the expected Y/X-ratio particularly 1.1, 1.2, 2.2, and 3.4 were consistently identified by operators as points exhibiting increased tactile resistance, irregularity, or asymmetry. This indicates that relatively small geometric deviations in the eyelet profile are sufficiently pronounced to be detected during manual evaluation, suggesting a direct link between localized geometric distortion and perceived surface roughness.

Compression	***Test***	***OVERALL rating (R1-R5)***	***Tags***	***Comments***
Small-compression	*1*	*R2*	*R, B, H*	*Harsh edges across holes (1.1,2.4,3.4)*
	2	*R2*	*R, B, A*	*Clear roughness and asymmetry (1.1,2.3)*
	3	*R2*	*R, B, H*	*Noticeable harsh edges especially near holes (1.4,2.4,3.4)*
Non-compression	*1*	*R4*	*B*	*Smooth surface with minor irregularities*
	2	*R4*	*B*	*Even texture, slightly bumpy*
	3	*R4*	*B*	*Smooth, barely bumpy*

Table 8: Summary of all tactile evaluation results for manufacturer A (Operator 2 verification data available in Appendix C).

For manufacturer A, all small-compression samples received an overall tactile rating of R2. The comments consistently pointed to harsh or irregular edges at positions 1.1, 1.2, 2.4, and 3.4. These positions correspond directly to the largest proportional deviations identified in the geometric analysis. In Test 1, eyelet 1.1 and 1.2 showed the highest deviations within manufacturer A (+8.5 % and –9.0 %,, and both were noted by operators as rough or asymmetric. In Test 3, additional deviations at 2.4 (+3.19 %) and 3.4 (+2.58 %) aligned with comments describing noticeable harshness around these same positions. This strong correspondence between high %ΔR values and low tactile ratings. The non-compressed manufacturer A samples received uniform R4 ratings and showed no significant geometric deviations, confirming that the eyelet profile remains smooth and largely free of irregularity when not subjected to mechanical loading.

Compression	***Test***	***Overall rating(R1-R5)***	***Tags***	***Comments***
Small-compression	*1*	*R2*	*B, H, A*	*Harsh edges and rough feel across holes (1.1,2.2)*
	2	*R2*	*B, R, H*	*Roughness and harsh edges (2.4)*
	3	*R2*	*R, H*	*Harsh edges and asymmetry (1.4,2.4)*
Non - compression	*1*	*R4*	*B*	*Smooth minor bumps around row 2 (2.4 B)*
	2	*R4*	*B*	*Smooth, slightly bumpy texture*
	3	R5	B	Slightly bumpy

Table 9: Summary of tactile evaluation results for manufacturer B (Operator 2 verification data in Appendix C).

Manufacturer B showed a similar pattern. The small-compression samples were rated R2, with tactile comments concentrated around eyelets 1.1, 1.4, 2.2 and 2.4. These positions correspond to the highest geometric deviations detected in the proportionality analysis. In Test 1, eyelet 2.2 showed the largest deviation within manufacturer B dataset (+7.01 %), accompanied by additional deviations at 1.1 (+3.35 %), 1.4 (–2.59 %), 2.3 (–3.26 %) and 2.4 (–3.36 %). Operators noted harsh edges, roughness or asymmetry at these same positions, indicating a strong correlation between elevated %ΔR values and perceived tactile irregularity. In Test 3, deviations at 1.1 (2.15 %), 1.4 (2.12 %) and 2.4 (2.46 %) were likewise reflected in tactile reports of harshness and asymmetry. In contrast, the non-compressed manufacturer B samples received higher smoothness ratings (R4–R5), with only minor bumps noted around row 2 in Test 1. These results confirm that small-compression introduces detectable geometric distortion in manufacturer B samples, but the magnitude of these deviations is generally lower than for manufacturer A, resulting in milder tactile responses.

4.2 FRICTION

The calculated friction results are presented for catheter sizes CH10, CH12, CH14 and CH16 (see Table 4 for detailed information). These tables summarize all measurements, while detailed row-level curves and flagged points are provided in Appendix E-H. A few of the catheters used in the friction tests were also measured under the microscope, but the geometric data could not be correlated to the friction behavior. The measurements were therefore only used as raw supporting data (Appendix D).

4.2.1 Results for CH10

Table 10 presents the friction results for CH10, showing the mean and standard deviation for K and θ for each test. The table includes both entry and exit zones and compares small and medium compression.

Zone	*Test*	*K mean (mm/10)*	*K SD (mm/10)*	*θ mean (°)*	*θ SD (°)*	*Flags*
Entry - medium compression	***Test 1***	-1.978	0.442	62.126	6.879	
	Test 2	-2.00	0.455	62.582	5.325	Row 3: K - 3.1,3.3,3.4
	Test 3	-2.074	0.633	62.490	8.345	
Exit- medium compression	***Test 1***	3.352	0.209	73.331	1.017	
	Test 2	3.493	0.289	73.927	1.274	
	Test 3	2.242	0.255	72.764	1.305	Row 2: θ -- 2.2,2.4
Entry -small compression	***Test 1***	-2.519	0.554	67.648	4.059	
	Test 2	-2.433	0.6514	66.291	6.750	Row 3: K -all
	Test 3	-2.508	0.237	68.112	1.966	Row 2: Ø -' 2.3,2.4
Exit- small compression	***Test 1***	3.842	0.229	75.363	0.838	
	Test 2	3.859	0.207	74.950	1.791	
	Test 3	3.893	0.191	75.562	0.725	Row 2: θ -2.4

Table 10: Values represent mean average and SD for K and θ per test for CH10. Full row data and flags are presented in Appendix E.

Table 10 shows that CH10 exhibited the highest friction variation in the entry zone. Under medium-compression, only localized deviations were observed, including K-deviations in Row 3 (Test 2) and θ-deviations in Row 2 (Test 3). Under small-compression, variation increased, with a complete K-flag in Row 3 (Test 2) and additional θ deviations in Row 2 (Test 3). In contrast, the exit zone remained stable across both compression levels, with consistently low SD values and only isolated θ-peaks.

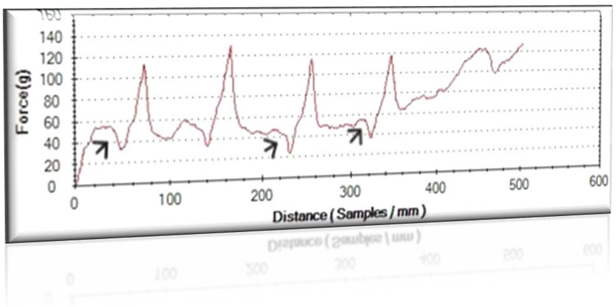

Figure 11: CH10, Test 2 – Row 3, medium- compression. Eyelets 3.1, 3.3 and 3.4 were flagged for K, the markers show where the deviations occur along the entry zone.

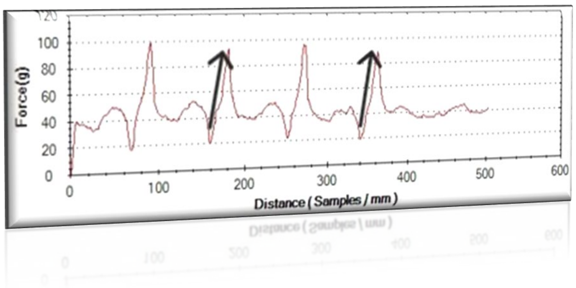

Figure 12: CH10, Test 3 – Row 2, medium-compression. Eyelets 2.2 and 2.4 were flagged for θ, indicated by increased angular deviation at the marked positions.

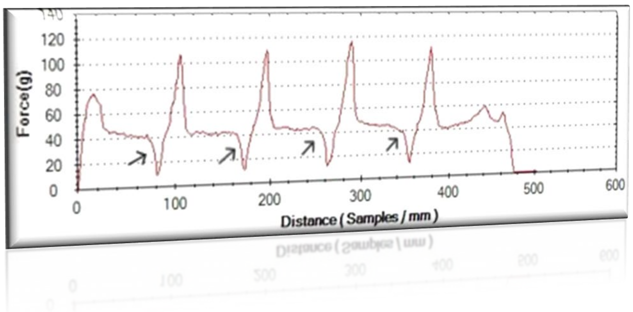

Figure 13: CH10 Test 2 – Row 2, small- compression All four eyelets were flagged for K in the entry-zone. The curve shows broadened peaks and increased variations

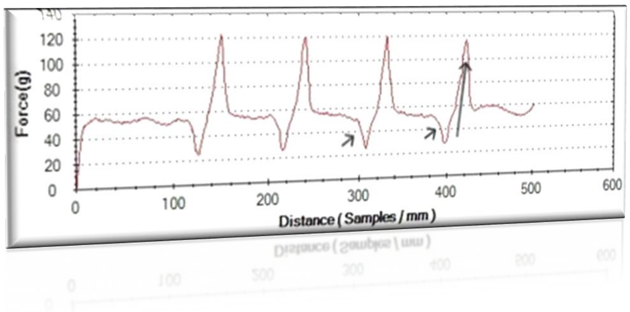

Figure 14: CH10, Test 3 – Row 2, small-compression. Row 2 showed deviations in both entry and exit. Entry-zone θ deviation occurred at 2.3 and 2.4, and the exit zone also showed a θ-deviation at 2.4

4.2.2 Results for CH12

Table 11 summarizes the friction values for CH12, including the mean and standard deviation values for K and θ across all tests. Results are shown separately for entry and exit zones and for both compression levels.

Zone	*Test*	*K mean (mm/10)*	*K SD (mm/10)*	*θ mean (°)*	*θ SD (°)*	*Flags*
Entry - medium compression	***Test 1***	-1.607	0.722	62.473	3.641	
	Test 2	-2.239	0.227	65.752	2.395	Row 3: K – 3.3,3.4
	Test 3	-2.372	0.262	66.967	2.065	Row 2: θ – 2.1,2.2
Exit-medium compression	***Test 1***	2.749	0.098	69.992	0.652	
	Test 2	3.003	0.539	71.245	2.287	
	Test 3	2.701	0.148	69.637	1.055	Row2: θ – 2.1
Entry -small compression	***Test 1***	-2.085	0.337	63.965	3.423	
	Test 2	-2.477	0.143	67.962	1.122	Row 3: K- 3.3,3.4
	Test 3	-2.505	0.200	68.137	1.609	
Exit- small compression	***Test 1***	3.160	0.607	71.873	3.598	
	Test 2	3.418	0.230	73.635	1.028	
	Test 3	3.547	0.298	74.164	1.260	Row 2: θ – 2.2,2.4

Table 11: Values represent mean average and SD for K and θ per test for CH12. Full row data and flags are presented in Appendix F.

Table 11 indicates that CH12 had the largest entry-zone variation in medium-compression Test 1, reflected in the high SD. Tests 2 and 3 were more consistent but still contained flagged values. For small-compression, the entry K values remained stable but showed repeated flagged points. The exit zone remained stable across all tests, with relatively low SD values and only minor deviations. Exit K increased slightly under small-compression but remained consistent across tests. Overall, CH12 showed entry-zone sensitivity, while the exit-zone region displayed consistently stable friction behavior.

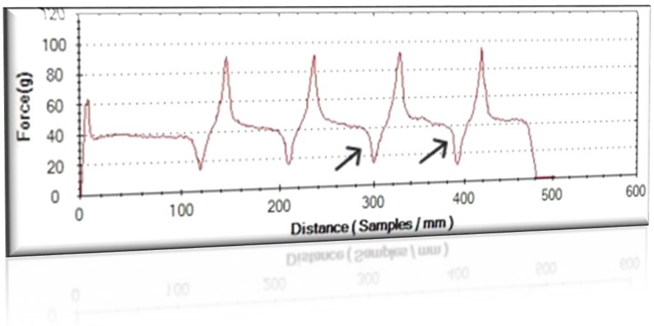

Figure 15: CH12, Test 2 – Row 3, medium-compression. Eyelets 3.3 and 3.4 were flagged for K due to elevated deviation from the row mean. The arrows show increased variation at the corresponding peak positions in the friction curve.

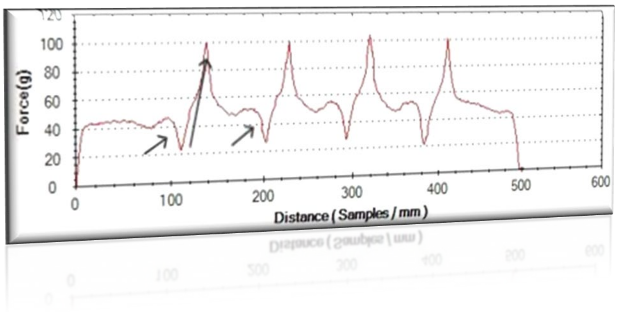

Figure 16: CH12, Test 3 – Row 2, medium-compression. Row 2 displayed deviations in both entry and exit zones. Entry-zone θ-deviations occurred at 2.1 and 2.2. The exit-zone showed a θ-deviation at 2.1. The markers indicate where the angular peaks deviate from the row mean.

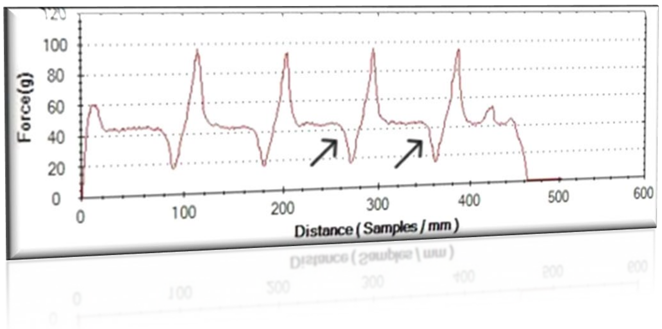

Figure 17: CH 12, Test 2 – Row 3, small-compression. Eyelets 3.3 and 3.4 were flagged for θ in the entry zone, showing localized angular deviations. The marked points indicate where these increases occurred in the curve.

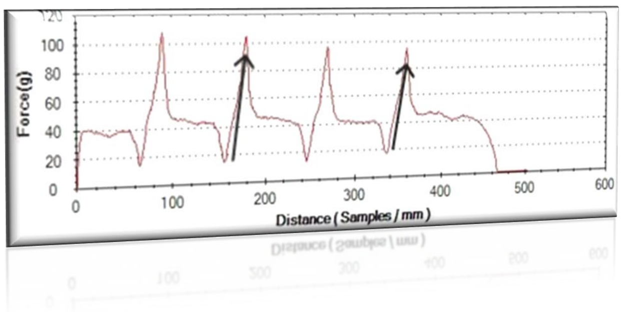

Figure 18: CH12, Test 3 – Row 2, small-compression. Eyelets 2.2 and 2.4 were flagged for θ in the exit zone. These deviations are highlighted with arrows where the curve departs from the row mean

.

4.2.3 Results for CH14

Table 12 shows the friction performance of CH14, including the mean K and θ values and their variation for each test. Both entry and exit zones are reported for non-compression and small-compression.

Zone	*Test*	*K mean (mm/10)*	*K SD (mm/10)*	*θ mean (°)*	*θ SD (°)*	*Flags*
Entry non-compression	***Test 1***	-1.780	0.667	58.136	10.227	
	Test 2	-2.229	0.523	64.947	5.041	Row 3: K – All eyelets
	Test 3	-2.149	0.563	63.995	5.395	Row 2: θ - 2.1,2.2,2.3
Exit non-compression	***Test 1***	2.792	0.280	70.136	1.934	
	Test 2	3.043	0.249	71.720	1.348	
	Test 3	3.048	0.318	71.680	1.838	Row 2: θ- 2.4
Entry -small compression	***Test 1***	-2.244	0.268	65.745	2.608	
	Test 2	-2.373	0.226	66.995	2.039	Row 3: K – All eyelets
	Test 3	-2.336	0.255	66.632	2.269	Row 2: θ- 2.1.2.4
Exit- small compression	***Test 1***	3.532	0.301	74.098	1.322	
	Test 2	3.645	0.401	74.516	1.534	
	Test 3	3.483	0.346	73.856	1.479	Row 2: θ - 2.1,2.3,2.4

Table 12: Values represent mean average and SD for K and θ per test for CH14. Full row data and flags are presented in Appendix G.

CH14 displayed the highest entry-zone variation among all catheter sizes. Under non-compression, both K and θ showed large variation with multiple flagged points, and Test 1 had an unusually high θ SD. Entry-zone values at small-compression were more consistent but still included repeated flagged points. The exit zone was substantially more stable across tests and compression levels, with narrow K and θ variation. CH14 therefore exhibited clear instability in the entry-zone, while exit-zone friction remained stable.

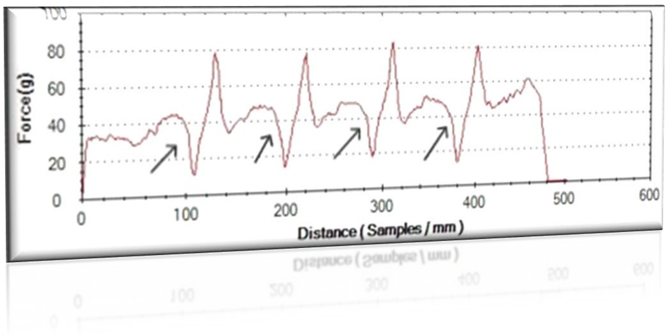

Figure 19: CH14, Test 2 – Row 3, Non- compression. Row 3 showed K-deviations across all four eyelets in the entry zone, representing the largest variation for CH14 under non-compression. The markers highlight the broadened force peaks responsible for the K-flags.

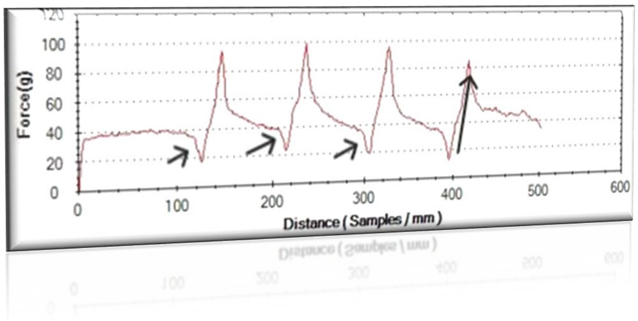

Figure 20: CH14, Test 3 – Row 2, Non-compression. Row 2 displays deviations in both friction zones. Entry zone θ-deviations occurred at eyelets 2.1, 2.2 and 2.3, while the exit zone showed an additional θ-deviation at 2.4. The highlighted points indicate where the angular spikes deviate from the row mean.

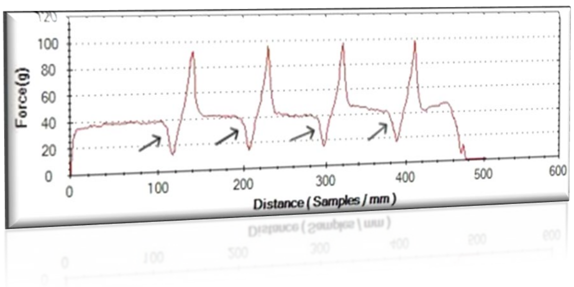

Figure 21: CH14, Test 2 – Row 3, small-compression. All eyelets in Row 3 were flagged for K, showing repeated K-variation similar to the non-compression test. The figure shows widened force peaks across the entry region.

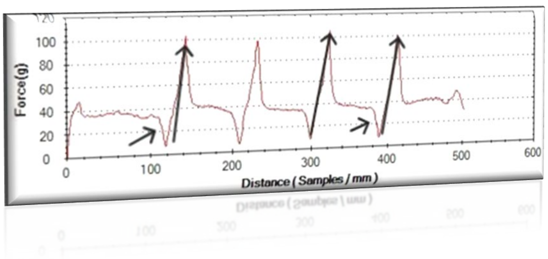

Figure 22; CH14, Test 3 – Row 2, small-compression. Row 2 showed extensive deviations in both entry and exit zones. Entry zone θ deviations occurred at 2.1 and 2.4, and the exit zone θ – deviations appeared at 2.1, 2.3 and 2.4. The arrows mark the multiple angular peaks where the friction curve depart from the row-level uniformity.

4.2.4 Results for CH16

Table 13 presents the friction measurements for CH16, reporting the mean and variation of K and θ for each test. Results are divided into entry and exit zones for non-compression and small-compression.

Zone	*Test*	*K mean (mm/10)*	*K SD (mm/10)*	*θ mean (°)*	*θ SD (°)*	*Flags*
Entry non-compression	***Test 1***	-2.189	0.335	65.027	3.7383	
	Test 2	-2.029	0.234	63.548	2.554	Row 3: K – 3.3,3.4
	Test 3	-2.368	0.285	66.86	2.583	
Exit non-compression	***Test 1***	2.955	0.261	71.196	1.533	
	Test 2	2.956	0.273	71.196	1.500	Row 3: K-3.2
	Test 3	3.047	0.212	71.761	1.220	Row 2: θ-2.4
Entry – small compression	***Test 1***	-1.958	0.435	61.790	7.674	Row 1: K – 1.1
	Test 2	-2.000	0.462	62.060	8.996	Row 3: K – 3.3
	Test 3	-1.960	0.378	62.288	4.982	Row 2: θ - 2.1,2.2
Exit - small compression	***Test 1***	2.925	0.530	70.621	3.460	
	Test 2	2.991	0.149	71.222	1.79	Row 3: K – 3.1,3.2
	Test 3	2.918	0.192	75.562	1.153	Row 2: θ-2.2,2.4

Table 13: Values represent mean average and SD for K and θ per test for CH16. Full row data and flags are presented in Appendix H.

Table 13 shows that CH16 exhibited the most stable overall friction behavior. Under non-compression, the entry-zone variation was moderate, with only a few flagged values. At small-compression, the entry-zone SD increased slightly but remained within a controlled range. The exit-zone also showed low and consistent variation, with a similar number of flagged points as the entry zone across the tests. Overall, CH16 presented the most uniform exit-zone friction and moderate but controlled variation in the entry zone.

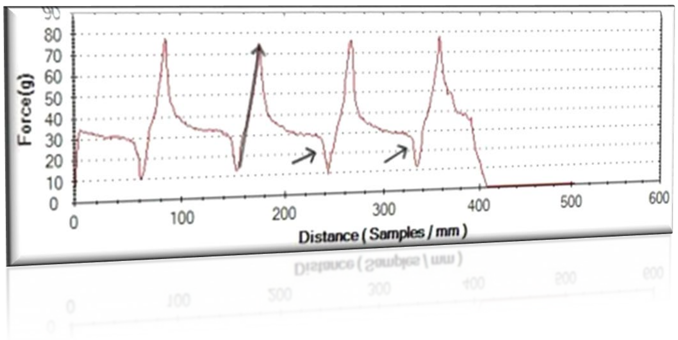

Figure 23: CH16, Test 2 – Row 3, Non-compression. All flagged points in Row 3 are shown for this test. Eyelets 3.3 and 3.4 were flagged for K in the entry zone, while eyelet 3.2 was flagged for K in the exit zone. The markers indicate where the slope deviations occur in both zones.

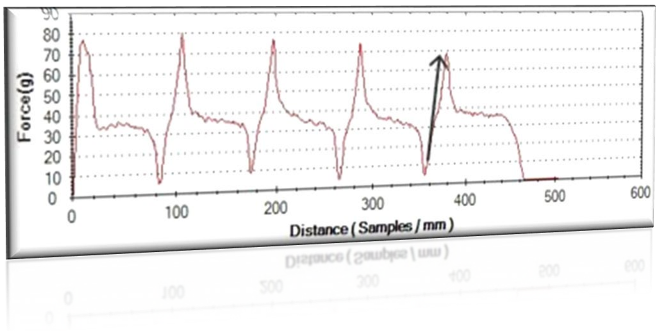

Figure 24: CH16, Test 3 – Row 2, Non-compression. Eyelet 2.4 was flagged for a θ-deviation in the exit zone. The markers indicate the angular spike relative to the row mean

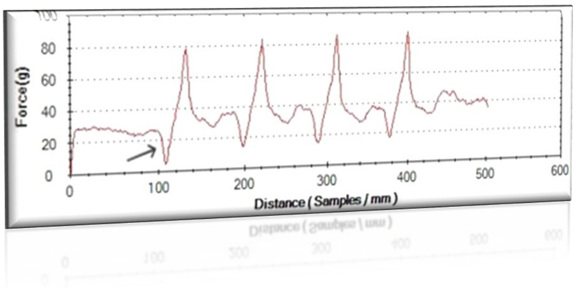

Figure 25: CH16, Test 1 – Row 1, small-compression. Eyelet 1.1 was flagged for a K-deviation in the entry zone. The marked point shows the increased entry- slope peak.

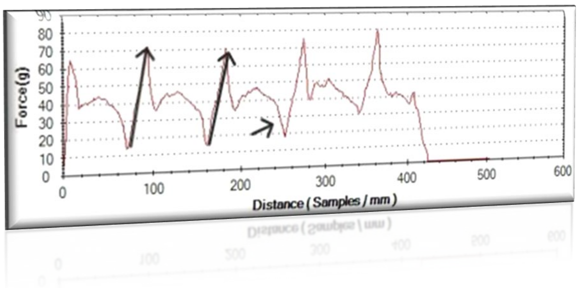

Figure 26: CH16, Test 2 – Row 3, small-compression. Row 3 displayed deviations in both friction zones. Eyelet 3.3 was flagged for K in the entry zone, while eyelets 3.1 and 3.2 were flagged for K in the exit zone. The arrows indicate the widened peaks along the curve.

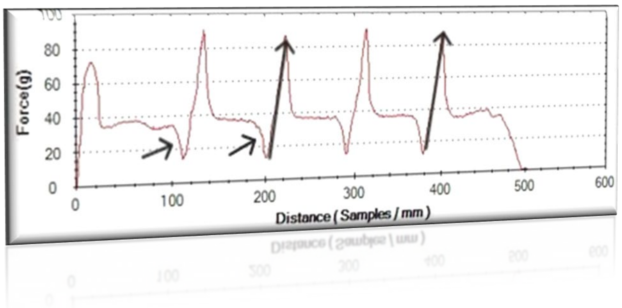

Figure 27: CH16, Test 3 – Row 2, small-compression. *Row 2 showed θ-deviation in both zones. Entry- zone deviations occurred at 2.1 and 2.2, while the exit zone deviations occurred at 2.2 and 2.4. The markers show where the angle spikes deviate from the row mean.*

4.3 Results for the developmental product.

In addition to the samples earlier, six samples from the developmental product version were analyzed. These samples were tested using optical microscopy and friction testing of the finished design. The results below summarize these measurements and are later compared to the earlier tested samples presented earlier.

4.3.1 Optical microscopy

Microscopy	***Test***	***Mean X(mm)***	***Mean Y(mm)***	***SD X***	***SD Y***	***Flagged eyelets (Y/X)***	*ΔR(deviation)*	*%ΔR* ***(deviation)***
Test 1	*Row 1*	2.317	1.123	0.035	0.032	1.4	+0.0112	+2.30%
	Row 2	2.337	1.129	0.028	0.029	2.1	-0,111	-18.7%
	Row 3	2.310	1.115	0.017	0.017			
Test 2	*Row 1*	2.319	1.1186	0.020	0.157	1.3	+0.0107	+2.20%
	Row 2	2.308	1.119	0.030	0.0143			
	Row 3	2.335	1.1155	0.0368	0.0305			
Test 3	*Row 1*	2.305	1.102	0.0328	0.0137			
	Row 2	2.327	1.323	0.0321	0.3362	2.1,2.2,2.3,2.4	2.1 = +0.258 2.2 = +0.093 2.3 = +0.082 2.4 = +0.082	+45.36% +16.4% +14.56% +14.40%
	Row 3	2.320	1.116	0.0319	0.0145			

Table 14: Values represent mean average and standard deviation for X and Y per row for all three microscopy tests of the developmental product. Flagged eyelets (Y/X) are included in the table. Full raw data and complete ratio calculations are presented in Appendix I.

The microscopy results for the developmental product showed that the X-dimensions remained stable across all three tests, varying only by about ±0.02–0.03 mm between rows. The Y-dimensions displayed similarly small variations in most rows, typically within ±0.01–0.02 mm. Test 1 and Test 2 showed low standard deviations, and only a few isolated eyelets were flagged in the Y/X-ratio analysis. In Test 3, Row 1 and Row 3 followed the same pattern, with Y-values around 1.10–1.12 mm and low SD. Row 2 in Test 3, however, behaved differently. While its X-dimension remained comparable to the other rows, its Y-dimension increased to 1.323 mm with a markedly higher SD (0.3362). All four eyelets were flagged with proportional deviations of +14–16 %, and one clear outlier reached +45 %. To illustrate the outliers, figure 28 presents the plot visually highlights how eyelet 2.1 deviated far above the row average.

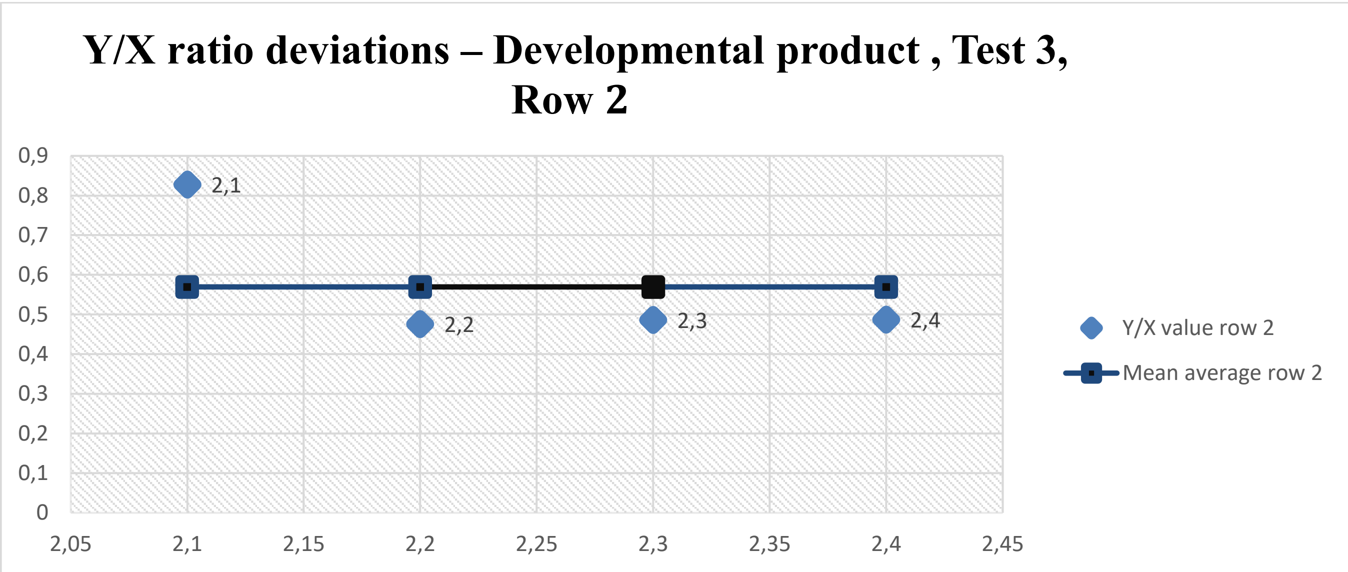

Figure 28 Y/X-ratio deviations for developmental product, Test 3 Row 2. The figure highlights that eyelet 2.1 deviated clearly from the row and that all four eyelets in this row were flagged. This test showed the largest geometric imbalance among all developmental samples.

4.3.2 Friction

Friction testing of the developmental product followed the same methodology described in Section 3.3.3. Across all three tests, frictional behavior remained highly stable.

Test	***Zone***	***Row***	***Mean K-value (10 /mm)***	***SD K (10/mm)***	***θ MEAN (°)***	***θ SD (°)***	***Flag***
1	*Entry*	*Row 1*	–2.09	0.08	64.44	0.79	*OK*
		Row 2	–1.89	0.09	62.09	1.06	*OK*
		Row 3	–2.44	0.16	67.66	1.30	*OK*
	Exit	*Row 1*	3.08	0.22	71.94	1.16	*OK*
		Row 2	2.79	0.04	70.30	0.27	*OK*
		Row 3	2.93	0.22	71.12	1.27	*OK*
2	*Entry*	*Row 1*	–1.97	0.12	63.00	1.50	*OK*
		Row 2	–2.17	0.03	65.23	0.25	*OK*
		Row 3	–2.66	0.06	69.36	0.41	*OK*
	Exit	*Row 1*	2.88	0.17	70.82	1.11	*OK*
		Row 2	2.80	0.25	70.28	1.68	*OK*
		Row 3	2.92	0.08	71.06	0.45	*OK*
3	*Entry*	*Row 1*	–2.33	0.17	66.70	1.50	*OK*
		Row 2	-1.72	0.25	59.39	3.76	*OK*
		Row 3	–2.51	0.20	68.19	1.64	*OK*
	Exit	*Row 1*	3.11	0.05	72.15	0.28	*OK*
		Row 2	2.80	0.30	70.21	2.08	*OK*
		Row 3	2.59	0.16	68.80	1.20	*OK*

Table 15: Values represent mean K-values, standard deviations and mean θ per row for test 1-3 for entry and exit zone. Full raw data for all eyelets is presented in Appendix J.

Across all three friction tests, the developmental product showed highly consistent frictional performance. In the entry zone, the mean K-values had a range from -1.72 to -2.66, while angle values had a range between 59.39° and 69.36°. In almost all rows, standard deviations were low, except for Test 3, Row 2, showing somewhat higher variation of θ. Similarly, the exit zone exhibited consistent behavior with K-values ranging from 2.59 to 3.11, and angle values ranging from 68.80° to 72.15°. All standard deviations stayed low and more importantly, no eyelet was flagged in any test. That means that the developmental product exhibits consistent frictional performance with no statistically abnormal behavior between rows and tests.

5. DISCUSSION

5.1 Microscopic measurements and tactile evaluation

The combined results from the microscopic measurements, the proportionality analysis and the Feel and Touch method provide a coherent understanding of how mechanical compression affects eyelet geometry and how these changes are perceived during handling. The small-compression produced the largest geometric variations for both manufacturers A and B, most distinctly in the Y-dimension, which is the direction most influenced by the forming. This was most obvious in the samples from manufacturer A, where the Small-level rows reached Y-values around 1.11–1.12 mm and showed higher SDs, while the non-formed samples stayed close to about 1.08 mm. Manufacturer B showed the same overall trend, just with slightly less variation.

The proportionality analysis made this even clearer. The small-compressed rows for both materials generated the highest number of flagged positions, where the non-compressed rows showed only occasional isolated deviations. The same eyelet positions (1.1, 1.2, 2.2 and 3.4) kept showing up outside the proportional interval, which suggests that these locations are more sensitive to deformation, even when the forming level is not that extreme.

There was also a strong match between the geometry and what operators felt. A direct correspondence between geometric deviations and tactile impressions was identified. The positions flagged in the proportionality analysis were the same positions operators most frequently described as harsh, rough or asymmetric. All small-compressed manufacturer A samples received an overall R2 rating with comments referring to roughness or harsh edges. Manufacturer B showed an equivalent response, compressed rows were consistently rated R2 and tactile descriptions highlighted the same positions that deviated geometrically. This consistent overlap demonstrates that even relatively small local distortions in the eyelet contour remain perceptible by touch. Some exceptions were found where the tactile ratings did not align with the geometric measurements. Several non-compressed rows were assigned lower ratings (R4) with comments describing mild bumpiness, although their Y/X-ratios were fully within the normal range.

This is expected, because the microscopic method captures only the edge contour, while the Feel and Touch take the whole coated surface. Even small coating imperfections, slight differences in surface texture or tiny variations in how the operator handles the catheter can create tactile impressions that don’t show up in the geometric data. Another practical limitation is that it’s hard to place the measurement points in the same spot on every sample. Things like edge clarity, lighting and coating blur can all shift the placement a little, even when the procedure is controlled. These small differences in measurement placement can affect the results, even though the eyelet geometry itself has not changed.

Overall, the results show a strong relationship between geometric balance and Feel and Touch. Compression introduces quantifiable shape deviations, the proportionality analysis identifies them and the operators detect them at the same locations. At the same time, the Feel and Touch method captures surface level irregularities outside the scope of microscopy, explaining the few cases where the two methods did not fully align. Together, the methods provide a comprehensive understanding of how eyelet geometry, surface character and perceived smoothness interact.

5.2 Friction

The friction measurements give another way of understanding how the eyelet design behaves when the catheter moves through the test fixture. One thing that stood out across all catheter sizes was that most of the variation happened in the entry part of the curve, while the exit part was much more stable. This difference can be understood by looking at how the pin moves inside the eyelet. When it enters, it moves downward toward the geometric minimum of the hole, which causes the force to drop. During this downward movement, even small changes in geometry or surface texture can interrupt the force, which makes the entry region extra sensitive to any irregularities. The exit behaves differently, where the pin must climb upward out of the minimum and toward a local maximum. This uphill movement naturally requires more force, creating a higher and steadier baseline. Because the force level is already elevated and dominated by this upward motion, small disturbances in geometry or coating have far less influence.

Catheter size also played an important role. Even though the eyelet geometry is identical across CH sizes, the smaller diameters such as CH10 and CH12 produced noticeably more variation in their entry K-values. For example, CH10 compressed at the small-compression showed an entry K of roughly -2.5 ± 0.55, while the much larger CH16 remained closer to -2.0 with far smaller differences between rows. All this suggests that smaller diameter tubes amplify the effect of local shape variations. A small irregularity that barely affects a larger catheter can have a much bigger impact when the shaft is thinner and more flexible. In the same way, the small-compression samples also had a consistent effect throughout the dataset. It gave rise to the most unstable friction curves, with more frequent and more noticeable deviations in the entry region. Medium-compression and the non-compression samples still had some variation but clearly were more controlled. Manufacture B generally showed smaller spreads and fewer outliers than manufacturer A, which aligns with geometric and proportionality analyses.

The eyelets from manufacturer B tended to stay more balanced in shape and therefore created less variation in friction. This supports the idea that small geometric differences translate directly into mechanical differences when the catheter interacts with the fixture. The exit region continued to behave in a stable and predictable way across all CH sizes and compression conditions. The exit angle θ consistently clustered between 75–80°, with only occasional flagged deviations. This suggests that the exit zone is governed mostly by coating behavior and the natural upward slope of the eyelet rather than by minor geometric changes. Coating features, like texture, dryness or slight surface variations may influence the shape of the curve, but they did not generate the type of large disturbances seen in the entry region.

5.2.1 Sources of error in the friction measurements

Even though the main patterns were clear, several practical factors affected individual measurements. One possible source of error is the order of testing. Row 1 was always measured first, meaning that Rows 2 and 3 may have had slightly longer drying times before testing. This effect cannot be confirmed in the results, but it remains a plausible procedural source of variation.

A second source of error was misalignment in the fixture. If the catheter was not perfectly centered, even a small deviation could cause the pin to miss part of the eyelet or fail to properly capture the geometric minimum. This could lead to irregular or missing values, as seen in CH10 Test 3, Row 3, where the final eyelet was not recorded at all (see Appendix E).

Another limitation lies in the test setup, which measures friction only in one direction. As a result, the system records entry and exit behavior from a single perspective. If the fixture allowed the catheter to be run in the opposite direction, the entry region would instead be observed as the exit region, this would reveal whether a disturbance in the entry region is inherent to the eyelet or dependent on the direction of travel. An eyelet that shows a disturbance in the entry region but appears completely normal when reversed would paint a very different picture of its condition. The current setup provides reliable information, but only for one side of the eyelet.

The system picked up some unexpected artifacts, such as the “double values” observed once in CH12 at small-compression (Test 1), where the X-axis registered the same Y-value twice. Although this happened only once and cannot be interpreted as a systematic error, it shows how sensitive the setup is to even small fluctuations.

Despite these limitations, the overall trends in the friction data were clear. The smaller CH sizes consistently showed more variation, the small-compression produced the most unstable and irregular friction behavior and the exit region remained far less affected by disturbances than the entry zone. Taken together, these patterns show that both the eyelet geometry and the condition of the coating strongly influence the mechanical response. The same types of differences that appeared in microscopic measurements and the proportionality analysis were also reflected in the friction curves, showing a clear relationship between geometric imbalance, surface characteristics and frictional behavior.

5.3 Evaluation of the developmental product

In both the microscopy and friction measurements, the developmental product showed stable and well controlled behavior. The X and Y dimensions remained tight across nearly all tests, with only small variations between rows. The only notable exception was Row 2 in Test 3, which showed a wider spread and several flagged proportional deviations. Eyelet 2.1 deviated more than the others and stood out clearly from the row average. Since the remaining rows in the same test did not show similar behavior, this deviation appears to be an isolated irregularity rather than part of a systematic pattern.

The friction result supported this overall picture, all rows produced smooth and uniform curves with low variation in both exit and entry zones with no flagged points were observed in any test. This indicates that the developmental product behaves predictably when moving through the fixture and does not exhibit the unstable entry-zone behavior that appeared in some of the compressed developmental samples.

Compared to the prototype, the developmental product stays well within the variation levels. During the prototype phase, the small-compression samples created wider spreads and more irregular friction responses, especially in the smaller catheter sizes. Such consistent behavior from the developmental product suggests that it can serve as a practical reference when defining preliminary tolerance limits. The Y/X ratios and friction curves represent the upper boundary of variation where predictable performance is still maintained. Future samples can therefore be evaluated against these ranges and provided both geometry and friction stay within this window, the samples are expected to perform reliably in use.

6. CONCLUSION

This study shows that the smoothness of catheter eyelets can be assessed in a meaningful way using microscopic measurements, friction testing and a manual tactile method. The clearest result was the strong link between what the microscope measured and what operators felt. Eyelets with larger geometric deviations were consistently described as rougher, while those with stable dimensions were experienced as smoother. This confirms that the manual method is closely connected to measurable differences in the eyelet.

At the same time, the manual evaluation captured details that microscopy cannot detect, such as coating behavior and local surface variations. These aspects influence how smooth the eyelet feels in practice and are an important complement to purely geometric data. The friction testing provided clear and representative mechanical information, especially about how the catheter behaves during movement.

However, the method was also sensitive to several practical factors, such as drying time, alignment in the fixture and its one-direction setup. Because of this, it is difficult to determine exactly which parts of the friction curve reflect true smoothness and which parts are influenced by the test conditions themselves. Friction testing therefore works best as an additional method rather than a direct comparison to the manual evaluation.

The developmental product performed strongly in both microscopy and friction testing. The dimensions were stable, and the friction curves were smooth and consistent. Overall, the study shows that these measurement-based methods can provide valuable and objective information about catheter eyelets. They cannot yet replace the manual method, but they can support it and help reduce subjectivity. With more testing, better control of error sources and further refinement of procedures, microscopy and friction testing have the potential to evolve into reliable tools that complement the current manual inspection and strengthen the quality-control process.

7. FUTURE WORK

The clearest link found in this project was the strong agreement between 2D microscopy measurements and the tactile Feel & Touch results. Friction testing also produced meaningful trends, but the method showed higher sensitivity to fixture alignment, coating hydration and other variables, indicating that it requires further development before it can be used reliably. Future work could therefore compare the same eyelets using both 2D microscopy and high-resolution 3D techniques, such as confocal microscopy or micro-CT, to understand which geometric features matter most for smoothness. Since 3D imaging provides a more complete description of the eyelet surface, it could be used as a reference to define threshold values that 2D microscopy can measure quickly in routine quality control. Combining improved friction testing with 2D and 3D data may help build a more robust and objective method for evaluating catheter eyelets in the future.

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APPENDIX

Appendix A - Raw data and calculations for microscopy

Manufacturer	Comp-ression	Sample	Row	Eyelet	X	Y	Y/X	X average	X std dev	Y average	Y std dev	Y/X average	Y/X std dev	Y/X - Y/X-average	Flag	%ΔR
A	**Small - compression**	**Test 1**	**1**	1.1	2,666	1,223	0,459	2,687	0,0207	1,13575	0,0776	0,4228496	0,0305	0,036	1	8,5%
				1.2	2,686	1,035	0,385							0,038	1	8,9%
				1.3	2,715	1,132	0,417							0,006	0	1,4%
				1.4	2,679	1,153	0,430							0,008	0	1,8%
			2	2.1	2,652	1,126	0,425	2,679	0,0240	1,1215	0,0103	0,4186223	0,0063	0,006	0	1,4%
				2.2	2,667	1,127	0,423							0,004	0	0,9%
				2.3	2,694	1,106	0,411							0,008	0	1,9%
				2.4	2,704	1,127	0,417							0,002	0	0,4%
			3	3.1	2,619	1,117	0,426	2,663	0,0297	1,11875	0,0289	0,4200964	0,0112	0,006	0	1,5%
				3.2	2,674	1,096	0,410							0,010	1	2,4%
				3.3	2,678	1,102	0,412							0,009	0	2,1%
				3.4	2,682	1,160	0,433							0,012	1	3,0%
A	**Small - compression**	**Test 2**	**1**	1.1	2,664	1,120	0,420	2,691	0,0189	1,12625	0,0065	0,4184952	0,0028	0,002	0	0,5%
				1.2	2,700	1,123	0,416							0,003	0	0,6%
				1.3	2,694	1,135	0,421							0,003	0	0,7%
				1.4	2,707	1,127	0,416							0,002	0	0,5%
			2	2.1	2,662	1,079	0,405	2,685	0,0206	1,1035	0,0224	0,4110595	0,0074	0,006	0	1,4%
				2.2	2,696	1,132	0,420							0,009	0	2,2%
				2.3	2,707	1,095	0,405							0,007	0	1,6%
				2.4	2,673	1,108	0,415							0,003	0	0,8%
			3	3.1	2,624	1,106	0,421	2,652	0,0213	1,09725	0,0142	0,4137371	0,0072	0,008	0	1,9%
				3.2	2,648	1,098	0,415							0,001	0	0,2%
				3.3	2,666	1,077	0,404							0,010	0	2,4%
				3.4	2,671	1,108	0,415							0,001	0	0,3%
A	**Small - compression**	**Test 3**	**1**	1.1	2,615	1,130	0,432	2,646	0,0217	1,1185	0,0172	0,4227121	0,0086	0,009	0	2,2%
				1.2	2,650	1,100	0,415							0,008	0	1,8%
				1.3	2,665	1,108	0,416							0,007	0	1,6%
				1.4	2,655	1,136	0,428							0,005	0	1,2%
			2	2.1	2,660	1,105	0,415	2,685	0,0256	1,09875	0,0212	0,4092946	0,0114	0,006	0	1,5%

				2.2	2,704	1,081	0,400							-0,010	0	-2,3%
				2.3	2,710	1,083	0,400							-0,010	0	-2,4%
				2.4	2,666	1,126	0,422							0,013	1	3,2%
			3	3.1	2,645	1,110	0,420	2,658	0,0290	1,11625	0,0104	0,4200202	0,0080	0,000	0	0,1%
				3.2	2,671	1,116	0,418							-0,002	0	-0,5%
				3.3	2,691	1,108	0,412							-0,008	0	-2,0%
				3.4	2,625	1,131	0,431							0,011	1	2,6%
A	**Non-comp-ression**	**Test 1**	**1**	1.1	2,704	1,08	0,399	2,701	0,0060	1,09225	0,0094	0,4043891	0,0036	0,005	0	1,2%
				1.2	2,704	1,103	0,408							0,004	0	0,9%
				1.3	2,692	1,093	0,406							0,002	0	0,4%
				1.4	2,704	1,093	0,404							0,000	0	0,0%
			2	2.1	2,694	1,06	0,393	2,690	0,0058	1,081	0,0203	0,4019398	0,0079	0,008	0	2,1%
				2.2	2,691	1,106	0,411							0,009	0	2,3%
				2.3	2,681	1,088	0,406							0,004	0	1,0%
				2.4	2,692	1,07	0,397							0,004	0	1,1%
			3	3.1	2,696	1,08	0,401	2,701	0,0132	1,08275	0,0108	0,4009497	0,0042	0,000	0	0,1%
				3.2	2,695	1,097	0,407							0,006	0	1,5%
				3.3	2,691	1,071	0,398							0,003	0	0,7%
				3.4	2,72	1,083	0,398							0,003	0	0,7%
A	**Non-comp-ression**	**Test 2**	**1**	1.1	2,673	1,07	0,400	2,674	0,0116	1,05425	0,0174	0,394344	0,0071	0,006	0	1,5%
				1.2	2,665	1,068	0,401							0,006	0	1,6%
				1.3	2,666	1,035	0,388							0,006	0	1,6%
				1.4	2,69	1,044	0,388							0,006	0	1,6%
			2	2.1	2,75	1,106	0,402	2,724	0,0187	1,09125	0,0264	0,4006235	0,0082	0,002	0	0,4%
				2.2	2,724	1,121	0,412							0,011	1	2,7%
				2.3	2,709	1,07	0,395							0,006	0	1,4%
				2.4	2,712	1,068	0,394							0,007	0	1,7%
			3	3.1	2,695	1,109	0,412	2,692	0,0088	1,098	0,0216	0,4078695	0,0075	0,004	0	0,9%
				3.2	2,696	1,123	0,417							0,009	0	2,1%
				3.3	2,679	1,08	0,403							0,005	0	1,2%
				3.4	2,698	1,08	0,400							0,008	0	1,9%
A	**Non-comp-ression**	**Test 3**	**1**	1.1	2,657	1,079	0,406	2,642	0,0143	1,05475	0,0169	0,3992107	0,0047	0,007	0	1,7%
				1.2	2,65	1,051	0,397							0,003	0	0,7%
				1.3	2,636	1,049	0,398							0,001	0	0,3%
				1.4	2,625	1,04	0,396							0,003	0	0,8%
			2	2.1	2,686	1,07	0,398	2,690	0,0199	1,064	0,0244	0,395471	0,0064	0,003	0	0,7%
				2.2	2,714	1,092	0,402							0,007	0	1,7%
				2.3	2,666	1,033	0,387							0,008	0	2,0%
				2.4	2,695	1,061	0,394							0,002	0	0,5%
			3	3.1	2,695	1,13	0,419	2,685	0,0138	1,105	0,0278	0,4115947	0,0085	0,008	0	1,9%
				3.2	2,696	1,128	0,418							0,007	0	1,7%
				3.3	2,68	1,079	0,403							0,009	0	2,2%

				3.4	2,667	1,083	0,406							0,006	0	1,3%
B	**Small - compression**	**Test 1**	**1**	1.1	2,315	1,225	0,529	2,356	0,0348	1,20575	0,0140	0,5120223	0,0128	0,017	1	3,4%
				1.2	2,353	1,194	0,507							0,005	0	0,9%
				1.3	2,354	1,207	0,513							0,001	0	0,1%
				1.4	2,4	1,197	0,499							0,013	1	2,6%
			2	2.1	2,31	1,18	0,511	2,345	0,0291	1,2025	0,0576	0,5128389	0,0250	0,002	0	0,4%
				2.2	2,347	1,288	0,549							0,036	1	7,0%
				2.3	2,342	1,162	0,496							0,017	1	3,3%
				2.4	2,381	1,18	0,496							0,017	1	3,4%
			3	3.1	2,334	1,131	0,485	2,356	0,0326	1,144	0,0258	0,4856366	0,0053	0,001	0	0,2%
				3.2	2,342	1,144	0,488							0,003	0	0,6%
				3.3	2,342	1,121	0,479							0,007	0	1,4%
				3.4	2,404	1,18	0,491							0,005	0	1,1%
B	**Small - compression**	**Test 2**	**1**	1.1	2,365	1,158	0,490	2,376	0,0235	1,17	0,0136	0,4924949	0,0058	0,003	0	0,6%
				1.2	2,374	1,188	0,500							0,008	0	1,6%
				1.3	2,355	1,161	0,493							0,000	0	0,1%
				1.4	2,409	1,173	0,487							0,006	0	1,1%
			2	2.1	2,325	1,167	0,502	2,350	0,0238	1,1795	0,0161	0,5019043	0,0026	0,000	0	0,0%
				2.2	2,35	1,172	0,499							0,003	0	0,6%
				2.3	2,343	1,176	0,502							0,000	0	0,0%
				2.4	2,382	1,203	0,505							0,003	0	0,6%
			3	3.1	2,308	1,165	0,505	2,324	0,0376	1,17675	0,0200	0,5063336	0,0080	0,002	0	0,3%
				3.2	2,311	1,197	0,518							0,012	1	2,3%
				3.3	2,298	1,155	0,503							0,004	0	0,7%
				3.4	2,38	1,19	0,500							0,006	0	1,3%
B	**Small - compression**	**Test 3**	**1**	1.1	2,311	1,158	0,501	2,322	0,0221	1,18925	0,0347	0,5121016	0,0105	0,011	1	2,2%
				1.2	2,324	1,206	0,519							0,007	0	1,3%
				1.3	2,301	1,163	0,505							0,007	0	1,3%
				1.4	2,352	1,23	0,523							0,011	1	2,1%
			2	2.1	2,317	1,156	0,499	2,338	0,0359	1,18125	0,0362	0,5051721	0,0092	0,006	0	1,2%
				2.2	2,344	1,166	0,497							0,008	0	1,5%
				2.3	2,305	1,168	0,507							0,002	0	0,3%
				2.4	2,386	1,235	0,518							0,012	1	2,5%
			3	3.1	2,296	1,152	0,502	2,325	0,0399	1,1795	0,0343	0,5072388	0,0064	0,005	0	1,1%
				3.2	2,329	1,175	0,505							0,003	0	0,5%
				3.3	2,295	1,162	0,506							0,001	0	0,2%
				3.4	2,38	1,229	0,516							0,009	0	1,8%
B	**Non-comp-ression**	**Test 1**	**1**	1.1	2,308	1,107	0,480	2,344	0,0261	1,12125	0,0191	0,4784556	0,0066	0,001	0	0,3%
				1.2	2,348	1,141	0,486							0,007	0	1,6%
				1.3	2,347	1,103	0,470							0,008	0	1,8%
				1.4	2,371	1,134	0,478							0,000	0	0,0%
			2	2.1	2,287	1,076	0,470	2,298	0,0120	1,11	0,0322	0,4830097	0,0129	0,013	1	2,6%

				2.2	2,315	1,124	0,486							0,003	0	0,5%
				2.3	2,294	1,092	0,476							0,007	0	1,5%
				2.4	2,296	1,148	0,500							0,017	1	3,5%
			3	3.1	2,284	1,075	0,471	2,305	0,0186	1,09175	0,0171	0,4736825	0,0049	0,003	0	0,6%
				3.2	2,329	1,107	0,475							0,002	0	0,3%
				3.3	2,301	1,079	0,469							0,005	0	1,0%
				3.4	2,305	1,106	0,480							0,006	0	1,3%
B	**Non-comp-ression**	**Test 2**	**1**	1.1	2,312	1,113	0,481	2,311	0,0048	1,12575	0,0116	0,4871242	0,0045	0,006	0	1,2%
				1.2	2,313	1,137	0,492							0,004	0	0,9%
				1.3	2,304	1,119	0,486							0,001	0	0,3%
				1.4	2,315	1,134	0,490							0,003	0	0,6%
			2	2.1	2,279	1,092	0,479	2,280	0,0058	1,104	0,0112	0,484153	0,0041	0,005	0	1,0%
				2.2	2,28	1,112	0,488							0,004	0	0,7%
				2.3	2,274	1,097	0,482							0,002	0	0,4%
				2.4	2,288	1,115	0,487							0,003	0	0,7%
			3	3.1	2,278	1,086	0,477	2,338	0,0401	1,1	0,0169	0,4705825	0,0065	0,006	0	1,3%
				3.2	2,363	1,117	0,473							0,002	0	0,5%
				3.3	2,359	1,112	0,471							0,001	0	0,2%
				3.4	2,351	1,085	0,462							0,009	0	1,9%
B	**Non-comp-ression**	**Test 3**	**1**	1.1	2,255	1,116	0,495	2,302	0,0334	1,124	0,0130	0,4884129	0,0053	0,006	0	1,3%
				1.2	2,312	1,115	0,482							0,006	0	1,3%
				1.3	2,305	1,122	0,487							0,002	0	0,3%
				1.4	2,334	1,143	0,490							0,001	0	0,3%
			2	2.1	2,313	1,117	0,483	2,333	0,0155	1,12075	0,0140	0,4804475	0,0058	0,002	0	0,5%
				2.2	2,333	1,103	0,473							0,008	0	1,6%
				2.3	2,351	1,128	0,480							0,001	0	0,1%
				2.4	2,334	1,135	0,486							0,006	0	1,2%
			3	3.1	2,315	1,13	0,488	2,310	0,0125	1,14	0,0076	0,4935686	0,0039	0,005	0	1,1%
				3.2	2,299	1,143	0,497							0,004	0	0,7%
				3.3	2,3	1,139	0,495							0,002	0	0,3%
				3.4	2,325	1,148	0,494							0,000	0	0,0%

Appendix B- Inner dimensions for manufacturer A and B

Manufacturer A Inner dimension

small - compression Test 1		small - compression Test 2		small - compression Test 3		Non-compression Test 1		Non-compression Test 2		Non-compression Test 3
X2	Y2	X2	Y2	X2	Y2	X2	Y2	X2	Y2	X2
2,499	0,76	2,504	0,758	2,482	0,783	2,361	0,599	2,35	0,645	2,324
2,519	0,726	2,509	0,736	2,493	0,755	2,368	0,617	2,364	0,629	2,337
2,486	0,71	2,48	0,728	2,461	0,734	2,354	0,602	2,329	0,62	2,324
2,456	0,723	2,455	0,733	2,422	0,74	2,352	0,606	2,354	0,627	2,353
2,474	0,749	2,518	0,772	2,502	0,768	2,359	0,609	2,41	0,664	2,386
2,248	0,733	2,511	0,77	2,511	0,767	2,378	0,647	2,4	0,659	2,392
2,477	0,741	2,482	0,755	2,478	0,733	2,348	0,628	2,379	0,641	2,37
2,468	0,747	2,469	0,775	2,444	0,751	2,37	0,654	2,376	0,629	2,372
2,51	0,799	2,511	0,764	2,507	0,769	2,417	0,652	2,394	0,655	2,398
2,523	0,775	2,507	0,755	2,525	0,764	2,418	0,683	2,409	0,675	2,383
2,496	0,757	2,505	0,736	2,493	0,77	2,406	0,658	2,379	0,649	2,391
2,471	0,775	2,47	0,757	2,454	0,803	2,38	0,632	2,382	0,657	2,379

Manufacturer B inner dimension

small - compression Test 1		small - compression Test 2		small - compression Test 3		Non-compression Test 1		Non-compression Test 2		Non-compression Test 3	Test 1
X2	Y2	X2	Y2	X2	Y2	X2	Y2	X2	Y2	X2	Y2
2,077	0,784	2,074	0,768	2,049	0,75	1,892	0,659	1,876	0,657	1,843	0,646
2,11	0,802	2,092	0,765	2,086	0,744	1,896	0,653	1,851	0,652	1,867	0,656
2,075	0,788	2,044	0,723	2,035	0,743	1,891	0,64	1,866	0,635	1,86	0,648
2,07	0,77	2,078	0,722	2,066	0,735	1,919	0,658	1,884	0,661	1,884	0,662
2,047	0,725	2,075	0,785	2,076	0,785	1,897	0,646	1,891	0,632	1,905	0,644
2,092	0,751	2,101	0,774	2,103	0,771	1,887	0,645	1,887	0,634	1,904	0,641
2,055	0,738	2,074	0,755	2,061	0,754	1,875	0,632	1,873	0,621	1,91	0,624
2,058	0,736	2,073	0,751	2,076	0,751	1,872	0,664	1,885	0,622	1,892	0,644
2,078	0,813	2,095	0,79	2,082	0,792	1,918	0,661	1,932	0,657	1,914	0,654
2,096	0,805	2,104	0,785	2,103	0,789	1,93	0,678	1,939	0,664	1,919	0,67
2,078	0,792	2,075	0,776	2,075	0,777	1,91	0,658	1,924	0,65	1,913	0,688
2,067	0,766	2,095	0,769	2,073	0,774	1,926	0,673	1,919	0,677	1,189	0,671

APPENDIX C – Feel and Touch operator 2 results

Manufacturer A, Operator 2 Feel and Touch			
Small-compression	**Comment**	**Non-compression test**	**Comment**
1	All rows are harsh	1	The transition at 3.3 feels slightly irregular, overall it feels good.
2	All rows are harsh	2	The lowest holes at all rows (point 4) feel slightly bumpy.
3	All rows are harsh.	3	3.3 and 2.4 B

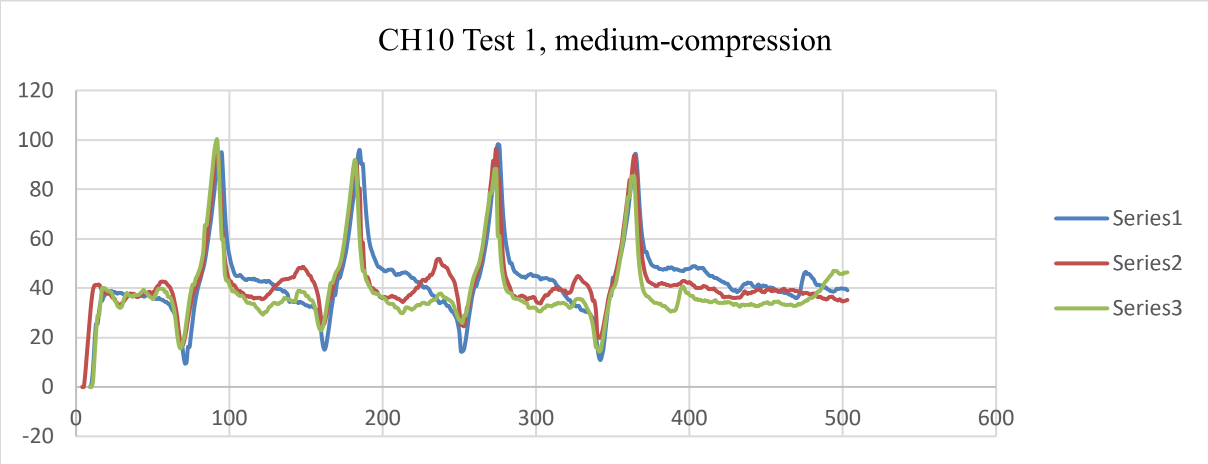
Manufacturer B ,Operator 2 Feel and Touch			
Small-compression	**Comment**	**Non-compression test**	**Comment**
1	All three are slightly irregular, harsh and rough. Row 2 is harsh.	1	You can feel the holes, but nothing unusual.
2	All three rows are harsh and rough, row 2 is harsh.	2	Approved, slightly bumpy.
3	All feel harsh and rough, row 1 is harsh.	3	Approved, row 2.4 is slightly rough

Appendix D - Microscopy out and inner dimensions X and Y for friction

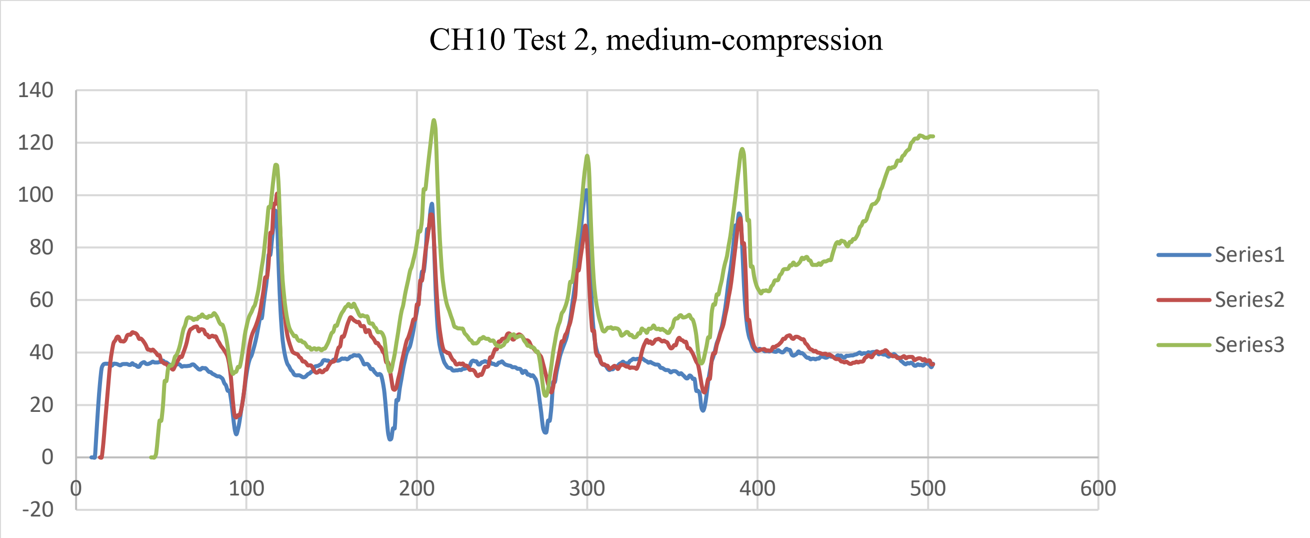
CH10 SMALL-COMPRESSION	X_{out}	Y_{out}	X_{inner}	X_{Inner}	CH10 MEDIUM-COMPRESSION	X_{out}	Y_{out}	X_{inner}	X_{Inner}
1.1	2,319	1,163	2,079	0,809	**1.1**	2,263	1,137	1,935	0,668
1.2	2,364	1,186	2,123	0,786	**1.2**	2,248	1,115	1,934	0,675
1.3	2,347	1,186	2,082	0,765	**1.3**	2,281	1,12	1,92	0,672
1.4	2,359	1,19	2,082	0,773	**1.4**	2,83	1,17	1,895	0,704
2.1	2,296	1,171	2,079	0,778	**2.1**	2,312	1,119	1,935	0,668
2.2	2,294	1,189	2,088	0,771	**2.2**	2,289	1,076	1,91	0,669
2.3	2,312	1,178	2,051	0,765	**2.3**	2,315	1,107	1,932	0,675
2.4	2,345	1,221	2,065	0,758	**2.4**	2,319	1,16	1,935	0,655
3.1	2,311	1,144	2,059	0,786	**3.1**	2,256	1,077	1,933	0,671
3.2	2,338	1,197	2,096	0,764	**3.2**	2,312	1,135	1,928	0,665
3.3	2,29	1,145	2,07	0,759	**3.3**	2,314	1,131	1,925	0,657
3.4	2,373	1,198	2,069	0,751	**3.4**	2,282	1,135	1,934	0,66
CH10 SMALL-COMPRESSION	X_{out}	Y_{out}	X_{inner}	X_{Inner}	**CH10 Medium-compression**	X_{out}	Y_{out}	X_{inner}	X_{Inner}
1.1	2,303	1,151	2,095	0,8	**1.1**	2,271	1,076	1,934	0,668
1.2	2,313	1,18	2,121	0,783	**1.2**	2,266	1,1	1,944	0,664
1.3	2,283	1,18	2,087	0,777	**1.3**	2,27	1,144	1,926	0,66
1.4	2,361	1,241	2,071	0,774	**1.4**	2,265	1,197	1,935	0,657
2.1	2,313	1,148	2,112	0,774	**2.1**	2,306	1,111	1,942	0,668
2.2	2,343	1,169	2,11	0,768	**2.2**	2,36	1,12	1,946	0,662
2.3	2,335	1,179	2,069	0,762	**2.3**	2,388	1,119	1,938	0,671
2.4	2,35	1,188	2,12	0,755	**2.4**	2,332	1,163	1,942	0,668
3.1	2,309	1,147	2,073	0,774	**3.1**	2,295	1,117	1,933	0,663
3.2	2,321	1,174	2,104	0,753	**3.2**	2,351	1,165	1,944	0,665
3.3	2,32	1,155	2,065	0,751	**3.3**	2,356	1,106	1,94	0,659
3.4	2,367	1,197	2,101	0,747	**3.4**	2,329	1,177	1,39	0,662
CH12 SMALL-COMPRESSION	X_{out}	Y_{out}	X_{inner}	X_{Inner}	**CH12 Medium-compression**	X_{out}	Y_{out}	X_{inner}	X_{Inner}
1.1	2,318	1,148	2,101	0,853	**1.1**	2,679	1,101	2,319	0,694
1.2	2,352	1,158	2,123	0,828	**1.2**	2,707	1,064	2,4	0,688
1.3	2,357	1,164	2,078	0,83	**1.3**	2,711	1,066	2,39	0,654
1.4	2,415	1,183	2,067	0,747	**1.4**	2,702	1,081	2,352	0,675
2.1	2,348	1,153	2,103	0,798	**2.1**	2,624	1,07	2,31	0,64
2.2	2,338	1,179	2,1	0,811	**2.2**	2,668	1,086	2,345	0,636
2.3	2,355	1,202	2,043	0,79	**2.3**	2,658	1,071	2,327	0,633
2.4	2,385	1,231	2,012	0,722	**2.4**	2,647	1,064	2,319	0,628
3.1	2,357	1,173	2,109	0,844	**3.1**	2,689	1,1	2,289	0,64
3.2	2,31	1,217	2,119	0,846	**3.2**	2,709	1,097	2,343	0,615
3.3	2,34	1,205	2,074	0,853	**3.3**	2,685	1,088	2,321	0,624
3.4	2,354	1,196	2,036	0,763	**3.4**	2,683	1,086	2,313	0,621
CH12 SMALL-COMPRESSION	X_{out}	Y_{out}	X_{inner}	X_{Inner}	**CH12 Medium -compression**	X_{out}	Y_{out}	X_{inner}	X_{Inner}
1.1	2,33	1,159	2,088	0,847	**1.1**	2,634	1,099	2,321	0,68
1.2	2,326	1,167	2,111	0,827	**1.2**	2,64	1,08	2,375	0,658
1.3	2,331	1,159	2,072	0,833	**1.3**	2,653	1,071	2,387	0,66
1.4	2,404	1,236	2,059	0,798	**1.4**	2,631	1,065	2,338	0,667
2.1	2,284	1,145	2,09	0,83	**2.1**	2,662	1,079	2,313	0,654
2.2	2,303	1,208	2,13	0,813	**2.2**	2,699	1,115	2,369	0,677
2.3	2,317	1,208	2,07	0,828	**2.3**	2,713	1,062	2,366	0,639
2.4	2,366	1,223	2,035	0,776	**2.4**	2,682	1,057	2,336	0,635
3.1	2,336	1,172	2,092	0,859	**3.1**	2,639	1,053	2,291	0,636
3.2	2,361	1,218	2,117	0,8	**3.2**	2,676	1,07	2,325	0,63
3.3	2,338	1,229	2,071	0,807	**3.3**	2,663	1,056	2,31	0,624
3.4	2,382	1,255	2,04	0,75	**3.4**	2,676	1,086	2,304	0,63
CH14 1SMALL-COMPRESSION	X_{out}	Y_{out}	X_{inner}	X_{Inner}	**CH14 non-compression**	X_{out}	Y_{out}	X_{inner}	X_{Inner}
1.1	2,293	1,148	2,105	0,909	**1.1**	2,296	1,088	1,793	0,595

1.2	2,346	1,173	2,115	0,874	**1.2**	2,288	1,108	1,791	0,619
1.3	2,305	1,144	2,091	0,862	**1.3**	2,308	1,103	1,805	0,609
1.4	2,36	1,229	2,076	0,83	**1.4**	2,304	1,108	1,78	0,61
2.1	2,314	1,168	2,079	0,861	**2.1**	2,303	1,1	1,755	0,614
2.2	2,313	1,206	2,064	0,848	**2.2**	2,327	1,123	1,777	0,61
2.3	2,331	1,2	2,06	0,834	**2.3**	2,33	1,125	1,687	0,6
2.4	2,361	1,225	2,047	0,775	**2.4**	2,347	1,13	1,59	0,63
3.1	2,353	1,179	2,118	0,937	**3.1**	2,325	1,1	1,79	0,598
3.2	2,367	1,22	2,137	0,89	**3.2**	2,336	1,115	1,802	0,608
3.3	2,354	1,2	2,092	0,862	**3.3**	2,36	1,1	1,762	0,6
3.4	2,41	1,21	2,07	0,827	**3.4**	2,356	1,146	1,784	0,615
CH16 SMALL-COMPRESSION	X_{out}	Y_{out}	X_{inner}	X_{Inner}	**CH16 non - compression**	X_{out}	Y_{out}	X_{inner}	X_{Inner}
1.1	2,243	1,09	2,017	0,963	**1.1**	2,292	1,043	1,638	0,541
1.2	2,291	1,087	2,07	0,92	**1.2**	2,333	1,073	1,62	0,57
1.3	2,313	1,3	2,08	0,936	**1.3**	2,313	1,053	1,646	0,573
1.4	2,364	1,198	2,023	0,967	**1.4**	2,329	1,076	1,63	0,556
2.1	2,306	1,117	2,072	0,9	**2.1**	2,318	1,074	1,623	0,537
2.2	2,345	1,138	2,054	899	**2.2**	2,333	1,095	1,637	0,571
2.3	2,376	1,177	2,05	0,21	**2.3**	2,329	1,083	1,64	0,54
2.4	2,406	1,17	2,062	0,961	**2.4**	2,331	1,099	1,628	0,512
3.1	2,342	1,11	2,019	0,932	**3.1**	2,342	1,056	1,619	0,506
3.2	2,333	1,098	2,042	0,934	**3.2**	2,348	1,095	1,624	0,541
3.3	2,337	1,8	2,017	0,912	**3.3**	2,35	1,089	1,38	0,572
3.4	2,389	1,156	2,032	0,91	**3.4**	2,351	1,066	1,624	0,494

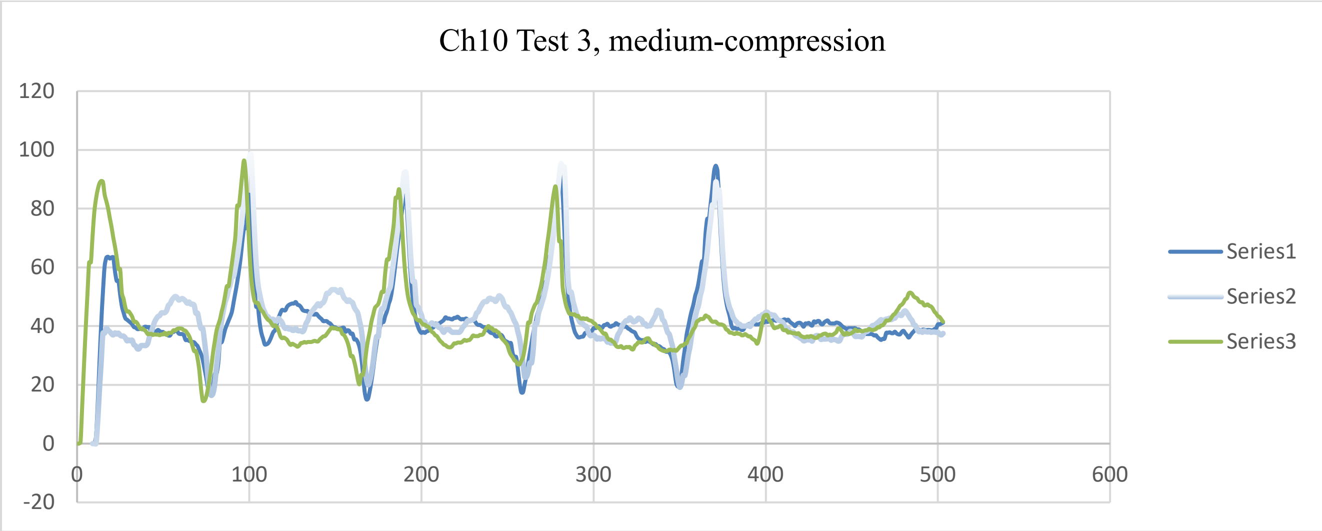
Appendix E - Friction values and graphs for CH10



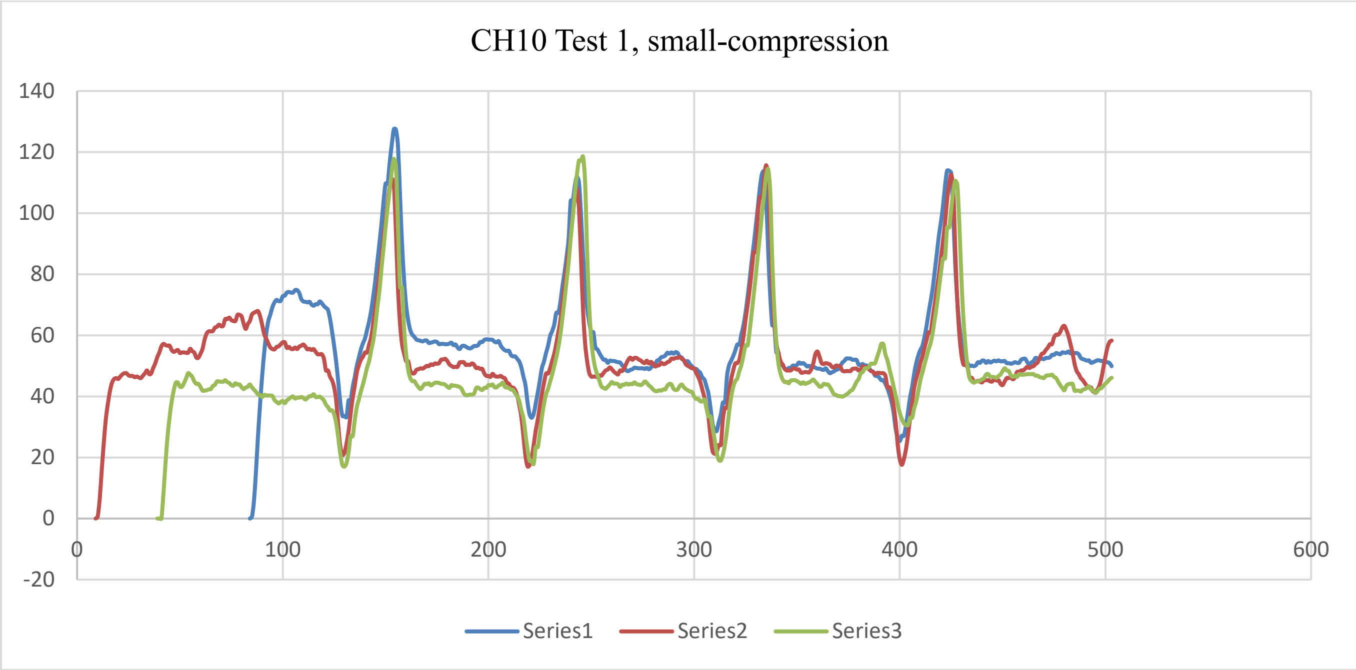
Test 1	Row 1	Exit						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,558	3,544	0,064	OK	74,303	74,240	0,267	OK
2	3,513			OK	74,111			OK
3	3,479			OK	73,964			OK
4	3,626			OK	74,582			OK
Test 1	Row 1	Entry						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,390	-2,005	0,275	OK	67,295	63,247	2,983	OK
2	-1,740			OK	60,113			OK
3	-1,930			OK	62,610			OK
4	-1,960			OK	62,969			OK
Test 1	Row 2	Exit						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,457	3,340	0,141	OK	73,864	73,311	0,687	OK
2	3,138			OK	72,325			OK
3	3,414			OK	73,675			OK
4	3,350			OK	73,379			OK
Test 1	Row 2	Entry						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,530	-2,273	0,180	OK	68,433	66,168	1,610	OK
2	-2,110			OK	64,642			OK
3	-2,210			OK	65,654			OK
4	-2,240			OK	65,943			OK
Test 1	Row 3	Exit						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,521	3,173	0,242	OK	74,144	72,442	1,198	OK
2	3,127			OK	72,267			OK
3	2,964			OK	71,354			OK
4	3,078			OK	72,003			OK
Test 1	Row 3	Enry						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,210	-2,083	0,605	OK	65,654	62,966	8,115	OK
2	-2,680			OK	69,538			OK
3	-2,200			OK	65,556			OK
4	-1,240			OK	51,116			OK



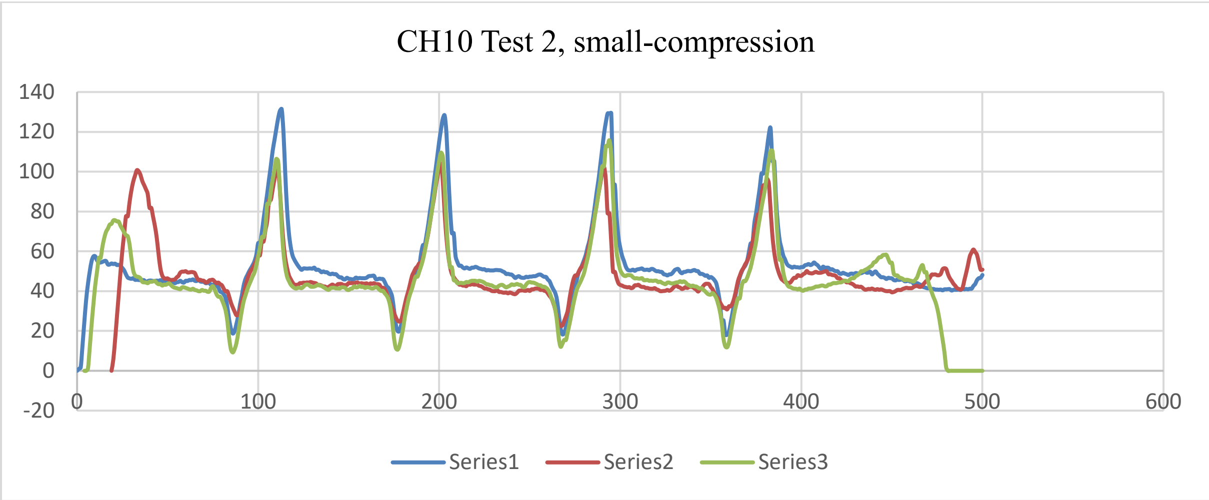
Test 2	Row 1	Exit						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,71	3,72	0,20	OK	74,91	74,92	0,75	OK
2	3,58			OK	74,39			OK
3	4,00			OK	75,98			OK
4	3,58			OK	74,40			OK
Test 2	Row 1	Entry						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,21	-2,08	0,60	OK	65,65	62,97	8,11	OK
2	-2,68			OK	69,54			OK
3	-2,20			OK	65,56			OK
4	-1,24			OK	51,12			OK
Test 2	Row 2	Exit						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,56	3,26	0,20	OK	74,30	72,93	0,92	OK
2	3,17			OK	72,50			OK
3	3,18			OK	72,52			OK
4	3,15			OK	72,40			OK
Test 2	Row 2	Entry						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,85	-1,99	0,58	OK	70,67	62,30	5,65	OK
2	-1,78			OK	60,67			OK
3	-1,63			OK	58,47			OK
4	-1,69			OK	59,39			OK
Test 2	Row 3	Exit						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,05	3,50	0,35	OK	71,85	73,93	1,57	OK
2	3,69			OK	74,83			OK
3	3,84			OK	75,39			OK
4	3,41			OK	73,65			OK
Test 2	Row 3	Enry						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,24	-1,93	0,21	FLAG	65,94	62,48	2,43	OK
2	-1,83			OK	61,35			OK
3	-1,90			FLAG	62,24			OK
4	-1,76			FLAG	60,40			OK



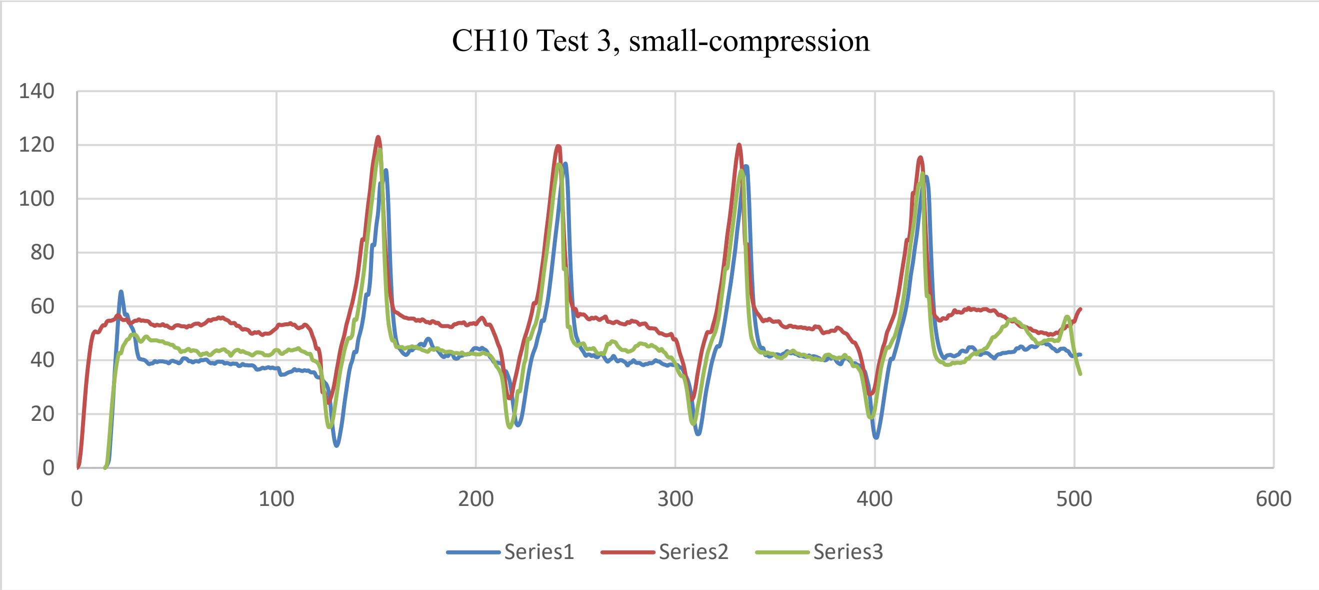
Test 3	Test 1	Row 1	Exit						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	2,92	3,19	0,26	OK	71,11	72,50	1,32	OK
2	2,00	3,01			OK	71,64			OK
3	3,00	3,39			OK	73,57			OK
4	4,00	3,42			OK	73,69			OK
Test 3	Test 1	Row 1	Entry						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	-1,71	-1,79	0,41	OK	59,68	60,13	5,53	OK
2	2,00	-2,33			OK	66,77			OK
3	3,00	-1,79			OK	60,81			OK
4	4,00	-1,34			OK	53,27			OK
Test 3	Test 1	Row 2	Exit						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	3,57	3,44	0,16	OK	74,35	73,75	0,70	OK
2	2,00	3,28			OK	73,03			FLAG
3	3,00	3,57			OK	74,35			OK
4	4,00	3,32			OK	73,26			FLAG
Test 3	Test 1	Row 2	Entry						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	-3,07	-2,65	0,36	OK	71,96	69,07	2,59	OK
2	2,00	-2,83			OK	70,54			OK
3	3,00	-2,38			OK	67,21			OK
4	4,00	-2,31			OK	66,59			OK
Test 3	Test 1	Row 3	Exit						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	3,41	3,06	0,30	OK	73,65	71,80	1,60	OK
2	2,00	2,89			OK	70,93			OK
3	3,00	2,88			OK	70,83			OK
4	4,00	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet
Test 3	Test 1	Row 3	Enry						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	-2,38	-1,68	0,72	OK	67,21	56,86	12,12	OK
2	2,00	-1,72			OK	59,83			OK
3	3,00	-0,95			OK	43,53			OK
4	4,00	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet	No detected eyelet



Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,93	3,72	0,14	OK	75,71	74,96	0,53	OK
2	3,59			OK	74,44			OK
3	3,70			OK	74,86			OK
4	3,69			OK	74,83			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-3,58	-2,44	0,76	OK	74,39	66,62	5,19	OK
2	-2,05			OK	64,00			OK
3	-2,03			OK	63,77			OK
4	-2,08			OK	64,32			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	4,20	3,98	0,37	OK	76,61	75,79	1,40	OK
2	4,14			OK	76,41			OK
3	4,15			OK	76,45			OK
4	3,42			OK	73,69			OK
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,17	-2,16	0,20	OK	65,26	65,07	1,98	OK
2	-2,42			OK	67,55			OK
3	-1,94			OK	62,73			OK
4	-2,12			OK	64,75			OK
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,78	3,83	0,09	OK	75,16	75,34	0,32	OK
2	3,79			OK	75,21			OK
3	3,78			OK	75,18			OK
4	3,96			OK	75,82			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-3,30	-2,96	0,25	OK	73,14	71,25	1,44	OK
2	-2,74			OK	69,95			OK
3	-2,80			OK	70,35			OK
4	-3,00			OK	71,57			OK

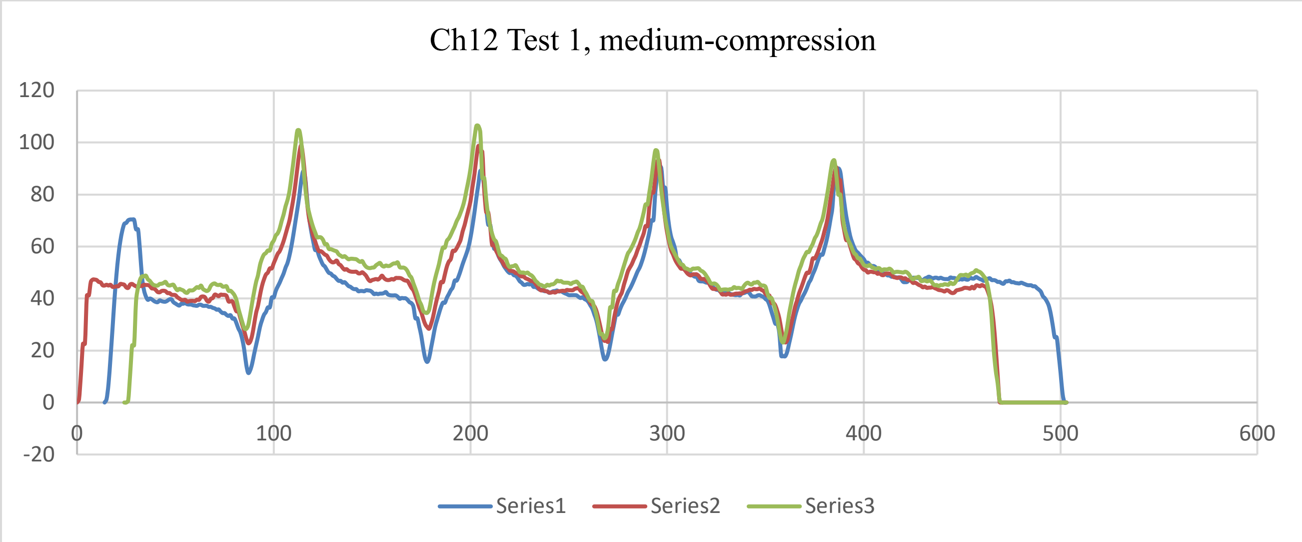


Test 1	Row 1	**Exit**							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	4,174074074	4,28	0,15	OK	76,52734272	76,84	0,45	OK
2	4,5125			OK	77,50480671			OK
3	4,114814815			OK	76,34053709			OK
4	4,320833333			OK	76,96907154			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,44	-2,73	0,25	OK	67,71441	69,80	1,48	OK
2	-2,62			OK	69,10918			OK
3	-2,89			OK	70,91332			OK
4	-2,98			OK	71,44977			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,304545455	3,27	0,17	OK	73,16347736	72,94	0,87	OK
2	3,443478261			OK	73,80648935			OK
3	3,333333333			OK	73,30075577			OK
4	2,986363636			OK	71,48659968			OK
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,64	-1,61	0,21	OK	58,62699	57,82	3,62	OK
2	-1,7			OK	59,53446			OK
3	-1,83			OK	61,34569			OK
4	-1,27			OK	51,78305			OK
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	4,05	4,03	0,12	OK	76,13031356	76,06	0,39	OK
2	4,125			OK	76,37300514			OK
3	3,837037037			OK	75,39263492			OK
4	4,1125			OK	76,33313681			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-3,16	-2,96	0,19	FLAG	72,43973	71,25	1,16	OK
2	-3,01			FLAG	71,62218			OK
3	-3,01			FLAG	71,62218			OK
4	-2,65			FLAG	69,32558			OK

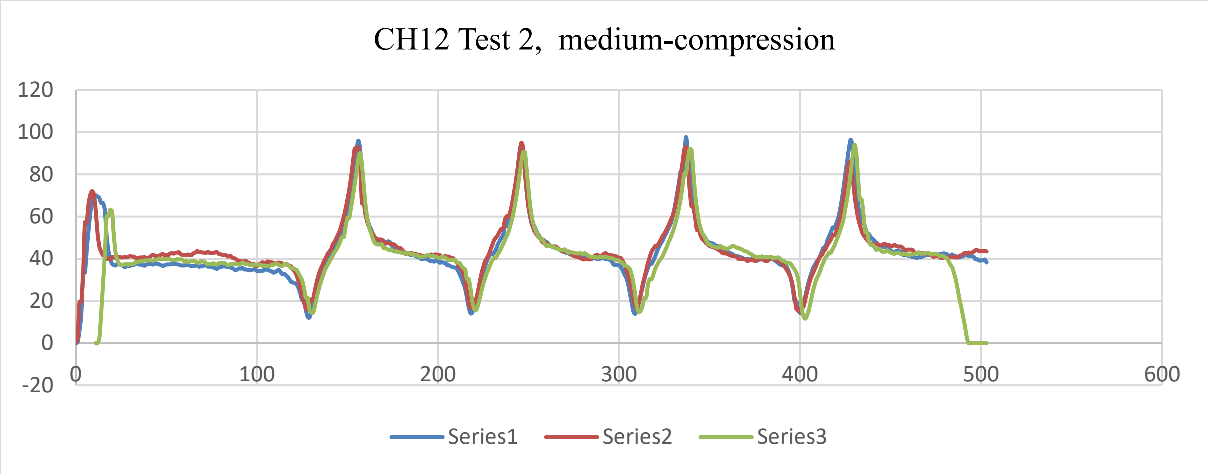


Test 1	Test 3	Row 1	**Exit**						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	4,09	4,00	0,10	OK	76,27	75,95	0,33	OK
2	2,00	4,05			OK	76,12			OK
3	3,00	3,98			OK	75,90			OK
4	4,00	3,87			OK	75,50			OK
Test 1	Test 3	Row 1	**Entry**						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	-2,58	-2,55	0,16	OK	68,81	68,50	1,25	OK
2	2,00	-2,33			OK	66,77			OK
3	3,00	-2,56			OK	68,66			OK
4	4,00	-2,71			OK	69,75			OK
Test 1	Test 3	Row 2	**Exit**						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	3,95	3,83	0,21	OK	75,80	75,33	0,81	OK
2	2,00	3,90			OK	75,63			OK
3	3,00	3,95			OK	75,78			OK
4	4,00	3,52			OK	74,12			FLAG
Test 1	Test 3	Row 2	**Entry**						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	-2,79	-2,52	0,31	OK	70,28	68,11	2,59	OK
2	2,00	-2,73			OK	69,88			OK
3	3,00	-2,43			OK	67,63			FLAG
4	4,00	-2,11			OK	64,64			FLAG
Test 1	Test 3	Row 3	**Exit**						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	4,11	3,85	0,27	OK	76,33	75,41	1,02	OK
2	2,00	3,90			OK	75,63			OK
3	3,00	3,93			OK	75,71			OK
4	4,00	3,48			OK	73,95			OK
Test 1	Test 3	Row 3	**Enry**						
Eyelet	Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	1,00	-2,70	-2,46	0,28	OK	69,68	67,73	2,35	OK
2	2,00	-2,68			OK	69,54			OK
3	3,00	-2,35			OK	66,95			OK
4	4,00	-2,12			OK	64,75			OK

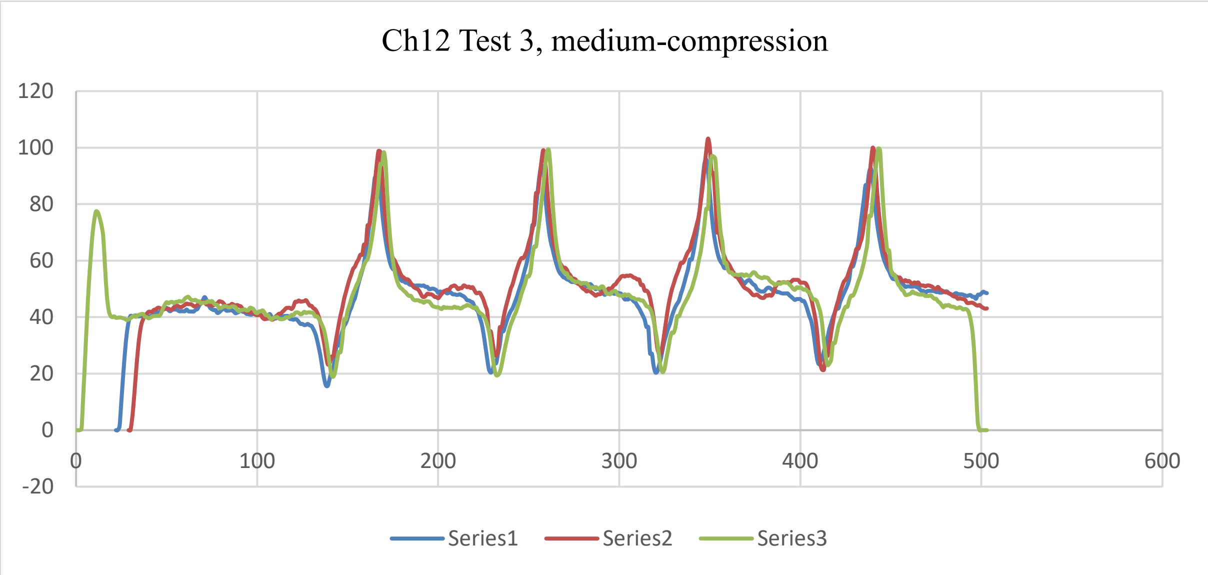
Appendix F - Friction values and graphs for CH12



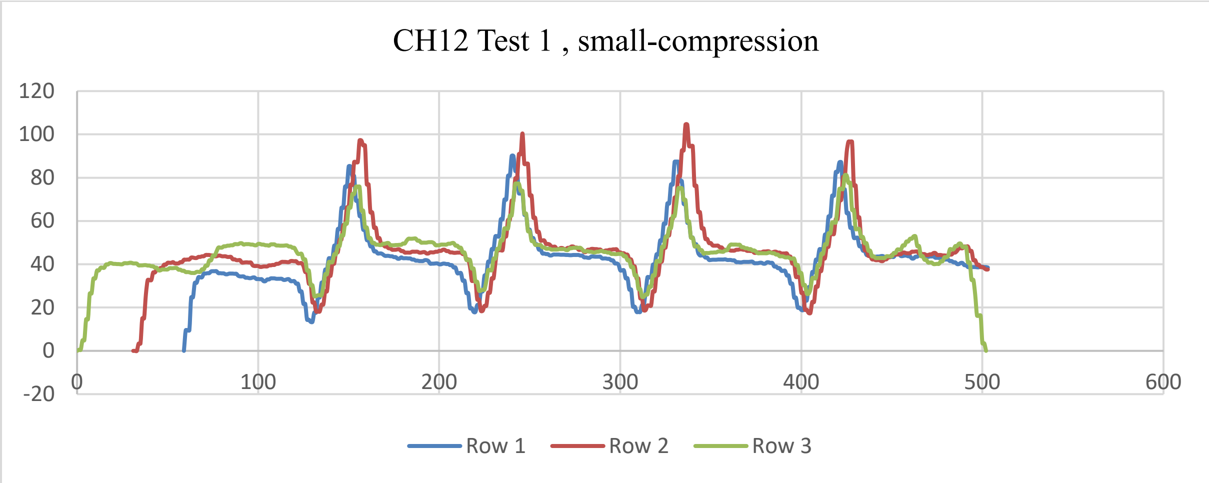
Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,77	2,73	0,04	OK	70,16	69,88	0,29	OK
2	2,72			OK	69,83			OK
3	2,75			OK	70,03			OK
4	2,67			OK	69,50			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,19	-2,27	0,10	OK	65,46	66,23	0,88	OK
2	-2,39			OK	67,30			OK
3	-2,31			OK	66,59			OK
4	-2,20			OK	65,56			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,82	2,73	0,11	OK	70,47	69,83	0,75	OK
2	2,81			OK	70,42			OK
3	2,68			OK	69,54			OK
4	2,59			OK	68,91			FLAG
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,61	-1,71	0,11	OK	58,15	59,62	1,62	OK
2	-1,71			OK	59,68			OK
3	-1,65			OK	58,78			FLAG
4	-1,87			OK	61,86			FLAG
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,93	2,79	0,13	OK	71,18	70,26	0,87	OK
2	2,88			OK	70,83			OK
3	2,66			OK	69,42			OK
4	2,69			OK	69,62			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,64	-0,84	1,96	OK	58,63	61,57	3,81	OK
2	-1,60			OK	57,99			OK
3	2,07			OK	64,22			OK
4	-2,19			OK	65,46			OK



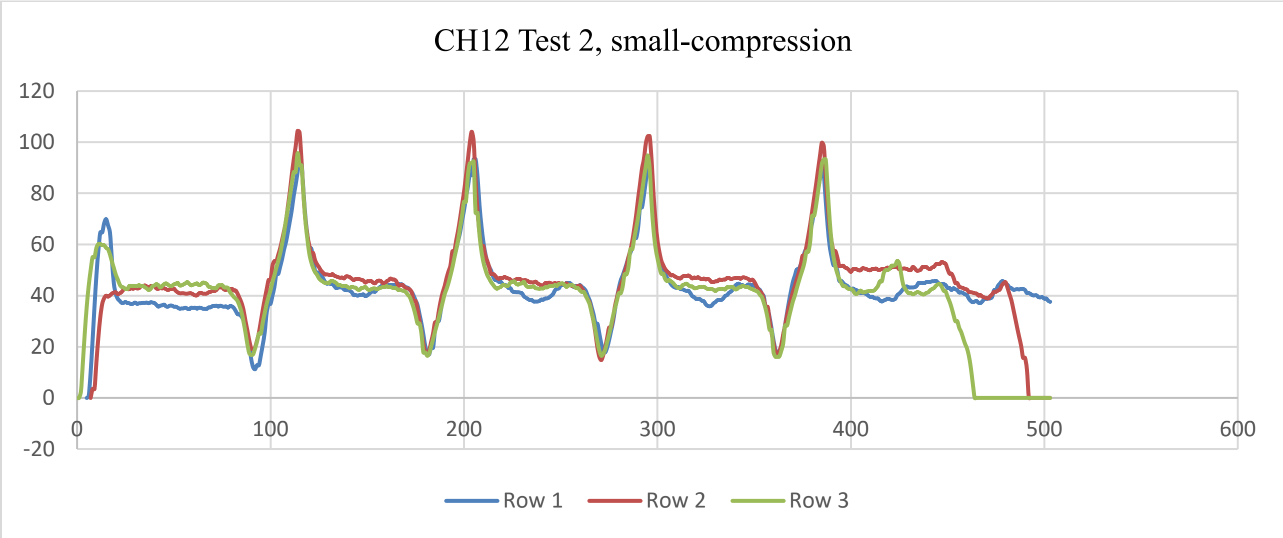
Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,10	3,38	0,85	OK	72,14	72,97	3,32	OK
2	2,85			OK	70,69			OK
3	4,65			OK	77,86			OK
4	2,93			OK	71,17			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,69	-2,11	0,28	OK	59,39	64,37	3,34	OK
2	-2,20			OK	65,56			OK
3	-2,30			OK	66,50			OK
4	-2,25			OK	66,04			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,75	2,75	0,15	OK	69,99	69,99	1,07	OK
2	2,90			OK	70,95			OK
3	2,83			OK	70,51			OK
4	2,54			OK	68,50			FLAG
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,07	-2,27	0,13	OK	64,22	66,13	1,31	OK
2	-2,30			OK	66,50			OK
3	-2,38			OK	67,21			FLAG
4	-2,31			OK	66,59			FLAG
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,90	2,87	0,14	OK	72,65	71,47	0,79	OK
2	2,77			OK	71,00			OK
3	2,76			OK	71,22			OK
4	3,05			OK	71,00			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,10	-2,34	0,23	OK	64,54	66,76	2,01	OK
2	-2,24			OK	65,94			OK
3	-2,39			FLAG	67,30			OK
4	-2,64			FLAG	69,25			OK



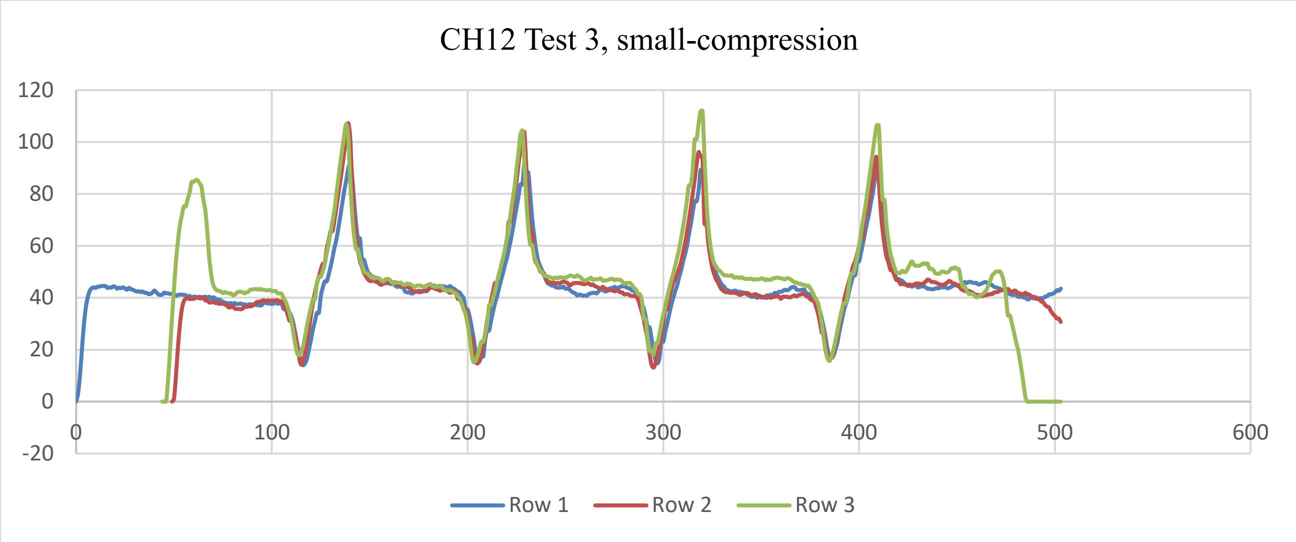
Test 3	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,650	2,590	0,140	OK	69,326	68,830	1,080	OK
2	2,621			OK	69,120			OK
3	2,693			OK	69,627			OK
4	2,383			OK	67,233			OK
Test 3	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,180	-2,330	0,130	OK	65,358	66,710	1,120	OK
2	-2,480			OK	68,039			OK
3	-2,360			OK	67,036			OK
4	-2,290			OK	66,410			OK
Test 3	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,593	2,780	0,130	OK	68,911	70,190	0,910	FLAG
2	2,823			OK	70,495			OK
3	2,793			OK	70,298			OK
4	2,911			OK	71,042			OK
Test 3	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,080	-2,450	0,430	OK	64,323	67,430	3,270	FLAG
2	-2,220			OK	65,751			FLAG
3	-2,450			OK	67,797			OK
4	-3,050			OK	71,847			OK
Test 3	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,839	2,740	0,130	OK	70,598	69,900	0,850	OK
2	2,850			OK	70,665			OK
3	2,634			OK	69,214			OK
4	2,621			OK	69,114			OK
Test 3	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,140	-2,340	0,200	OK	64,954	66,760	1,800	OK
2	-2,200			OK	65,556			OK
3	-2,450			FLAG	67,797			OK
4	-2,570			FLAG	68,739			OK



Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,590	3,390	0,150	OK	74,435	73,550	0,690	OK
2	3,429			OK	73,740			OK
3	3,300			OK	73,142			OK
4	3,248			OK	72,885			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,880	-1,850	0,060	OK	61,991	61,590	0,780	OK
2	-1,790			OK	60,810			OK
3	-1,920			OK	62,488			OK
4	-1,810			OK	61,080			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,435	3,700	0,190	OK	73,768	74,870	0,780	OK
2	3,723			OK	74,964			OK
3	3,895			OK	75,603			OK
4	3,767			OK	75,132			OK
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,230	-2,500	0,180	OK	65,847	68,150	1,540	OK
2	-2,620			OK	69,109			OK
3	-2,560			OK	68,663			OK
4	-2,600			OK	68,962			OK
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,196	2,380	0,140	OK	65,513	67,200	1,260	OK
2	2,352			OK	66,970			OK
3	2,505			OK	68,238			OK
4	2,486			OK	68,090			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,080	-1,900	0,170	OK	64,323	62,160	2,190	OK
2	-1,980			OK	63,204			OK
3	-1,870			FLAG	61,864			OK
4	-1,680			FLAG	59,237			OK

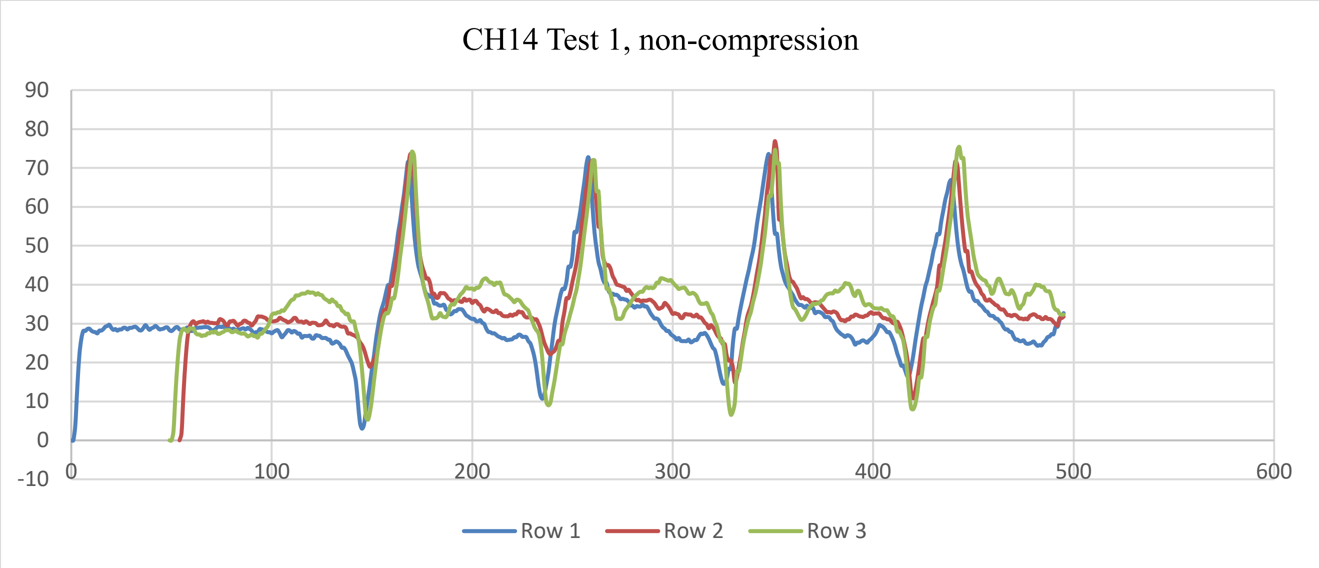


Test 2	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,713	3,680	0,080	OK	76,871	76,360	0,800	OK
2	3,783			OK	75,793			OK
3	3,646			OK	77,196			OK
4	3,591			OK	75,562			OK
Test 2	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,280	-2,430	0,110	OK	66,318	67,600	0,970	OK
2	-2,520			OK	68,356			OK
3	-2,400			OK	67,380			OK
4	-2,520			OK	68,356			OK
Test 2	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,713	3,680	0,080	OK	76,871	76,360	0,800	OK
2	3,783			OK	75,793			OK
3	3,646			OK	77,196			OK
4	3,591			OK	75,562			OK
Test 2	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,300	-2,550	0,200	OK	66,501	68,530	1,550	OK
2	-2,570			OK	68,739			OK
3	-2,790			OK	70,281			OK
4	-2,550			OK	68,587			OK
Test 2	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,288	3,430	0,100	OK	73,081	72,970	0,390	OK
2	3,496			OK	72,453			OK
3	3,408			OK	72,959			OK
4	3,517			OK	73,389			OK
Test 2	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,370	-2,450	0,100	OK	67,123	67,760	0,780	OK
2	-2,380			OK	67,209			OK
3	-2,460			FLAG	67,878			OK
4	-2,580			FLAG	68,814			OK

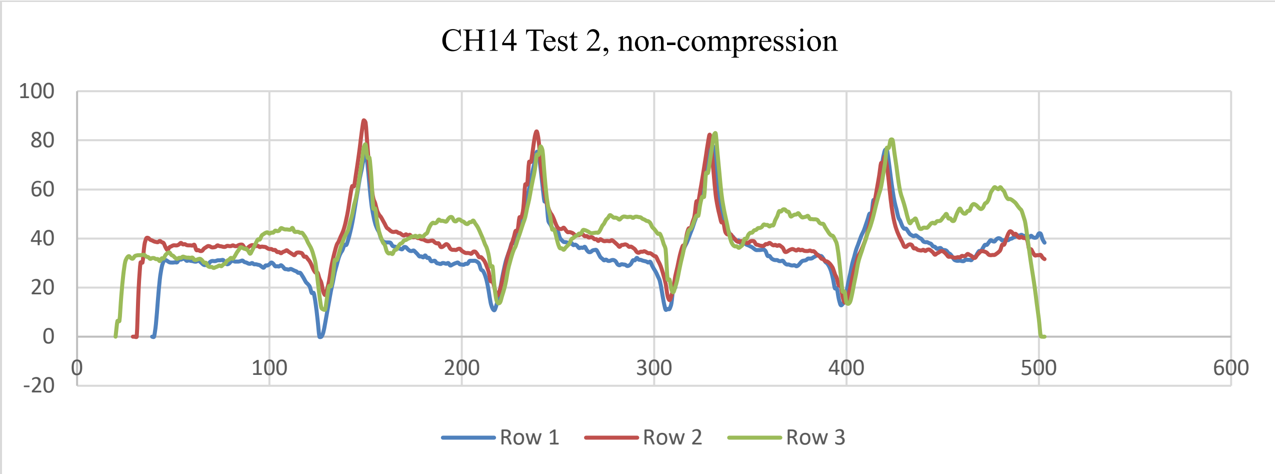


Test 3	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,242	3,220	0,080	OK	72,856	72,750	0,430	OK
2	3,304			OK	73,163			OK
3	3,239			OK	72,843			OK
4	3,104			OK	72,144			OK
Test 3	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,170	-2,430	0,220	OK	65,258	67,540	1,890	OK
2	-2,660			OK	69,397			OK
3	-2,570			OK	68,739			OK
4	-2,330			OK	66,772			OK
Test 3	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,879	3,760	0,310	OK	75,545	75,020	1,210	OK
2	3,713			OK	74,925			FLAG
3	4,078			OK	76,223			OK
4	3,352			OK	73,389			FLAG
Test 3	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,440	-2,480	0,210	OK	67,714	67,960	1,700	OK
2	-2,490			OK	68,119			OK
3	-2,760			OK	70,084			OK
4	-2,240			OK	65,943			OK
Test 3	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,708	3,660	0,090	OK	74,908	74,720	0,340	OK
2	3,560			OK	74,310			OK
3	3,752			OK	75,076			OK
4	3,628			OK	74,590			OK
Test 3	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,380	-2,600	0,180	OK	67,209	68,900	1,320	OK
2	-2,660			OK	69,397			OK
3	-2,560			FLAG	68,663			OK
4	-2,8			FLAG	70,346			OK

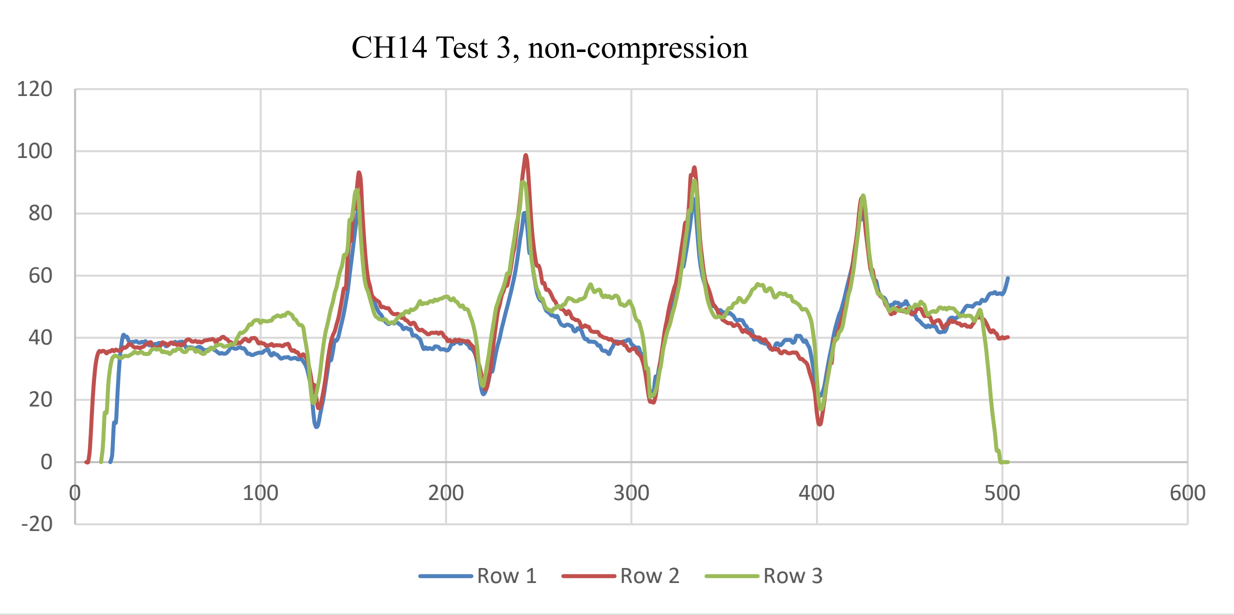
Appendix G - Friction values and graphs for CH14



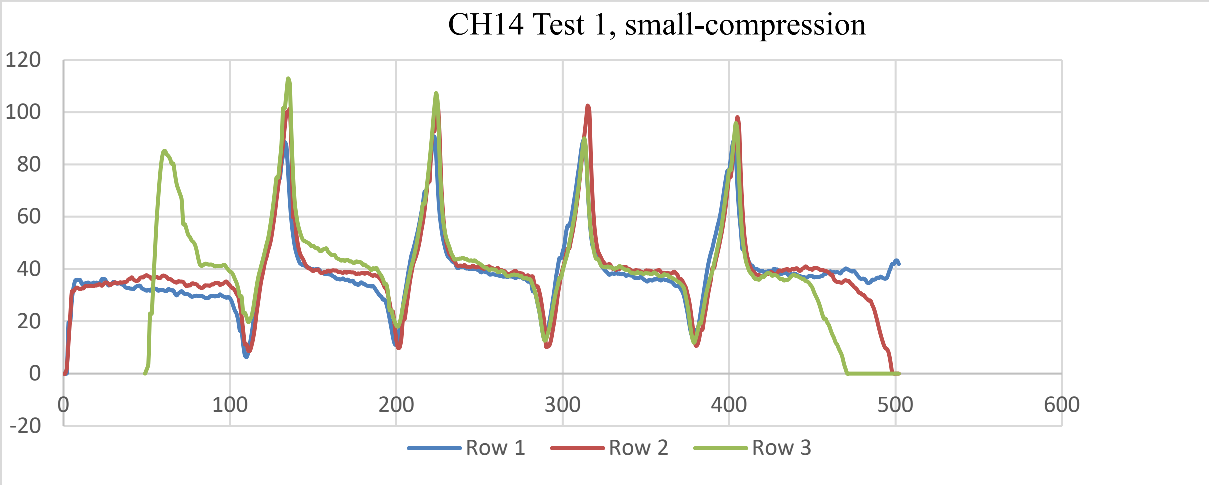
Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,98	2,66	0,29	OK	71,46	70,41	2,26	OK
2	2,70			OK	67,09			OK
3	2,67			OK	72,12			OK
4	2,29			OK	70,97			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,08	-1,53	0,42	OK	64,32	55,77	6,87	OK
2	-1,59			OK	57,83			OK
3	-1,30			OK	52,43			OK
4	-1,13			OK	48,49			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,61	2,74	0,32	OK	69,03	69,81	2,21	OK
2	2,37			OK	67,09			FLAG
3	3,10			OK	72,12			OK
4	2,90			OK	70,97			FLAG
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-0,86	-1,28	0,49	OK	40,70	50,18	10,04	OK
2	-0,95			OK	43,53			OK
3	-1,37			OK	53,87			OK
4	-1,93			OK	62,61			OK
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,13	2,97	0,18	OK	72,29	71,36	1,08	OK
2	2,73			OK	69,91			OK
3	3,09			OK	72,07			OK
4	2,93			OK	71,16			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,72	-2,54	0,16	OK	69,81	68,46	1,24	OK
2	-2,43			OK	67,63			OK
3	-2,63			FLAG	69,18			OK
4	-2,38			FLAG	67,21			OK



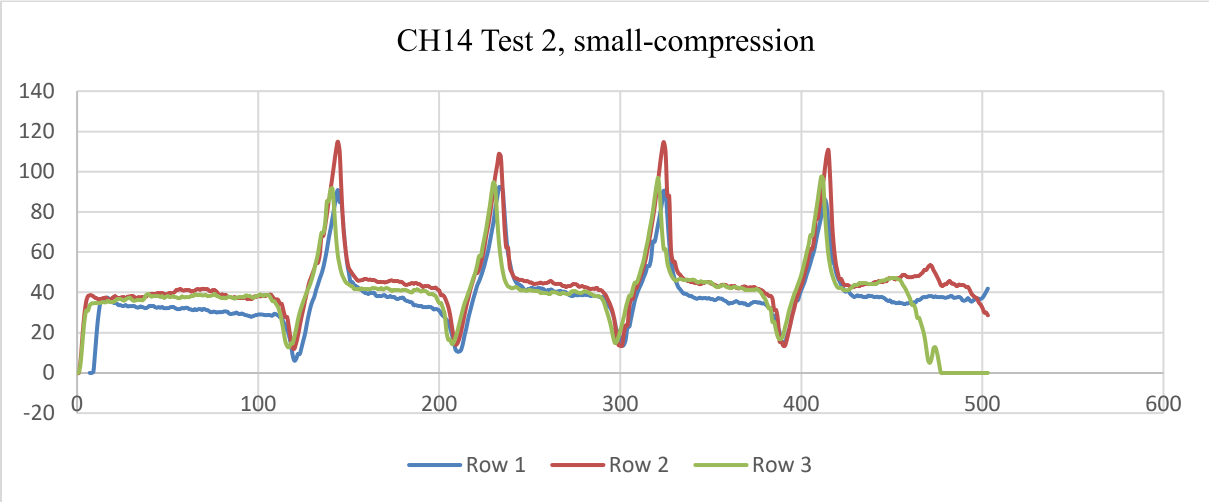
Test 2	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,265	2,950	0,260	OK	72,972	71,180	1,530	OK
2	2,932			OK	71,166			OK
3	2,961			OK	71,338			OK
4	2,638			OK	69,236			OK
Test 2	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,600	-2,140	0,310	OK	68,962	64,700	2,850	OK
2	-2,010			OK	63,549			OK
3	-1,960			OK	62,969			OK
4	-1,990			OK	63,320			OK
Test 2	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,555	3,190	0,300	OK	74,289	72,520	1,540	OK
2	3,186			OK	72,573			FLAG
3	3,205			OK	72,670			OK
4	2,829			OK	70,530			FLAG
Test 2	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,560	-1,710	0,150	OK	57,339	59,620	2,070	OK
2	-1,700			OK	59,534			OK
3	-1,910			OK	62,365			OK
4	-1,680			OK	59,237			OK
Test 2	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,200	2,990	0,140	OK	72,646	71,470	0,790	OK
2	2,905			OK	71,002			OK
3	2,941			OK	71,220			OK
4	2,904			OK	71,001			OK
Test 2	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,900	-2,840	0,180	FLAG	70,974	70,520	1,180	OK
2	-2,990			FLAG	71,508			OK
3	-2,580			FLAG	68,814			OK
4	-2,870			FLAG	70,790			OK



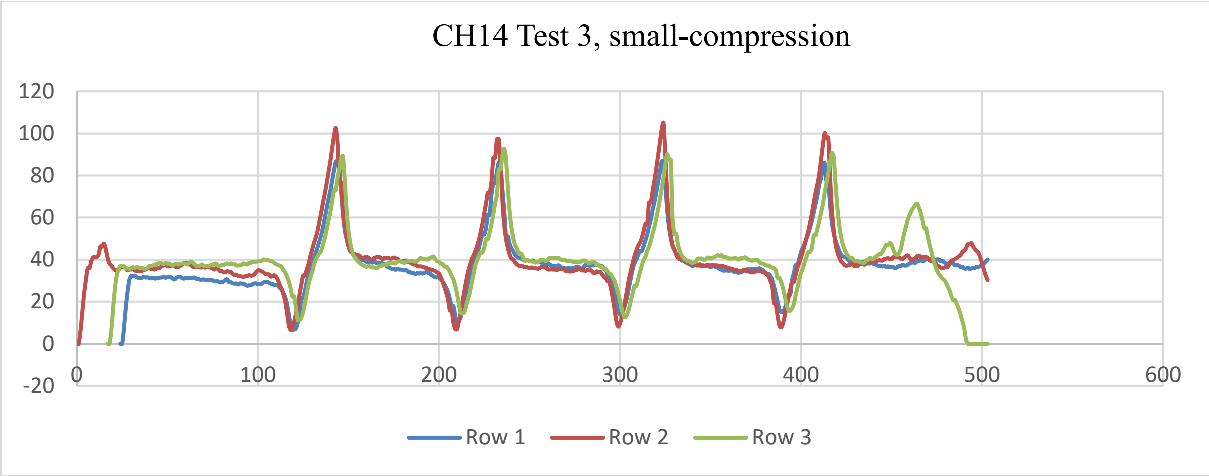
Test 3	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,117	2,750	0,260	OK	67,465	64,690	1,880	OK
2	2,526			OK	63,320			OK
3	2,748			OK	63,775			OK
4	2,604			OK	64,215			OK
Test 3	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,180	-1,850	0,250	OK	65,358	61,360	3,130	OK
2	-1,700			OK	59,534			OK
3	-1,620			OK	58,314			OK
4	-1,900			OK	62,241			OK
Test 3	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,710	-2,590	0,140	OK	73,795	73,610	0,310	OK
2	-2,480			OK	73,734			OK
3	-2,700			OK	73,775			OK
4	-2,460			OK	73,142			FLAG
Test 3	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,680	-1,760	0,230	OK	59,237	60,200	3,060	FLAG
2	-1,550			OK	57,171			FLAG
3	-1,730			OK	59,971			FLAG
4	-2,090			OK	64,430			OK
Test 3	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,970	2,990	0,090	OK	71,389	71,530	0,520	OK
2	3,119			OK	72,224			OK
3	2,900			OK	70,974			OK
4	2,991			OK	71,515			OK
Test 3	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,690	-2,840	0,320	FLAG	69,608	70,420	2,030	OK
2	-2,480			FLAG	68,039			OK
3	-2,960			FLAG	71,333			OK
4	-3,210			FLAG	72,697			OK



Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,574	3,350	0,300	OK	74,368	73,270	1,430	OK
2	3,614			OK	74,532			OK
3	3,196			OK	72,625			OK
4	3,000			OK	71,565			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,250	-2,080	0,190	OK	66,038	64,240	2,050	OK
2	-1,890			OK	62,117			OK
3	-2,240			OK	65,943			OK
4	-1,950			OK	62,850			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,444	3,660	0,230	OK	73,811	74,700	0,900	OK
2	3,875			OK	75,530			OK
3	3,842			OK	75,409			OK
4	3,496			OK	74,037			FLAG
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,390	-2,520	0,130	OK	67,295	68,300	0,980	FLAG
2	-2,450			OK	67,797			FLAG
3	-2,680			OK	69,538			FLAG
4	-2,550			OK	68,587			OK
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,883	3,590	0,350	OK	75,559	74,320	1,450	OK
2	3,883			OK	75,557			OK
3	3,221			OK	72,752			OK
4	3,360			OK	73,426			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,900	-2,130	0,250	FLAG	62,241	64,700	2,560	OK
2	-1,940			FLAG	62,731			OK
3	-2,350			FLAG	66,949			OK
4	-2,340			FLAG	66,861			OK

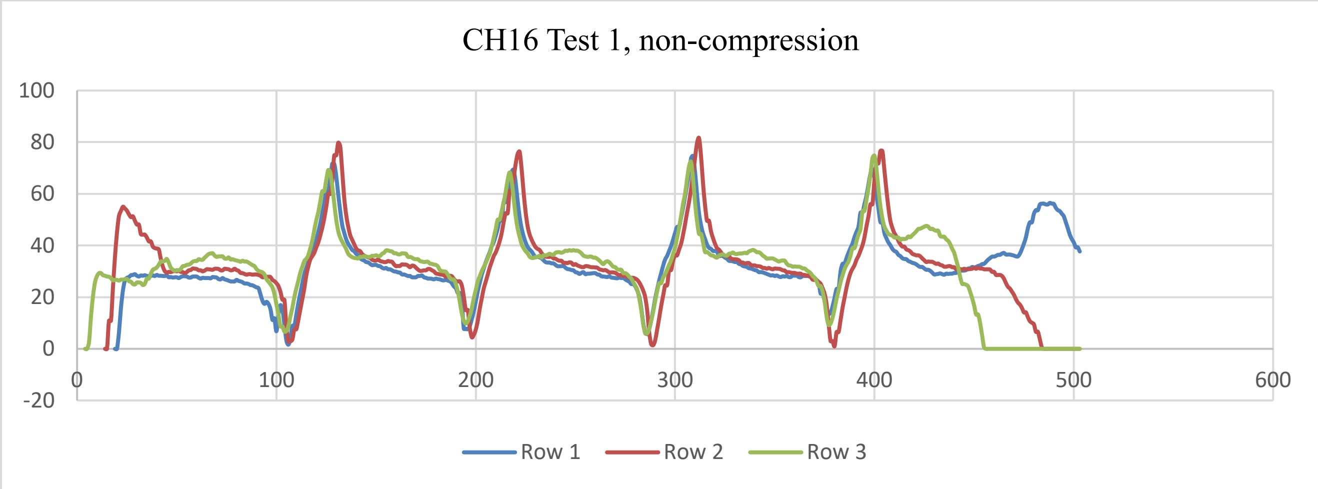


Test 2	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,529	3,380	0,210	OK	74,180	73,470	0,980	OK
2	3,548			OK	74,259			OK
3	3,326			OK	73,266			OK
4	3,109			OK	72,168			OK
Test 2	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,290	-2,150	0,180	OK	66,410	64,980	1,890	OK
2	-2,030			OK	63,775			OK
3	-2,330			OK	66,772			OK
4	-1,960			OK	62,969			OK
Test 2	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	4,288	4,130	0,250	OK	76,871	76,360	0,800	OK
2	3,950			OK	75,793			OK
3	4,400			OK	77,196			OK
4	3,884			OK	75,562			FLAG
Test 2	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,450	-2,600	0,120	OK	67,797	68,940	0,880	FLAG
2	-2,740			OK	69,950			FLAG
3	-2,610			OK	69,036			FLAG
4	-2,600			OK	68,962			OK
Test 2	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,288	3,430	0,100	OK	73,081	73,720	0,480	OK
2	3,496			OK	74,036			OK
3	3,408			OK	73,648			OK
4	3,517			OK	74,129			OK
Test 2	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,430	-2,370	0,080	FLAG	67,632	67,070	0,670	OK
2	-2,430			FLAG	67,632			OK
3	-2,320			FLAG	66,682			OK
4	-2,280			FLAG	66,318			OK

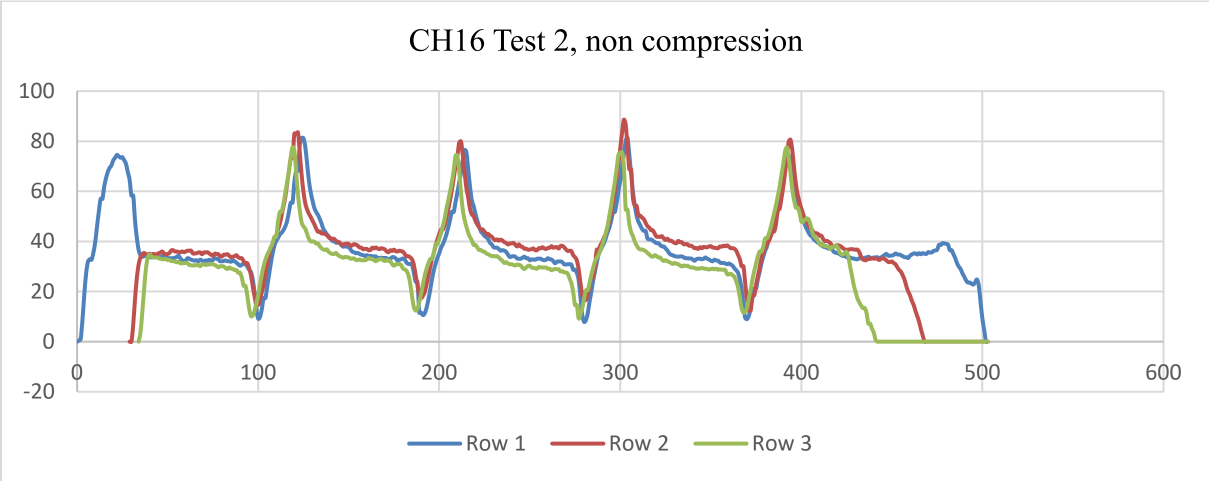


Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,470	3,220	0,210	OK	73,922	72,690	1,030	OK
2	3,300			OK	73,142			OK
3	3,025			OK	71,707			OK
4	3,074			OK	71,979			OK
Test 3	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,110	-2,130	0,130	OK	64,642	64,780	1,310	OK
2	-2,130			OK	64,851			OK
3	-2,290			OK	66,410			OK
4	-1,980			OK	63,204			OK
Test 3	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,836	3,910	0,130	OK	75,389	75,650	0,430	FLAG
2	4,100			OK	76,293			OK
3	3,864			OK	75,490			FLAG
4	3,846			OK	75,425			FLAG
Test 3	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,550	-2,620	0,060	OK	68,587	69,070	0,420	FLAG
2	-2,690			OK	69,608			OK
3	-2,600			OK	68,962			FLAG
4	-2,620			OK	69,109			OK
Test 3	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,242	3,320	0,080	OK	72,856	73,230	0,380	OK
2	3,404			OK	73,630			OK
3	3,370			OK	73,470			OK
4	3,265			OK	72,972			OK
Test 3	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,580	-2,270	0,220	FLAG	68,814	66,050	2,010	OK
2	-2,230			FLAG	65,847			OK
3	-2,200			FLAG	65,556			OK
4	-2,050			FLAG	63,997			OK

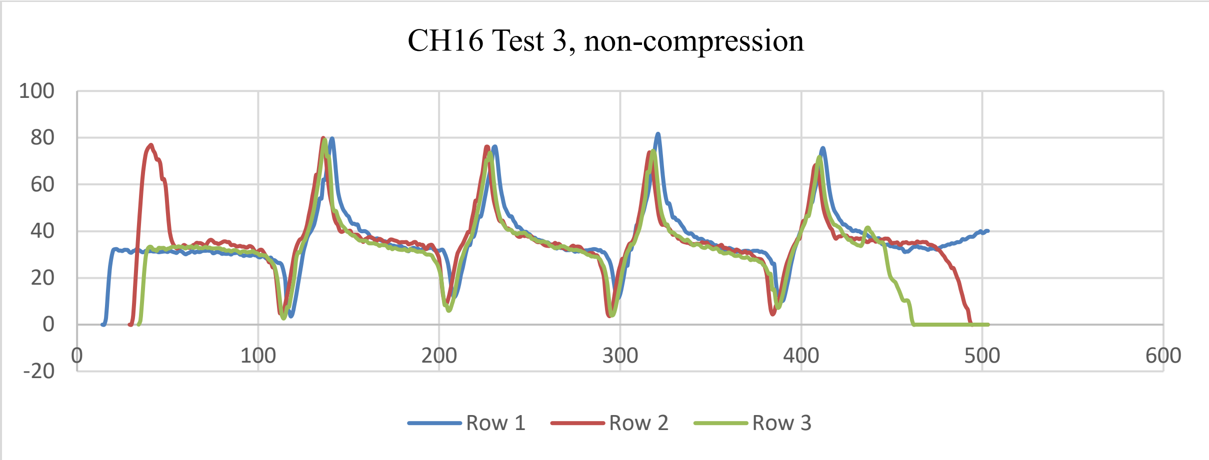
Appendix H - Friction values and graphs for CH16



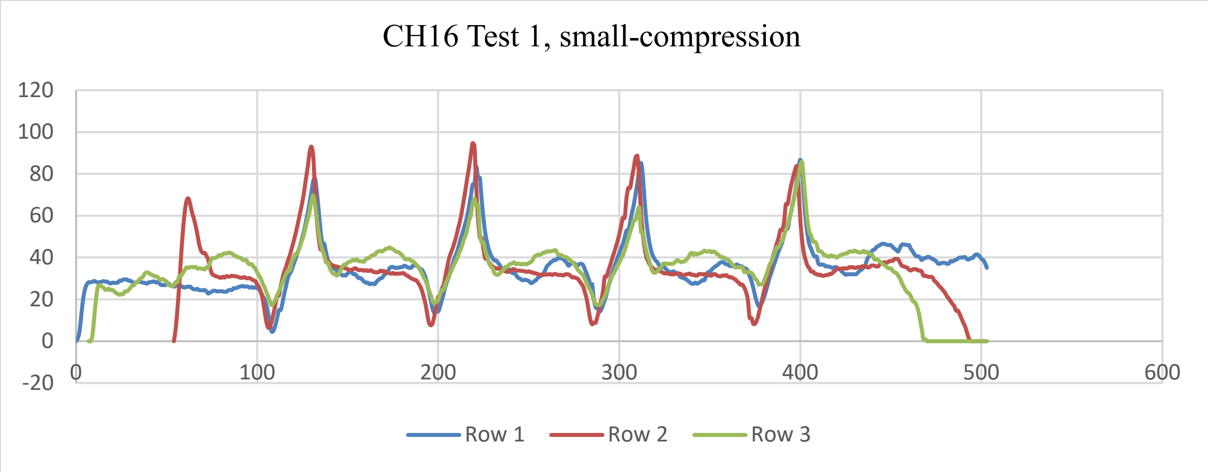
Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,043	2,820	0,240	OK	71,811	70,360	1,570	OK
2	2,683			OK	69,556			OK
3	2,996			OK	71,540			OK
4	2,545			OK	68,552			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1		-1,810	0,300	OK		60,780	4,180	OK
2	-1,880			OK	61,991			OK
3	-2,070			OK	64,215			OK
4	-1,490			OK	56,133			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,204	3,210	0,210	OK	72,667	72,640	1,030	OK
2	2,992			OK	71,517			OK
3	3,487			OK	73,998			OK
4	3,150			OK	72,387			OK
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,500	-2,510	0,110	OK	68,199	68,250	0,880	OK
2	-2,360			OK	67,036			OK
3	-2,610			OK	69,036			OK
4	-2,570			OK	68,739			OK
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,841	2,840	0,150	OK	70,608	70,580	0,930	OK
2	2,659			OK	69,390			OK
3	3,018			OK	71,669			OK
4	2,848			OK	70,652			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,210	-2,150	0,150	FLAG	65,654	64,990	1,510	OK
2	-2,000			FLAG	63,4349			OK
3	-2,330			FLAG	66,771			OK
4	-2,060			FLAG	64,106			OK



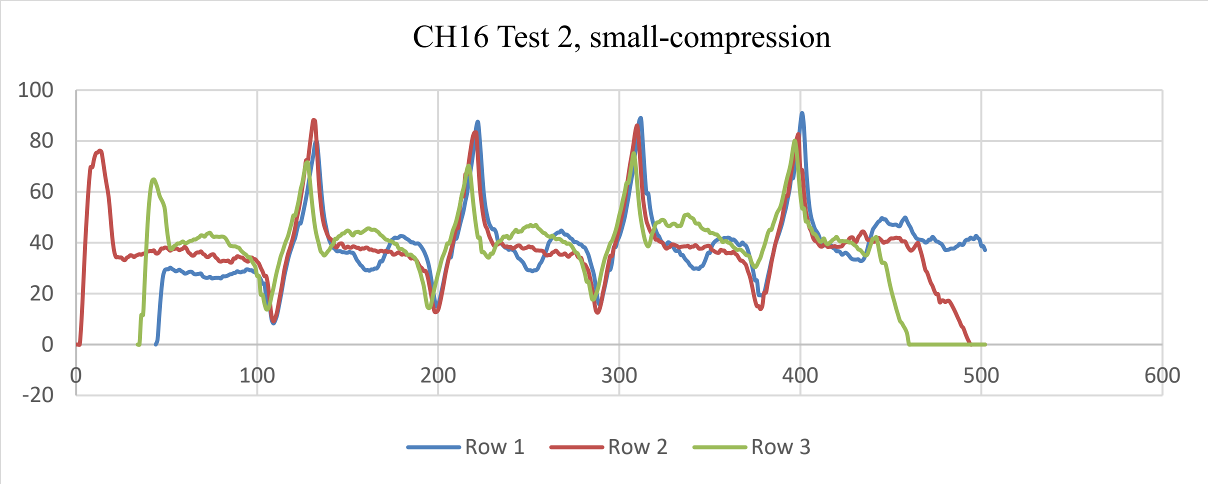
Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,880	2,870	0,150	OK	70,852	70,740	0,920	OK
2	2,830			OK	70,542			OK
3	3,058			OK	71,894			OK
4	2,700			OK	69,677			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,110	-2,210	0,070	OK	64,642	65,610	0,730	OK
2	-2,210			OK	65,654			OK
3	-2,290			OK	66,410			OK
4	-2,220			OK	65,751			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,514	3,220	0,310	OK	74,113	72,650	1,610	OK
2	2,841			OK	70,608			OK
3	3,429			OK	73,740			OK
4	3,100			OK	72,121			OK
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,860	-2,060	0,300	OK	61,736	63,780	3,040	OK
2	-1,850			OK	61,607			OK
3	-2,020			OK	63,662			OK
4	-2,490			OK	68,119			OK
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,926	2,780	0,100	OK	71,132	70,200	0,650	OK
2	2,691			FLAG	69,617			OK
3	2,758			OK	70,073			OK
4	2,746			OK	69,989			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-1,880	-1,830	0,080	OK	61,991	61,250	1,150	OK
2	-1,850			OK	61,607			OK
3	-1,870			FLAG	61,864			OK
4	-1,700			FLAG	59,534			OK



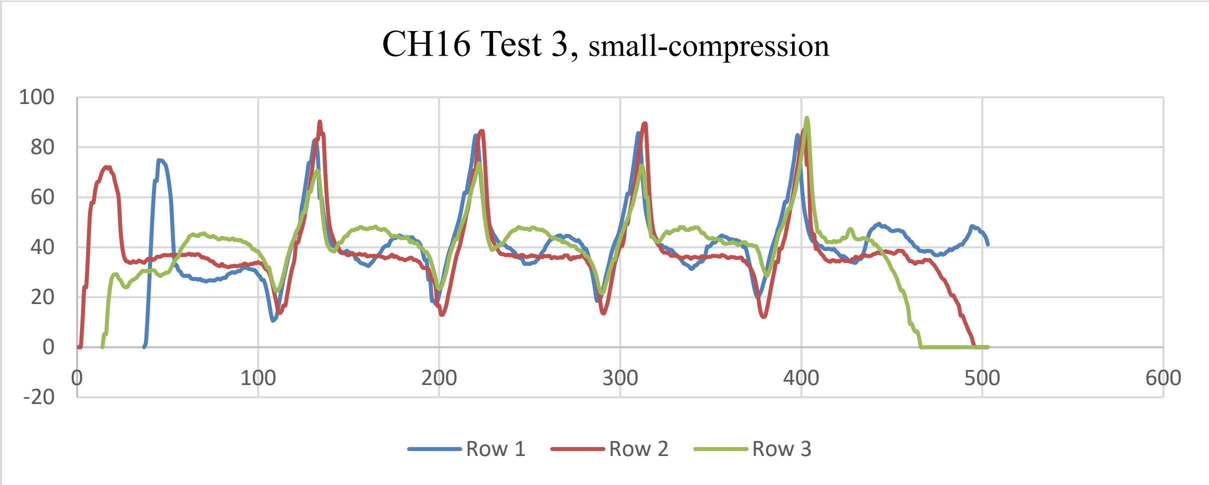
Test 3	Row 1	**Exit**							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag	
1	3,309	3,070	0,230	OK	73,183	71,880	1,260	OK	
2	2,800			OK	70,346			OK	
3	3,191			OK	72,600			OK	
4	2,973			OK	71,408			OK	
Test 3	Row 1	**Entry**							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag	
1	-2,410	-2,130	0,190	OK	69,746	68,840	1,010	OK	
2	-1,990			OK	68,039			OK	
3	-2,030			OK	69,677			OK	
4	-2,070			OK	67,878			OK	
Test 3	Row 2	**Exit**							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag	
1	3,125	3,010	0,240	OK	72,255	71,530	1,440	OK	
2	3,055			OK	71,873			OK	
3	3,186			OK	72,576			OK	
4	2,663			OK	69,414			OK	
Test 3	Row 2	**Entry**							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag	
1	-2,710	-2,590	0,140	OK	59,237	60,200	3,060	OK	
2	-2,480			OK	57,171			OK	
3	-2,700			OK	59,971			OK	
4	-2,460			OK	64,430			OK	
Test 3	Row 3	**Exit**							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag	
1	3,322	3,070	0,230	OK	73,246	71,870	1,300	OK	
2	2,939			OK	71,210			OK	
3	3,195			OK	72,623			OK	
4	2,809			OK	70,402			OK	
Test 3	Row 3	**Enry**							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag	
1	-2,700	-2,390	0,310	OK	69,677	67,050	2,890	OK	
2	-2,390			OK	67,295			OK	
3	-2,510			OK	68,277			OK	
4	-1,960			OK	62,969			OK	



Test 1	Row 1	**Exit**						
Eyelet	K	Average	STD	Flag	***θ***	Average	STD	Flag
1	3,050	3,050	0,020	OK	71,847	71,870	0,130	OK
2	3,039			OK	71,787			OK
3	3,087			OK	72,051			OK
4	3,039			OK	71,787			OK
Test 1	Row 1	**Entry**						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-2,090	-2,140	0,180	OK	64,430	64,830	1,860	OK
2	-2,270			OK	66,225			OK
3	-2,280			OK	66,318			OK
4	-1,910			OK	62,365			OK
Test 1	Row 2	**Exit**						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	3,588	3,450	0,240	OK	74,424	73,780	1,080	OK
2	3,722			OK	74,960			OK
3	3,220			OK	72,747			OK
4	3,270			OK	72,994			OK
Test 1	Row 2	**Entry**						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-2,360	-2,240	0,100	OK	67,036	65,890	0,910	OK
2	-2,210			OK	65,654			OK
3	-2,250			OK	66,038			OK
4	-2,130			OK	64,851			OK
Test 1	Row 3	**Exit**						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	2,278	2,270	0,130	OK	66,302	66,210	1,200	OK
2	2,264			OK	66,166			OK
3	2,118			OK	64,728			OK
4	2,433			OK	67,659			OK
Test 1	Row 3	**Enry**						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-1,840	-1,500	0,470	OK	61,477	54,640	10,420	OK
2	-1,810			OK	61,080			OK
3	-1,520			OK	56,659			OK
4	-0,820			OK	39,352			OK



Test 2	Row 1	Exit						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	2,979	3,143	0,119	OK	71,444	72,336	0,643	OK
2	3,148			OK	72,376			OK
3	3,183			OK	72,556			OK
4	3,263			OK	72,964			OK
Test 2	Row 1	Entry						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-2,010	-2,213	0,238	OK	63,549	65,524	2,312	OK
2	-2,470			OK	67,959			OK
3	-2,360			OK	67,036			OK
4	-2,010			OK	63,549			OK
Test 2	Row 2	Exit						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	3,595	3,351	0,172	OK	74,457	73,355	0,781	OK
2	3,204			OK	72,669			OK
3	3,336			OK	73,315			OK
4	3,266			OK	72,979			OK
Test 2	Row 2	Entry						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-2,440	-2,098	0,257	OK	67,714	64,313	2,627	OK
2	-1,900			OK	62,241			OK
3	-2,150			OK	65,056			OK
4	-1,900			OK	62,240			OK
Test 2	Row 3	Exit						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	2,618	2,478	0,155	FLAG	69,095	67,975	1,293	OK
2	2,540			FLAG	68,517			OK
3	2,495			OK	68,164			OK
4	2,259			OK	66,123			OK
Test 2	Row 3	Enry						
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-2,040	-1,690	0,677	OK	63,886	56,342	14,769	OK
2	-2,100			OK	64,536			OK
3	-1,940			FLAG	62,731			OK
4	-0,680			OK	34,216			OK



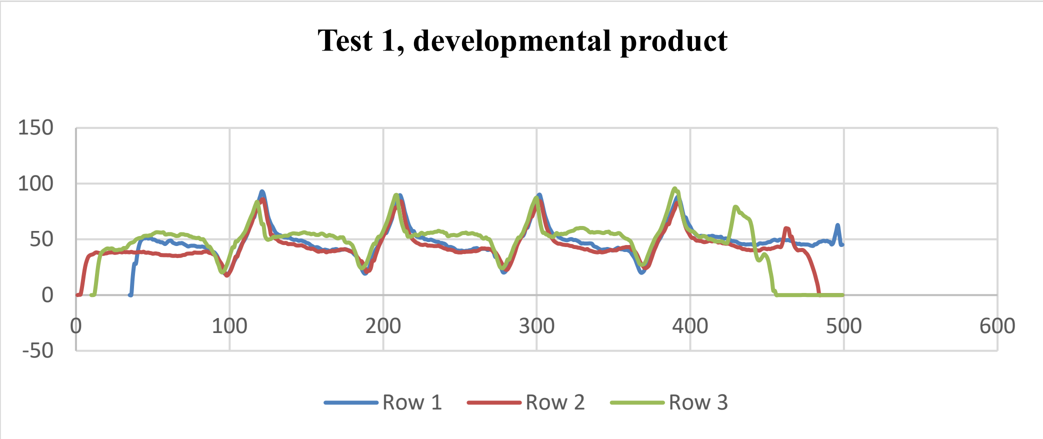
Test 3	**Row 1**	**Exit**						
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	2,996	2,978	0,0542	OK	71,541	71,435	0,313	OK
2	2,9217			OK	71,105			OK
3	3,045			OK	71,820			OK
4	2,950			OK	71,274			OK
Test 3	Row 1	**Entry**						
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	-2,020	-2,292	0,211	OK	63,662	66,317	2,004	OK
2	-2,50			OK	68,198			OK
3	-2,410			OK	67,464			OK
4	-2,240			OK	65,942			OK
Test 3	Row 2	**Exit**						
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	3,481	3,382	0,101	OK	73,975	73,519	0,468	OK
2	3,332			OK	73,293			FLAG
3	3,450			OK	73,835			OK
4	3,265			OK	72,972			FLAG
Test 3	Row 2	**Entry**						
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	-1,970	-2,062	0,171	OK	63,087	64,037	1,893	FLAG
2	-1,870			OK	61,863			FLAG
3	-2,170			OK	65,258			OK
4	-2,240			OK	65,942			OK
Test 3	Row 3	**Exit**						
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	2,096	2,394	0,337	OK	64,490	67,0917	2,677	OK
2	2,282			OK	66,334			OK
3	2,322			OK	66,706			OK
4	2,877			OK	70,835			OK
Test 3	Row 3	**Enry**						
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	-1,590	-1,525	0,192	OK	57,832	56,509	3,625	OK
2	-1,660			OK	58,934			OK
3	-1,610			OK	58,154			OK
4	-1,240			OK	51,115			OK

APPENDIX I – developmental product dimensions and calculations

Developmental product calculations

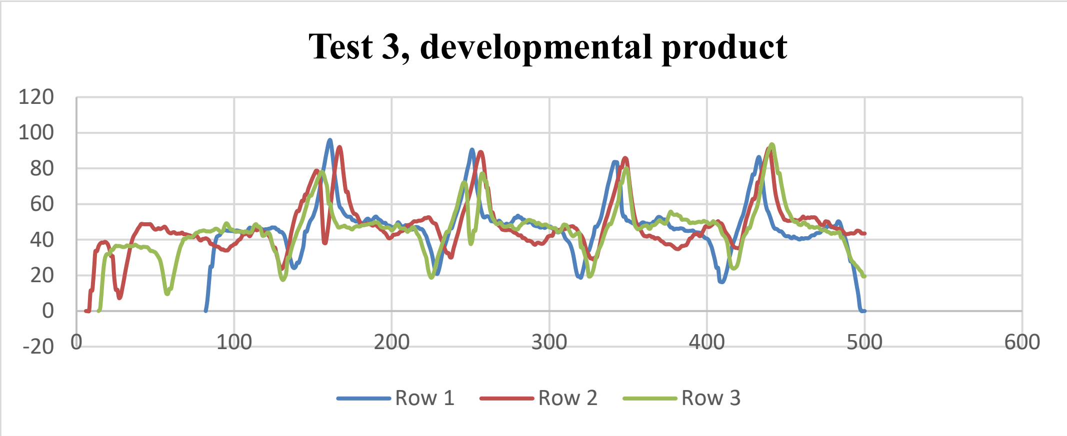
Sample	Row	Eyelet	X	Y	Y/X	X average	X std dev	Y average	Y std dev	Y/X average	Y/X std dev	Y/X - Y/X-average	Flag	%ΔR
Test 1	1	1.1	2,273	1,105	0,486	2,305	0,0408	1,1245	0,0372	0,4877063	0,0078	0,002	0	0,32%
		1.2	2,293	1,111	0,485							0,003	0	0,65%
		1.3	2,29	1,102	0,481							0,006	0	1,33%
		1.4	2,365	1,18	0,499							0,011	1	2,30%
	2	2.1	2,301	1,086	0,472	2,337	0,0328	1,129	0,0336	0,4830751	0,0080	0,011	1	2,30%
		2.2	2,342	1,132	0,483							0,000	0	0,06%
		2.3	2,325	1,13	0,486							0,003	0	0,61%
		2.4	2,379	1,168	0,491							0,008	0	1,63%
	3	3.1	2,306	1,131	0,490	2,310	0,0202	1,114	0,0192	0,482197	0,0070	0,008	0	1,71%
		3.2	2,312	1,095	0,474							0,009	0	1,78%
		3.3	2,287	1,1	0,481							0,001	0	0,25%
		3.4	2,336	1,13	0,484							0,002	0	0,32%
Test 2	1	1.1	2,321	1,106	0,477	2,314	0,0228	1,1215	0,0181	0,4847813	0,0079	0,008	0	1,70%
		1.2	2,286	1,107	0,484							0,001	0	0,11%
		1.3	2,307	1,143	0,495							0,011	1	2,20%
		1.4	2,34	1,13	0,483							0,002	0	0,39%
	2	2.1	2,293	1,103	0,481	2,308	0,0347	1,11875	0,0165	0,4846831	0,0030	0,004	0	0,75%
		2.2	2,281	1,114	0,488							0,004	0	0,76%
		2.3	2,3	1,116	0,485							0,001	0	0,11%
		2.4	2,359	1,142	0,484							0,001	0	0,12%
	3	3.1	2,294	1,098	0,479	2,335	0,0425	1,1155	0,0352	0,4776073	0,0075	0,001	0	0,22%
		3.2	2,334	1,108	0,475							0,003	0	0,60%
		3.3	2,319	1,089	0,470							0,008	0	1,68%
		3.4	2,394	1,167	0,487							0,010	0	2,06%
Test 3	1	1.1	2,288	1,088	0,476	2,305	0,0379	1,102	0,0158	0,4781099	0,0031	0,003	0	0,54%
		1.2	2,293	1,105	0,482							0,004	0	0,79%
		1.3	2,278	1,092	0,479							0,001	0	0,26%
		1.4	2,361	1,123	0,476							0,002	0	0,52%
	2	2.1	2,301	1,905	0,828	2,328	0,0371	1,3235	0,3882	0,5696108	0,1723	0,258	1	45,35%
		2.2	2,335	1,112	0,476							0,093	1	16,39%
		2.3	2,297	1,118	0,487							0,083	1	14,55%
		2.4	2,377	1,159	0,488							0,082	1	14,40%
	3	3.1	2,287	1,094	0,478	2,320	0,0368	1,11625	0,0167	0,4812152	0,0047	0,003	0	0,59%
		3.2	2,304	1,124	0,488							0,007	0	1,38%
		3.3	2,316	1,114	0,481							0,000	0	0,04%
		3.4	2,372	1,133	0,478							0,004	0	0,74%

APPENDIX J – Friction for developmental product



Developmental Test 1		**Entry**						
Test 1	**Row 1**							
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	-1,990	-2,040	0,042	OK	63,320	63,880	0,462	OK
2	-2,090			OK	64,430			OK
3	-2,030			OK	63,775			OK
4	-2,050			OK	63,997			OK
Test 1	Row 2							
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	-2,010	-1,883	0,094	OK	63,549	61,988	1,170	OK
2	-1,840			OK	61,477			OK
3	-1,790			OK	60,810			OK
4	-1,890			OK	62,117			OK
Test 1	Row 3							
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	-2,550	-2,478	0,215	OK	68,587	67,924	1,695	OK
2	-2,310			OK	66,592			OK
3	-2,750			OK	70,017			OK
4	-2,300			OK	66,501			OK
Developmental Test 1		Exit						
Test 1	Row 1							
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	3,368	3,076	0,217	OK	73,464	71,937	1,164	OK
2	3,065	3,076	0,217	OK	71,932	71,937	1,164	OK
3	3,026	3,076	0,217	OK	71,713	71,937	1,164	OK
4	2,846	3,076	0,217	OK	70,639	71,937	1,164	OK
Test 1	Row 2							
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	2,970	2,854	0,107	OK	71,389	70,671	0,672	OK
2	2,730			OK	69,885			OK
3	2,805			OK	70,376			OK
4	2,910			OK	71,035			OK
Test 1	Row 3							
Eyelet	**K**	**Average**	**STD**	**Flag**	***θ***	**Average**	**STD**	**Flag**
1	2,757	2,935	0,224	OK	70,060	71,119	1,266	OK
2	2,852			OK	70,679			OK
3	2,868			OK	70,779			OK
4	3,262			OK	72,956			OK

Developmental Test 2	Entry							
Test 2	Row 1							
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-2,100	-1,958	0,158	OK	64,537	62,847	1,950	OK
2	-1,950			OK	62,850			OK
3	-2,040			OK	63,886			OK
4	-1,740			OK	60,113			OK
Test 2	Row 2							
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-2,140	-2,175	0,057	OK	64,954	65,299	0,563	OK
2	-2,140			OK	64,954			OK
3	-2,260			OK	66,132			OK
4	-2,160			OK	65,158			OK
Test 2	Row 3							
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	-2,684	-2,651	0,054	OK	69,566	69,328	0,387	OK
2	-2,610			OK	69,036			OK
3	-2,600			OK	68,962			OK
4	-2,710			OK	69,746			OK
Developmental Test 2	Exit							
Test 2	Row 1							
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	3,050	3,073	0,318	OK	71,847	71,858	1,645	OK
2	2,829			OK	70,533			OK
3	2,883			OK	70,872			OK
4	3,529			OK	74,180			OK
Test 2	Row 2							
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	2,468	2,805	0,249	OK	67,942	70,276	1,682	OK
2	2,846			OK	70,639			OK
3	3,070			OK	71,955			OK
4	2,835			OK	70,569			OK
Test 2	Row 3							
Eyelet	K	Average	STD	Flag	*θ*	Average	STD	Flag
1	2,708	2,884	0,127	OK	69,734	70,852	0,802	OK
2	2,909			OK	71,030			OK
3	3,014			OK	71,643			OK
4	2,904			OK	71,001			OK



Developmental Test 3		Entry						
Test 3	Row 1							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,150	-2,330	0,168	OK	65,056	66,703	1,504	OK
2	-2,510			OK	68,277			OK
3	-2,230			OK	65,847			OK
4	-2,430			OK	67,632			OK
Test 3	Row 2							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,030	-1,693	0,330	OK	63,775	58,862	5,260	OK
2	-1,860			OK	61,736			OK
3	-1,610			OK	58,155			OK
4	-1,270			OK	51,783			OK
Test 3	Row 2							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	-2,650	-2,510	0,203	OK	69,326	68,192	1,642	OK
2	-2,690			OK	69,608			OK
3	-2,250			OK	66,038			OK
4	-2,450			OK	67,797			OK
Developmental Test 3		Exit						
Test 3	Row 1							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	3,122	3,037	0,160	OK	72,238	71,739	0,930	OK
2	3,168			OK	72,482			OK
3	2,809			OK	70,402			OK
4	3,048			OK	71,835			OK
Test 3	Row 2							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,505	2,850	0,253	OK	68,234	70,570	1,668	OK
2	3,100			OK	72,121			OK
3	2,850			OK	70,665			OK
4	2,947			OK	71,259			OK
Test 3	Row 3							
Eyelet	K	Average	STD	Flag	θ	Average	STD	Flag
1	2,424	2,601	0,154	OK	67,582	68,924	1,135	OK
2	2,552			OK	68,605			OK
3	2,635			OK	69,216			OK
4	2,792			OK	70,294			OK

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