Absorption & Transfer Rate of Sweat Properties from Pelvic Human Skin to Space Underwear during 1G, Hyper and Micro Gravity Conditions – Searching for Suitable Fabric as Space Underwear

Captain Dr. Mohd Harridon[1], Mohd Helmy Hashim[2], Mhd. Fairos Asillam[3], Muhammad Syafiq[4], Ahmad Marzuqi[5]

[1]Universiti Kuala Lumpur, mdharridon@unikl.edu.my

[2]ANGKASA, helmy@angkasa.gov.my

[3]ANGKASA, fairos@angkasa.gov.my

[4]Universiti Kuala Lumpur

[5]Universiti Kuala Lumpur

Abstract

The team from Universiti Kuala Lumpur is in the midst of developing a better Space Underwear and to achieve it several testing and experimentations were actuated to search for a suitable fabric. The experimentations include testing of fabrics during hyper and microgravity conditions and also 1 G condition. Hyper and micro gravity conditions were achieved through Parabolic Flights in Japan. 4 fabrics were tested and overall aramid had shown the potential as the most suitable fabric for Space Underwear. This paper elucidates the experimentations and their results. We also delineated the anomalies that were found during our experimentations.

Introduction

Astronauts that transverse space are equipped with special attires in order to protect them and keep them in optimum conditions. One of the attires is Space Underwear which is designed for optimum hygienic purposes and comfort.

The Parabolic Flights that we had actuated in Japan were of the purpose of collecting micro and hyper gravity data of different fabrics or materials of Space Underwear. The data of the different fabrics that we had collected were analyzed to support our quest of developing a better Space Underwear and answering the question which fabric is suitable for the fabrication of Space Underwear.

The flights were also of great importance as we were able to observe the characteristics of different fabrics in micro and hyper gravity conditions. During the experimentation, artificial sweat were protruded out from the artificial human pelvic skin onto the fabrics (materials) of the Space Underwear. Data of the absorption and transfer rate of sweat were collected via sensors attached to the fabrics.

Current Space Underwear

Currently there exist space underwears which are worn by astronauts. Jockey is one of the companies that manufactured underwears for astronauts [1]. These underwears are usually made of cotton [2]. Thus cotton is denoted as the "baseline fabric" where other materials are compared against cotton.

Materials of Underwear that were Tested during Experimentations

We had tried 3 different materials which are not cotton and we had observed whether these 3 materials are better or not from cotton. We had actuated the experiment at 3 different orientations (vertical, horizontal, and 45° position). The 3 different materials are stated below along with their properties. They were chosen based upon these properties.

<u>Modacrylic</u> : Soft, Resilient, Abrasion Resistent, Flame Resistent, Quick Drying, Resistant to Acid and Alkalies, Shape Retentive

<u>Aramid</u> : Resistant to Solvents and Heat, Rigid, Straight, High Melting, Largely Insoluble Molecules, High Performance Fibres, Flame Proof Protective Clothing, High Strength Fibre

<u>Olefin</u> : Abrasion Resistant, Stain Resistant, Sunlight Resistant, Fire Resistant, Chemical Resistant, Low Melting Point, Keeps its Strength in Wet or Dry Conditions, Very Resilient

As mentioned earlier, cotton is the material currently used for the fabrication of Space Underwear. In lieu with this, we had included cotton in our parabolic experiment since it is important to compare data from similar environment.

Mathematical Equation governing the Experimentations

Washburn Equation, which is shown below, governs our experiment.

$$L^2 = (\gamma\, d\, t) / (4 \mu)$$

L is the distance a liquid has travelled in time *t* , γ is the surface tension of the liquid, *d* is the pore diameter, and μ is the liquid viscosity. This can be re-written in terms of the mass (M) of fluid absorbed, the permeability, *K* , and driving pressure Δ*P*.

$$M = \rho\, T\, W \quad \sqrt{(2K\, \Delta P / \mu)} \quad \sqrt{t}$$

T and *W* are the thickness and width of the porous material and ρ is the liquid density, and the relationship of fluid absorbed vs. time is a square root relationship for a one-dimensional linear flow [3]. Our experiment would measure the values of M which indirectly is the transfer rate of sweat. All other parameters of the equation are controlled parameters. We have a simplistic view and postulated that a change in gravitational value would affect the driving pressure Δ*P*, thus altering the value of M.

Pressure as equated by (mass * gravitational acceleration)/area and (mass * gravitational acceleration * height) comprises of the gravitational component [4][5].

We also take into account radial absorption. The equation of radial absorption is shown below.

$$Q = 2\pi KT(P_f - P_i) / [\ \mu \ln(R_f/R_i)\ ]$$

Q = flow rate

K = permeability

T = thickness

P_f = pressure fluid front

P_i = pressure fluid inlet

μ = fluid viscosity

R_f = radius of fluid front

R_i = radius of fluid inlet

As stated earlier, the change of gravitational value would affect the pressure, thus the change would also affect P_f and P_i which would affect the values of R_f and R_i . R_f and R_i are parameters that represent radial absorption [6] and we would measure or collect the values of these parameters in the experiment. We also see the importance of taking into account the penetration of the sweat onto the fabric and the rate and amount of penetration depend upon the permeability of the fabric which is represented by the symbol K in the equation above.

Setup of Experimentation

The general layout of the experimentation is shown in Figure 1.

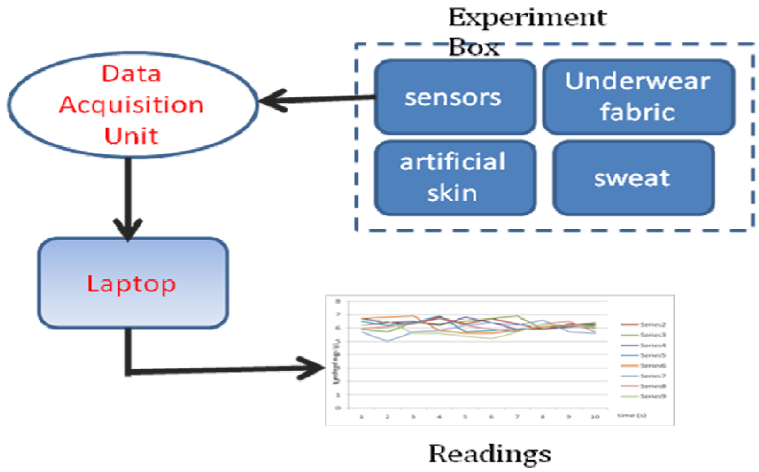

Figure 1. General Layout of the Experimentation

From Figure 1, data collected by the sensors were sent to the Data Acquisition Unit (DAU) which is connected to a laptop. The laptop had stored these data for further analyses.

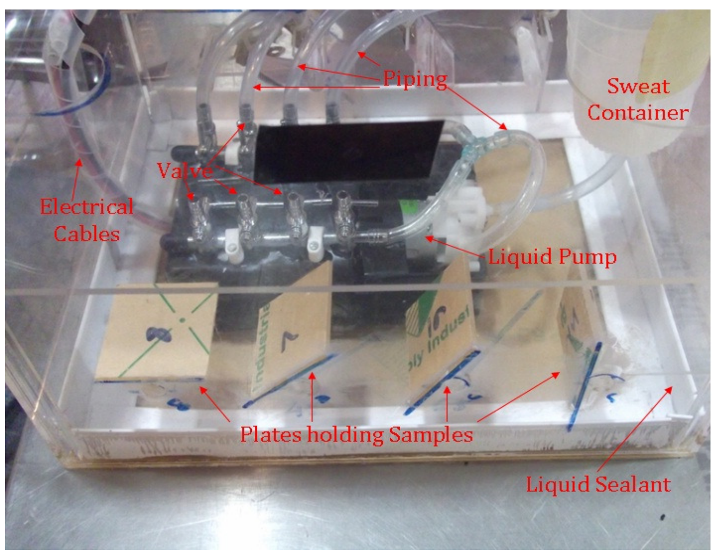

Figure 2. The Discreet Layout of the Experimentation

From Figure 2, we can observe plates which hold the different fabrics. The plates were at angles 0 degrees, 45 degrees, 60 degress, and 90 degrees. Overall there were 8 plates (shown in the picture were only 4 plates) which hold 4 different fabrics (cotton, modacrylic, aramid, and olefin). The plates also hold the artificial human pelvic skin.

The artificial sweat was hold in the container and was pumped onto the plate (the orientation was from the artificial skin to the underwear fabric) by the liquid pump at an interval of once every 20 minutes starting from the takeoff till the landing of the aircraft.

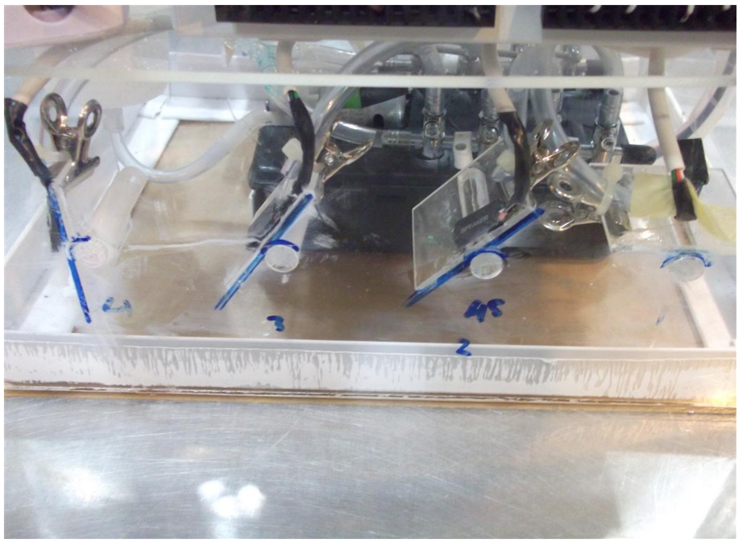

Figure 3. Sensors Attached to the Plates

As shown in Figure 3, the sensors were attached to the plates. The sensors sent data to the DAU (shown in the Figure 4) which functioned as a collector of signals.

Figure 4. The Data Acquisition Unit

The experimentation was automated where the system is ON throughout the parabolic flight and data were constantly collected from the takeoff till the landing of the aircraft. Hence our laptop had collected data of 1G, micro and hyper gravity.

Result of Experimentations

There were 2 flights and we had managed to successfully record data of 8 parabolic cycles of each flight (each flight consisted of more than 8 parabolic cycles but we had encountered several anomalies which gave us useful data of only 8 parabolic cycles of each flight).

All fabrics had encountered micro and hyper gravity and also 1G environment during the 2 flights. All the fabrics were put at 0, 45, 60, and 90 degrees orientation during the 2 flights. Since the data collected were enormous, the graphs shown in this section represent average results of all 8 parabolic cycles of the 2 flights.

<u>Microgravity</u>

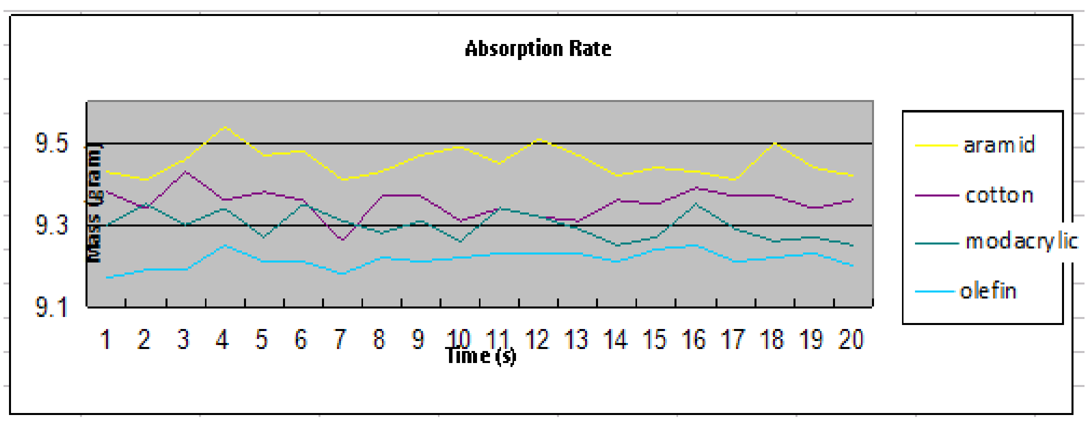

Figure 5. Fabrics at 0 Degrees Orientation

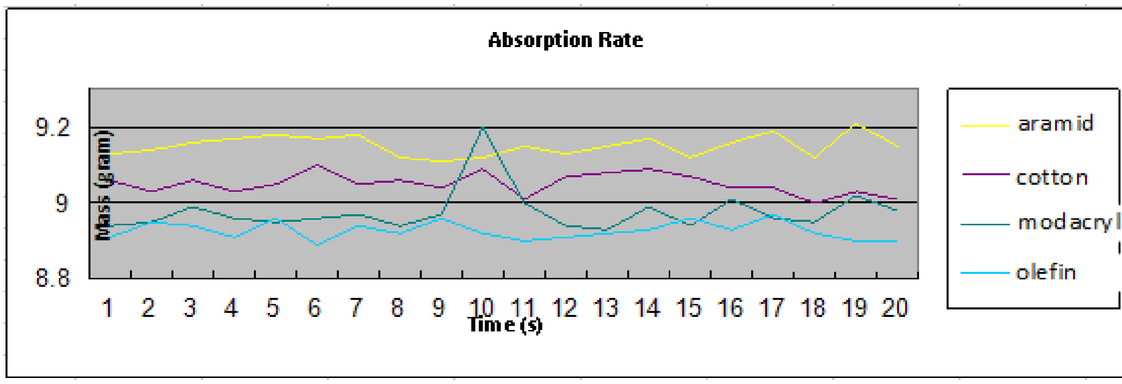

Figure 6.   Fabrics at 45 Degrees Orientation

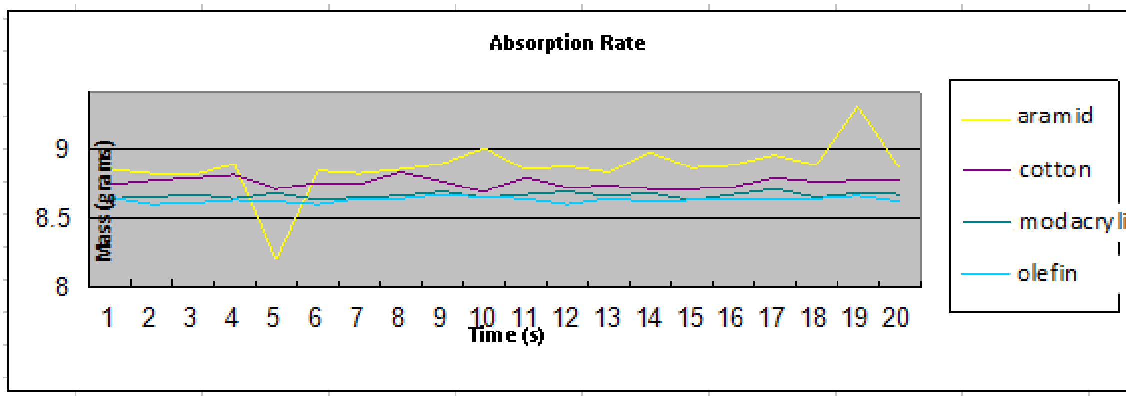

Figure 7.   Fabrics at 60 Degrees Orientation

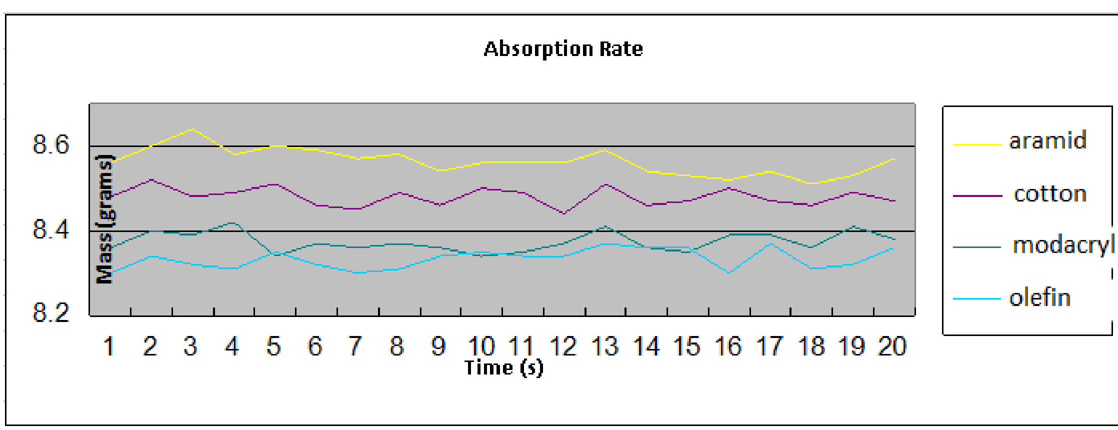

Figure 8.   Fabrics at 90 Degrees Orientation

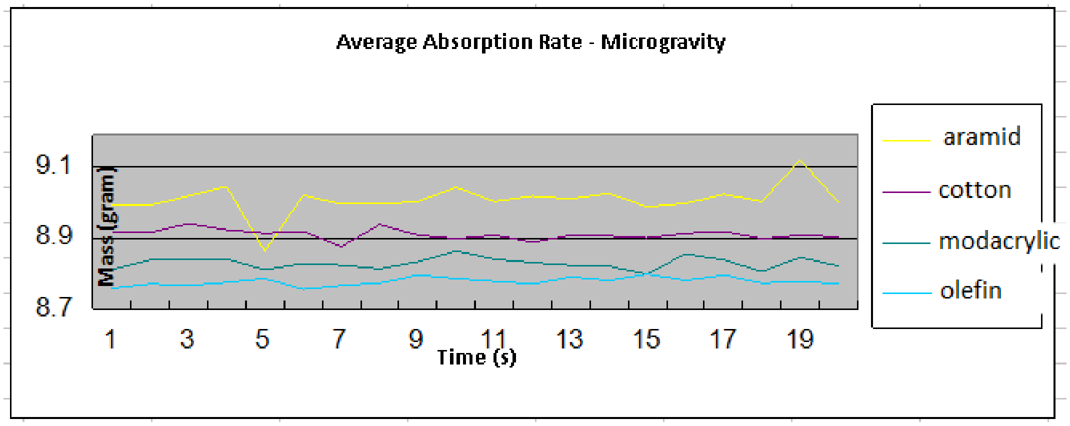

Figure 9. Average of All Orientations

<u>Hypergravity</u>

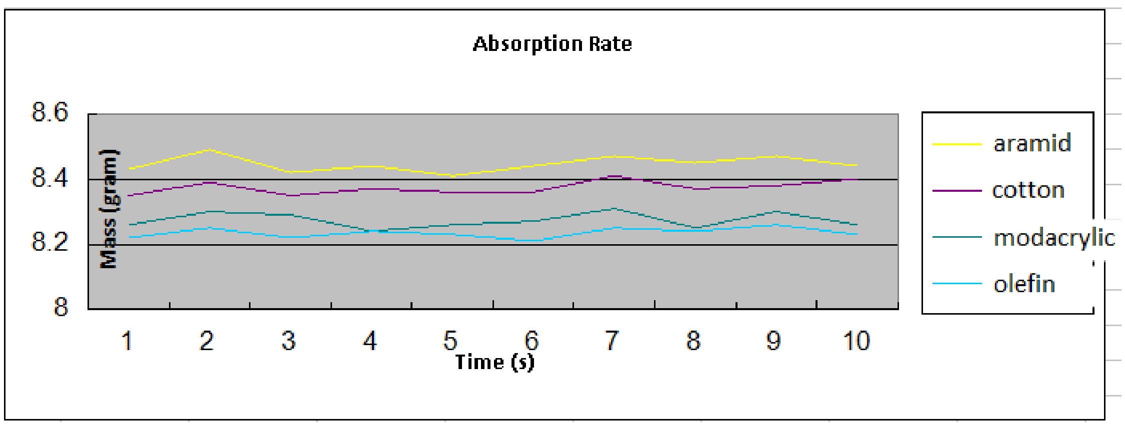

Figure 10. Fabrics at 0 Degrees Orientation

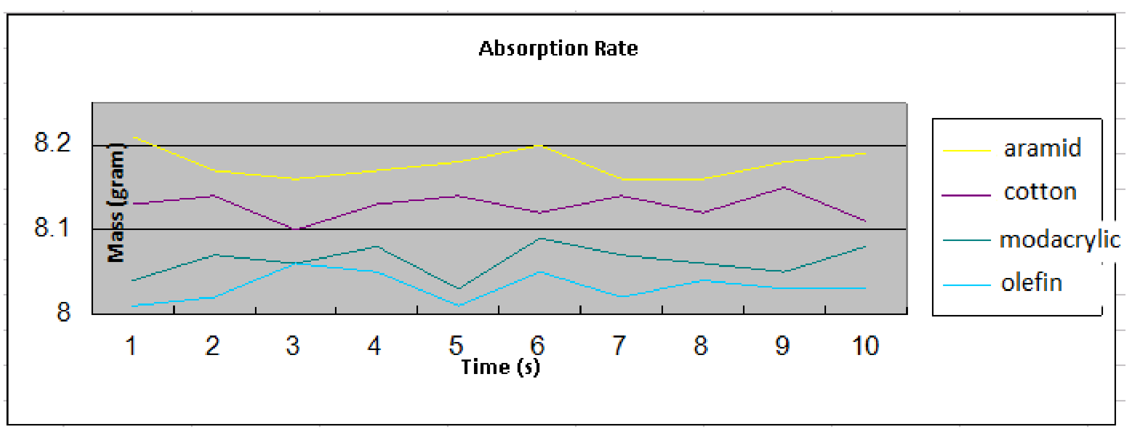

Figure 11. Fabrics at 45 Degrees Orientation

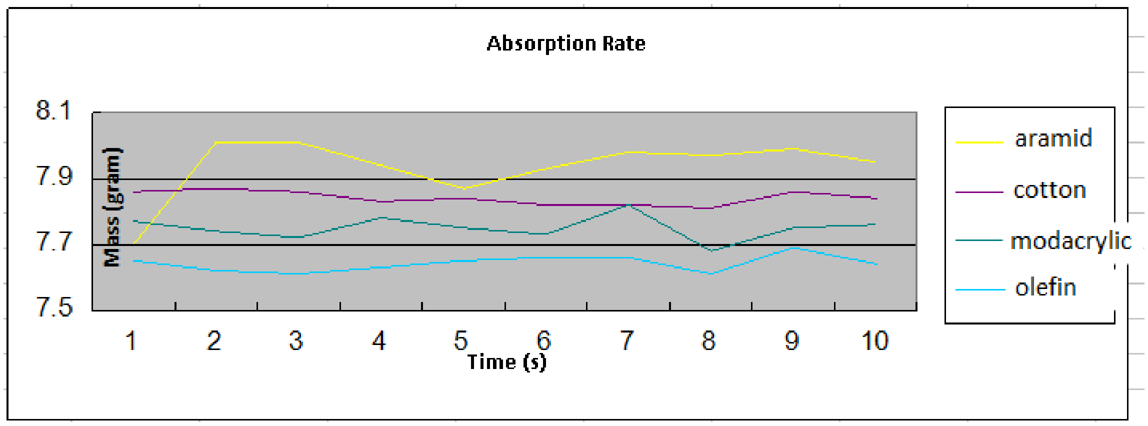

Figure 12. Fabrics at 60 Degrees Orientation

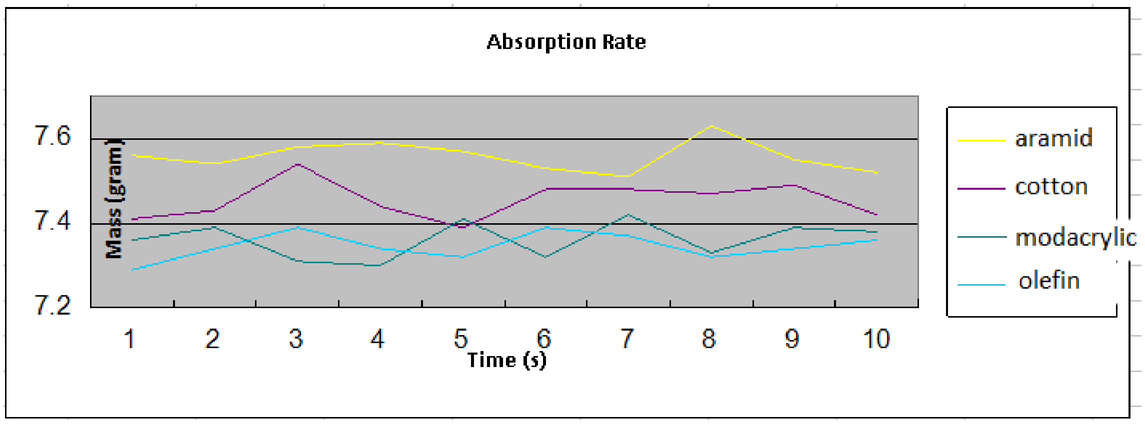

Figure 13. Fabrics at 90 Degrees Orientation

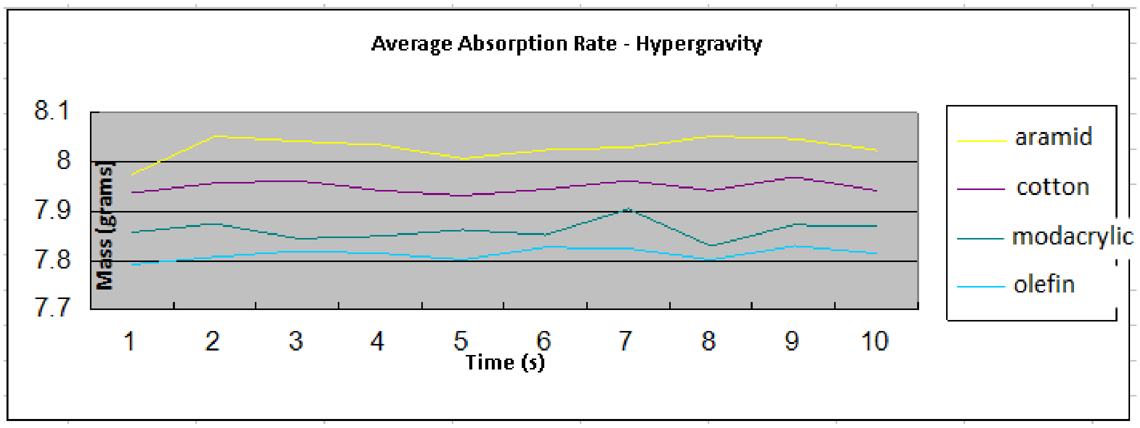

Figure 14. Average of All Orientations

1 G

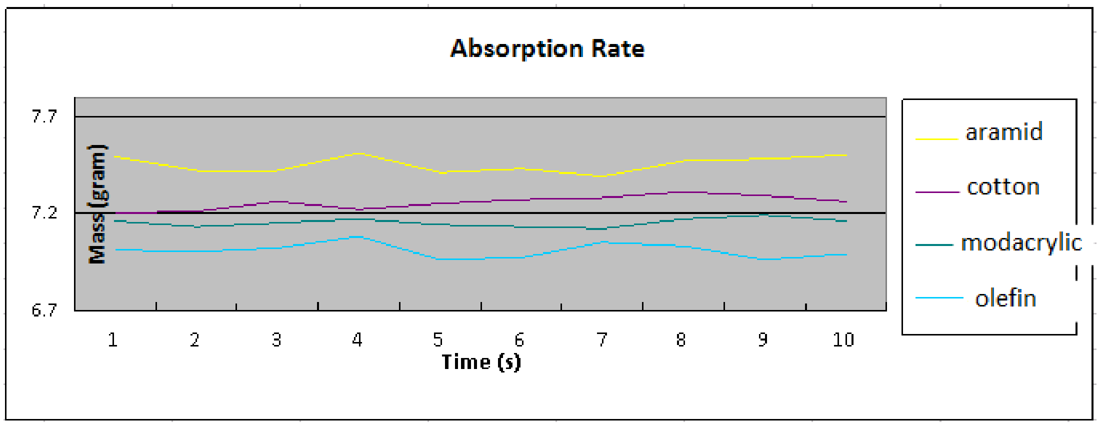

Figure 15. Fabrics at 0 Degrees Orientation

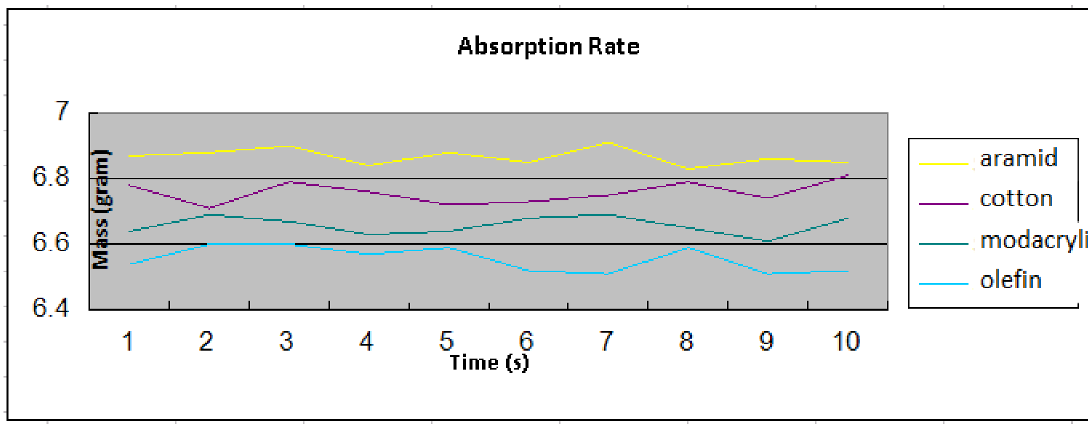

Figure 16. Fabrics at 45 Degrees Orientation

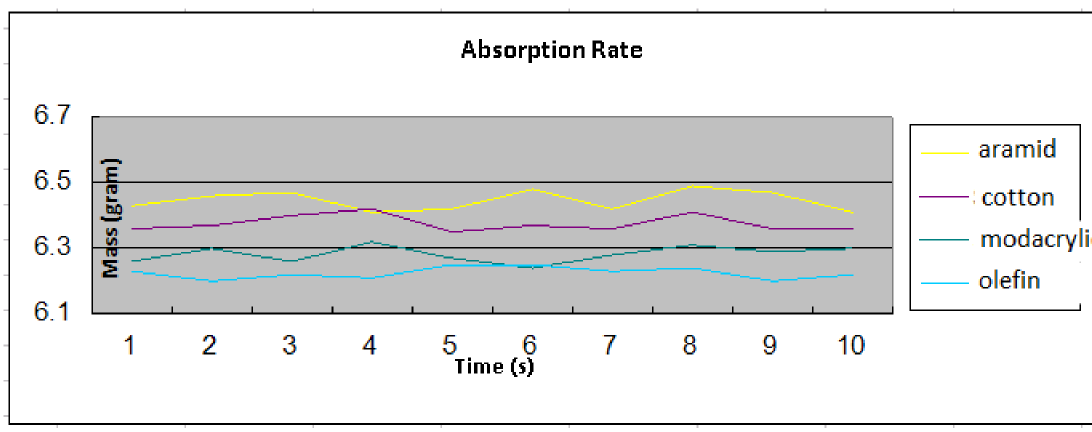

Figure 17. Fabrics at 60 Degrees Orientation

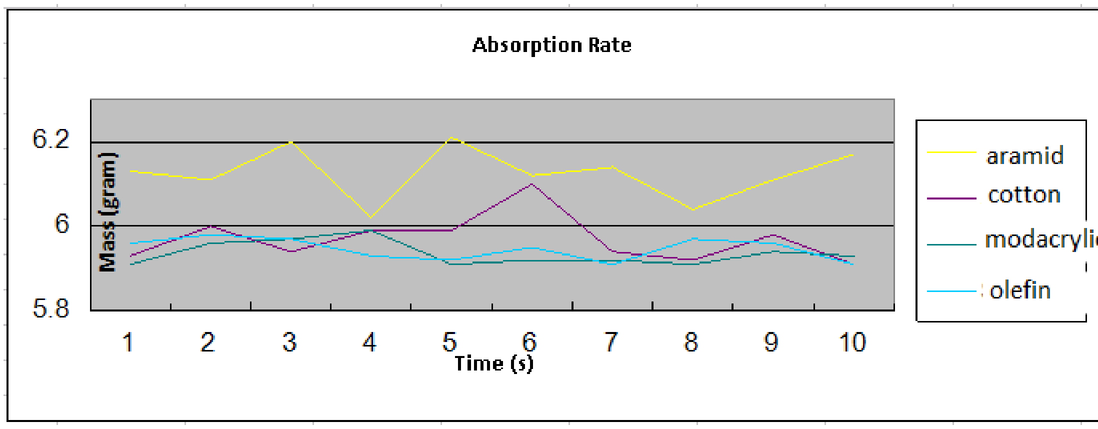

Figure 18. Fabrics at 90 Degrees Orientation

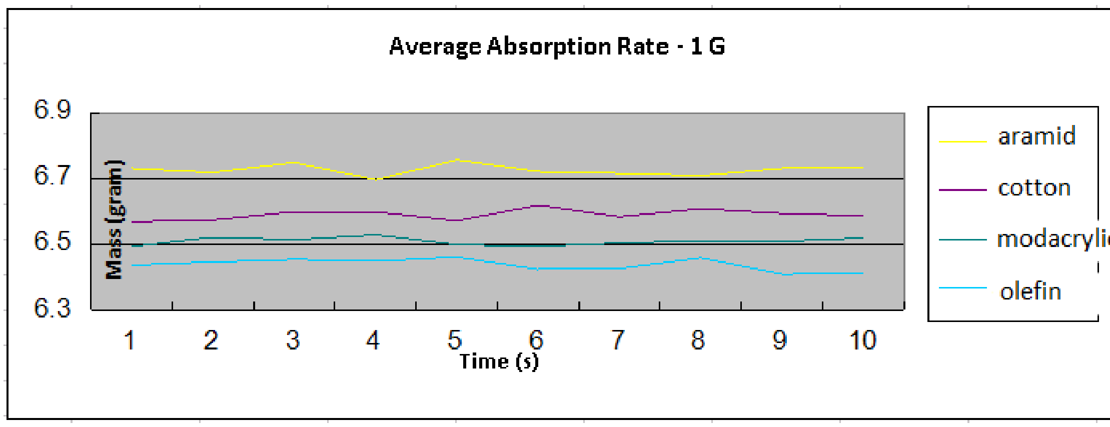

Figure 19. Average of All Orientations

Observation and Conclusion

During microgravity, for all orientations (0 degrees, 45 degrees, 60 degrees, and 90 degrees), aramid had shown to be the fabric that absorbed high amount of mass as compared to other fabrics. This is evidently shown in figures 5, 6, 7, and 8. Figure 9 shows the average of all orientations in microgravity condition and aramid had also demonstrated that it had absorbed high amount of mass as compared to other fabrics.

We also observed anomalies in the readings. In figure 6, there is a spike at time 10 seconds where modacrylic had gained mass tremendously in the short period of time.

Perhaps this is due to sudden misalignment of sensor but we are not fully certain. This pattern repeated itself in figure 7 at time 5 seconds where aramid had a sudden drop in mass absorption.

During hypergravity, olefin showed that it has the characteristics of absorbing the least amount of mass as compared to other fabrics for all orientations (0 degrees, 45, degrees, 60 degrees, and 90 degrees). We however noticed that aramid still retained its title of absorbing high amount of mass as compared to other fabrics, also for all orientations.

We found one anomaly during hypergravity which is shown in figure 12 where during 60 degrees orientation from 1 second to 2 seconds, there was a tremendous rise of absorption for aramid. We are somehow perplex and could not offer any explanation at this moment.

During 1 G, aramid showed that it had the highest absorption rate among the fabrics in all orientations (0 degrees, 45 degrees, 60 degrees, and 90 degrees) but at the orientation of 90 degrees, the absorption rate of aramid was fluctuating wildly. The rate was not constant and values shifted between 6 and 6.2 grams.

Cotton at 90 degrees orientation during 1 G had also shown fluctuation but not as wild as aramid. We perhaps could call this little fluctuation of cotton as an anomaly with one prominent spike as shown in figure 18 (time at 6 second). Perhaps this is also due to misalignment of the sensor.

By looking at all the average results from figures 9, 14, and 19, we can observe that aramid has the best absorption properties among all the fabrics and olefin has the least. We caution however that data were from 16 parabolic cycles only (8 on the first day and 8 on the second day). Data from other cycles were corrupted thus we were left with only 16 parabolic cycles of usable data.

With that caveat we recommend the usage of aramid for the development of Space Underwear based upon the circumstances of data that we managed to collect. Our recommendation would however change if more data collected shows otherwise. Our recommendation seems one sided as it took into account only absorption rate as the primary criteria of selection. We thus made several recommendation to aid us in the selection of appropriate fabric in the future.

Recommendation

We recommend more parabolic flights are carried out in order to collect more data and give a more holistic picture on the suitability of the fabric. Currently, aramid is the best but perhaps with more data, the situation could change.

We also recommend adding another criteria of measurement such as retention rate. Retention rate would measure the amount of liquid that a fabric would retain at a specific period of time. Along with absorption rate, the combination might be a concrete way of selecting the best fabric for Space Underwear.

In out experimentation, it was evidently shown that anomalies exist where we had deduced that perhaps sensor misalignment contributed to the anomalies. We recommend the installation of the sensors be done "rigidly" and additional sensors be installed to serve as backup and collect uncorrupted data if primary sensors fail

References

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