# Effect of- Islamic motif sizes and filament types- for 3D printing fabrics on drapeability properties

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## Abstract:

This study focuses on the great development in 3D printing materials and the possibility of using them in fabrics that can be employed in the field of fashion, which leads to the search for the effectiveness of these materials in terms of function. This research examines the drape ability of materials created by 3D printing with TPU filament with varying degrees of elasticity, and comes to work and benefit from previous experiences in this field and the search for its applicability to suit the functional aspect of fashion, which gives the ease of movement of the body, and thus feel comfortable.

the motifs used is inspired by Islamic art with varying sizes on tulle in order to know the material with the highest drape ability based on the size of units and the type of filaments used in 3D printing.

During the research 6 materials were created using the difference of size, TPU filament, and inspired by Islamic motif which were printed using 3D printing techniques which were printed at the Kyoto Design Lab, Kyoto Institute of Technology (KIT), Japan.

## Keywords:

Fabric drapeability, 3d printing, Islamic motif

## 1- Introduction:

The rise of fused deposition modeling (FDM) has disturbed the decades old methods of industrial manufacturing focused on injection molding. (Prasad, A. and Kandasubramanian, B., 2019)

And many thermoplastics have been developed to work with 3D printing with the introduction of modern methods, and Research has also led to creating a wide variety of new materials to accommodate a growing number of applications. (Stansbury, J.W. and Idacavage, M.J., 2016)

The problem of the research lies in Determining the effect of the material and the size of the printed motifs shapes on the fabrics,by using the Thermoplastic polyurethane (TPU) filaments

to employ them to create materials with drapeability, which is one of the most important factors of clothing comfort, through the use of 3D printing technology on the tulle fabric, so the research objectives lie in creating units inspired by Islamic art Using 3D printing and testing the effect of variation in motifs sizes and different degrees of elasticity of TPU filaments on the drapeability of the innovative material from the integration of 3D printing with tulle fabric.

The importance of the research lies in contributing to the development of the clothing materials industry in line with modern technology through the use of 3D printing to reach materials bearing 3D motifs that achieve the important drapeability of the clothing comfort, and knowing the extent to which this can be achieved and the possibility of developing it.

The research hypothesizes that the size of the motifs inspired by Islamic art and the flexibility of the TPU threads used in printing have a clear impact on the drapeability of the innovative materials by 3D printing on tulle.

**1-1- 3d printer type:**

In the end of the 20th century Scott Crump[1] worked for company named Stratasys, whose been founded in the 1980s (Bandyopadhyay, A. and Bose, S. eds., 2019), mainly the first to developed and applied FDM technology.

Many activities have been carried out by massively extending the variety of 3D printing tools that have existed alone in the hands of craftsmanship for decades, and can be worked out by s omeone with sufficient experience in 3D modeling and 3D printing. (MacDonald, E. and Wicker, R., 2016.) (Tidd, J. and Bessant, J.R., 2020)

Therefore, 3D printing materials may be seen to be progressed to the democratization of fast manufacturing (Wittbrodt, B. and Pearce, J.M., 2015) (Reymond, D. and Dematraz, J., 2014). For processing end-user materials, FDM is commonly used (Šafka, J., et al. 2016). In particular, it has been applied to tiny informative parts and specialized manufacturing instruments. In food or even medicine wrapping, some thermoplastics (such as non-toxic PLA) could also be used, allowing FDM to be the favorite 3D printing process in the medical industry (Munteanu, S.B. and Vasile, C., 2020) (Tan, L.J., Zhu, W. and Zhou, K., 2020) (Lin, L., et al., 2019) (Chiulan, I., et al.2018)

After that some close technique has been adopted by other 3D printing businesses, perhaps under widely differing names. MakerBot[2], a well-known manufacturer, patented a nearly similar technique called Fused Filament Fabrication (FFF) (Johansson, F., 2016).

Nowadays, FDM is definitely the most popular 3D printing technologywhich is used in many industries including automotive manufacturing, food industry, toys makers, product innovation, prototyping,and even end-product production we can find the effectively FDM is used (Ngo, T.D., Kashani, A., Imbalzano, G., Nguyen, K.T. and Hui, D., 2018).

Also one of the strength points is that FDM technology uses inexpensive 3D printers which makes it widely spread, even as a home 3d printer (Ćwikła, G., et al, 2017). This method is considered to be use -friendly and also eco-friendly (Khosravani, M.R. and Reinicke, T., 2020) (Liu, J.,et al., 2019). It became possible to construct objects with complex geometries and cavities through the use of this 3d printing technique.(Godoi, F.C., Prakash, S. and Bhandari, B.R., 2016)

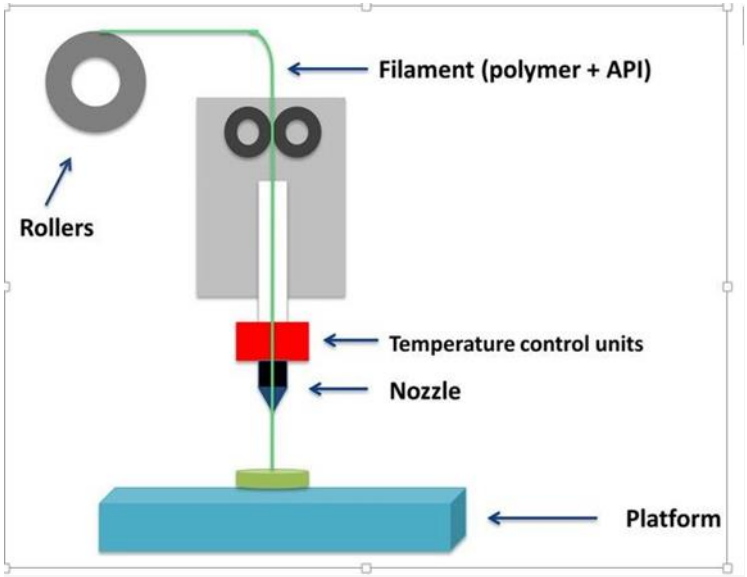
FDM might be the only 3D printing technique that uses thermoplastics of production grade, so printed products have outstanding mechanical, thermal and chemical qualities. (Fischer, F., 2011)

Via thermoplastic filament heating and extrusion, 3D printers using FDM Technology build structures layer by layer from the very bottom up. The entire approach is somewhat analogous to stereo lithography. Specialized programmers or slicers "cut" Computer-aided design (CAD) templates into layers and measure how each sheet will be assembled by the printer's extruder. (France, A.K., 2013)

In addition to thermoplastics, supporting components may also be extruded by a printer. The printer then heats the thermoplastic to its melting temperature and extrudes it on a printing platform from the nozzle (Gkartzou, E., Koumoulos, E.P. and Charitidis, C.A., 2017).

The software program running on the 3D printer-connected device converts an object's dimensions into X, Y, and Z co-ordinates and guides the nozzle and the base bed along the measured path during printing.

It melts and then solidify as the thin layer of plastic attaches to the layer under it. The groundwork is lowered after the sheet is finished (as seen in step 5) to allow the next layer's printing, as seen in steps 1 to 5 in the diagram below -figure (1).




**Figure(1) :The full FDM process in 5 steps**

The complete 5-step FDM process the printing time will depend on your model's size and complexity.

Considering the printing filaments with FDM printers, we can often use multiple types of thermoplastics. ABS (Acrylonitrile Butadiene Styrene) and PLA (Polylactic Acid) plastic seem to be the most common of these, but in our case to produce wearable material the ABS, and the PLA could be stiff to use, so the flexible filaments like the TPU seems to be more applicable with.

**1-2- (TPU) 3d printing materials:**

Thermoplastic polyurethane (TPU) belongs to the family of polyurethane plastics with several substantial characteristics, such as elasticity, transparency, with abrasion resistance to grease,

and oil (Campo, E.A., 2008). Owing to its highly modular nature, it is exceptional. TPUs are composed of thermoplastic elastomers that are why it is safer to distinguish them from acids, solvents and fuels that may have an effect on their properties (Pichaiyut, S., Nakason, C. and Vennemann, N., 2012).

Usually, TPU filaments are either 1.75mm or 3mm in diameter. It is possible to store flexible TPU filaments in a cool container that is airtight. While certain types of TPUs are resistant to water, sustained contact with water may lead to product degradation.

For elastic TPU filaments the print speed should be in the range of 30 to 50 mm/sec. The thickness of the printed layer should be placed above 0.1mm. With the heated bed platform set between 80 and 100 C, the extrusion temperature will ranges from 200 to 220 C. For better performance, many types of TPU filaments may be printed on direct extruders regardless of the filament form, it is essential to always print in a well-ventilated space.

**1-3-.3d printing on fabrics process:**

There are many innovative methods used in employing 3D printing with TPU filament in the field of fashion, and most of these experiments were based on printing the material of the clothing entirely from TPU filaments, and there are other experiments that depended on printing on fabrics such as tulle or any other flexible materials, which is the method used in this research to create materials in which functional factors that goes with clothing comfort, such as air permeability, water absorption and other comfort factors, and one of the important factors are fabric drapeability , which are considered one of the biggest challenges facing developers of technically 3d printed materials , the solutions can be developed by creating a material from fabrics with high elasticity and high air permeability and water absorption, as well as high heat resistance that exceeds 200c when printing TPU filaments, and using these fabrics witch is tulle in the experiment that we are about ,as a base for printing on .

After that comes the role of the 3D-printed design in creating clear distances between its units or motif and their size to preserve as much as possible the fabric Characteristics, in addition to using flexible printing threads such as TPU.

**1-4- Motif design:**

In the design stage that precedes the 3D printing, decorative motif was created, inspired by Islamic art, and based on 4 Islamic stars with 10 vertices and some complementary units, and as we indicated earlier, spaces were left between the motifs to ensure of the fabric drapeability of the printed fabric as a ease of movement.

The motif was designed on the 3D design program Rhino 6- figure (2), and the imaginary shape rendering was created to imagine the final look of the motifs after print it - figure (3), and two sizes were made in an area of 10 cm * 10 cm for each size, while the first size consists of 16 stars and we call it the large size (B-16), and a small size consists of 36 stars, and we call it the small size (S-36).

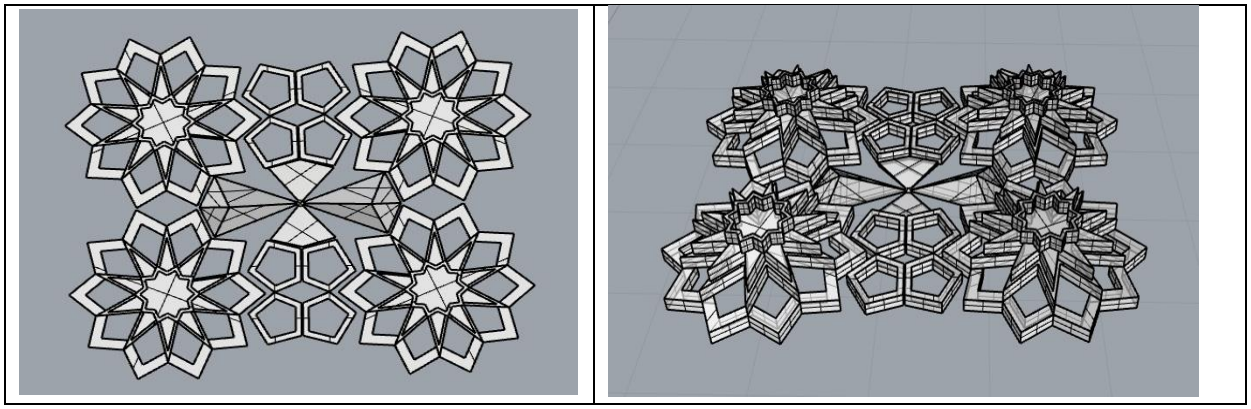


**Figure ( 2 ) the design of the Islamic motif on Rhino program**

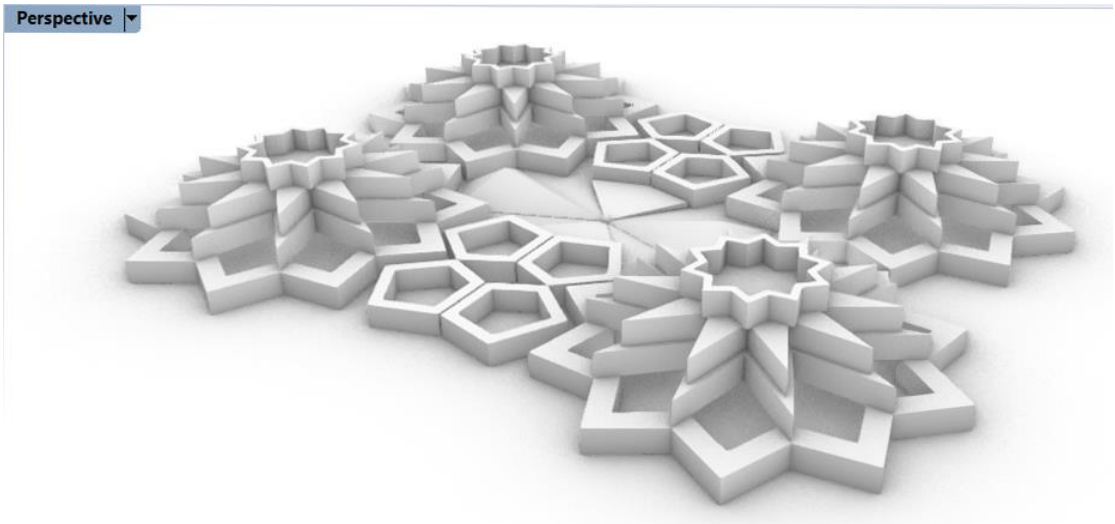



**Figure (3) the design of the Islamic motif on perspective rendering on Rhino program**

When starting to prepare for printing, the settings of the 3D printer, which uses the FDM technology, as previously mentioned, were adjusted to fit the flexible TPU filaments1.75mm.

**And were test three types of varying elasticity and differentiation between it with colors as follows:**

1. The red filament is high flexibility.
2. Blue filament is medium flexibility.
3. The white filament is lower flexibility.

The small and large sizes of each thread were printed to see the effect of the elastic of TPU filament types and the size of the printed motif on the drapeability of the used tulle.

And to have the results with the TPU filaments it had been sit the software program of the 3D printer called (simplify 3D) on the following standards:

**Advanced table**

(activate ) avoid crossing outline for travel movements

maximum allowed detour factor = 10.0

**Extruder sitting**

nozzle diameter = 0.50 mm

Extrusion multiplier = 1.10

**(deactivate) Retraction**

(activate ) Coast end - coasting distance = 0.20 mm

(activate ) wipe nozzle - wipe distance = 2.00 mm

**Additions table**

(activate ) use skirt

(deactivate) use Raft

**Other sitting**

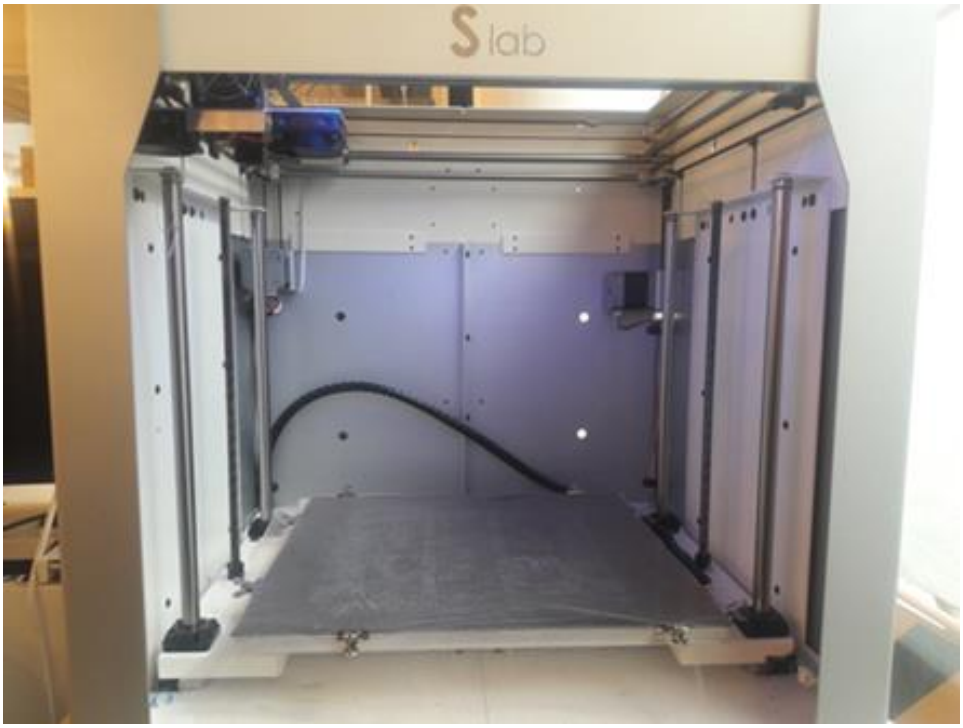
default printing speed= 900 mm/min OR 15.0 mm /s

under speed 80% for all

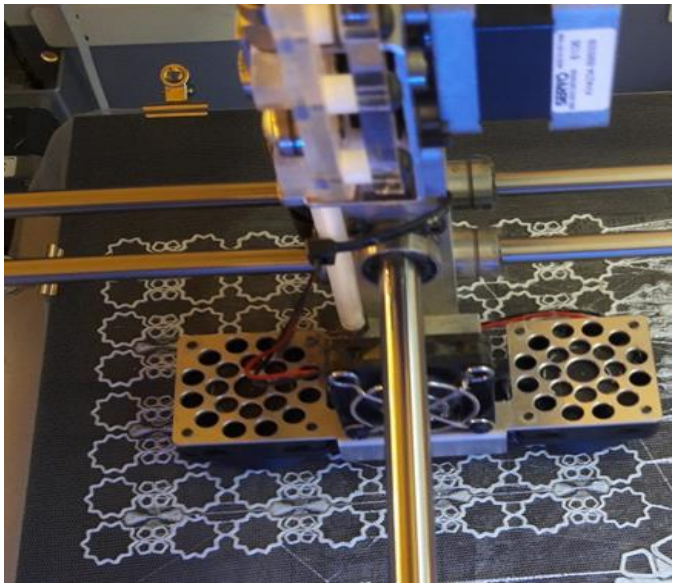
Details of the print settings for each size of motif and the type of TPU filament can be explained in Table No. (1)

Before operating the 3D printer, a layer of tulle was stretched- figure (4 ), which had been previously tested to withstand the printing temperature, which reached a maximum of 240c°, by using 8 small paper clips to ensure that the fabric is attached to the printing bed during the process of extruding the first layer of the printed motif?

The temperature of the extruder for the first layer is always higher than the temperature of the rest of the layers, and the first layer is the most important for its high temperature , which leads to the incorporation of thermoplastics with and interspersed with the tulle openings and fixing the fabric on the printing bed -figure (5 ) whose temperature is set to 60 ° C During the printing process, after the first layer, the role of the paper clips ends and passes the stage in which the problems usually happened.

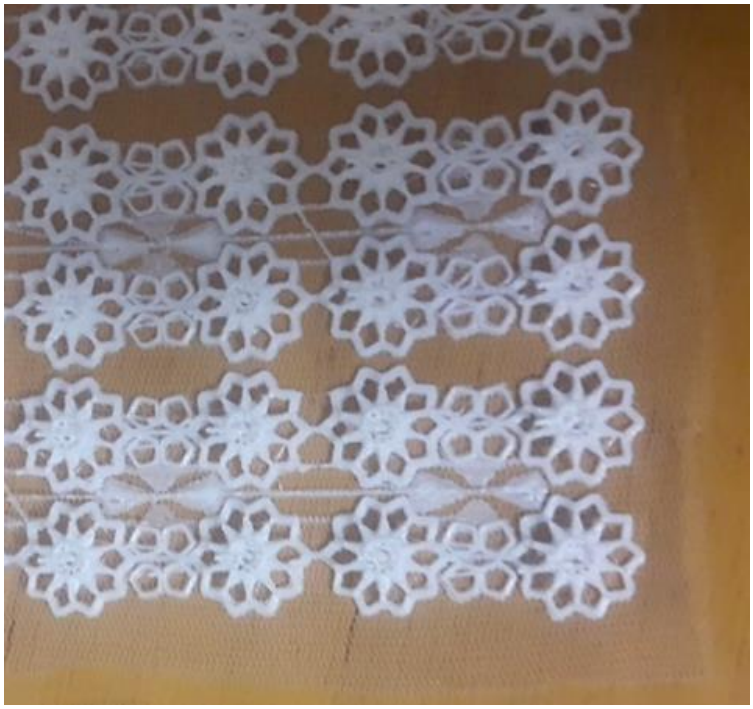



**Figure(4 ) layer of tulle fabric stretched on the 3D printer bed**



**Figure(5 ) the first layer on the 3D printer bed**

After the printing process is completed, the printed fabric is carefully removed and the tulle fabric is integrated into the printed 3D units. The excess that may result during the printing process is then removed-figure (6). The print bed must be cleaned of any residue that may be attached to it, and sometimes the extruder also needs to be cleaned to prepare it for the next printing.



**Figure( 6) the final look of the 3D printing**

To know more data about the differences between the samples printed with different TPU filament materials and different sizes, it was necessary to measure the thickness and weight of each sample and had a test report from the national research center -Egypt -figure (7 ) to come with the following results in table ( 2 ),and chart (1), To determine if this affects the fabric drapeability coefficient of each sample.

| Without | Mass per unit area g/m² | Thickness mm |
|---|---|---|
| | 20 | 0.19 |

| Group | Mass per unit area g/m² Results | | | Group | Mass per unit area g/m² Results | | | Group | Mass per unit area g/m² Results | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | Small | Medium | Large | Group | Small | Medium | Large | Group | Small | Medium | Large |
| White | 384 | 600 | 652 | Blue | 469 | 556 | 582 | Red | 346 | 528 | 536 |

| Group | Thickness mm Results | | | Group | Thickness mm Results | | | Group | Thickness mm Results | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | Small | Medium | Large | Group | Small | Medium | Large | Group | Small | Medium | Large |
| White | 2.00 | 3.47 | 4.17 | Blue | 2.55 | 3.38 | 4.31 | Red | 2.14 | 3.34 | 3.97 |

**Figure (7 ) :the thickness and weight for samples, cropped from test report (85-2020)-national research center -Egypt**

**Table No. (1 ) the 3D printer settings**

| | SIZE UNIT/10cm² | FILAMENT-COLOR | PRINT TEMP | PRINTING SPEED | G-CODE /Z AXIS | Nozzle diameter |
|---|---|---|---|---|---|---|
| **B** | 16 | TPU/FLEX-BLUE | 220c° IST LAYER ,210c° 2ND LAYER | 900 mm\min | **0** | **0.5** |
| **S** | 36 | TPU/FLEX-BLUE | | | **0** | **0.5** |
| **B** | 16 | TPU/NINJA FLEX-RED | 240c° IST LAYER ,235c° 2ND LAYER | 900 mm\min | **0** | **0.5** |
| **S** | 36 | TPU/NINJA FLEX-RED | | | **0** | **0.5** |
| **B** | 16 | TPU/FLEX-White | 220c° IST LAYER ,210c° 2ND LAYER | 900 mm\min | **0** | **0.5** |
| **S** | 36 | TPU/FLEX-White | | | **0** | **0.5** |

**Table (2), the results thickness and weight for samples**

| N. | filament color & motif size | Thickness mm | Weight g/m² |
|---|---|---|---|
| 1 | Fabric without | 0.19 | 20 |
| 2 | white\small | 2 | 384 |
| 3 | white\medium | 3.47 | 600 |
| 4 | white\large | 4.17 | 652 |
| 5 | red\small | 2.14 | 346 |
| 6 | red\medium | 3.34 | 528 |
| 7 | red\large | 3.97 | 536 |
| 8 | blue\small | 2.55 | 469 |
| 9 | blue\medium | 3.38 | 556 |
| 10 | blue\large | 4.31 | 582 |

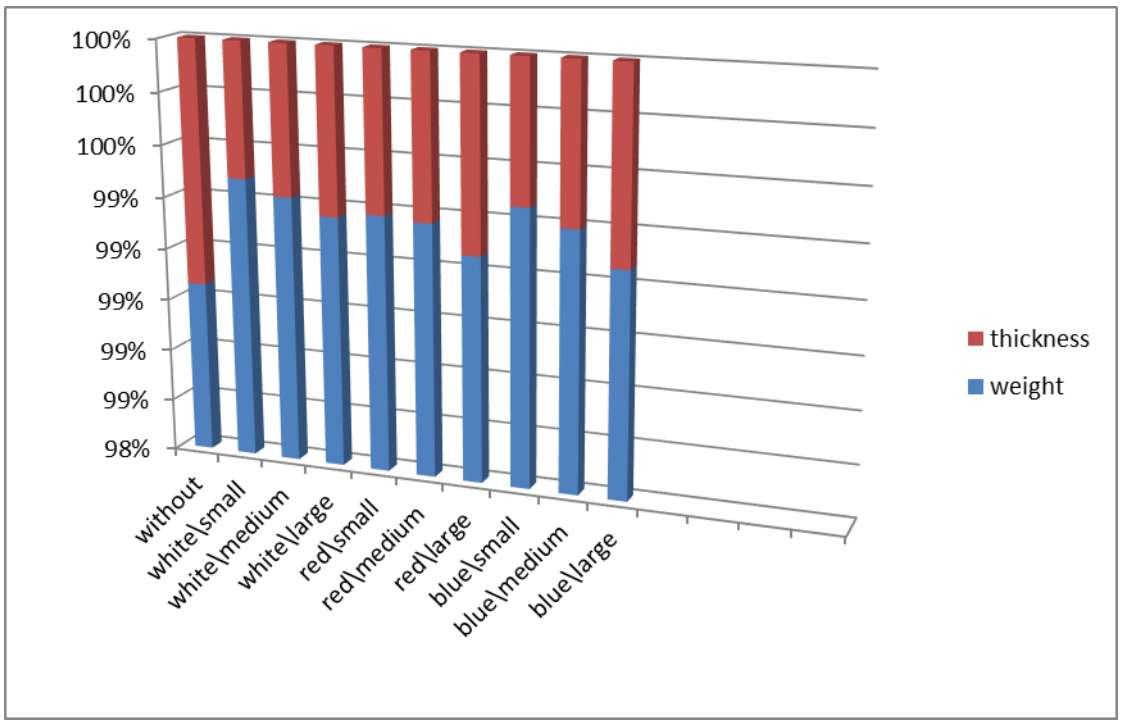



**Chart (1 ) : the results thickness and weight for samples**

By looking at the previous results closely, the samples printed with the blue color threads have a greater thickness, followed by the white printed samples. We find that the samples printed in red are the thinnest, which gives them the preference.

After carefully looking at the previous tests, the samples printed with white thread have the heaviest weight in most cases, followed by the blue printed samples. It has been found that the samples printed in red are the lightest, which gives them the preference.

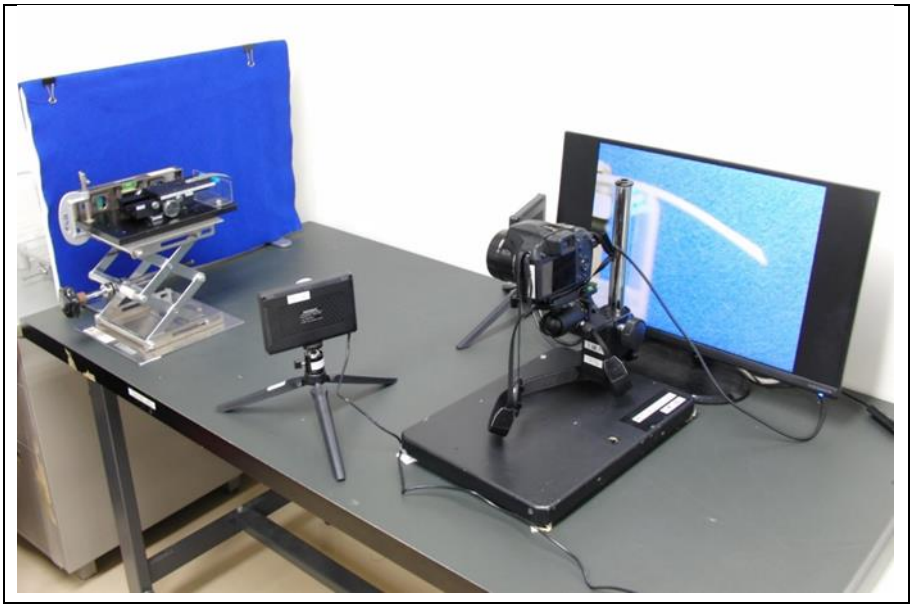
Thus, in terms of weight and thickness, red strings are the best.

To determine which printed samples are more drapeability, it had been used a digital curve tracer-and the components that used clarified in figure (8) and table (3) descript the components, so that each sample is placed on the device in a specific place parallel to the

ground line for a certain amount to hang from it and the sample is photographed horizontally to see the effect of gravity on it.

The images are entered into the digital curve tracer program to read the X and Y values on the sample curve, and the last point on the drooping end of the sample enables us to know the amount of drooping for each sample, and by comparing the results, it could determine the most staging samples.

These tests were done in a softness design laboratory, department of advanced fibro-science, KYOTO institute of technology, Japan.



**Figure(8 ): components that used for the digital curve tracer**

**Table No. (3) clarified components that used in drapeability test**

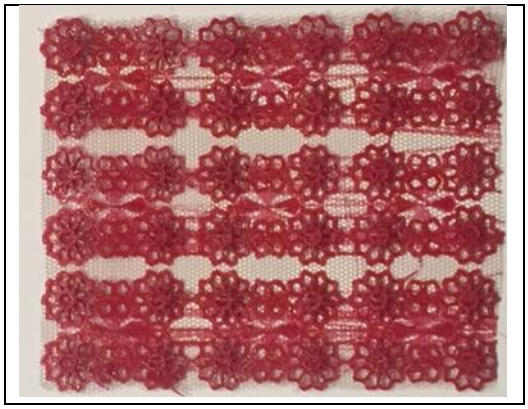
| | |
|---|---|
| **Camera** | Panasonic LUMIX DC-FZ85 |
| **Camera lens** | 20-1200 (60 times) |
| **Distance between specimens and camera** | 100cm |
| **Height of device** | 28cm |
| **Load of specimen** | Self-gravity |
| **Software for tracing** | Digital Curve Tracer |
| **Others** | W face tape |

In the following will review the results for each sample to make a comparison between the six samples.

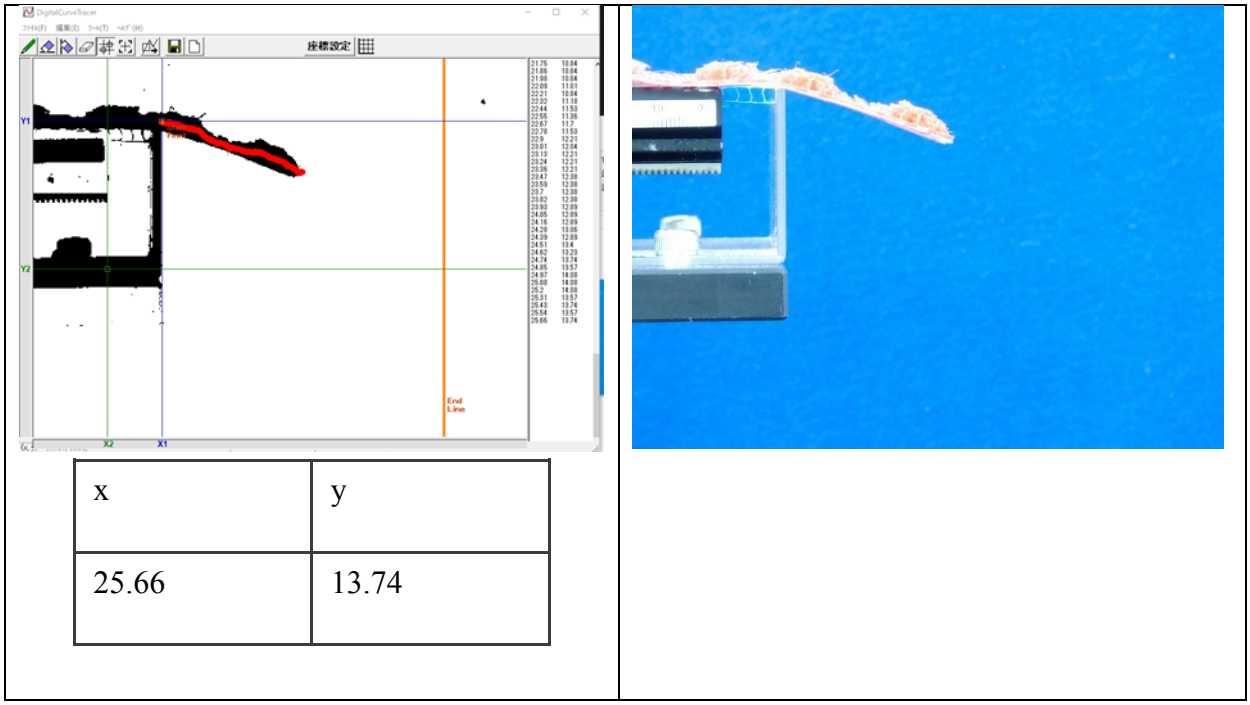
**1- Red filament /size big:**

To print this sample, it had been used TPU-NINJA FLEX filament, in order to produce units of size B-16, figure (9), as mentioned previously, so that the sample code is (RED\B-16).

by using images-figure (10), to be entered into the digital curve tracer program to extract the X, Y values by trace the curve that express the amount of sample drapeability.



**Figure(10 ):Sample printed with red TPU-NINJA FLEXfilament, sample code: (RED\B-16)**

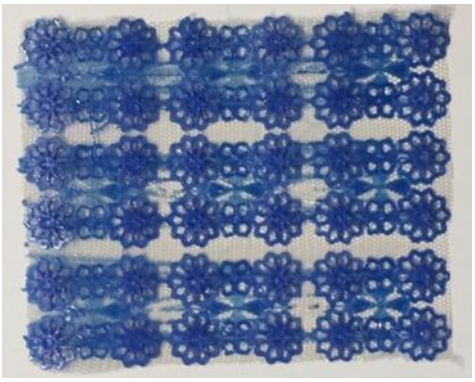


| x | y |
|---|---|
| 25.66 | 13.74 |

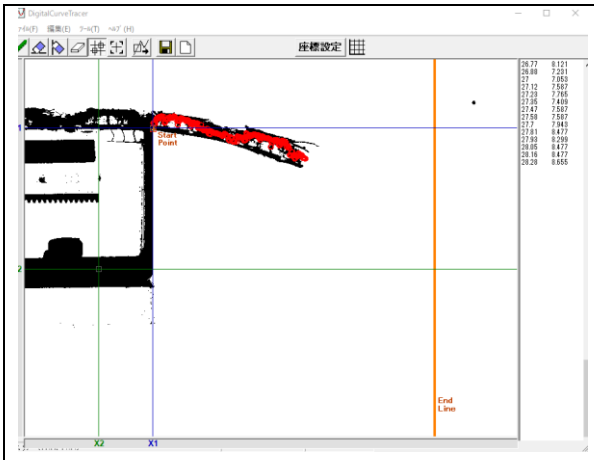
**Figure (10): photo of Digital Curve Tracer for the red filament /size(B-16)**

**2- Blue filament /size big:**

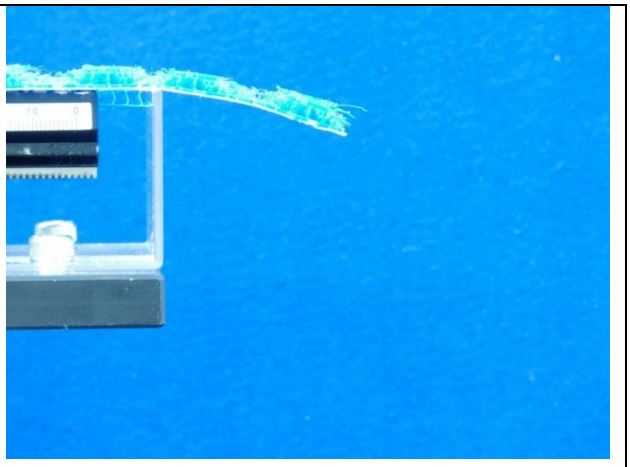
To print this sample, it had been used Blue TPU-FLEX filament, in order to produce sample size B-16, figure (11), as mentioned previously, so that the sample code is (Blue \B-16).
by using images –figure (12), to be entered into the digital curve tracer program to extract the X, Y values by trace the curve that express the amount of sample drapeability.



**Figure(11 ):Sample printed with BlueTPU-FLEXfilament, sample code: (Blue\B-16)**



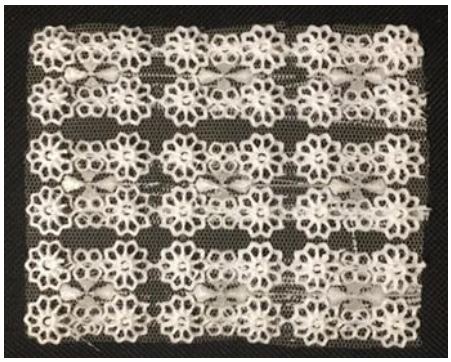
| x | y |
|---|---|
| 28.27 | 8.655 |



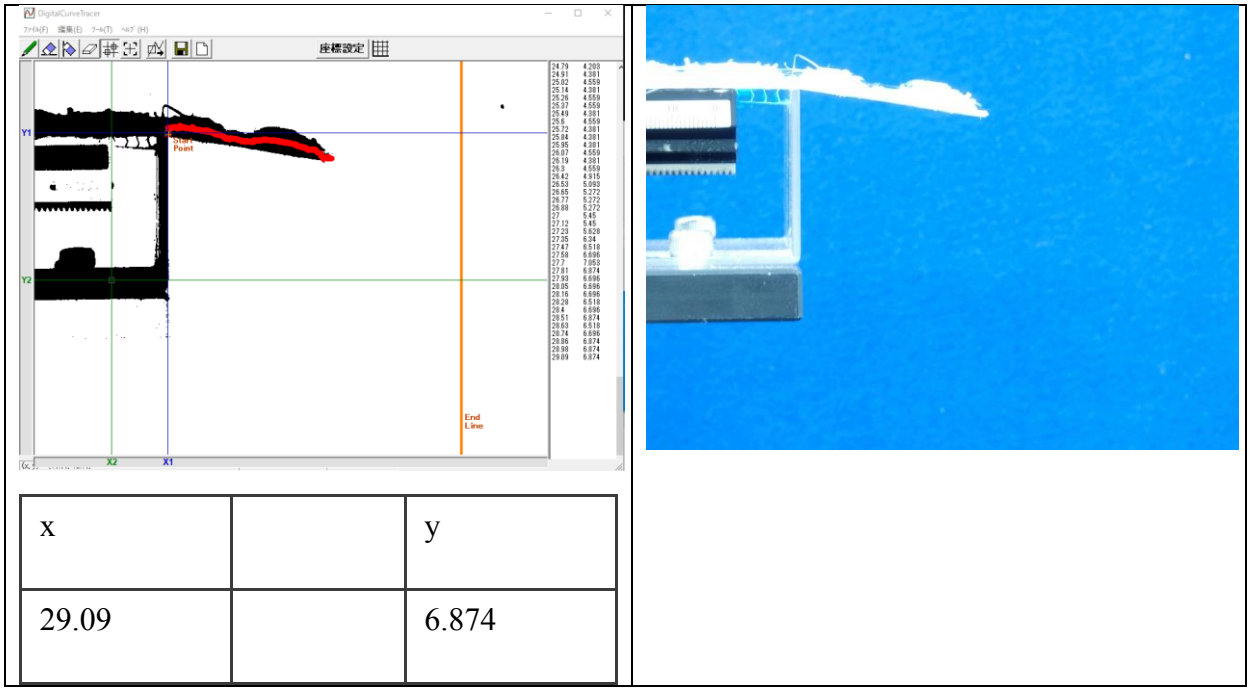
**Figure(12 ) : photo of Digital Curve Tracer for the Blue filament /size(B-16)**

### 3- White filament /size big:

To print this sample, it had been used white TPU-FLEX filament, in order to produce sample size B-16, figure (13), as mentioned previously, so that the sample code is (White \B-16).
by using images –figure (14), to be entered into the digital curve tracer program to extract the X, Y values by trace the curve that express the amount of sample drapeability.



**Figure(13 ):Sample printed with whiteTPU-FLEXfilament, sample code: (white\B-16)**



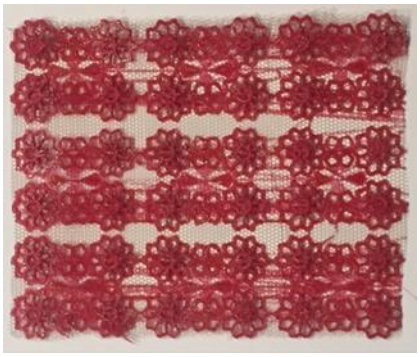
| x | | y |
|---|---|---|
| 29.09 | | 6.874 |

**Figure(14 ) : photo of Digital Curve Tracer for thewhite filament /size(B-16)**

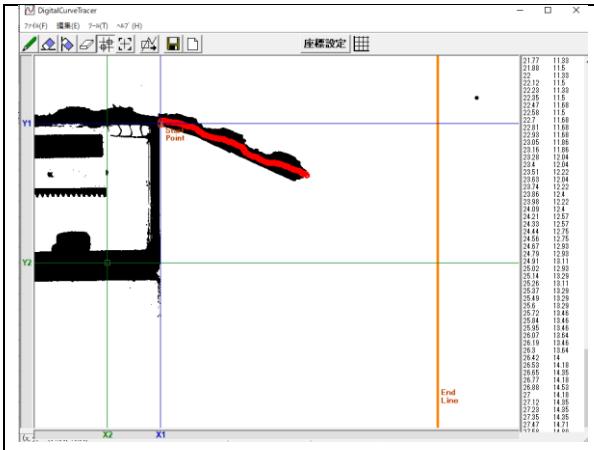
**4- Red \small size**

To print this sample, it had been used red TPU Ninja Flexfilament, in order to produce sample size B-16, figure (15), as mentioned previously, so that the sample code is (Red \B-16).

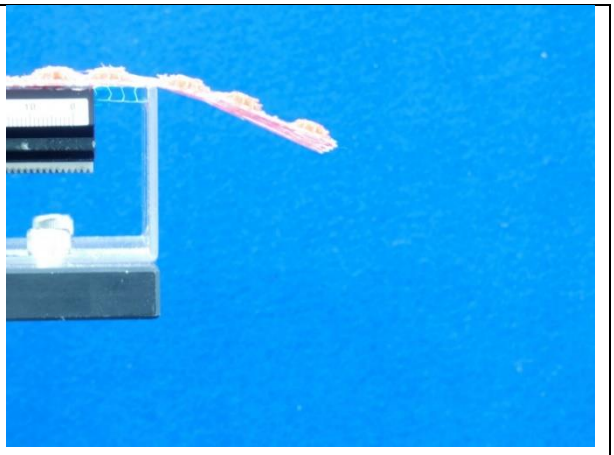
by using images –figure (16), to be entered into the digital curve tracer program to extract the X, Y values by trace the curve that express the amount of sample drapeability.



**Figure(15 ):Sample printed withRedTPU- Ninja Flex filament, sample code: (Blue\S-36)**



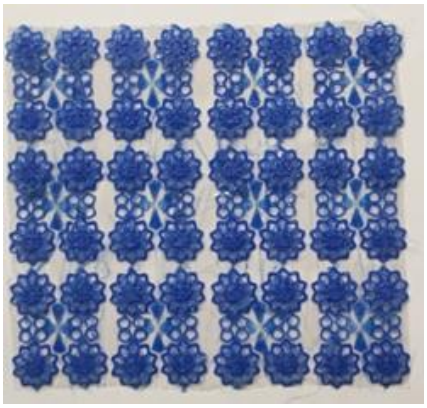
| x | y |
|---|---|
| 27.58 | 14.89 |



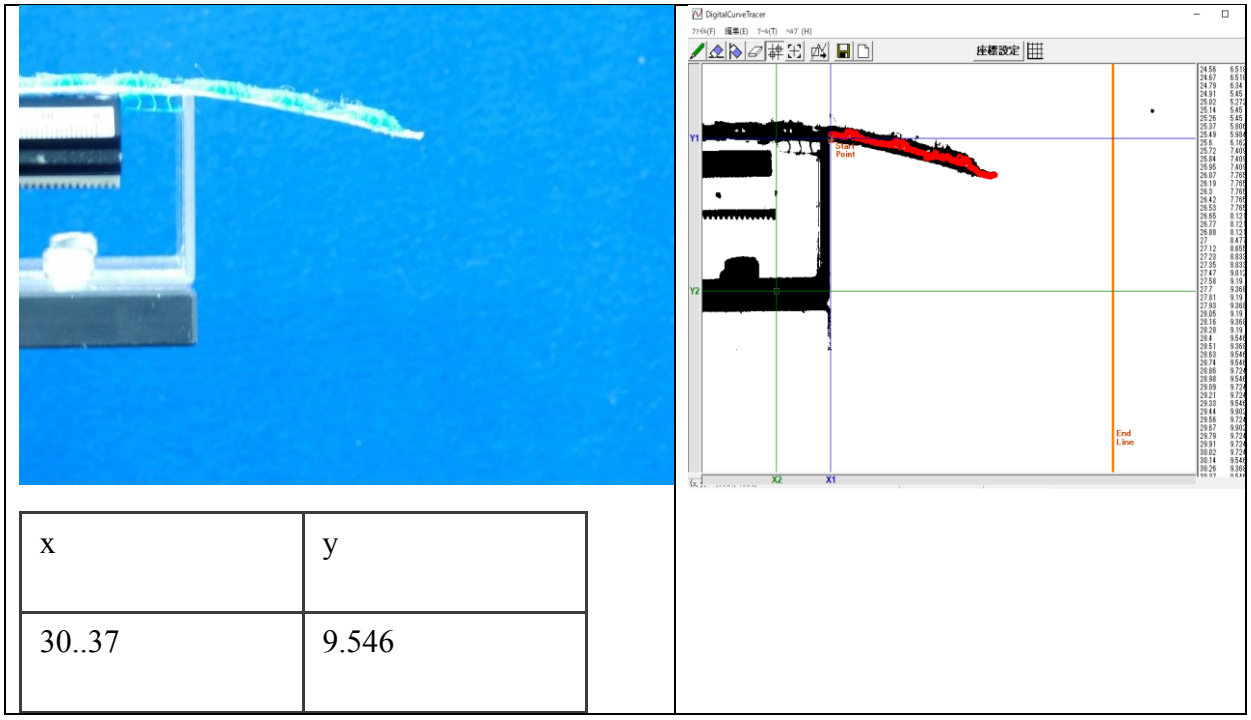
**Figure(16 ) : photo of Digital Curve Tracer for the Red Ninja Flex filament /size(s-36)**

**5- Blue \small size**

To print this sample, it had been used Blue TPU-FLEX filament, in order to produce sample size B-16, figure (17), as mentioned previously, so that the sample code is (Blue \B-16).
by using images –figure (18), to be entered into the digital curve tracer program to extract the X, Y values by trace the curve that express the amount of sample drapeability.



**Figure(17 ):Sample printed with Blue TPU-FLEXfilament, sample code: (Blue\S-36)**

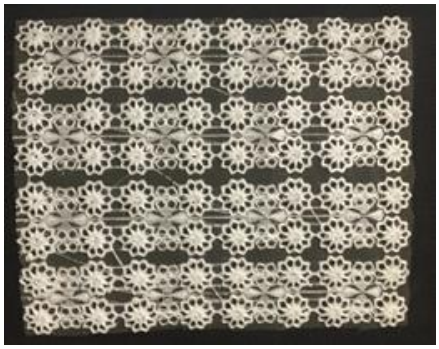


| x | y |
|---|---|
| 30..37 | 9.546 |

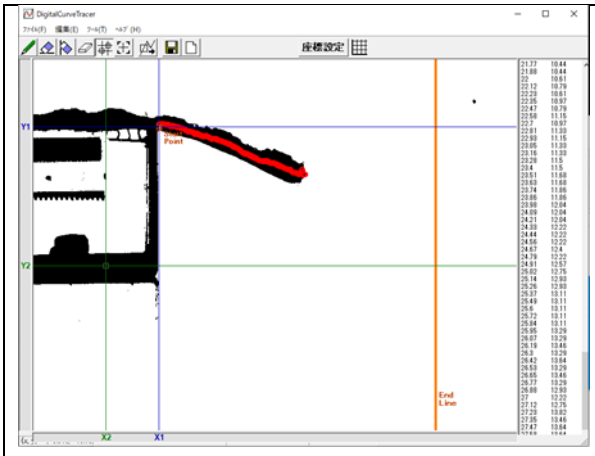
**Figure(18 ) : photo of Digital Curve Tracer for the Blue filament /size(s-36)**

### 6- white\small size

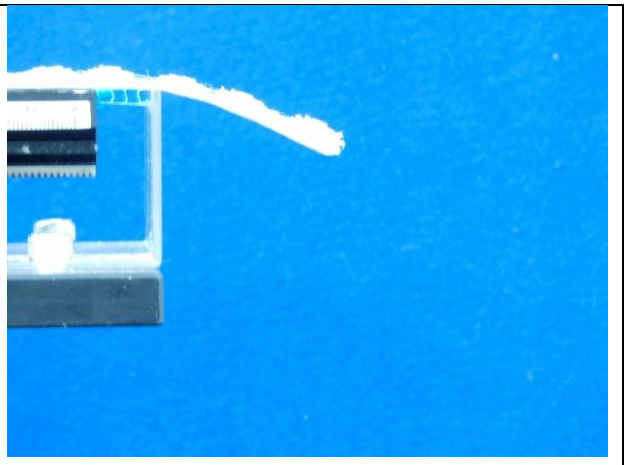
To print this sample, it had been used white TPU-FLEX filament, in order to produce sample sizeS-36, figure (19), as mentioned previously, so that the sample code is (white \S-36).
by using images –figure (20), to be entered into the digital curve tracer program to extract the X, Y values by trace the curve that express the amount of sample drapeability.



**Figure(19 ):Sample printed with whiteTPU-FLEXfilament, sample code: (Whit\S-36)**



| x | y |
|---|---|
| 27.58 | 13.64 |



**Figure(20 ) : photo of Digital Curve Tracer for the white filament /size(s-36)**

After completing the drapeability test and by looking at the resulting values from the Y point, it has been found that the TPU Ninja Flex material, which was in red color, was the best in terms of cleavage, and that the small size of units gave better results than the large ones in terms of drapeability as shown in table (4) and chart (2).

**Table (4): the results drapeability.Of the samples**

| | Samples | X | Y |
|---|---|---|---|
| **1** | **white\S-36** | 27.58 | 13.64 |
| **2** | **Blue \S-36** | 30.37 | 9.546 |
| **3** | **RED\S-36** | 27.58 | 14.89 |
| **4** | **white\B-16** | 29.09 | 6.874 |
| **5** | **Blue \B-16** | 28.27 | 8.655 |
| **6** | **RED\B-16** | 25.66 | 13.74 |

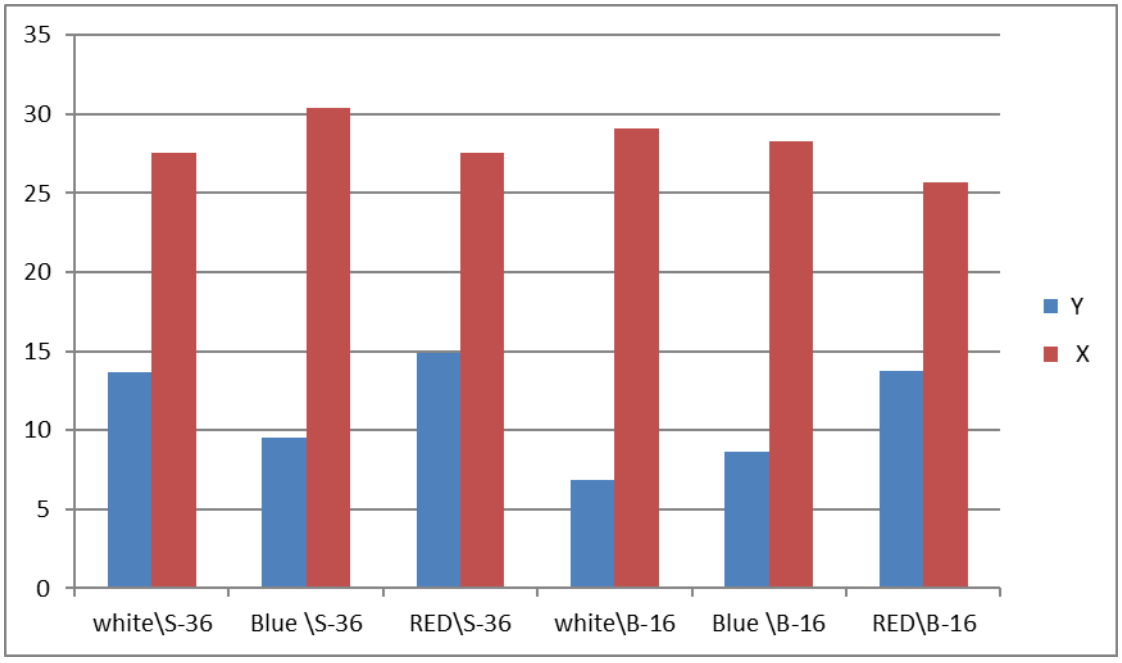



**Chart (2 )the results drapeability of the samples**

## Conclusion:

After completing the weight and thickness tests and attaching them to the drapeability test.
It has been found that the TPU Ninja Flex material, which was red in color, was the best in terms of light weight and less thickness, as well as the drapeability.
It is noticeable that the whiteTPU flex filaments material gave the best result in terms of appearance, as well as that the large unit size gave a better appearance with the flexible TPU yarns, because the units had fine details that did not correspond to the diameter of the extruder nozzle and the elasticity of the TPU filaments.

## Recommendation:

It is recommended to increase the research related to the comfort of 3D printing clothes manufactured with plastics filaments. Further studies are recommended to improve the comfort of the fabric in this area to reach natural materials that can be printed with 3D printing technology, which is in favor of the trend of sustainability fashion.

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الدقى - القاهرة - جمهورية مصر العربية
إدارة الوحدات ذات الطابع الخاص
شعبة بحوث الصناعات النسجية

| Test Report No.: | 85-2020 |
|---|---|

معمل اختبارات خامات النسيج

**بيانات العميل**

| اسم العميل: الدارسة/ محمد حامد خفاجي | عنوان العميل: كلية الفنون التطبيقية – جامعة حلوان |
|---|---|

**بيانات العينة**

| تاريخ استلام العينة: ٢٠٢٠/٠٩/١٠ | الظروف البيئية للأختبار: جو الغرفة |
|---|---|
| تاريخ التقرير : ٢٠١٩/٠٩/١٣ | وصف العينة: إختبار الوزن والسمك لعدد ثلاث مجموعات من الدانتيلا زخرفي على التل وبدون |

**نتيجة الاختبار**

| Without | Mass per unit area g/m² | Thickness mm |
|---|---|---|
| | 20 | 0.19 |

| Group | Mass per unit area g/m² Results | | | Group | Mass per unit area g/m² Results | | | Group | Mass per unit area g/m² Results | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | Small | Medium | Large | Group | Small | Medium | Large | Group | Small | Medium | Large |
| White | 384 | 600 | 652 | Blue | 469 | 556 | 582 | Red | 346 | 528 | 536 |

| Group | Thickness mm Results | | | Group | Thickness mm Results | | | Group | Thickness mm Results | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | Small | Medium | Large | Group | Small | Medium | Large | Group | Small | Medium | Large |
| White | 2.00 | 3.47 | 4.17 | Blue | 2.55 | 3.38 | 4.31 | Red | 2.14 | 3.34 | 3.97 |

* هذه النتيجة تخص العينات المقدمة وتمثيلها لأي كميات أخرى هي مسئولية جهة تقديم العينة .
*لا يجوز استخدام هذا التقرير فى الدعاية أو الإعلان عن المنتج الا بعد الرجوع إلى المركز والاتفاق على ذلك .
* صورة طبق الأصل لنتائج تقرير ٤٦- ٢٠١٩
* قيمة اللايقين المبينة مضروبة فى معامل K=2 لإعطاء مستوى ثقة حوالى ٩٥%.

التعليق:----------

يعتمـــــــــــد،

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[1] Scott Crump: is the inventor of fused deposition modeling (FDM) and co-founder of Stratasys.
[2] . MakerBot: is an American desktop 3D printer manufacturer company headquartered in New York founded in January 2009