International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Dimethicone Crosspolymer Effect on Bio Pad Material

Nur Nabila Mohd Nazali, Farah Nur Aisha Mohammad Nasir, Nor Fazli Adull Manan

Abstract*: Bio pad wound dressing is one of the current material in wound healing technology. This aim of this paper is to study the effects of dimethicone cross polymer on the biomaterial and to investigate the mechanical properties of the bio pad by the integration of experimental and numerical approach. In vitro uniaxial tensile test was performed to compute the stress-stretch response of the materials using ASTM D412 standard. The determination of material constants for the materials via numerical approach can be done by comparing with two hyper elastic constitutive models (Ogden and Neo-Hookean). The results show that Ogden's exponent and coefficient for the subject estimated to be (μ = 0.434 MPa, α = 1.299) for Sample 1, (μ = 0.428 MPa, α = 1.424) for Sample 2, (μ = 0.463 MPa, α = 1.256) for Sample 3 and (μ = 0.633 MPa, α = 1.001) for Sample 4 respectively. Meanwhile, value of material constants for Neo-Hookeen were estimated to be (C_1 = 0.00814 MPa), (C_2 = 0.0121 MPa), (C_3 = 0.00597 MPa) and (C_4 = 0.00739 MPa) for Sample 1, Sample 2, Sample 3 and Sample 4 respectively. Therefore, this study could be useful in future studies in analysis of healing especially in dermatology area.

***Keywords* : Bio pad, Neo-Hookean, Ogden, stress-stretch, wound healing.**

I. INTRODUCTION

Skin is the largest cell of human body with a total area of about 20 square feet or approximately 15% from human body weight. Human skin acts as an external protection from microbes and the harmful elements, help in the regulation of body temperature and permits the sensations of touch, heat and cold. Since the earliest centuries of medical science, skin substitution in a form of wound closure has been found very useful, for example in the management of acute burn injuries and post burn reconstruction[1]. Skin substitutes are heterogeneous group of wound coverage materials that aid in replacement of the function of skin. There are many classifications of skin substitutes that has been proposed based on different composition [2].

Revised Manuscript Received on January 30, 2020.
* Correspondence Author
Nur Nabila Mohd Nazali*, Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia.
Farah Nur Aisha Mohammad Nasir, Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Selangor Malaysia.
Nor Fazli Adull Manan, Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia.

Skin can be classified as a hyper elastic and non-linear materials as it exhibits a time dependent viscoelastic relaxation and creep back to its initial position [3]. This is due to the arrangement of fibre and collagen in human skin. To ease the understanding of bio pad material, two types of hyper elastic constitutive model have been proposed which is Ogden and Neo-Hookean are used to obtain the stress and strain values of the material. It is also important to gain the relationship between stress and stretch instead of stress-strain relationship in normal elastic material. rectification is not possible.

Currently, a biomaterial that can be defined as a synthetic material that is used to replace or restore function to a body tissue and is continuously in contact with body fluids[4]. Due to an advance technology in medical sector, certain injuries can be countered by using bio pad wound dressing. It is one of the potential materials that can be replaced an artificial skin and have a fast recovery in wound healing stages. Bio pad was classified as biomaterial because it has been engineered to interact with biological systems for medical purpose such as bleeding control, and blood loss minimization.

Apart from that, dimethicone cross polymer is one of the types of silicone. Basically, the silicone particles itself are unable to penetrate cell membrane in human body. And in this study, the polymer that need to be used which is the dimethicone cross polymer or its scientific name is polydimethylsiloxane (PDMS) created by using the procedures for rapid prototyping of PDMS micro fluids systems. Therefore, the dimethicone cross polymer is suitable for external uses only such as cosmetics ingredients, and body care purposes. For example, it can be used in the treatment of head lice on the scalp [5] and dimethicone is widely used in skin moisturizer for a skin protection. Some cosmetic formulations use dimethicone cross polymer and related to siloxane polymers in concentration of use up to 15% because they are safe as used in cosmetic formulations [6]. It is believed that this polymer can helps to form a protective barrier on the skin, fill in the lines and wrinkles, help reduce inflammation and irritation and form a sort of plastic-like barrier on the outside of the skin. Therefore, dimethicone cross polymer is applied on the top layer of bio pad to obtain the effects or differences it might have on the mechanical properties of the material. Another material used in this study is aloe vera gel which reveals the presence of diverse biologically active compounds associated with curing different ailments such as wound, inflammations, sunburns and many more [7].

Aloe vera has the large range of medicinal properties [8] which is consists of more than 200 different biological active substances. The combination of aloe vera gel and dimethicone cross polymer can cover the wound on the human skin and boost up the healing process and at the same time to know whether they will influence the mechanical properties of the materials or vice versa.

II. METHODOLOGY

A. Sample Preparation

The main material for this study is the bio pad wound dressing which can be represented as the artificial skin as refer to Fig. 3. This material can be found from the medical supply retail. It acts as a sponge shaped material, constituted exclusively by lyophilized Type I native heterologous equine collagen. In other words, bio pad has porous silicone structures. This material will act as a collagen-like substance. The other additional material that will be used in this experiment are the skincare products which are dimethicone cross polymer and aloe vera gel. Dimethicone cross polymer was one of the ingredients in pore minimizer or primer in cosmetic purposes while aloe vera gel product were used from 100% from its extract as Fig. 1 below.

Fig. 1. Aloe vera.

B. Template Preparations

The template to visualize the actual dimension of the sample by referring to ASTM D412 was sketched using CATIA. It was printed and traced with vinyl board as refer to Fig. 2. To produce an easy template, the whole assemble was cut first. According to the standard, the dumbbell shape was chosen compared to the ring shape because the dumbbell shape is preferable for the determination of tensile strength according to ASTM D412. Hence, in order to get the desired dumbbell shape of the sample, the template was traced using precision knife on the bio pad wound dressing. The total of 20 samples were prepared for tensile test.

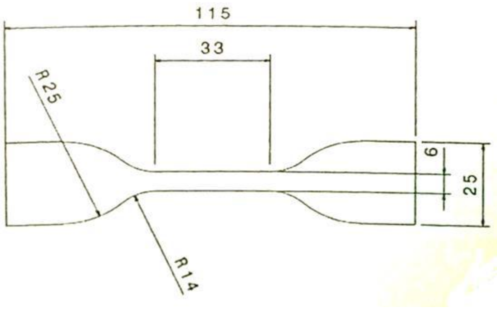

Fig. 2. Schematic drawing of ASTM D412 samples with units in mm.

Basically, a set of samples in Fig. 3 is bio pad wound dressing only without additional material applied on it. The dimethicone cross polymer product was applied on top of the layer of bio pad wound dressing as refer to Fig. 4. The same step was by using aloe vera gel to observe the mechanical experiment by different type of material. Both aloe vera gel and dimethicone are colourless. To differentiate it, an additional colour were added as an indicator for dimethicone.

Fig. 3. Bio pad wound dressing only.

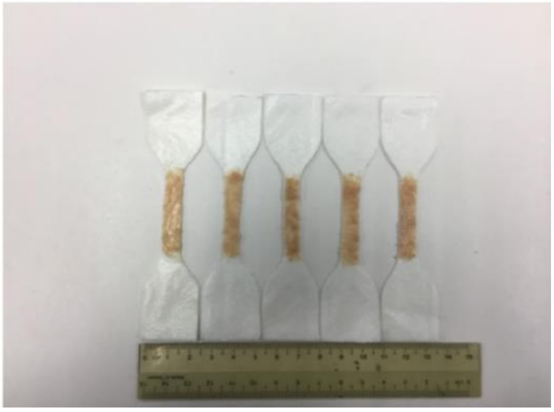

Fig. 4. Bio pad wound dressing with dimethicone cross polymer.

C. Experimental Procedures

Based on N. F. Adull Manan, J. Mahmud, M. H. Ismail, the biomechanical testing were done by using bovine skin and compared with Ogden model [9][10]. Technically, bovine or cow skin has most of the same characteristic in human skin. Starting from the case, the biomaterial engineering especially in wound healing technology improving to produce an artificial skin with medication.

The uniaxial tensile test has been carried out by using the Universal Testing Machine (INSTRON 3382) at Strength of Materials Laboratory, University Teknologi MARA. The test on the material was done according to the ASTM D412 with the speed rate of 500mm/min. It is important to choose a correct size of load cell to obtain an excellent result as if the load cell is too large for the specimen, there will be no reading of load applied to the sample correctly because it cannot detect smallest difference between each load.

After the samples were prepared, each of them was mounted to the tensile machine's jig by clamping the sample to the jig. The speed rate was maintained as 500 mm/min.

The test was performed until the sample was ruptured into two parts. It is important to ensure that the machine was fully stopped performing the test, only then the ruptured sample can be removed from the jig. The same procedure was repeated for all sets of samples. Both of aloe vera gel and dimethicone cross polymer are colorless. Therefore,

the indicator was added onto the bio pad wound dressing with dimethicone crosspolymer to differentiate between all of the sets of the samples.

D. Data Extraction

The raw data of the samples was obtained from the computer in term of spreadsheet files. The raw data consists of various results such as load, extension, stress and strain. Thus, for the obtained data, three sets of graph were plotted which are load-extension, stress-strain and stress-stretch were plotted. Other than that, statistical analysis such as mean, variance and standard deviation were also executed to assess the reliability and accuracy of the data collected from the experiment works. Bio pad wound dressing seem to have a good hype realistic behavior. Therefore, Ogden model and Neo-Hookean model are adapted to this experiment to determine the mechanical properties of the material as normal strain equation cannot describe the behavior of the hyper elastic material accurately.

III. RESULTS AND DISCUSSIONS

From the experiment, the data have been gathered and analyzed in the form of load-extension, stress-strain and stress-stretch. It is also important to apply the data of standard deviation and variance to this study to prove the reliability of the data. The result gained from the experimental approach is essential for the numerical approach as it will be used to determine the value of material constants of the bio pad wound dressing by occupying hyper elastic constitutive model which are Ogden and Neo-Hookean Model. The Fig. 5 to Fig. 8 shows the physical condition after the samples undergoes tensile test.

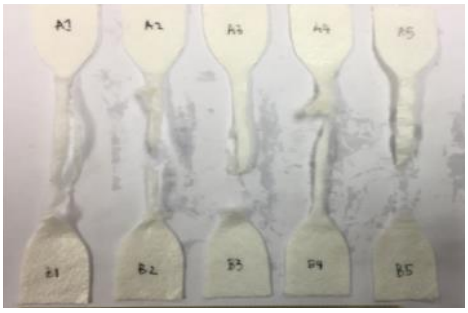

Fig. 5. Bio pad without aloe vera gel.

Fig. 6. Bio pad with aloe vera gel.

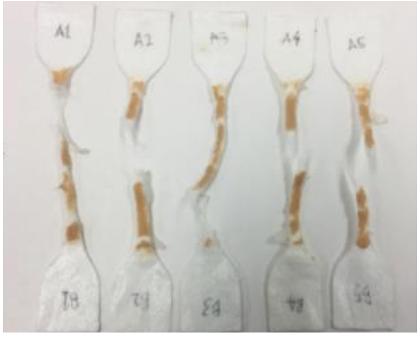

Fig. 7. Bio pad with dimethicone crosspolymer and aloe vera gel.

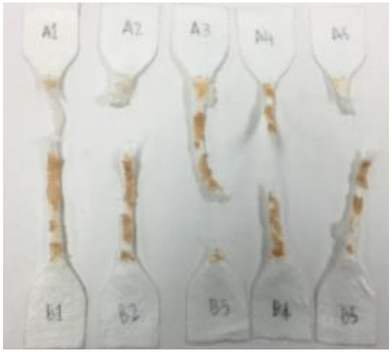

Fig. 8. Aloe vera gel without dimethicone crosspolymer.

A. Load versus Extension

The black solid curve in Fig. 9 is the mean value of the data for for each sample sets. Based on Table I, BP is stands for bio pad, DC is dimethicone crosspolymer while AV is aloe vera as their short forms in the table. It has an extension rate that increase quite steadily and proportional to the applied load. Although the increasing value of load and extension is seen not to be smooth, but the trend of the curve remains increasing. This is due to the condition of the sample that too thin which could cause slipping while being pulled axially. Based on Table I, the highest mean value was at the load of 18N by the sample of bio pad with DC.

Table I. Extension data for bio pad wound dressing only.

Load (N)	Extensions (mm)			
	Bio pad only	BP with AV	BP with DC and AV	BP with DC
0	0	0	0	0
2	0.38	0.57	0.57	0.57
4	1.30	1.51	1.71	1.9
6	4.12	4.62	8.67	7.33
8	9.50	10.5	14.17	15.17
10	15.50	15.99	20.33	21.17
12	20.17	19.67	24.67	26.6
14	24.0	22.33	26.83	31.83
16	27.67	25.5	31.67	34.67
18	31.0	27.99	37.6	39.9

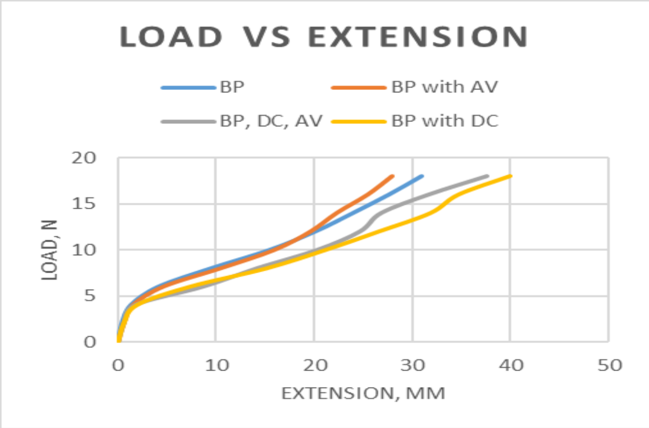

Fig. 9. The mean value of each set of samples.

The sample of bio pad wound dressing and applied layer of dimethicone cross polymer and aloe vera gel was firstly tested. Based on observation, there is no obvious differences of data between graphs Fig. 9. At maximum load (18.0 N), BP with DC shows the highest extension with 39.9 mm while BP with AV recorded the lowest extension mean at 27.99 mm. Aloe vera gel is absorptive and would reduce the elasticity of the bio pad. Dimethicone crosspolymer has a large particle that would not easily penetrate human skin. Therefore, the dimethicone crosspolymer in cosmetic products would make it long lasting.

B. Stress versus Strain

Based on the graphs plotted in Fig. 10 to 13, it shows different forms of line as each of the sample set has respective minimum stress. Therefore, the graph is plotted in Fig. 17 shows again same as the previous type of samples, an opposite behavior from nonlinear elastic material stress-strain curve. The last five samples of bio pad wound dressing is tested by applying the dimethicone cross polymer to its surface layer and the strain results are documented in the Table VIII. At maximum stress of 0.50 MPa, Sample 3 shows the highest value of strain which is 88.89 and Sample 5 recorded as the lowest for 69.44. The difference between the highest and lowest value of strain is 19.45. The graph is plotted, and it shows same trend of graph as the previous sample.

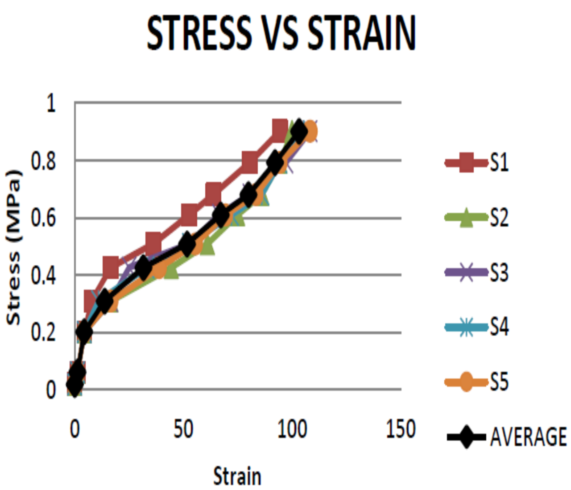

Fig. 10. Bio pad wound dressing.

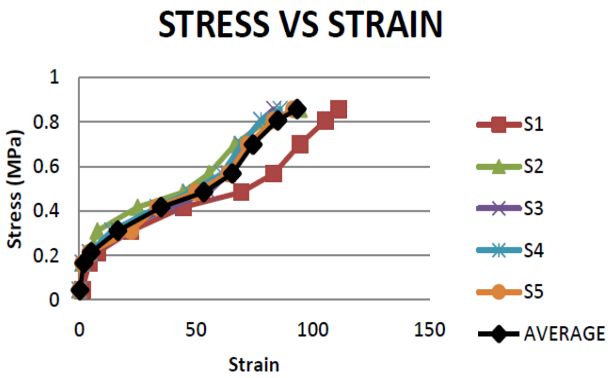

Fig. 11. Bio pad wound dressing with aloe vera gel applied.

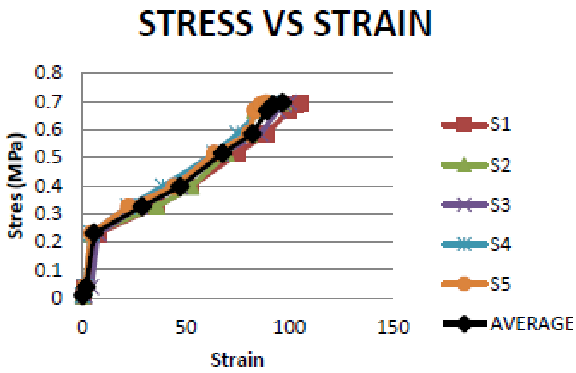

Fig. 12. Bio pad wound dressing applied with dimethicone cross polymer and aloe vera gel.

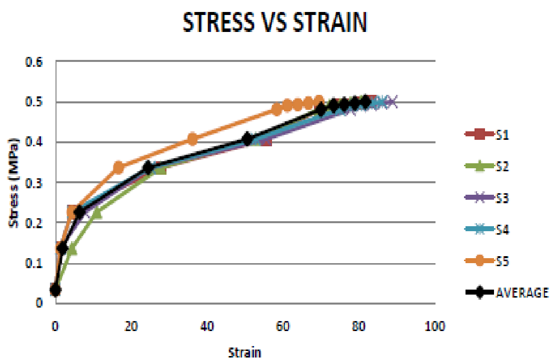

Fig. 13. Bio pad wound dressing applied with dimethicone cross polymer.

Table II shows the data of stress-strain for the bio pad wound dressing only which is without applying a layer of dimethicone cross polymer. The five samples behave similarly and having a low variance between each other, thus show that the data is reliable. The maximum stress to failure is up to 0.90 MPa. The highest value of strain at this maximum stress is 108.33 showed by Sample 3 and Sample 5. Sample 1 recorded the lowest value of strain which is 94.44. The difference between the highest and the lowest value of strain at maximum stress is 13.89. The graph of stress-strain based on the data is then plotted to obtain the mean curve. The graph shows the behaviour of the material which behaving oppositely from nonlinear elastic material stress-strain curve for soft tissue.

Table II. Stress-strain values for bio pad wound dressing.

Load (MPa)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean	Standard Deviation	Variance
0	0	0	0	0	0	0	0	0
2	0.38	1.30	0.38	0.38	0.38	0.57	0.0039	0.000015
4	1.30	3.27	2.32	1.30	1.30	1.90	0.0077	0.000059
6	8.33	8.33	7.50	7.50	4.99	7.33	4.16	17.27
8	16.67	15.83	16.66	15.83	10.83	15.17	11.05	122.14
10	21.66	20.83	23.33	22.50	17.50	21.17	9.34	87.17
12	26.49	27.67	28.16	25.33	25.33	26.60	8.65	74.85
14	31.33	32.50	33.99	32.17	29.17	31.83	9.30	86.42
16	35.16	35.33	37.83	34.99	30.00	34.67	13.11	171.91
18	39.00	40.17	41.67	39.83	38.83	39.90	6.02	36.26

Apart from that, the aloe vera gel is applied on top of the layer of bio pad and the stress-strain data received was tabulated in the Table III. For the maximum stress of 0.86 MPa, the highest strain recorded was 111.11 for Sample 1, while the lowest strain is shown by Sample 3 at 83.33. The difference between the two values is 27.78. The graph plotted then shows an opposite behavior from nonlinear elastic material stress-strain curve for soft tissue. However, the trend of curves among the five samples does behave similarly with very small variance in data.

Table III. Stress-strain values for bio pad wound dressing applied with aloe vera gel.

Load (MPa)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean	Standard Deviation	Variance
0	0	0	0	0	0	0	0	0
0.17	4.36	1.27	1.27	1.27	1.27	1.89	1.38	1.91
0.21	7.7	4.36	4.35	4.35	4.35	5.03	1.53	2.34
0.31	22.22	7.78	16.64	13.81	22.22	16.53	6.10	37.18
0.42	44.45	24.99	38.89	33.33	33.33	34.99	7.24	52.49
0.48	69.44	44.45	55.56	47.22	50.00	53.33	9.89	97.98
0.57	83.33	55.56	63.89	61.11	63.89	65.56	10.50	110.34
0.69	94.44	66.67	69.44	69.44	72.22	74.44	11.31	128.86
0.81	105.56	80.56	77.78	77.78	83.33	84.99	11.72	137.34
0.86	111.11	94.44	83.33	86.11	91.67	93.33	10.87	118.05

The next type of samples that are tested was the bio pad wound dressing and applied layer of dimethicone cross polymer and aloe vera gel. Five samples were undergoes tensile test and stress-strain data was recorded on the Table IV. It is seen that at the highest stress of 0.70 MPa, the highest strain value recorded was Sample 1 which is 105.56. The difference between highest and lowest value of strain is 16.67.

Table IV. Stress-strain values for bio pad wound dressing applied with dimethicone cross polymer and aloe vera gel.

Load (MPa)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean	Standard Deviation	Variance
0	0	0	0	0	0	0	0	0
0.034	1.27	1.27	4.35	1.27	1.27	1.88	1.38	1.89
0.23	7.76	4.34	7.76	4.34	4.35	5.71	1.87	3.50
0.33	36.11	36.11	27.78	22.22	22.21	28.89	6.98	48.65
0.39	52.78	52.78	47.22	38.89	44.44	47.22	5.89	34.72
0.52	74.99	69.44	66.67	63.89	63.89	67.78	4.65	21.60
0.58	88.89	80.56	86.11	74.99	80.56	82.22	5.41	29.32
0.66	100.00	83.33	94.44	86.11	83.33	89.44	7.45	55.57
0.69	102.78	86.11	97.22	88.89	86.11	92.22	7.45	55.55
0.70	105.56	97.22	100.00	91.67	88.89	96.67	6.63	43.99

The result of bio pad wound dressing applied with dimethicone cross polymer are not too differ with previous materials. As refer to Table V and Fig. 13, it can be considered as an optimum result.

Table V. Stress-strain values for bio pad wound dressing applied with dimethicone cross polymer.

Load (MPa)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean	Standard Deviation	Variance
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.14	1.27	4.34	1.28	1.27	1.28	1.89	1.37	1.88
0.23	4.34	10.89	7.75	4.34	4.35	6.34	2.95	8.69
0.34	27.78	27.77	24.99	24.99	16.64	24.44	4.58	20.94
0.41	55.56	52.78	55.56	52.78	36.11	50.56	8.19	67.12
0.48	69.44	69.44	77.78	74.99	58.33	69.99	7.45	55.56
0.49	74.99	72.22	80.56	77.78	61.11	73.33	7.51	56.33
0.49	77.78	74.99	83.33	80.56	63.89	76.11	7.51	56.32
0.49	80.56	77.78	86.11	83.33	66.67	78.89	7.51	56.33
0.50	83.333	80.56	88.89	86.11	69.44	81.67	7.51	56.33

C. Standard Deviation for Stress, Strain and Young's Modulus, E

Fig. 14 to 16 illustrates the standard deviation of tensile stress, strain and Young's Modulus, E respectively. The error bars are shown in each of the figures that indicate the small result of dispersion values. Based on Table VI, all of five variances are less than 5%. It was proved that the results are acceptable for this type of material. Based on Laura A. Fasce[11], determination of mechanical properties of this class of solids is a challenging task because they are much softer compared to metals, ceramics and glassy polymers. However, different composition of biomaterials will indicate another different range of mechanical data in the future.

Table VI. Standard deviation and variance for tensile stress, strain and young's modulus.

Bio pad Wound Dressing and Other Materials	Bio pad Wound Dressing Only	With Aloe Vera Gel	With Dimethicone Cross polymer and Aloe Vera Gel	With Dimethicone Cross polymer
Tensile Stress (MPa)	0.892	1.0044	0.762	0.733
Standard Deviation	0.008269	0.009252	0.006511	0.01899
Variance	0.09093	0.09619	0.0807	0.1378
Strain	107.7818	105.0004	107.7768	106.1108
Standard Deviation	28.4726	51.7016	40.1290	225.3069
Variance	5.3360	7.1904	6.3347	15.0102
Young's Modulus	3.4656	3.6916	3.3638	2.8282
Standard Deviation	0.3199	0.8234	0.4689	0.9536
Variance	0.5656	0.9074	0.6848	0.9765

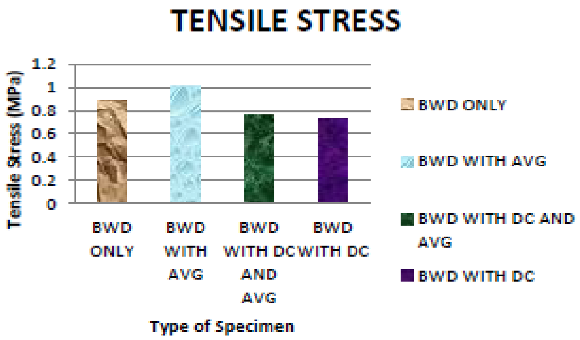

Fig. 14. Standard deviation for tensile stress.

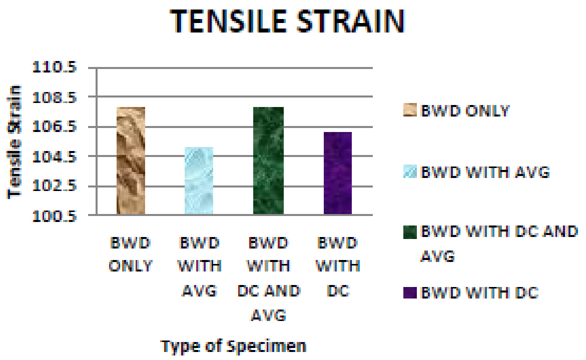

Fig. 15. Standard deviation for tensile strain.

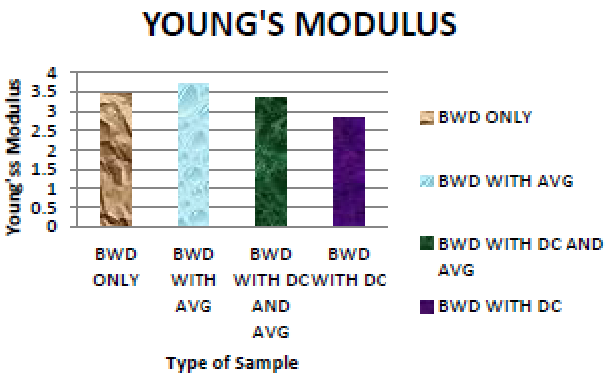

Fig. 16. Standard deviation for Young's Modulus, E.

D. Biomechanical Properties

In this section, based on the study the biomechanical properties are developed by tabulating the data for stress and stretch for each type of samples. For the sample set of bio pad wound dressing only, in Table VII shows the highest stress at 0.90 MPa for the bio pad wound dressing only without the application of aloe vera gel, Sample 3 and 5 have the highest value of stretch which is 109.33. The difference between highest and lowest value is 13.89. Based on the Table VIII which is a sample set of the bio pad wound dressing applied with aloe vera gel where the maximum stress recorded is 0.86 MPa, only slightly lower by 0.04 MPa from the ones that are not applied with aloe vera gel. With that maximum stress, the highest stretch value for this type of sample is 112.22 from Sample 1. The lowest value is 84.33 from Sample 3 and their difference is 27.89 which is higher compared to the other type of sample.

Table VII. Stretch value for bio pad wound dressing only.

Stress (MPa)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
0.00	1.00	1.00	1.00	1.00	1.00	1.00
0.062	2.26	2.27	2.27	2.27	2.27	2.27
0.20	5.33	5.33	5.35	5.35	5.35	5.34
0.31	8.75	17.64	17.64	11.91	17.64	14.72
0.43	17.64	45.45	25.99	34.33	39.89	32.66
0.51	37.11	62.11	53.78	53.78	56.56	52.67
0.61	53.78	75.99	67.67	73.22	70.44	68.22
0.68	64.89	87.11	81.56	87.11	84.33	81.00
0.79	81.56	95.44	98.22	95.44	95.44	93.22
0.90	95.44	101.00	109.33	106.56	109.33	104.33

Table VIII. Stretch value for bio pad wound dressing applied with aloe vera gel.

Stress (MPa)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
0.04	2.27	1.00	1.00	1.00	1.00	1.25
0.17	5.36	2.27	2.27	2.27	2.27	2.89
0.21	8.78	5.36	5.35	5.35	5.35	6.03
0.31	23.22	8.78	17.64	14.81	23.22	17.53
0.42	45.45	25.99	39.89	34.33	34.33	35.99
0.48	70.44	45.45	56.56	48.22	51.00	54.33
0.57	84.33	56.56	64.89	62.11	64.89	66.56
0.70	95.44	67.67	70.44	70.44	73.22	75.44
0.81	106.56	81.56	78.78	78.78	84.33	85.99
0.86	112.11	95.44	84.33	87.11	92.67	94.33

For the bio pad wound dressing when it is applied with both of dimethicone cross polymer and aloe vera gel on the surface layer, the maximum stress is at 0.70 MPa in Table IX. The highest stretch value is shown by Sample 1 which is 106.56. The difference between highest and lowest value is 16.67. Finally, when bio pad wound dressing applied with dimethicone cross polymer only, the maximum stress is at 0.50 MPa, while the highest stretch is at 89.89 in Table X. The values compared are not too differ, only the sample with dimethicone cross polymer and aloe vera gel is recorded slightly higher in the maximum stretch value which is 106.56.

Table IX. Stretch value for bio pad wound dressing applied with dimethicone cross polymer and aloe vera gel.

Stress (MPa)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
0.00	1.00	1.00	2.27	1.00	1.00	1.25
0.040	2.27	2.27	5.35	2.27	2.27	2.88
0.23	8.76	5.34	8.76	5.34	5.35	6.71
0.33	37.11	37.11	28.78	23.22	23.22	29.89
0.40	53.78	53.78	48.22	39.89	45.44	48.22
0.52	75.99	70.44	67.67	64.89	64.89	68.78
0.58	89.89	81.56	87.11	75.99	81.56	83.22
0.67	101.00	84.33	95.44	87.11	84.33	90.44
0.69	103.78	87.11	98.22	89.89	87.11	93.22
0.70	106.56	98.22	101.00	92.67	89.89	97.67

Retrieval Number: C9217019320/2020©BEIESP
DOI: 10.35940/ijitee.C9217.019320
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Table X. Stretch value for bio pad wound dressing applied with dimethicone cross polymer.

Stress (MPa)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
0.033	1.00	1.00	1.00	1.00	1.00	1.00
0.14	2.27	5.34	2.27	2.27	2.28	2.89
0.23	5.34	11.90	8.75	5.34	5.35	7.34
0.34	28.78	28.78	25.99	25.99	17.64	25.44
0.41	56.56	53.78	56.56	53.78	37.11	51.56
0.48	70.44	70.44	78.78	75.99	59.33	70.99
0.49	75.99	73.22	81.56	78.78	62.11	74.33
0.49	81.56	78.78	87.89	84.33	67.67	79.89
0.50	84.33	81.56	89.89	87.11	70.44	82.67

The stress-stretch graph on Fig. 17 were plotted based on the tabulated data. The stretch values were calculated from the strain values obtained previously for each type of samples. The mean or average value of stress-stretch data is highlighted by the respective curve on the graph. It is observed that for all the graphs of each type of sample, the curve does not behave similarly as the hyper elastic stress-stretch behavior for soft material such as skin. It is also observed that all the curves in the graph have a same trend and do not differ much to the mean curve which proves that the data obtained is homogenous.

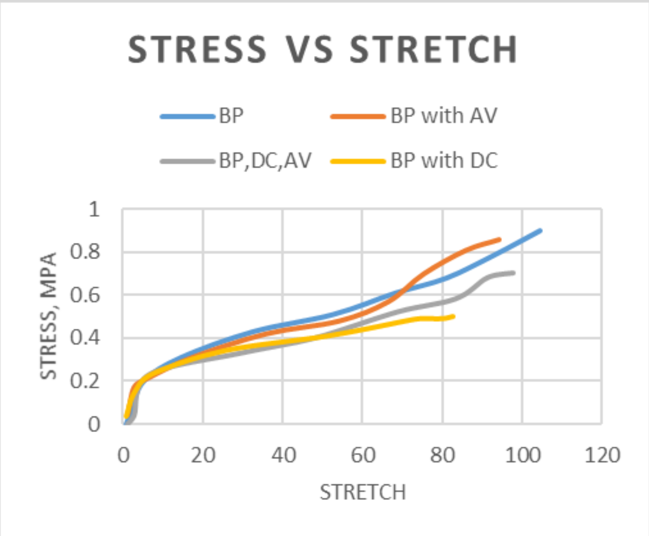

Fig. 17. The mean value of stretch.

E. Numerical Comparisons

In Table XI, the material parameter for both hyper elastic constitutive models, Ogden and Neo-Hookean were tabulated for each of type of samples tested. The parameter α and µ indicate the constant values for Ogden Model while C is for Neo-Hookean Model. For the bio pad wound dressing without dimethicone cross polymer category, it is seen value for α is higher which is 1.424 MPa when the bio pad wound dressing is applied with aloe vera gel. While the sample without a present of aloe vera gel the value of α is 1.299 MPa. The value for µ is higher when the bio pad wounds dressing is not applied with aloe vera gel which 0.434 MPa and the lowest value goes to the bio pad wound dressing that is applied with aloe vera gel which is at 0.428 MPa. Therefore, Neo-Hookean is the highest value of *C* is is that fits this study can be done by having the curve of best fit between the two models on the experimental curve. Fig. 18 and Fig. 19 describes the graph of comparison for categories of bio pad wound dressing without the application of dimethicone cross polymer. While Figure 20 and 21 describes the graph of comparison for bio pad wound dressing with the application of dimethicone cross polymer.

Table XI. Material parameters of α and µ for Ogden model and C for Neo-Hookean model.

Hyper Elastic Model	Parameters	Bio pad Wound Dressing	With Aloe Vera Gel	With Dimethicone Cross polymer and Aloe Vera Gel	With Dimethicone Cross polymer
Ogden	α	1.299	1.424	1.256	1.001
	µ	0.434	0.428	0.463	0.633
Neo-Hookean	C	0.00814	0.0121	0.00597	0.00740

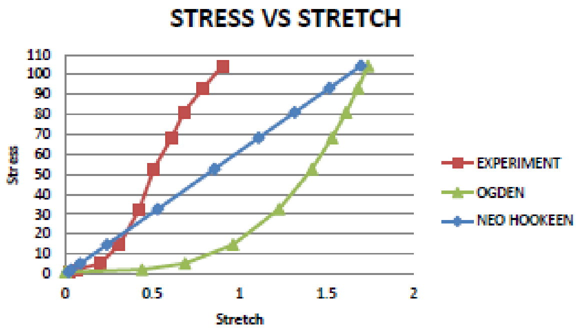

Fig. 18. Comparison between models for bio pad wound dressing only.

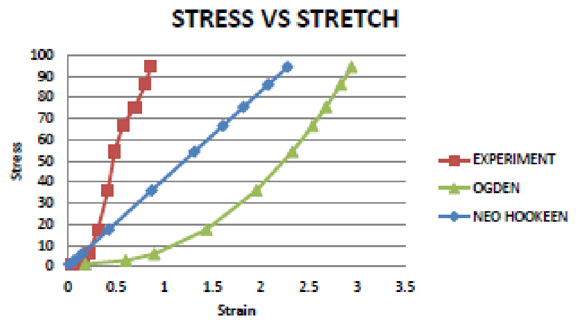

Fig. 19. Comparison between models for bio pad wound dressing with aloe vera gel.

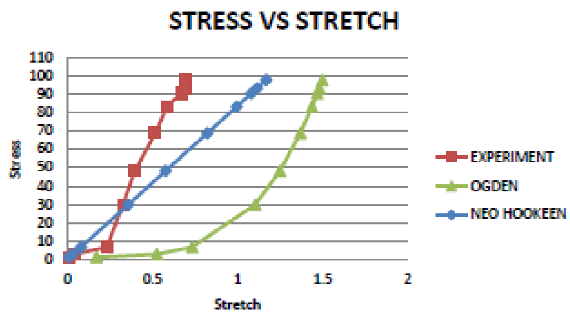

Fig. 20. Comparison between models for bio pad wound dressing with dimethicone cross polymer and aloe vera gel.

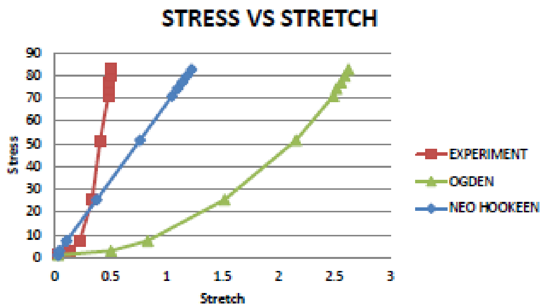

Fig. 21. Comparison between models for bio pad wound dressing with dimethicone crosspolymer.

In the graph, the lines of curve represent the experimental, Ogden and Neo-Hookean curves respectively. Based on the graph, for all categories, they show the curve trend which is increasing but different pattern to each other. As it can be seen, Neo-Hookean Model is the closest to the experimental curves but they have different pattern of curves. As refer to the previous research by N. F. Adull Manan about bovine skin undergoes uniaxial tensile test, the Ogden has a close data to experimental value[12]. Nevertheless, it is obviously seen that the Ogden curves are totally isolated from the experiment's curve of stress-stretch. The result can be considered as not having a close agreement to the experimental result. This is due to the average value of material constants obtained for each of the models.

IV. CONCLUSION

The main objectives of this study were achieved. By using the experimental and numerical approaches, the mechanical properties of bio pad wound dressing have been determined. The results showed that the application of aloe vera gel is to indicate the different value of material constants for the samples. The present of dimethicone cross polymer affected the value of material constants for both models used which is Ogden Model and Neo-Hookean Model. It is also believed that the average value of material constants influenced by the value of predicted stress. Predicted stress is the numerical stress that have been calculated. The result shows that the graph of Stress-Stretch between the experimental and both hyper elastic constitutive models are not having a close agreement. Material properties gained using the models are $\mu = 0.434$ MPa, $\alpha = 1.299$ for Sample 1,($\mu = 0.428$ MPa, $\alpha = 1.424$ for Sample 2, $\mu = 0.463$ MPa, $\alpha = 1.256$ MPa for Sample 3 and $\mu = 0.633$ MPa, $\alpha = 1.001$ for Sample 4 respectively. Meanwhile, value of material constants for Neo-Hookean were estimated to be $C_1 = 0.00814$ MPa, $C_2 = 0.0121$ MPa, $C_3 = 0.00597$ MPa and $C_4 = 0.00739$ MPa for Sample 1, Sample 2, Sample 3 and Sample 4 respectively. Consequently, the data obtained could be a reference to a certain department such as dermatology area for an improvement to wound care management and artificial skin with medication.

ACKNOWLEDGMENT

The authors would like to thank the KPM funder the FRGS grant no. [600-IRMI/FRGS 5/3 (363/2019)], the Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM) Shah Alam for the financial supports.

REFERENCES

1. M. Nachman and S. E. Franklin, "Artificial Skin Model simulating dry and moist in vivo human skin friction and deformation behaviour," Tribol. Int., vol. 97, pp. 431–439, 2016.
2. P. Kumar, "Classification of skin substitutes," Burns, vol. 34, no. 1, pp. 148–149, 2008.
3. Y. Wang, K. L. Marshall, Y. Baba, G. J. Gerling, and E. A. Lumpkin, "Hyperelastic Material Properties of Mouse Skin under Compression," PLoS One, vol. 8, no. 6, 2013.
4. C. Mauli, "Reconstructing the Human Body Using Biomaterials," Jom, pp. 31–35, 1998.
5. I. F. Burgess, "The mode of action of dimeticone 4% lotion against head lice, Pediculus capitis," BMC Pharmacol., vol. 9, pp. 1–8, 2009.
6. B. Nair and Cosmetic Ingredients Review Expert Panel, "Final report on the safety assessment of stearoxy dimethicone, dimethicone, methicone, amino bispropyl dimethicone, aminopropyl dimethicone, amodimethicone, amodimethicone hydroxystearate, behenoxy dimethicone, C24-28 alkyl methicone, C30-45 alkyl methico," Int. J. Toxicol., vol. 22 Suppl 2, p. 11—35, 2003.
7. A. Baruah, M. Bordoloi, and H. P. Deka Baruah, "Aloe vera: A multipurpose industrial crop," Ind. Crops Prod., vol. 94, pp. 951–963, 2016.
8. M. H. Radha and N. P. Laxmipriya, "Evaluation of biological properties and clinical effectiveness of Aloe vera: A systematic review," J. Tradit. Complement. Med., vol. 5, no. 1, pp. 21–26, 2015.
9. N. F. Adull Manan, J. Mahmud, and M. H. Ismail, "Biomechanical testing of bovine skin using various sample specifications," Mater. Res. Innov., vol. 18, no. sup6, pp. S6-389-S6-394, Dec. 2014.
10. N. F. Adull Manan, S. N. Azizzati, M. Noor, N. N. Azmi, and J. Mahmud, "Numerical investigation of Ogden and Mooney-Rivlin material parameters," ARPN J. Eng. Appl. Sci., vol. 10, no. 15, pp. 6329–6335, 2015.
11. M. Czerner, L. S. Fellay, M. P. Suárez, P. M. Frontini, and L. A. Fasce, "Determination of Elastic Modulus of Gelatin Gels by Indentation Experiments," Procedia Mater. Sci., vol. 8, pp. 287–296, 2015.
12. N. F. Adull Manan, J. Mahmud, and M. H. Ismail, "Quantifying the Biomechanical Properties of Bovine Skin under Uniaxial Tension," J. Med. Bioeng., vol. 2, no. 1, pp. 45–48, 2013.

AUTHORS PROFILE

Nur Nabila Mohd Nazali, a postgraduate student in Faculty of Mechanial Engineering, Universiti Teknologi MARA (UiTM), Shah Alam and pursuing in Master of Science (Mechanical Engineering). She graduated with a Bachelor Degree of Engineering (Hons.) Mechanical from the same university in July 2017. She has been certified as a member of Board of Engineers Malaysia (BEM) since December 2018. Since she registered as a postgraduate student, she wants to explore more about biomaterial engineering and wound healing technology.

Farah Nur Aisha Mohammad Nasir was an undergraduate student from Faculty of Mechanical Engineering in UiTM Shah Alam. Her major field is more to biomaterial engineering which is under supervision of Dr Nor Fazli Adull Manan. As one of the author, she contributed her ideas in terms of experiments originality and also a part of theory about wound healing technology.

Nor Fazli Adull Manan,a Senior Lecturer in the Department of Engineering Mechanics, Faculty of Mechanical Engineering, UiTM Shah Alam. He also a member of Board of Engineers Malaysia (BEM) since 2008 and a Graduate Member of Institute of Engineers Malaysia (IEM) since 2010. Before he become a lecturer since 2006, he started his career as a Design Engineer at UBC Commercial Vehicle (M) Sdn. Bhd. officially in 2005. Based on the experience he gained, he published a lot of articles and journals for other researchers' reference.