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

# Effect of Temperature and Tanning Agent on Mechanical Properties of Animal Skin

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***Abstract*: Open exposure to the extraordinary amount of the heat under the sun can causes the damage to the skin and lead to diseases. The analysis of the mechanical properties on cow skin which investigated by analyzing the uniaxial tensile test in order to produce the outcome based on the situation stated. Besides that, cow skin was selected in order to compare with the previous study on sheep skin. The aim of the study is to investigate the effect of varies temperature on mechanical properties of the animal skin. Experimental and numerical is part of the integration process of the data. Uniaxial tensile test was performed to measure the basic mechanical parameter of stress-stretch by according to the ASTM D2209-00 testing standard. Other than that, the hyperelastic constitutive model Arruda & Boyce (A&B) equation is simplified via numerical approach for finding the material parameter. A graph of Stress-Stretch ($\sigma$-$\lambda$) plotted for curve fit with the experimental data to obtain the mechanical properties of parameter. Overall, the samples applied with lanolin coating is more elastic even though it dried at 40$^{o}$C compared to the sample sets without lanolin coating. With having the specific mechanical data of the skin by computational program and analysis it become more reliable by showing the real skin behavior to the variable.***

***Keywords* : Arruda Boyce, ASTM D2209-00, Animal, hyper elastic, sheep skin.**

## I. INTRODUCTION

Animal skin have been specifically act like the primary layer of the body amour that protect from microbe such as bacteria and germ. Skin act most likely like the radiator as it helps control body temperature beside permits the sensations of touch, heat and cold. Therefore, it is advantageous for animal with fur skin to regulate body temperature by its own. Understanding the important of skin behavior has generated to lead the humanity to study deeper and research were carried out with experiment on the human, animal and synthetic skin. Wide research has used the human skin for different purpose and investigation, one of the purposes is for studying the biomechanical properties of the skin. As been said by A. N. Annaidh has used excised human skin for characterizing the anisotropic Mechanical properties of excised human skin[1].

**Revised Manuscript Received on January 30, 2020.**
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Not only is study of the movement or the mechanism of the skin, T. A. Andre investigate Ex-vivo model of the human skin as the alternative to animal use for the cosmetic tests [2]. In research for the animal skin, N. F. Adull Manan has used the bovine skin to in quantifying the biomechanical properties of the skin via uniaxial tension [3]. Furthermore, other research is 24 adult female mice has been used to study the hyperelastic material properties of mouse skin under compression tests. There are also researches conducted on animal that live in the water. With all the research, it will can gave the benefit to the society.

Our world does not the same as the previous hundred or thousand years before. The development in the world lead to climate changes. Some part of the earth was very hot and other were very cold. For the more specific study, the phenomenon was called El Nino. El Nino are the complex patterns that variations occur in the ocean temperature in the central and eastern Pacific Ocean become hotter. Malaysia only experience this phenomenon once in two or seven years. In 2016, Malaysia has experienced again the hot environment beyond the average temperature of 27$^{o}$C. The temperature recorded was 37$^{o}$C and reaching up to 40$^{o}$C at the time based on the situation stated [4]. The hot experience can do damage on skin or even affecting the health of the living human. Heat, fever, heat exhaustion, heat cramp, heat rash and even worst it also can lead to cancer. The research on the hot temperature affecting the skin behavior is part of the society needs.

### A. Animal as Specimen

Animal in our eye view have the different body structure compare to human but at the physiology and anatomical it has the almost similarity. Animals such as monkey, mice, sheep etc. have the same organ (heart, lungs, and brain) and systemic organ (respiratory, cardiovascular, nervous system) which carry out the same function as the human. Those similarity can be compared 90% of the veterinary medicines that are used to treat animals are compatible with the development to treat human patients [5].

The difference is small compared to the similarities. The difference can helps provide an important data about the disease and how they might be treated. Besides that, the skin with muscular dystrophy suffers less muscle wasting than human patients, this might lead to a treatment for this debilitating and fatal disorder. About 99% of human DNA is same to mice [6] besides we can use “knockout” mice to work out the effect individual human genes have in our body.

By recreating human genetic diseases in this way can begin to look for treatment.

Furthermore, more of the study that use the animal as to provide data and solution to human kind. O.A Shergold [7] has used pig skin for the uniaxial stress vs strain response of pig skin and silicone rubber at low and high strain rates.

On the other hand, some researcher used the bovine skin for quantifying the biomechanical properties of skin via uniaxial tension [3]. As for that, the cow skin is used to study the biomechanical properties of the skin and it behavior after expose certain amount of heat.

### B. Chemical Grease Lanolin

Lanolin is a wool wax or wool grease; its wax produces by purifying wool bearing animal. Lanolin produce by nature to soften the both skin and wool fibers besides against the bad weather condition and environment which damage the skin. Lanolin structure is the set of intercellular lipids of the stratum corneum. This is the outermost layer of skin, which consist of cholesterol, cholesterol derivatives and free fatty acids. These lipids play a critical role in skin's moisture control, where under normal condition water continuously evaporates from skin's surfaces which makes the skin dry, dull, inflexible and brittle stratum corneum [8].

The advantages of the lanolin on human skin and hair have been discover and valued by humans for thousands of years. Emollient form lanolin is absorbed by the skin and makes the skin hydrated with correct balance of moisture and softness without impairing natural skin functions. Other than that, lanolin has great power of emulsifying properties which means that lanolin can bind the large amount of water by performing a stable emulsion. Therefore, lanolin is use in this project as the tanning agent.

### C. Hyperelastic Constitutive Model

To understand the hyperelastic material on skin, adapting hyperelastic constitutive models to skin modeling is the solution. The solution consists of non-linear, hyperelastic material that exhibits time-dependent viscoelastic and measuring properties is a complex undertaking [9]. Based on G.Chagnon [10] studies, an efficient hyperelastic model can be defined by four major qualities. First, it should be able to accurately produce the whole "S" shaped response of rubbers. Second, no problem in changes of deformation modes, if the model behave satisfactorily in uniaxial tension, it should also be quite accurate in simple shear or equiaxial extension. Third, in order to reduce the number of experiment test needed for the identification, the number of relevant material parameters must be as small as possible. Fourth, the mathematical formulation should be simple to make possible the numerical of the model.

According to A. Ali [11], there are eight hyperelastic constitutive model which are Polynomial model, Reduced Polynomial model, Ogden model, Yeoh model, Moneey-Rivlin model, Neo-Hokean model, Aruda and Boyce model, and Van der Waals model. For these studies, Aruda and Boyce model is to be used for the analysis. Physical models such as Aruda and Boyce are based on an explanation of the molecular chains network. The strain energies of the individual chain oriented in space in randomly. The relation of Aruda and Boyce strain energy potential is given as below [12].

$$U = \mu \sum_{i=1}^{5} \frac{C_i}{\lambda_m^{2i-2}} \left( \bar{I}_1^i - 3^i \right) + \frac{1}{D} \left( \frac{J_{el}^2 - 1}{2} - \ln J_{el} \right), \quad (1)$$

### D. Factor That Affect the Properties of Skin

*1) Position and condition of the sampling*

Based on the previous study, the skin can produce different outcome with several condition and positioning is the factor. The effect of skin orientation on biomechanical properties by using sheepskin as specimen that was prepare into two groups hair and shaved fur [13]. The result shows, the sample taken from the parallel with near spine line has larger mean stretch value compared to vertical sampling. With the sample unshaved it produce higher result compared to the shaved skin. It can be concluded that fur on skin can give effect on biomechanical properties of the skin.

*2) Tanning agent*

The skin consists of several or combination of properties such as water, mineral, natural fat, protein, pigments and carbohydrates which in other fact it's retains and absorb water with great capacity. Tanning agent is one of the great products that is used to maintain the quality of the skin. According to C. Lu [14] experiment, the use of tanning agents such chrome, glutaraldehyde and chestnut extract can influence on water absorption capacity of the goatskin. The tanning agents maintain the fibers structure and increased the crosslinking of collagen matrices. From the result that have been collected, it is not easy for tanned collagen matrices to swell and the water absorption capacity of sample was subsequently reduced.

*3) Heating temperature*

The different in heating temperature show the different result. In B. Zhou research [15][16], the skin tends to be softer at the same stress level with increased temperature and the transition region changes. Stress-Stretch value under low temperature is higher compared to skin under high temperature but the discrepancy at the low stretch region is not that large. In F. Xu [17] studies which is the characterization of thermo mechanical behavior of skin tissue via tensile and compressive behavior. The result shows that the temperature has great influence on both the tensile and compressive properties of the skin tissue, but the mechanism are different. The increasing temperature result the variation of skin tensile properties which is caused by thermal denaturation which the variation of skin compressive behavior of the skin tissue due to the hydration changes with thermal denaturation.

## II. METHODOLOGY

### A. Sample Preparation

For material preparation, the material that used for this project is cow skin that was obtained from Pasar Besar Klang. The cow skin condition was ensured dried and remain unshaved before the specimen was prepared as refer to Fig. 1.

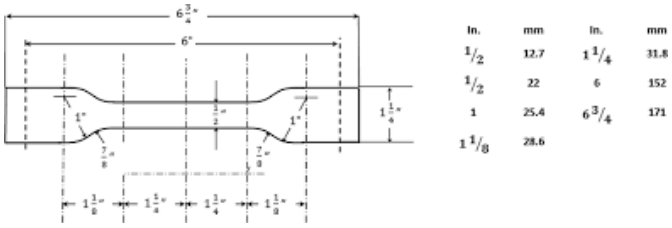
**Fig.1. Cow skin preparation**

### B. Material Separation

The first thing to do in specimen preparation is the cow skin will be remained unshaved and it will be prepared into a dumbbell shaped, the size and dimension with reference from ASTM International Standard. The specimen will be prepared based on standard testing method for tensile strength of leather according to International ASTM (D2209-00). In order to obtain the accurate dimension as standard required, a dumbbell shaped template was prepared first by schematic diagram as refer to Fig. 2 on vinyl cardboard. The template act as guideline when cutting the skin according to the outer line of the dumbbell shaped template for obtain the specimen. Based on Table I, the specimen was prepared into two main categories that had been predetermined based on heat treatment temperature which are 30℃ and 40℃. Each of these will be divided into two groups between specimen with non-lanolin (WL) and specimen with lanolin (L). The specimen with lanolin (L) means a chemical degree grease lanolin which act as tanning agent is applied to the specimens for protecting the skin against ravages of climate and environment.

**Table I. Notation for every category.**

| Specimen Categories | Description |
|---|---|
| **L Temp 30** | Specimen with lanolin, 30℃ of heat treatment temperature |
| **WL Temp 30** | Specimen with non-lanolin, 30℃ of heat treatment temperature |
| **L Temp 40** | Specimen with lanolin, 40℃ of heat treatment temperature |
| **WL Temp 40** | Specimen with non-lanolin, 40℃ of heat treatment temperature |




| In. | mm | In. | mm |
|---|---|---|---|
| 1/2 | 12.7 | 1 1/4 | 31.8 |
| 1/2 | 22 | 6 | 152 |
| 1 | 25.4 | 6 3/4 | 171 |
| 1 1/8 | 28.6 | | |

**Fig. 2. Standard Measurement according to ASTM International Standard.**

### C. Heating Treatment

The specimens ware undergoing heating treatment at different temperatures (30℃, 40℃) by using heating machine in a control environment. The specimens were heated by using High-Temp Oven PHH-201 model which are in Composite Laboratory, Faculty of Mechanical Engineering UiTM Shah Alam. The heat treatment time is four (4) hours which are fixed for all specimens.

### D. Mechanical Testing

The uniaxial tensile test was conducted by using the tensile test machine model INSTRON 3382 located in Strength of Material Laboratory, Faculty of Mechanical Engineering UiTM Shah Alam. The testing procedure was conducted by followed the Standard Test Method for strength of leather (D2209-00). The load of 240 N was applied together with the speed of 254 ± 50 mm/min. there are tendency of specimen to slip during testing, so a sand paper was used to clamp at the both end of the specimen and tighten as much as it could as refer to Fig. 3. The parameters obtained from the tensile testing are stress, elongation, and strain that can help in determined the mechanical properties of skin by applying formula of stretch-strain.

**Fig. 3. The skin during Tensile Test**.

### E. Numerical Approach

From the basic mechanical parameter obtain from experimental, a conversion of stress–stretch ($\sigma - \lambda$) was done. By having strain values from the experimental, the stretch can be calculated by using equation of strain associate with stretch.

$$\varepsilon = \lambda - 1 \tag{2}$$

Where, $\varepsilon$ and $\lambda$ are strain and stretch respectively.

Arruda and Boyce model equation was derived to a simpler hyper elastic equation so that the integration of experimental stress-stretch ($\sigma - \lambda$) data and simplify Arruda and Boyce equation can be done by using Microsoft Excel programming. For determining the material parameter, a graph of stress-stretch plotted and curve fitting the experimental graph along with stress-stretch was done.
The hyperelastic constitutive Arruda and Boyce model equation [16] was reviewed and simplified before applying the equation in the analysis.

The main equation [18] is

$$\sigma = 2(\lambda - \lambda^{-2})\mu_0 \sum_{p=1}^{5} \frac{p\ C_{\square}}{N^{p-1}}\ \mathrm{I}_{1\,uni}^{p-1} \tag{3}$$

After considering it is an incompressible and isotropic characteristic material and under uniaxial tensile, the simplified equation is

$$\sigma = \frac{\mu}{N}\left(\lambda - \frac{1}{\lambda^2}\right) \quad (4)$$

Where,

$\sigma$ = Predicted stress

$\mu$ = Arruda and Boyce coefficient (MPa)

N = associated with maximum stretch (no unit)

The material parameter for Arruda and Boyce model is $\mu$ and N.

## III. RESULTS AND DISCUSSIONS

This section presents the basic mechanical properties and biomechanical properties only because the cow skin is incompressible and in a category of hyperelastic materials.

### A. Basic Mechanical Properties

Fig. 4 and Fig. 5 show that the basic mechanical properties which the stress-strain for the specimen. This specimen was heated with 30°C. The specimen also was coated with linolin for L30 and without linolin for WL30. Specimen 2 have larger strain value compared to the specimen 1. The highest stress recorded is 0.7 MPa. Furthermore, based on the different without and with coating of linolin, the affect the result as the strain value for L30 is greater than WL30.

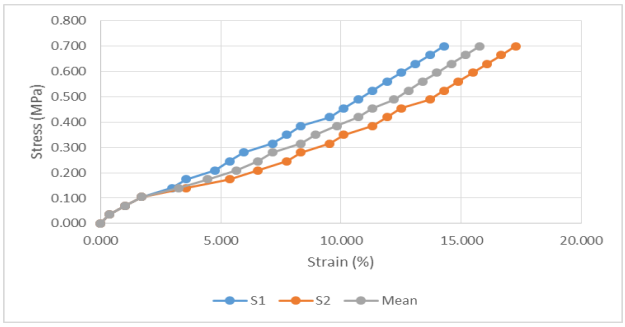



**Fig. 4. Specimen WL30.**

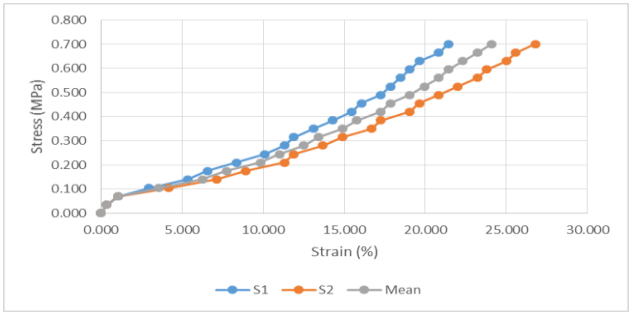



**Fig. 5. Specimen L30.**

Fig. 6 and Fig. 7 show that the basic mechanical properties which the stress-strain for the specimen. This specimen was heated with 40°C. The specimen also was coated with linolin for L40 and without linolin for WL40. Specimen 2 have larger strain value compared to the specimen 1. The highest stress recorded is 2.5 MPa. Furthermore, based on the different without and with coating of linolin, the affect the result as the strain value for L40 is greater than WL40.

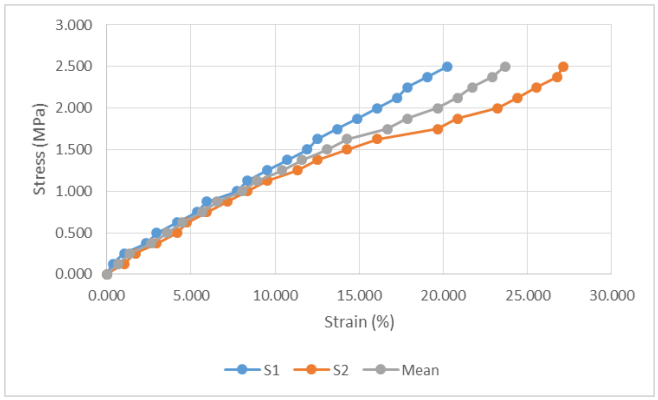



**Fig. 6. Specimen WL40.**

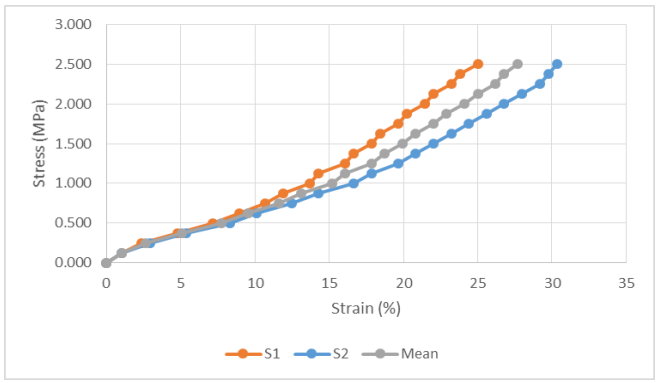



**Fig. 7. Specimen L40.**

There are different in stress value for both temperatures. The 40°C specimen have higher stress value which different from the accepted theory. The reason this happen is that the specimen for temperature 30°C are from soft part of the cow skin which away from the back-bone line.

### B. Biomechanical Properties

All four the categories of the specimen were plotted into Stress-Stretch graph as shown in Fig. 8 to Fig. 11 Every graph shows almost a good curve. The mean value of each sample set were not too differ each other. However, the samples applied with lanolin much elastic compared to the samples without lanolin. In other words, the natural sebum produced in our skin is important for elasticity, same goes to animals with fur.

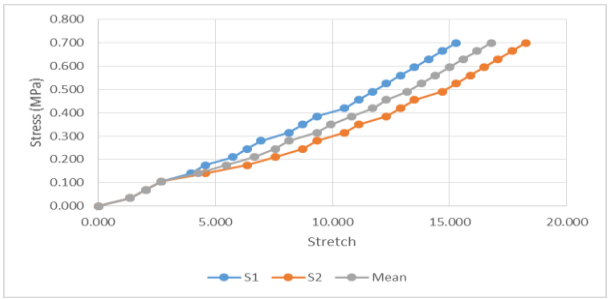



**Fig. 8. Specimen WL30.**

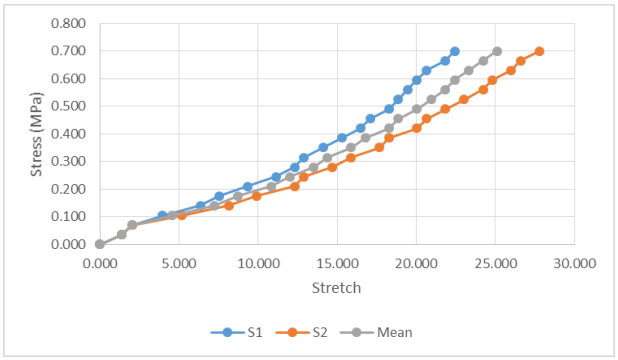



**Fig. 9. Specimen L30.**

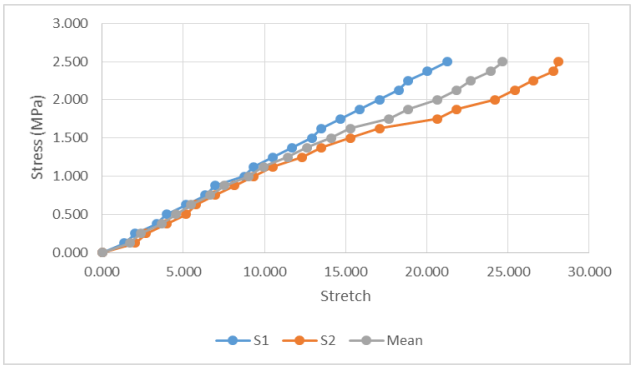



**Fig. 10. Specimen WL40.**

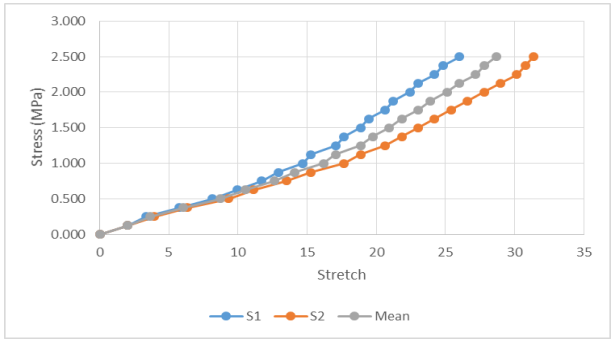



**Fig. 11. Specimen L40.**

### C. Comparison experimental approach and numerical approach

All the data collected are shown in to Stress-Stretch graph. Fig. 12 to Fig. 15 are the experimental data been compared with Arruda & Boyce model data based on Microsoft programming. Besides that, inside the graph also been shown the data from the previous experiment of sheep skin by A. Aziz [18]. The stress for the sheep skin is lower at the maximum compare with other data.

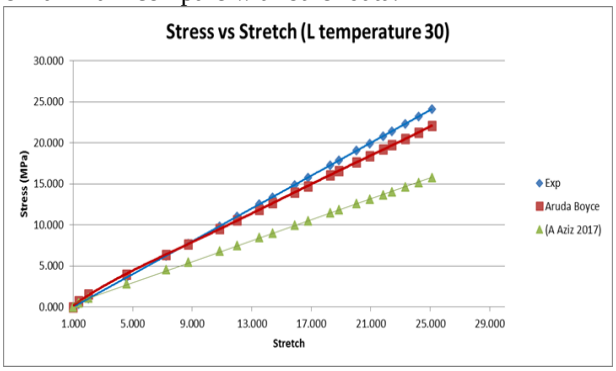



**Fig. 12. Comparison of experiential and Arruda & Boyce model for L30.**

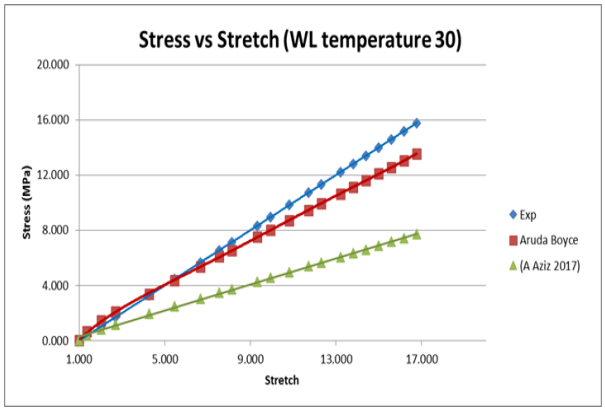



**Fig. 13. Comparison of experiential and Arruda & Boyce model for WL30.**

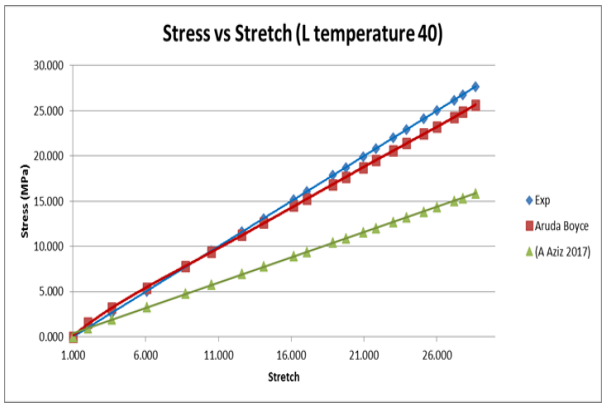



**Fig. 14. Comparison of experiential and Arruda & Boyce model for L40.**

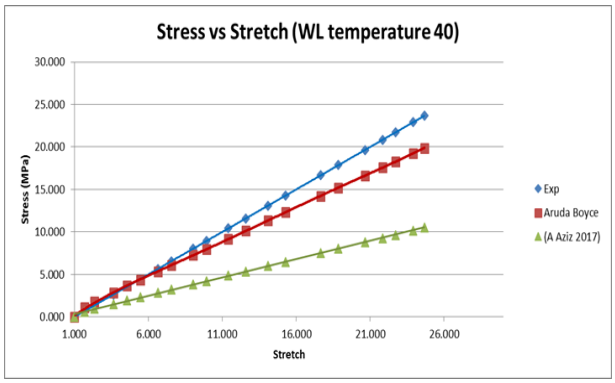



**Fig. 15. Comparison of experiential and Arruda & Boyce model for WL40.**

## IV. CONCLUSION

For the conclusion of the study, the objectives has been achieved which is to analyze the effect of the dryness on animal skin. Besides that, quantifying the biomechanical properties of the skin using the experimental and the numerical. The experiment can be concluded based on the specimen view as the temperature give impact to the skin. Furthermore, the coating also give impact to the result of the mechanical testing. The lanolin coating gave the skin more ductility which the moisture of the skin still stored inside the specimen. Other than that, as the experiment also reveal that the skin part which further to the

back-bone line is softer compare to the skin that are nearer to the back-bone line. As for the future recommendation, the experiment can be manipulated by using higher technology equipment such biaxial tensile test machine. This will give more variety the data collected. Other than that, the period also can be change into about period such as 8 hours or 24 hours. Besides that, the adapting with other models also recommended such as Neo-Hookean model, Mooney-Rivlin model or Yeoh model.

## ACKNOWLEDGMENT

The authors would like to thank the Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM) Shah Alam Selangor Malaysia for the supports.

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**Mohammad Nur Syahir bin Shaharuddin** was an undergraduate student from Faculty of Mechanical Engineering in UiTM Shah Alam. His major field is more to biomaterial engineering which is under supervision of Dr Nor Fazli Adull Manan. As one of the authors, he contributed the ideas in terms of experiments originality and also a part of theory about hyper elastic material studies.

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