BE 209 – Group BEW6
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Tensile Properties of Chicken Skin

INTRODUCTION:

Human skin is amazingly versatile and displays a range of topographically varying properties. A person's skin on the sole of the feet, for example, is very different from that on the back of the hand, which is also different form that on the palm of the hand. Skin covers the body and is essential in protecting the body from damaging microorganisms. Thus, when the skin becomes injured in large areas, it is crucial to find a replacement for the vital organ. The original skin properties should be thoroughly investigated so as to facilitate the design of the replacement. An important property of the skin is the tensile property, or the ability of the skin to stretch and release tension.

In this lab the chicken skin was used to investigate the tensile property of the skin. The Instron™ Model 4444 mechanical testing machine was used to stretch the chicken skin and software called LabView™ was used to take the data. With the aid of these accurate instruments, we hope to determine certain crucial mechanical material properties of the chicken skin. These are the values of: 1) yield strength, which is the stress at which the skin begins to stretch irreversibly, 2) breaking strength, which it the stress at which failure occurs, and 3) elongation, which is the degree to which the material stretched before it breaks. In addition, we are going to calculate Young's Modulus and stiffness value for the samples as well. We expect to see that the values of Young's modulus on all chicken skin samples to be the same. We also expect the stiffness value to be greater for a chicken skin with smaller dimensions, and vice versa. All of these qualitative values will be the basis for the design of skin replacement if one is needed.

METHODS & MATERIALS:

The materials used in this experiment include:

- Chicken skin samples of various dimensions
- Scalpel
- Scissors
- Cutting board
- Rulers
- Calipers
- Instron Model 4444 benchtop testing machine
- Saline solution
- Weight set (for constructing calibration curve)

Chicken skin samples of various dimensions were cut with the use of a scalpel and ruler. Samples were cut in groups of three, with the samples of each group containing "identical" dimensions. Three samples of "identical" dimensions were cut for each group to allow for multiple trials of a certain dimension. Two groups of three samples were cut for an overall total of 6 samples that were tested. Samples of group one had average dimensions of 20mm length and 30mm width with varying thickness due to the non-homogeneity of chicken skin. Samples of group two had average dimensions of 20mm length and 50mm width, once again with varying thickness. The actual dimensions for group one were: 22.02 x 14.42 x 0.59mm, 15.70 x 16.20 x 0.50mm and 12.00 x 14.75 x 0.75mm. The actual dimensions for group two were: 21.70 x 10.84 x 0.70mm, 17.00 x 13.01 x 0.30mm and 11.39 x 19.30 x 0.90mm. After being cut, the samples were placed on paper towels immersed in saline solution to prevent drying of the chicken skin.

The Instron Model 4444 table-top mechanical testing machine was used to apply tensile stresses on the samples. Before samples were tested, a calibration curve was constructed. Standard metric weights were massed and then hung from a hook attached to the force transducer of the Instron machine. Figure 1 shown in the Appendix displays this calibration curve.

Instructions provided for calibrating and balancing the Instron machine prior to each trial were used, that is, the load and gauge length were set to zero before each trial was performed. The samples were held into place on the machine with pneumatic clamps. The samples were loaded into the top clamp first and then the bottom clamp. The samples were placed in the clamps so as to allow the bottom and top portions of the samples to fill most of the clamp length as was allowable in accordance with the original dimensions of the samples. This was done to ensure minimal slipping of the oily chicken skin from the grasp of the clamps.

Once the samples were placed in the clamps, the samples were "jogged" using the jog buttons to prevent much slack of the samples between the clamps prior to testing. Once jogged, measurements of length, width and thickness were once again taken (by means of a caliper) since the dimensions of the sample between the clamps prior to testing would be those used in data analysis. Next, safety stops were put into place and the Instron was set to a crosshead speed of 100mm/min and a data collection speed of 100 data points per second. The program was started and allowed to run until the sample tore or started to slip from between the clamps. Once tearing or slippage was observed, the machine was manually stopped. After a sample was tested a final width measurement was taken. It should be noted that for the first sample, it was observed that a crosshead speed of 125 mm/min might have caused the tearing and slippage of the chicken skin prematurely, thus the crosshead speed was reduced to 100mm/min for all samples tested after the first.

Group BEW6 utilized similar methods, though using an average crosshead speed of 75mm/min. This data was used in conjunction with the data collected for a crosshead speed of 100mm/min for the intent of comparing the affect of force speed on the tensile properties of chicken skin.

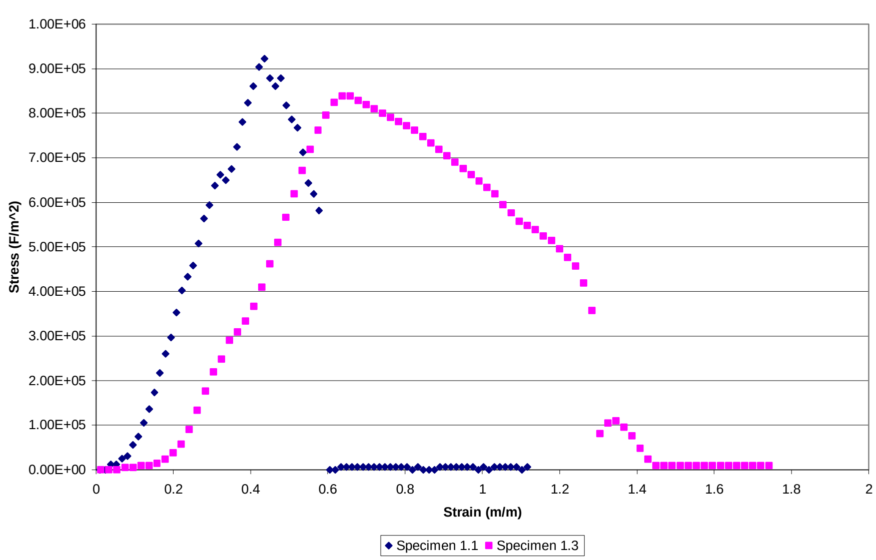
RESULTS:

The results from this experiment were inadequate to determine the yield strength, breaking strength, and elongation of the chicken skin samples. Data collection ended prematurely for all trials. The clamps holding the chicken skin were not able to secure the skin in place as the Instron™ machine stretched it. Slippage occurred during elongation, rendering the displacement values inaccurate. Ultimately, total grasp of the skin was lost before tearing could occur.

Enough data, however, were obtained to produce tentative stress-strain diagrams. The figure below as well as the figures displayed in the Appendix is an example of such a diagram for two specimens.

Typically, the peak of the stress-strain curve would denote the point at which tearing of the sample occurred. However, for this experiment, this peak simply signifies the point where total slippage

Figure 2: Stress vs. Strain - Specimen 1



occurred. The linear portion of the graph would also indicate that an accurate value of Young's modulus and stiffness value could be determined. However, because slippage occurred along with elongation, the displacement values were not accurate measurement.

Nevertheless, tentative values for Young's modulus were calculated to quantify the consistency of the different trials. In theory, the stress versus strain graphs of each trial should produce equivalent values of E. Our results, however, lack this consistency. Collectively, the average value of E has a 104% error. When discarding data points that fall out of the +/- standard deviation range, the recalculated average E value has a 45% error. Due to this discrepancy, data collected from the BEW5 group was included in this analysis. Their data set proved to have more precision, showing an 18% error after outliers were discarded. Among the acceptable chicken skin trials, the average value for E was:

$$E_{chicken\ skin} = 2.62 \pm 0.84 \times 10^6\ N/m^2 \quad (\%error = 32\%)$$

Stiffness values (k) can be determined from the E values and the dimensions of the specimen. The table below displays the calculated stiffness values for the samples. Since stiffness is a structural property, mean values could not be calculated. These values are displayed in the table below.

Specimen	**Stiffness value (N/m)**
Group BEW6	
1.1	1.00E+03
1.3	1.76E+03
2.1	9.97E+02
2.2	2.42E+03
2.3	1.20E+03
Group BEW5	
Data 1	1.74E+03
Data 2	1.11E+03
Data 4	2.01E+03
Data 5	9.83E+02
Data 6	1.11E+03
Data 7	8.25E+02
Data 8	6.95E+02

DISCUSSION:

Testing chicken skin's ability to resist deformation and tearing under applied loads can provide a model of human skin's material properties. Such knowledge is vital in the development of suitable skin replacements that can endure the daily stresses and strains encountered by human skin with minimal degeneration. Yield strength, breaking strength, elongation, Young's modulus and stiffness are properties that demonstrate the material and structural properties of chicken. All these factors must be accounted for when developing artificial skin replacements that will be as functional and effective as real skin.

The material and structural properties were tested using the Instron™ machine so that tensile axial loads could be placed with more accuracy than manual loading. The Instron™ machine is able to apply a constant stress at a constant rate more accurately than a manual application and thus should produce precise results. Nevertheless, our data did not demonstrate precision among the values obtained for the "identical" samples of each group. The non-homogeneity of the chicken skin and the inescapable slippage that was encountered greatly attributed to the inconsistency of our data.

A major observation made was the effect of the crosshead speed on data quality. Our trials were run with a crosshead speed of 100mm/min and much of our data was inconsistent. Group 6 ran their trials with a crosshead speed of 75mm/min and obtained much more consistent results. This would lead one to believe that the rate at which the chicken skin was stretched is a major factor in the chicken skin's ability to withstand loads and resist premature tearing. The faster that a constant stress is applied to the chicken skin the more quickly it deforms and tears. Still, the samples stretched at 75mm/min were not immune to slippage. Since the samples that were stretched at 75mm/min provided more precise results, it was deduced that the deformation and tearing of the samples that occurred at a slower rate were more easily detected by the Instron machine. This suggests a limitation in the Instron™ machine that could account for the inconsistency encountered in the data application.

This observation also shows that skin replacements must be equipped with the ability to withstand loads at various rates. Consequently, skin replacements used for areas that undergo swift and continuous movement would need to be more tensile than skin used in less mobile areas. For example, skin used around the knee would need to be more tensile than skin used for the sole of the foot.

The fact that the results did not allow for a determination of the yield strength, breaking strength and elongation of the samples illustrates a very interesting point about skin. The non-homogeneity of skin makes it very difficult to test its material properties, thus creating inevitable obstacles in the development of effective replacements. The modulus of elasticity was the only variable for which we were able to calculate an average value and that value itself was difficult to obtain because of the inconsistency of the data. It would be necessary to run many trials so that average values for the yield strength, breaking strength and elongation could be calculated since these values are vital in the development of a competent skin replacement.

Perhaps the most significant source of error experienced throughout this experiment was the shifting of the skin beyond the edge of the clamps due to increased axial loading (from this point forward referred to as *sliding*). Not only did this incident produce erroneous elongation values and thus ruined the validity of all structural information, but also marred the accuracy of the material properties; that is the increased measure of elongation created an inflation of the displacement value and thus also exaggerated the individual strains relating to their respective stresses. The graphical interpretation of the modulus of elasticity was thus rendered inaccurate by the misconstrued relationship between respective stresses and strains. Sliding error is graphically evident by the step-like vertical increases at various points throughout each graph.

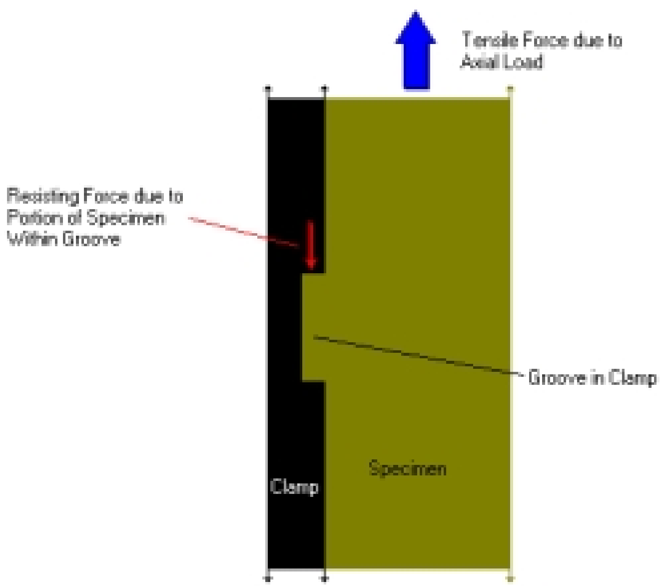
Although admittedly trivial when compared to sliding, the error due to creep played a significant role in the inaccuracy of the data obtained. Creep is the time-related plastic deformation of a specimen, thus the longer a load is applied to a specimen, the higher affinity that specimen possesses to undergo creep. Creep effects the elasticity of a substance by increasing the strain per given stress value. Even though the specimens within this lab were tested for mere seconds, the creep is evident in the concave sections of the posterior portions of some graphs.

An assortment of legitimate modifications could be implemented to facilitate a decrease in the error experienced throughout the lab, the first of which being a decrease in crosshead speed of the Instron™. Although this amendment plays no role in controlling sliding, a slower crosshead speed will allow for the collection of a greater amount of data. Thus, more points will exist, creating a more accurate graphical representation of the data and amplifying the variances due to sliding. These amplified variances would allow the data analysis specialists to utilize information up to the point where sliding is initially evident, thus producing a more accurate slope and, in turn, modulus of elasticity. The drawback to implementing this particular modification is that fact that a slower crosshead speed amplifies the effect of the creep error on the experiment. Nonetheless, error due to creep is far less serious than that of sliding.

A direct modification to reduce sliding is to use stronger clamps. The pressure exerted on opposite sides of the chicken skin creates increased friction, thus reducing the affinity to undergo sliding. The singular concern when implementing this modification is the increased pressure at the extremities of the clamps, causing the cells at these boundaries to lyse and lose some of their cytoskeletal rigidity. The specimen may therefore have a tendency to fracture near the clamps, which was evident even at the pressures utilized in the experiment.

To increase friction it is also quite viable to cut longer samples and place more between the clamps, thus increasing the total friction between the clamps. This however was tested and resulted in no noticeable improvement.

Another method of increasing friction between clamps is to score horizontal channels in the clamps, thus when pressure is applied to the specimen, portions of it will be forced into the grooves. A vertical load applying a vertical force on the system will thus be directly counteracted by a normal force applied by the portions of the specimens residing within the grooves as shown below.



The final procedural modification is to modify the specimen's dimensions, specifically to make the specimen thinner. This modification will increase relative stresses within the specimen, and thus facilitate fracture at smaller loads. This is beneficial in the sense that smaller loads will not be as prone to sliding. Despite its benefits, this modification may be detrimental in the sense that the range of data will be sacrificed in order to obtain more accurate results.

CONCLUSION:

The main objectives for this experiment of determining the yield strength, breaking strength, and elongation of chicken skin were unsuccessful. Excessive slippage of skin with the clamps did not allow proper stretching of specimens and therefore stretching to the point of tearing was not possible. This source of error is evident in the variance of the calculated Young's modulus for the different samples. The average E was 2.62×10^6 N/m^2 with a standard deviation of 0.84×10^6 N/m^2, a 32% error. This inconsistency demonstrates the need to modify the experimental setup and procedure. Some modifications that can be made are: usage of a slower crosshead speed, stronger clamps, clamps with grooves, increased amount of surface area in contact with clamp, and finally, usage of a thinner specimen.

Success in examining the tensile properties of chicken skin and materials in general is important for many biomedical applications. A successful method used to analyze chicken skin can directly be used to test other materials such as human skin. Proper analysis of the mechanical properties of skin, coupled with the knowledge of its chemical attributes which can be further investigated, allows the manufacturing of artificial skin that can substitute for the real skin in both elasticity and protective function.

APPENDIX:

Figure 1: Electronic Balance Mass vs. Instron Mass

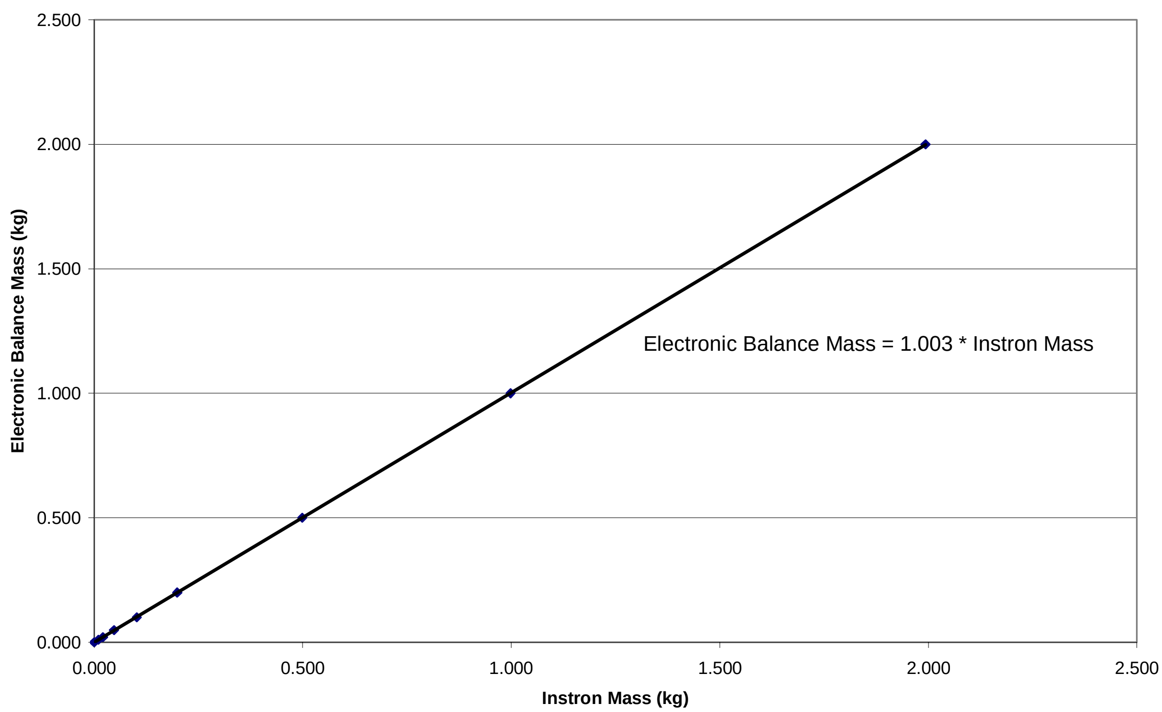


Figure 2: Stress vs. Strain - Specimen 1

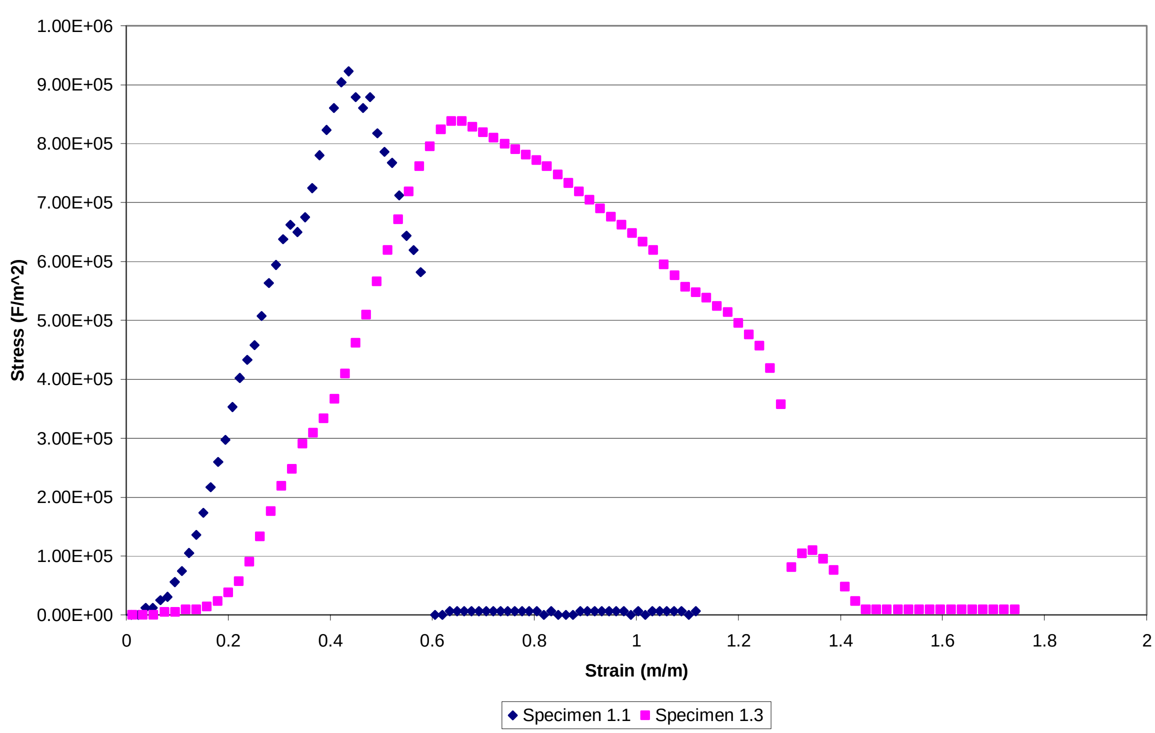


Figure 3: Stress vs. Strain - Specimen 2

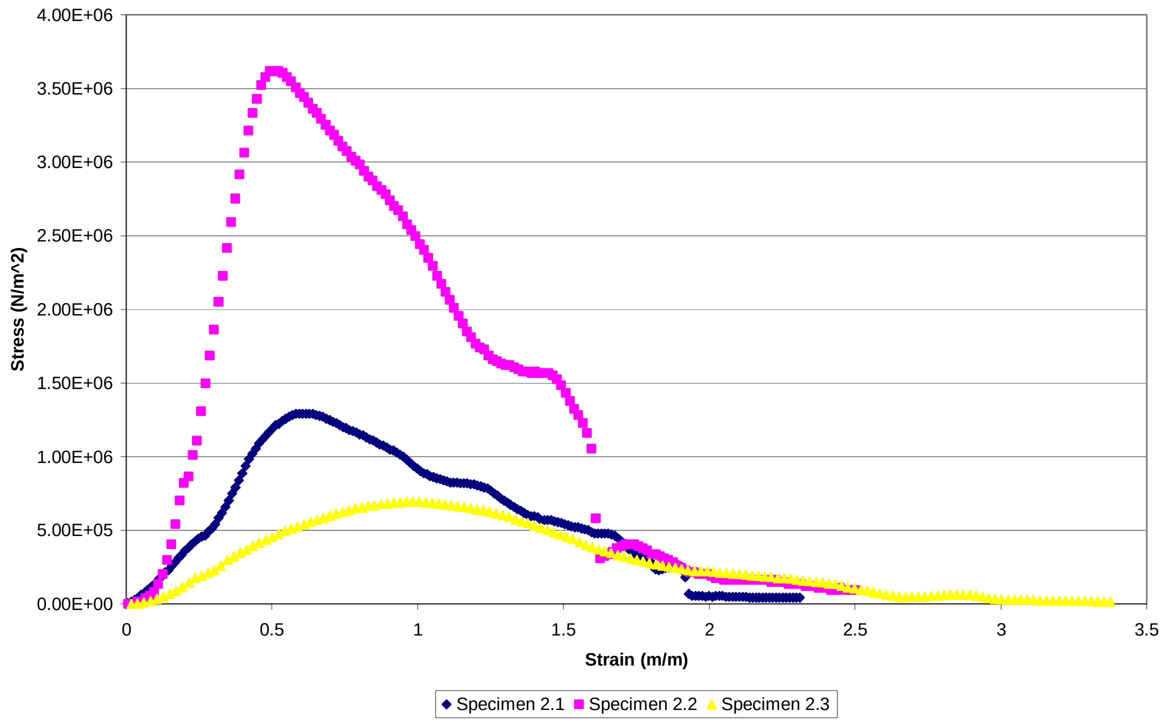


Figure 4: Stress vs. Strain - Grp. BEW5 Data Sets

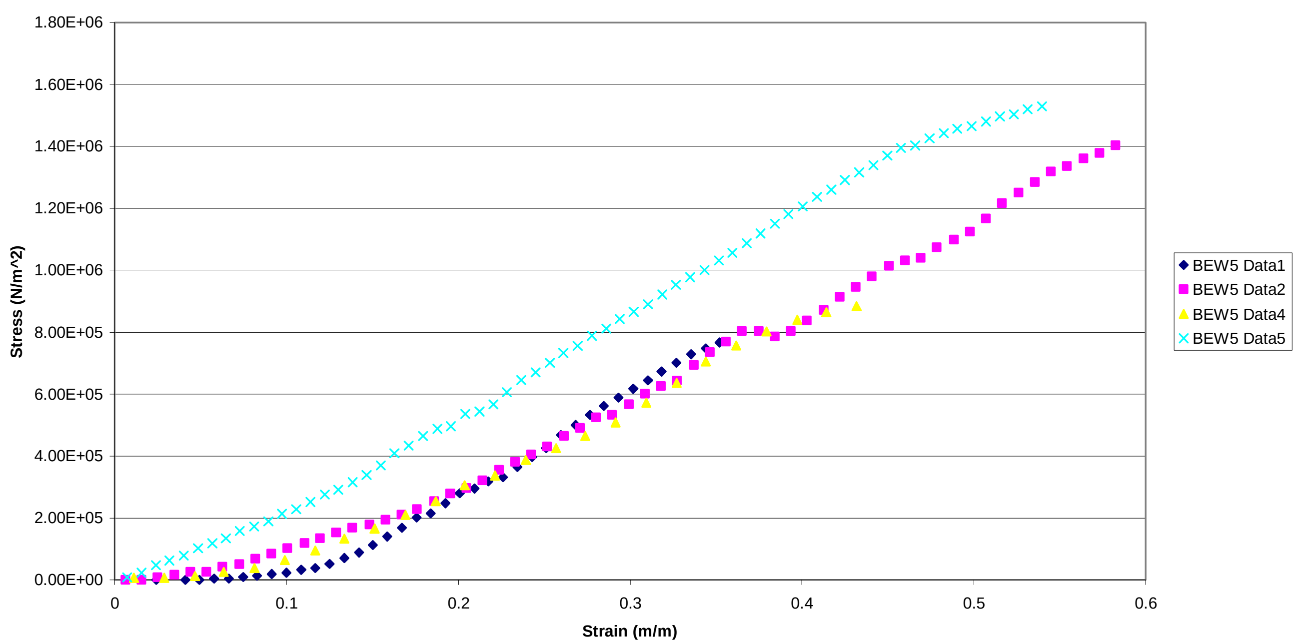


Figure 5: Stress vs. Strain - Grp. BEW5 Data Sets