Weekly Team Meeting Individual Report

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3-Point Bending Device

BME-4910

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Where I left off last week: Last week I focused on ordering the CCD camera and developing the transmural strain calculations. At the end of the week the camera was ordered (including the lens) and the transmural strain program was fully written. Between that time and now the camera has arrived and is being implemented into the LabView code by Xuan.

Difficulties last week: The transmural strain program is written, but to debug the logic and ensure that appropriate results are being given, I feel that we should add a pilot study of a homogeneous material that is wide enough to allow for several markers large enough to be seen with the naked eye to be placed through its thickness. For this reason, we have added a new pilot study where a thick (1-2"") piece of rubber or foam will be subjected to 3-point bending. Since the material used will be homogeneous, its neutral axis should be halfway through the thickness. This knowledge should allow us to debug and validate virtually all of the code. The experiment will likely be conducted at the end of this week.

Comments from last week’s team meeting: The only concern expressed was whether the projected goals will be met and whether project completion will be on-time. We have worked to address these concerns by purchasing and implementing the critical path item, the CCD camera.

Actions this week: This week I have been working on implementing and debugging the flexural rigidity experiment using the data from the pilot trials that were already performed (Fig. 1). During the first runs through the program, I noted that the flexural rigidity output graph was erratic. After tracing through the program, I saw that imaginary numbers were being generated and they apparently originated from the calculation of the tissue’s radius of curvature. As a result, I have changed the radius of curvature calculation several times and compared each method with actual radius measurements taken in CAD software. The radius of curvature was calculated from three marker point locations using a circumcircle equation. Debugging the radius of curvature also illuminated slight problems in the
implementation of the marker location input and distance calibration subroutines. Also, based on discussions with the client, I have altered the approach to radius calculations. Previously the program had taken the average of all markers to find a representative radius of curvature. The client, however, pointed out that an accurate description of the curvature in the area of the bending bar would be more desirable than a general trend (Fig. 2). This preference is based on the concept that the curvature will be compared to force applied, and the force applied is specific to that region.

![Figure 1 – Flexural rigidity mock experiment.](image1)

With the radius of curvature subroutine debugged, I moved on to debugging the calculation of the center-point. This correction process has proven to be more challenging, but is nearly complete. The circle center is calculated using two of the three points used to calculate the radius of curvature. The two points are entered into individual equations of a circle. The system of equations was then rearranged to leave a quadratic equation with one variable unknown. The quadratic equation was solved, which yielded two possible results. The other variable was solved using each of these options. The values were then plugged back into a modified version of the equation of the circle, where the right hand side was subtracted from the left hand side. In theory, for the correct choice of x,y center coordinate, this value should be very close to zero. The value chosen is the one closest to zero. There is apparently still a flaw though and although the x coordinate and radius value have been validated using CAD software, the y coordinate remains off. One of the factors that I believe is contributing to the error
is that the re-arranged quadratic approach requires that one of the two coordinates be set to zero. This requires an additional series of coordinate adjustments and additional possibilities for error. I remain confident that this bug will be worked out by the end of the week.

![Diagram](image.png)

**Figure 2** – Pictorial representation of two methods used to calculate radius of curvature.  

a) The original method used the point that each post met the tissue and then each of the marker points as the third point. The radius was the average of all points.  
b) The current method calculates only for the center point and its two adjacent points. The radius generated tends to be smaller in size and follows more closely with general curvature trend of the tissue specimen.

Each debugging event brings the program one step closer to providing usable results. Currently, the radius of curvature shows a general decreasing trend, and the radius of curvature vs. M/I curve is generated without imaginary components. Still, the curve clearly contains inaccuracies and the radius of curvature vs. E, which depends upon the first curve, also contains inaccuracies. The individual subroutines that calculate and display these parameters will be explored once the circle center algorithm has been thoroughly validated. Fortunately, many of the subroutines that have been debugged will be used for other portions of the device, including the measurement calibration, force calibration, point input, radius calculation, and finally, circle center calculation.

**Current Status:** The flexural rigidity subroutine remains in the implementation and debugging phase. Problems persist, particularly with the center of circle calculation. I am confident, however, that
these problems will be overcome. I have previously implemented such a subroutine in Microsoft Excel using the same logic. I believe that the problems have arisen from a combination of the changes in programming environment and input parameters. Once the circle center has been corrected and validated, two additional subroutines will need to be validated for completion of the entire flexural rigidity implementation.