Concept Selection

Introduction

The process of selecting and identifying the highest quality concept involves a variety of important tools. We were able to utilize the Binary Pairwise Comparison (BPwC), House of Quality (HoQ), Pugh Charts, Analytical Hierarchy Process, and a Final Concept Selection Chart. All the charts utilized in the process of selecting and identifying the highest quality concept are found in Appendix E.

House of Quality (HoQ)

The process to pinpoint the highest quality concept begins in the BPwC. This chart works by comparing the customer needs with each other. The need listed in each row was juxtaposed against itself in each column, assigning a value of 1 when deemed more critical, and a 0 for less critical, while a dash marked the matrix's principal diagonal. The results of this matrix produce priority targets that are utilized inside of the House of Quality. The customer needs used in the BPwC are listed in the table below.

Table 5
Customer Needs Used in BPwC.

Customer Needs
1. Works Inside a Vacuum
2. Operate in Spacelike Conditions
3. Reads and Stores input
4. Test 4-6 Samples
5. Compatible with previous GUI
6. Applies Unique Inputs to Unique Samples
7. Tests Multiple Samples Simultaneously
8. Reads and Stores Inputs

The priority target customer needs were given a weight factor and categorized from most important to least important. The target customer's need with the greatest weight factor was works inside a vacuum. The target customer need with the least weight factor was tied between test multiple samples simultaneously and returns outputs and critical targets.

Using these weight factors in the HoQ as well as engineering characteristics that originate from our targets and metrics, we were able to rank the customer needs. To begin, the needs were ranked in the form of a value of 0, 1, 3, or 9. In this case zero correlates to a null impact from the engineering characteristic on the specific target requirement. Whereas nine correlates to a large impact from the engineering characteristic on the specific target requirement. The values given were multiplied by their respective weights and then summed up. This results in a respective raw score value. The raw score value was then divided by the summation of all raw scores to produce a relative weight percent. The engineering characteristics were then ranked according to the largest relative weight percent calculated. That is, the highest percentage is equivalent to the most important characteristic whereas the lowest percentage is equivalent to the least important characteristics. According to the HoQ the most important engineering characteristic of designing our system is the holding of the samples followed by analyzing applied loads and processing electrical power. The two least important characteristics are the calculation and display of outputs. This is acceptable because of sponsor, Dr. Krick, has expressed the main focus of this project to be the simultaneous testing of multiple samples. The complete HoQ chart is in Appendix E of the evidence manual.

Table 6
Ranked Engineering Characteristics.

Engineering Characteristics
1. Holds Samples
2. Analyzes Applied Loads
3. Processes Electrical Power
4. Measures Internal Pressure
5. Senses Changes in Temperature
6. Emergency Stop
7. Display Outputs
8. Calculates Outputs

Pugh Chart

The Pugh Chart is used to compare viable design choices. The design choices selected were the high and medium fidelity options – they are outlined in section 1.5. To utilize a Pugh Chart effectively, a market leading datum is to be selected, so that our concepts can be benchmarked against the datum. Our team decided it was advantageous to use the current leading tribometer style that is utilized in the tribology lab in the AME building as our datum. To develop and produce accurate comparisons our team utilizes '+', '-', and 'S' characters. The '+' character suggests that the idea achieves the customer's needs better than the current solution. The '-' character suggests that the idea achieves the customer's needs worse than the current solution. The 'S' character suggests that the idea achieves the customers' needs at the same satisfaction as the current solution. As the process continues the medium ranked solution is selected as the datum, the highest ranked solutions are selected for comparisons, and the lowest ranked solutions are removed from the process. The initial Pugh Chart is shown below split between Table 7 and Table 8.

Table 7
Market Pugh Chart.

Market Pugh Chart						
			Concepts			
Selection Criteria	**Criteria Weight**	**AME Humidity Tribometer**	**Pin on Disk Tribometer that Can Run Four Different Samples at Four Radii**	**Inverted Existing Tribometer**	**Rake Tribometer**	**Modular Tribometer**
Processes Electrical Power	13.4%	Datum	S	S	S	S
Holds Samples	22.4%		-	+	-	-
Measures Internal Pressure	12.6%		+	+	+	+
Analyzes Applied Loads	16.8%		-	+	-	-

Senses Changes in Temperature	12.6%		+	+	+	+
Calculates Outputs	6.4%		S	S	-	-
Emergency Stop	8.1%		+	+	+	-
Display Outputs	7.6%		S	S	S	-
Pluses			3	5	3	2
Minuses			2	0	3	5

Table 8

Market Pugh Chart Cont'd.

Market Pugh Chart Cont'd.						
			Concepts			
Selection Criteria	**Criteria Weight**	**AME Humidity Tribometer**	**Six Mini-Identical Tribometers Side by Side**	**Cross Headed Sample Holder**	**Weights Loaded on Samples to Produce Normal Load**	**Tribological Samples are Nested Together**

Processes Electrical Power	13.4%		S	S	S	S
Holds Samples	22.4%		+	+	+	-
Measures Internal Pressure	12.6%		+	+	+	+
Analyzes Applied Loads	16.8%	Datum	S	-	+	-
Senses Changes in Temperature	12.6%		+	+	+	+
Calculates Outputs	6.4%		S	S	S	S
Emergency Stop	8.1%		+	+	+	+
Display Outputs	7.6%		+	S	S	S
Pluses			5	4	5	3
Minuses			0	1	0	2

Based on the data, the Cross Headed Sample Holder idea was our medium successful idea. Thus, it became the next Pugh Chart iterations datum. The ideas that were deemed quality and continued in the selection process were Six Mini-Identical Tribometers Side by Side, Weights Loaded on Samples to Produce Normal Load, and the Inverted Existing Tribometer. We followed the same comparison process as we did in the initial Pugh Chart and achieved results that could be used in the final Pugh Chart. We found that the Inverted Existing Tribometer would become our new datum. It became our new datum because it was better than the Cross Headed Sample Holder at calculating and displaying outputs. By this, it means that the new datum can obtain more outputs at a faster rate and display them in a shorter amount of time. Additionally, we found that the Six Mini-Identical Tribometers Side by Side and the Weights Loaded on Samples to Produce Normal Load would be the final ideas to be compared. The final Pugh Chart is show below in Table 9; however, all the Pugh Charts are shown in Appendix E of the evidence manual.

Table 9
Final Pugh Chart.

Concept Pugh Chart				
		Concepts		
Selection Criteria	Criteria Weight	Inverted Existing Tribometer	Six Mini-Identical Tribometers Side by Side	Weights Loaded on Samples to Produce Normal Load
Processes Electrical Power	13.4%	Datum	S	S
Holds Samples	22.4%		S	-
Measures Internal Pressure	12.6%		S	S
Analyzes Applied Loads	16.8%		S	+
Senses Changes in Temperature	12.6%		S	S
Calculates Outputs	6.4%		S	+
Emergency Stop	8.1%		S	S
Display Outputs	7.6%		S	S
Pluses			0	2
Minuses			0	1

Analytical Hierarchy Process (AHP)

Using the Analytical Hierarchy Chart, we can establish weights for our selection criteria so it can help us to determine our desired final selection. The chart compared our criteria against each other to determine how better one criterion was compared to the other. We ranked each comparison with odd numbers from 1 to 9, and the criteria that we determined to be more important gets to keep its rank number while the one that is less important gets the inverse value of the rank. A value of 1 would mean equivalent importance, but a higher value would mean dominance from that criterion over the other.

After assigning a value for each comparison in the table, we proceeded to normalize these values in a different comparison matrix. The normalized criteria comparison was made by dividing the value of each individual cell by the total addition of the entire column. Using the results of the normalized chart, we set criteria weights by averaging each row horizontally outputting values that will establish the influence each criterion in our design selection. Now, with these weights the Weighted Sum Vector and Consistency Vector were calculated using matrix operations and vector division. Finally, with these two values a consistency ratio was calculated.

Final Selection

To identify the best solution for our problem, we applied the procedure to each established criterion. We pitted the three remaining concepts from the Pugh chart, Inverted Tribometer, Six Mini-identical Tribometers, and Weights loaded on samples Tribometer, against each other. Ideally, the consistency ratios (CR) should be below 0.10, this indicates little to no bias is involved. This assessment was conducted for all eight criteria under consideration for this project, and detailed tables and charts presenting the results can be found in the document's appendix. A CR of 0.55 was established in the holds sample criterion signifying there may be some bias.

We computed a Final Rating Matrix to show the performance of each concept across each criterion. These values were then employed to assess the overall performance of each concept by multiplying them with the pre-established criteria weights determined in the AHP. The matrix operation involved transposing the Final Rating Matrix and subsequently multiplying it by the criteria weight matrix, yielding three final values. The highest among these values signifies a design that is best for the given task and is our final selection.

It was determined from the Final Rating Matrix that a tribometer with weights loaded on samples to produce normal load is the best solution to testing multiple samples simultaneously using a tribometer in a vacuum. However, the concept of six mini-tribometers side by side came in a close second place. Therefore, we will consult with our sponsor, Dr. Krick, with both ideas indicating our preference for a system that uses weights loaded on samples to produce normal load.