ANALYTICAL TASK 1

Team 18F02 – Kinetic A
Materials Corrosion Analysis and Selection

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1 INTRODUCTION

By definition, Galvanic/electromechanical corrosion is a "process where a potential difference, measured as voltage, exists between dissimilar metals and alloys when they are placed in electrical contact within an electrolytic solution" [11]. Contained within this report is an analysis of the electromechanical corrosive potentials of non-similar metallics to determine suitable materials in which to place in contact and shear with each other for the Kinetic Sculpture capstone.

1.1 CONTEMPORARY ISSUE

The Kinetic Sculpture capstone relates to the specific contemporary issues of short attention spans and lack of attentiveness commonly present in society today. This project hopes to capture the interest present and future engineering students and those who come into contact with it by showing them an artistic piece that moves and grabs attention. Through the process of movement, the "audience" of the sculpture will be, unknowingly, learning engineering principles through their interest and close looks of the sculpture.

1.2 DESCRIPTION AND MOTIVATION

Within the Kinetic Sculpture, the group has decided to have a cascading fluid flow (of oil) throughout the sculpture itself. Ans so, the group initially decided to do an analysis on the corrosiveness of an oil over the materials they had chosen. However, through research and discussion with Dr. Jennifer Wade, it was determined that a corrosion analysis was necessary for the different materials they wanted to mesh together within the sculpture in order to create visual contrast due to colors rather than the oil. This decision was made because the properties of oil tend to slow corrosion and improve life-times of metallics. Initially, the group was set on using alloys of bronze, copper, aluminum, and steel and so the analysis began with those materials in mind. As the analysis continued, it was discovered that better, less corrosive options exist. This is discussed further in the report.

2 ASSUMPTIONS AND METHODOLOGIES

Contained within this section of the report is a detailed explanation of the assumptions and methodologies used within this corrosion analysis. Through discussion with Dr. Jennifer Wade, it was determined that an analysis of a Galvanic Series/Table was necessary in order to find less non-similar metallics.

2.1 GALVANIC SERIES/TABLE EXPLAINED

To fully do and understand a corrosive analysis of non-similar metallics, it is imperative to create/find a Galvanic Series/Table. A Galvanic Series lists the corrosive potentials of different metallics (in Volts) in seawater. Once these potentials are determined through experiments and to a reference chemical (my data's' reference was Ag/AgCl), they are then listed and ordered by similarity.

Table 2.1a: Galvanic Series

Galvanic Series of Metals in Seawater

Metals and Alloys	Corrosion Potential (Volts DC ref. Ag/AgCl)				Corrosion Potential Difference (ΔV)
Magnesium and Magnesium Alloys	-1.60	to	-1.63	anodic - active (Resistant)	-0.03
Zinc	-1.00	to	-1.15		-0.15
Beryllium	-0.93	to	-0.99		-0.06
Aluminum - Anode	-1.10	to	-0.75		0.35
Zinc	-0.98	to	-1.03		-0.05
Aluminum Alloys	-0.76	to	-1.00		-0.24
Cadmium	-0.66	to	-0.72		-0.06
Mild Steel (Clean & Shiny)	-0.60	to	-0.71		-0.11
Mild Steel (rusted)	-0.46	to	-0.50		-0.04
Cast Iron (not Graphitized)	-0.43	to	-0.17		0.26
Stainless Steels	-0.31	to	-0.58		-0.27
Stainless Steel, Type 316 (active in saltwater)	-0.30	to	-0.54		-0.24
Aluminum Bronze (92% Cu, 8% Al)	-0.30	to	-0.42		-0.12
Tin	-0.31	to	-0.35		-0.04
Copper	-0.30	to	-0.57		-0.27
Naval Brass (60% Cu, 39% Zn)	-0.30	to	-0.40		-0.10
Yellow Brass (65% Cu, 35% Zn)	-0.30	to	-0.40		-0.10
Red Brass (85% Cu, 15% Zn)	-0.30	to	-0.40		-0.10
Muntz Metal (60% Cu, 40% Zn)	-0.30	to	-0.40		-0.10
Admirality Brass (71% Cu, 28% Zn, 1% Sn)	-0.28	to	-0.36		-0.08
Aluminum Brass (76% Cu, 22% Zn, 2% Al)	-0.28	to	-0.36		-0.08
Silicone Bronze (96% Cu max, .8% Fe, 1.5% Zn, 2% Si, .75% MN, 1.6% Sn)	-0.26	to	-0.29		-0.03
90% Cu, 10% Ni	-0.21	to	-0.28		-0.07
75% Cu, 20% Ni, 5% Zn	-0.19	to	-0.25		-0.06
Lead	-0.19	to	-0.25		-0.06
70% Cu, 30% Ni	-0.18	to	-0.23		-0.05
Stainless Steel, Type 304 (passive)	-0.05	to	-0.10		-0.05
Stainless Steel, Type 316 (passive)	0.00	to	-0.10		-0.10
Titanium	0.06	to	-0.05		-0.11
Platinum	0.25	to	0.19		-0.06
Carbon, Graphite, Coke	0.30	to	0.20	cathodic - noble (Non-Resistant)	-0.10

Once the metallics potentials are recorded and stored, one can create visual representation of the Galvanic Series (below). The Galvanic representation allows one to visualize the corrosive potentials to better select less non-similar metallics.

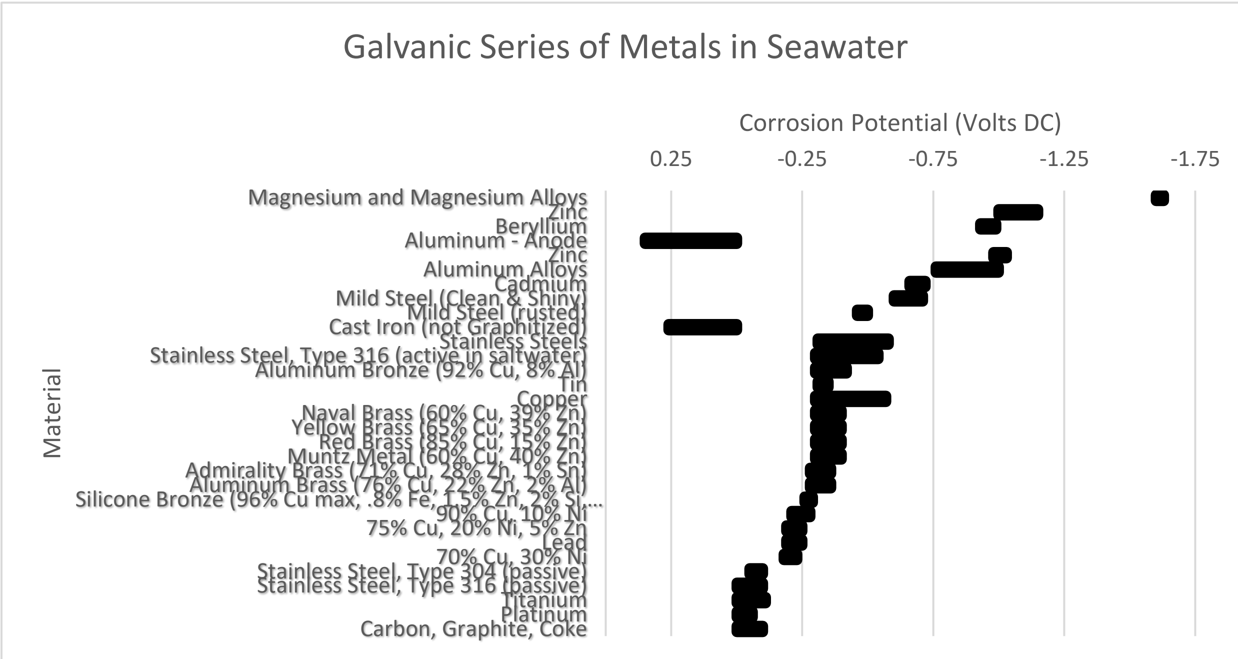

Figure 2.1a: Galvanic Series Visual

After the creation of a visual representation of a Galvanic Series, one is able to see metallics that will or will not corrode each other by noting the distance between the bars horizontally. Generally, the farther away (horizontally), the more electromechanical corrosion will occur. For example, Magnesium and Carbon will corrode each other very fast and, thus, they would not be a good pair meshed together. On the other hand, Naval Brass and Yellow Brass have essentially the same lines and corrosive potential, thus they would be a good match to mesh together with little to no electromechanical corrosion.

After compilation and creation of a Galvanic Series and Table, it is then possible to discern suitable metallics to mesh together.

2.2 METHODOLOGY

The methodology used after creation of a Galvanic Series and Table is to find more similar metallics in order to reduce electromechanical/Galvanic corrosion. By using a Galvanic Series, the group wished to find between four to ten suitable metallics to chose from to use in the Kinetic Sculpture. Then, after finding these materials, to find proper alloys for them and some of their material properties in order to determine suitable materials. For example, a material with a low Brinell hardness would not be suitable for a gear set.

3 SCHEMATICS AND/OR DIAGRAMS

After data was found and compiled (Table 2.1a), a large-scale Galvanic Series was created (Figure 2.1a). Once the large-scale series was analyzed, seven or eight suitable metallics were chosen by the group to research. From this research, a few materials were determined not to be suitable for gears and/or the Kinetic Sculpture and were eliminated from the options. From these six materials left, a smaller scale Galvanic Series was made with specifically found alloys in order to see exactly how similar/different the materials are (Figure 3a).

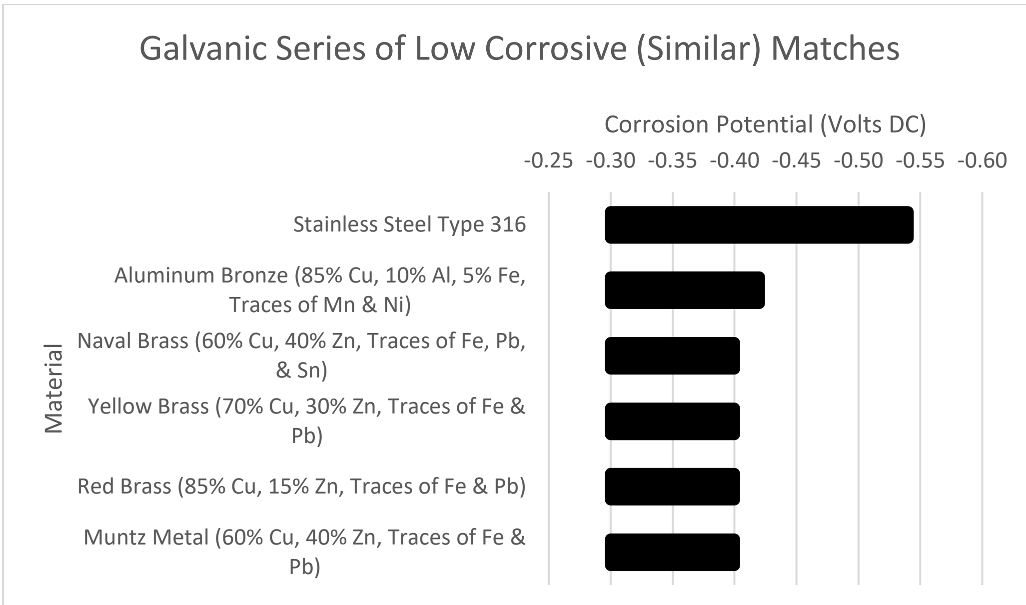

Figure 3a: Small-Scale Galvanic Series

Lastly, once the small-scale series was created, many material properties (Brinell Hardness, liquidus melting temperature, density, modulus of elasticity, yield strength, and specific heat) were found on these six materials in order to determine the most suitable metallics to use (Table 3a).

Table 3a: Materials and Their Properties

Material Choices For Project												
Choice #	Material Type	Alloy	Brinell Hardness	Corrosion Potential			ntial Differ	Melting Temperature	Density	ılus of Elas	Yield Strength	Specific Heat
			(HB)	(Volts DC)			(ΔV)	approx. (K)	(Kg/m^3)	(Gpa)	(Mpa)	(J/kg*K)
1	Stainless Steel Type 316	ASTM 316	217	-0.30	to	-0.54	-0.24	1670	8000.00	193.00	205 (Hot-Rolled)	502
2	Aluminum Bronze (85% Cu, 10% Al, 5% Fe, Traces of Mn & Ni)	Alloy C954	170	-0.30	to	-0.42	-0.12	1310	7450.00	10.69	221	419
3	Naval Brass (60% Cu, 40% Zn, Traces of Fe, Pb, & Sn)	Alloy C464	95	-0.30	to	-0.40	-0.10	1172	8410.00	10.34	30-400	377
4	Yellow Brass (70% Cu, 30% Zn, Traces of Fe & Pb)	Alloy C260	180	-0.30	to	-0.40	-0.10	1155	8530.00	11.03	145-615	375
5	Red Brass (85% Cu, 15% Zn, Traces of Fe & Pb)	Alloy C230	60	-0.30	to	-0.40	-0.10	1300	8746.85	11.72	69-434	385
6	Muntz Metal (60% Cu, 40% Zn, Traces of Fe & Pb)	Alloy C280	80	-0.30	to	-0.40	-0.10	1170	8442.37	10.34	380 (Hot-Rolled)	377

Table 3a and Figure 3a were then used to analytically understand the materials listed to discern utility in the Kinetic Sculpture.

4 EQUATIONS

In order to create an analyze a Galvanic Series/Table, no complex equations are needed beyond basic Algebra operations. A corrosive analysis of non-similar metallics is mainly a comparison of experimental results taken. Due to restrictions and budgetary limitations at NAU, experimental data from other sources was used for this analysis.

4.1 FLOW CHART

Because no equations are needed, below is a flow chart containing the process of how the Galvanic data was acquired and analyzed.

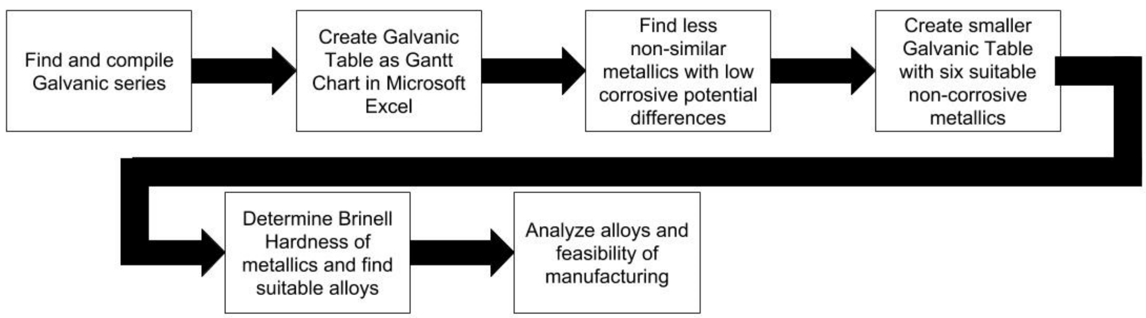

Figure 4.1a: Flow Chart

After the full analysis was compiled and put together, results were then determined.

5 RESULTS AND IMPACT

After completing the corrosive analysis for the Kinetic Sculpture, final conclusions were then able to be discerned and the impact of the analysis was able to be felt within the group through the next choices made.

5.1 CONCLUSIONS AND IMPACT

When looking through the Galvanic data, the group was able to determine six suitable metallic alloys in which to make their kinetic sculpture out of. These alloys are listed below:

1. ASTM 316
2. Alloy C954
3. Alloy C464
4. Alloy C260
5. Alloy C230
6. Alloy C280

From these alloys, the group can continue their project design and select which materials to use for the project that will not corrode each other at such an alarming rate. From this data, the three other group members are able to use the material properties found in their respective analyses to reduce the error and assumptions in their tasks.

6 REFERENCES

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