SCHOLARS' DAY
REVIEW
VOLUME 3

Beauty and Functionality: Applying Aesthetics to Residential Wind and Solar Appliances using 3-D Printing

Mona Oates

Faculty Sponsor: Prof. Christopher Kumar (Engineering)

ABSTRACT

This study investigated the relationship between engineering and the creative arts through 3-D printing. 3-D printing was chosen, as it builds a fundamental bridge between engineering and the arts—often perceived as two separate entities. To investigate the disciplines' compatibility, the 3D-modeling software Rhinoceros5 was used to render a painting of an imagined object into a 3-dimensional form. The object's dimensions were appropriated for 3D printing. After realization of the object, further research was done to find possible applications. Comparing the creative and scientific processes showed that practical objects can trigger an inert curiosity. The development of the object showed that engineering sciences and art are crucial entities to improve present technologies with social responsibility.

MLA Citation
Oates, Mona. " Beauty and Functionality: Applying Aesthetics to Residential Wind and Solar Appliances using 3-D Printing." *Scholars' Day Review* 3 (2015): 9-14. Web. Date of access

Beauty and Functionality: Applying Aesthetics to Residential Wind and Solar Appliances using 3-D Printing

Wind and solar power technologies are increasingly being developed to produce renewable energies. They offer an option to energy independence from oil, gas, and coal. Due to current trends in the energy industry, 37% of US carbon dioxide emissions were caused by electricity production (United States Environmental Protection Agency, 2015). This suggests that a shift in electricity production is necessary. However, current growth of consumer-level use of solar panels and windmills does not suggest a shift is occurring. A survey by the British magazine *Country Life* (Scientific American, 2009) found that many households and neighborhood associations reject solar and wind power technologies due to aesthetic concerns. Solar panels are large boards with reflective surfaces, and when used at utility-scale create complications around cultural heritage sites and historic neighborhoods. Cape Wind Associates, a New England energy company, has been advocating for offshore windmills while facing opposition from residents, politicians, and environmental groups (Cape Wind Associates, 2014). Windmills are also often perceived as intrusive to the landscape, as even small commercial windmills can cause complications in living and garden spaces (Solar Energy Development Programmatic EIS, 2013; Scientific American, 2009). For such reasons it becomes important to shift the available technology toward an aesthetic technology.

Currently, additive manufacturing, also called 3D printing technology, allows for custom design and the manufacture of small objects and machine parts. With further development, it may be possible to translate this process into large scale manufacturing of windmills and solar panels. As the industrial world moves toward a technoculture (the continuous interaction of technology with culture and politics), it becomes evident that in addition to practicality, beauty is also an important aspect of technology (Rutsky, 1999). As technology is fully integrated into modern societies, visual appeal becomes especially relevant. It is necessary to design technology so the object causes an aesthetic experience while maintaining the integrity of practical applications. By incorporating additive manufacturing, it is possible to create a concept and model from a 2-dimensional painting that will allow an aesthetic solution to bring solar and wind power to individual households and communal spaces.

Design Evolution

In order to investigate the possibilities of different 3D modeling software, original paintings by Mona Oates were analyzed. Categories to qualify the image were: complexity of the painted object, physical integrity, possible practical application, and execution in a given time frame.

The image in Figure 1 would have been a complex design. Its physical stability, however, would have been a risk. The given time constraint would have caused complications in creating a finalized object. In addition, the image could not immediately be associated with practical applications. The same accounted for the images in Figures 2 and 3. The image in Figure 4 was determined to have quick design and manufacturing potential as well as qualities to hold applied renewable energy technology.

Figure 1

Figure 2

Figure 3

Figure 4

Before continuing with the design process, it was important to investigate computer-aided design (CAD) software. Different resources were consolidated to find strong CAD software capable of designing organic objects. Even though Monroe Community College offers SolidWorks 2014, it is a rigid program. Additionally, it does not work well with non-uniform rational basis spline (NURBS) for generating curved surfaces, yet it offers easy functions and the quick modeling of individual organic shapes (Robert McNeel & Associates, 2014). For that reason, Rhinoceros5 was chosen to model the image in Figure 4 into a 3-dimensional design. Before using the software, the ideal image (Fig. 4) was conceptually analyzed in order to create a strategic plan for design and manufacturing. The object was separated into three sub-objects (see Figure 5).

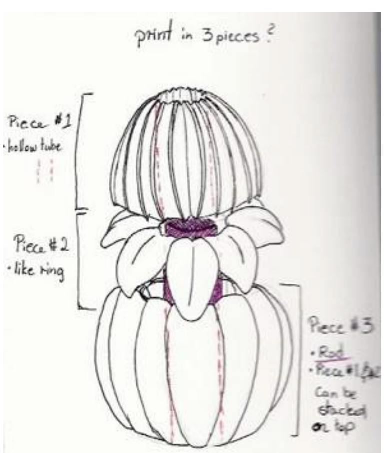

Figure 5 Conceptual drawing for 3D design and manufacturing.

The bottom piece was advanced with a supporting column connecting the entire object, while the top two pieces have openings in the center to fit the column.

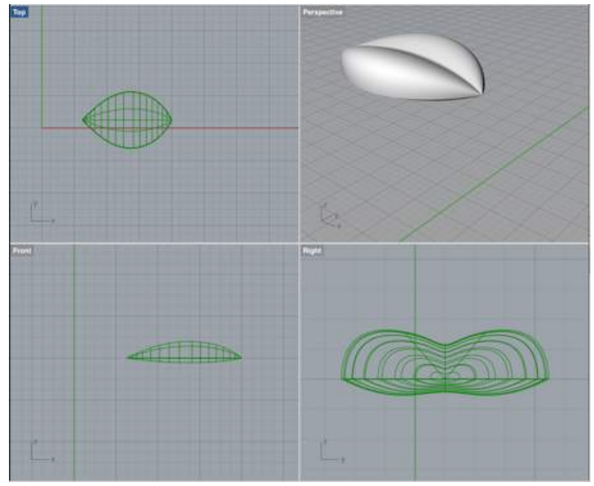

Figure 6 Three-dimensional design of the first leaf (clockwise: top, perspective, front & right)

The strategic plan of design in Rhinoceros5 was as follows. First, the leaves were modeled. One individual leaf was designed using two green, joined, horizontal reference lines to build an almond shape (Figure 6, top view). Three reference lines were added above and three below the horizontal frame (Figure 6, right view). Reference lines are lines in space to facilitate the software's rendering a surface. All reference lines were joined to create a singular wireframe. The command *EdgeSurfaces* was applied to stretch the surface over the topside of the frame. This was repeated for the bottom part. All edges of the polysurface were checked for open edges. An arc line was created on the top plane. *Sweep2* was used to sweep a tubular half circle with 0.1 cm thickness along the arc line. The finished leaf (Figure 6, perspective) was multiplied seven-fold along the curved tube. Each leaf was individually morphed, to create a natural form. The entire leaf-curve was mirrored and both halves were joined to form a ring (see Figure7).

Figure 7 Tubular Ring with individually shaped leaves

To model the sculpture's bottom half, a singular line was drawn along the original painting to recreate the exact shape. The line was extruded around the axis of its endpoints to form a circular shape. This piece was the inner wall of the form (see Figure 8). The originally-drawn line was also used as a reference to build the individual "ribs" extruding from the form. A technique similar to that used for the leaves was applied to the modeling of the ribs. At each endpoint of the original line, two reference curves were added and a polysurface was swept along the curve. The single rib was multiplied eight times around the inner shell and all edges were joined to produce one singular, solid shape. Separately, a decagonal tube was modeled and fitted in the center of the solid shape. Using *Boolean difference,* overlapping edges were eliminated and the tube was joined with the bottom shape to create the final model for the bottom piece (see Figure 9).

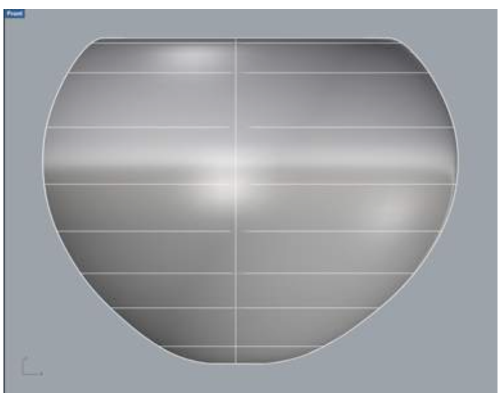

Figure 8 Inner Shell, extruded from singular line

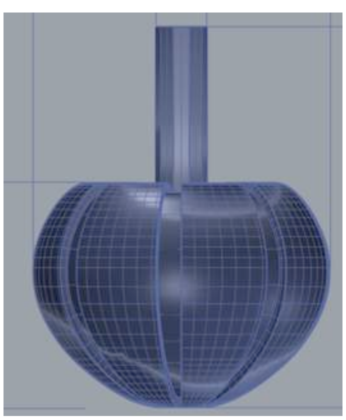

Figure 9 Final bottom piece with support column

The top piece's individual wings were modeled as the ribs of the bottom piece, using different reference curves along the polyline. However, instead of aligning the form along a pre-existing shell, the wing's top and bottom ends were connected by a vertical wall (see Figure 10). The original wing was multiplied twenty-fold using *Polar Array*. An internal tube was joined with the wings. The tube was decagonal inside (see Figure 11) to fit the support column of the bottom piece.

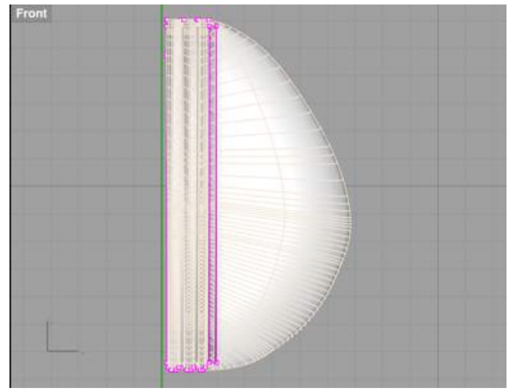

Figure 10 Front View of Partial Top Piece

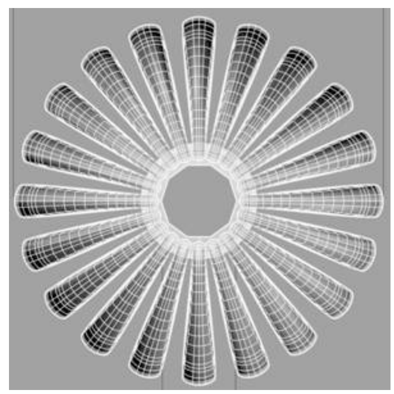

Figure 11 Top View showing internal decagonal tube

All final pieces were copied into polygonal mesh curves for surface control and file size reduction. Each individual mesh was exported as a Stereolithography (STL) file. The three files were uploaded to a Dimension 1200es printer. The printer manufactured three stackable individual forms, resulting in the final sculpture (see Figure 12).

Figure 12 Assembled 3D printed sculpture

Practical Application

Once the object was printed and assembled, further studies into possible practical applications, with a focus on renewable energies, were investigated. First, leaves undergo photosynthesis, a form of energy production using sunlight. Similarly, solar panels convert the energy of light into electricity. Thus, an association between the sculpture's leaves and solar energy was established. Initially, it was found that flexible solar panels could be mounted onto each leaf, maintaining the integrity of the original design. In the same way that leaves go through photosynthesis to produce energy, a leaf-shaped solar panel could build a direct relationship to energy production inspired by nature. Research has revealed that the introduction of veins into solar panels is 47% more efficient than solar panels of the same size and solar cell type (Kim et al., 2012), thus confirming that design should consider the natural environment for effective technological application. The Victorian Organic Solar Cell Consortium found a process to produce 3D printable solar panels using organic solar cells, a dye-sensitized mesoporous nanocrystalline titanium (Victorian Organic Solar Cell Consortium, 2013). Thus, personally designing and printing aesthetic solar panels is a possibility in the near future. The option to have customized solar panels is likely to improve sales in the consumer market, as personal aesthetics can be realized. As discussed earlier, consumer market consumption of solar panels is limited due to their appearance and bulky form (Scientific American, 2009).

An additional application is to apply windmill technology to the 3D printed sculpture. Vertical wind turbines are efficient and occupy little space. Such designs allow placement in close proximity, without interrupting air flow (Bell, 2014). A digital model was produced to propose experimental integration of a vertical wind turbine moto (see Figure13).

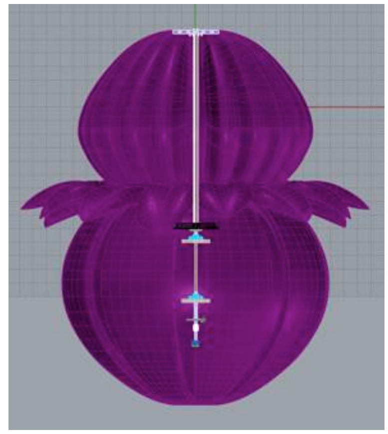

Figure 13 Digital model introducing Savonius wind turbine mechanism, to rotate the top piece

The Savonius wind turbine motor would be installed on the top piece. The wind-driven rotation of dynamos would generate electricity that could be stored in batteries or immediately added to the electric grid. Simultaneously, the lower piece would cover the mechanisms, protecting them from weather and maintaining aesthetic integrity. Such integration produces a hybrid mechanism that harnesses wind and solar energy for personal homes and public spaces.

Conclusion

As the environment is drastically changing and traditional energy resources are rapidly decreasing and influencing environmental stability, modern civilizations need to find other resources for energy. Options like solar and wind are well developed, yet few neighborhoods utilize such technology. It has been found that many neighborhood associations and individual owners do not acquire the technology due to aesthetic aversion (Solar Energy Development Programmatic EIS, 2013; Scientific American, 2009). By creating visually stimulating technology that people can relate to, an artificially-constructed environment could feel less manmade (Rutsky, 1999). Aesthetic experiences spark curiosity. Studies have shown individuals relate to beauty and learn better in a more appealing environment (Robinson, 2008). With advancing 3D printing technology, it could be possible to custom design wind turbines and solar panels in the near future. Designers have already started to create hybridized objects to harness renewable energies, while integrating aesthetic appeal. The Aard concept, for example, combines wind turbines with solar panels in a spherical object that can change form (using wind or sun) depending on wind strength (Energy Digital, 2011). Living spaces could become more personable, and the technology inhabiting these spaces could be better adjusted to the environment. Additionally, stimulating objects may trigger a more deeply-rooted educational experience because children and adults personally relate to them.

REFERENCES

Bell, B. (2014). *Caltech's unique wind projects move forward* [Website]. Retrieved from http://www.caltech.edu/news/caltechs-unique-wind-projects-move-forward-39703.

Cape Wind Associates. (2014). *Cape Wind Project timeline* [Website]. Retrieved from http://www.capewind.org/when/timeline

Energy Digital. (2011). *Concept turbines that are revolutionizing wind power* [Website]. http://www.energydigital.com/greentech/1753/Concept-Turbines-that-are-Revolutionizing-Wind-Power

Kim, J. B., Kim, P. Pégard, N. C., Oh, S.J., Kagan, C. R., Fleischer, J. W., … Loo, Y. (2012). Wrinkles and deep folds as photonic structures in photovoltaics. *Nature Photonics, 6,* 327-332.

Robert McNeel & Associates. (2014). *What are NURBS?* [Website]. Retrieved from http://www.rhino3d.com/nurbs

Robinson, S. K. (2008). Changing paradigms. Proceedings from *London: Royal Society for the Encouragement of Arts, Manufactures and Commerce.*

Rutsky, R. L. (1999). *High technē: Art and technology from the machine aesthetic to the posthuman.* Minneapolis:, MN: U of Minnesota Press.

Scientific American. (2009). *Are aesthetics a good reason not to be a fan of wind power?* [Website]. Retrieved from http://www.scientificamerican.com/article/earth-talks-aesthetics-good-reason/

Solar Energy Development Programmatic EIS. (2013). *Solar energy development environmental considerations* [Website]. Retrieved from http://solareis.anl.gov/guide/environment/

United States Environmental Protection Agency. (2015). *Overview of greenhouse gases* [Website]. Retrieved from http://www.epa.gov/climatechange/ghgemissions/gases/co2.html

Victorian Organic Solar Cell Consortium. (2003). New generation solar cells [Website]. Retrieved from http://www.vicosc.unimelb.edu.au/organicsolarcells.htm