Anatomy Based Design in Animatronics Application

I embarked on this project with the goal of creating a realistic mechanical simulacrum of the human head. The design of the head was derived from empirical measurements and scientific data.

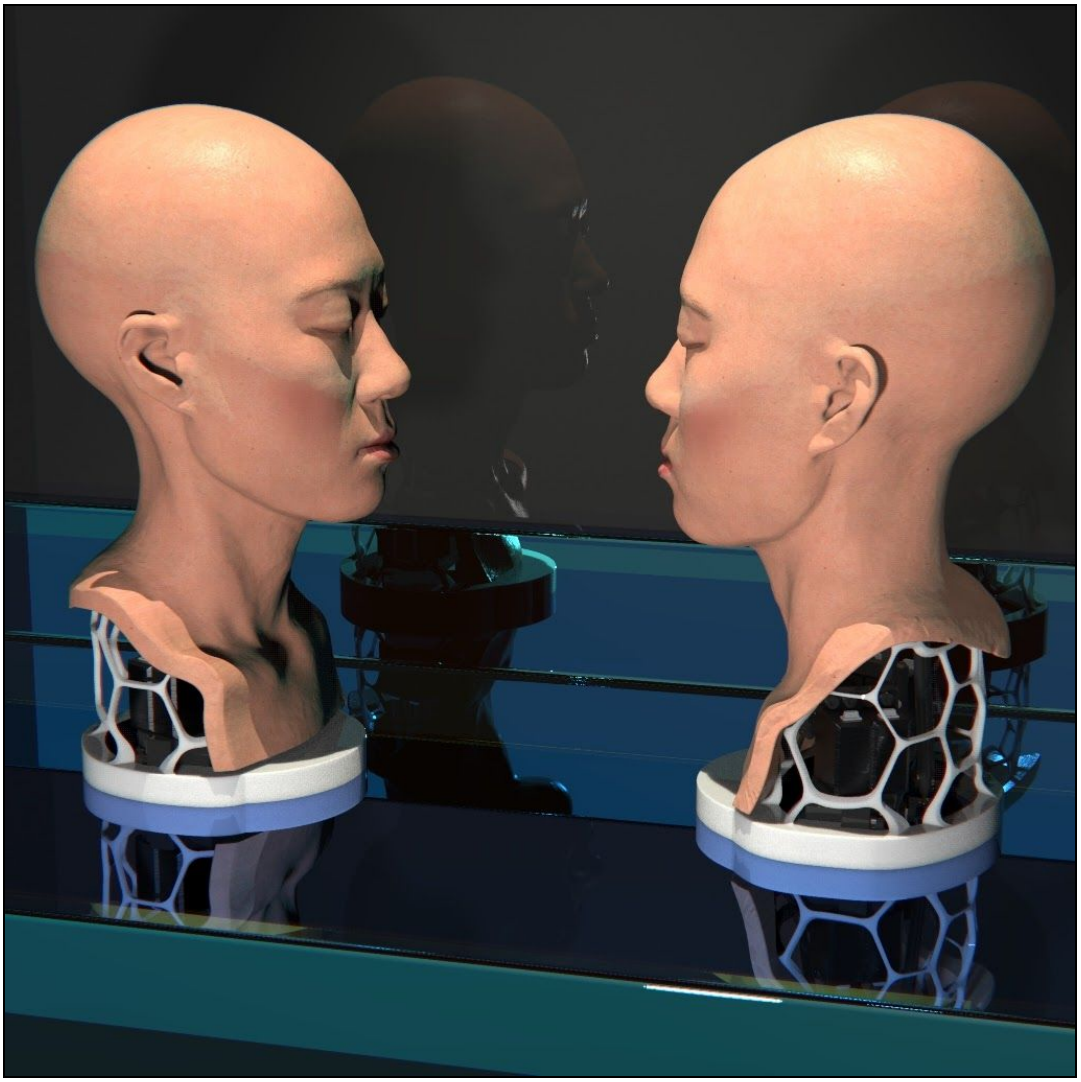


Figure 1: CAD model of the mechanical head (rendered in keyshot)

1. Life Casting Process

Following a preliminary selection process, a suitable subject was chosen, and a silicone life-casting was taken of her head and neck. The life cast was created by brushing on several layers of liquid silicone onto the model's head, giving each layer time to cure before application of the next layer. After the last layer of silicone had cured, the model's entire head was wrapped in wet gypsum bandage and given time to cure. Throughout this process the model was breathing through two straws fixed in their' nostrils. After the gypsum bandage had hardened the mold was carefully cut off of the model's head in a way that would not damage the mold or injure the model.

The process of life-casting the model's head took approximately 3 hours. Following the life-casting, a polymer clay master model of her head was cast from the mold. All surface imperfections on the surface of the clay were repaired manually, then a 3D scan of the master model was then taken, so that all remaining design could be done digitally.

Figure 2: Clay master model (Physical Model)

2. Mold Design

A blanket mold system was designed from the 3D scan of the head. The system uses a flexible polyurethane rubber blanket approximately 15 millimeters thick encasing the model, A rigid shell holding the polyurethane rubber blanket in position, a mold core that ensures correct skin thickness, and a base plate that registers the mold core to the rigid shell and the polyurethane. The material of the skin is injected from a small hole in the top of the mold and flows down to the base. The base of the mold has small vent holes to prevent air-traps from causing bubbles in the final skin.

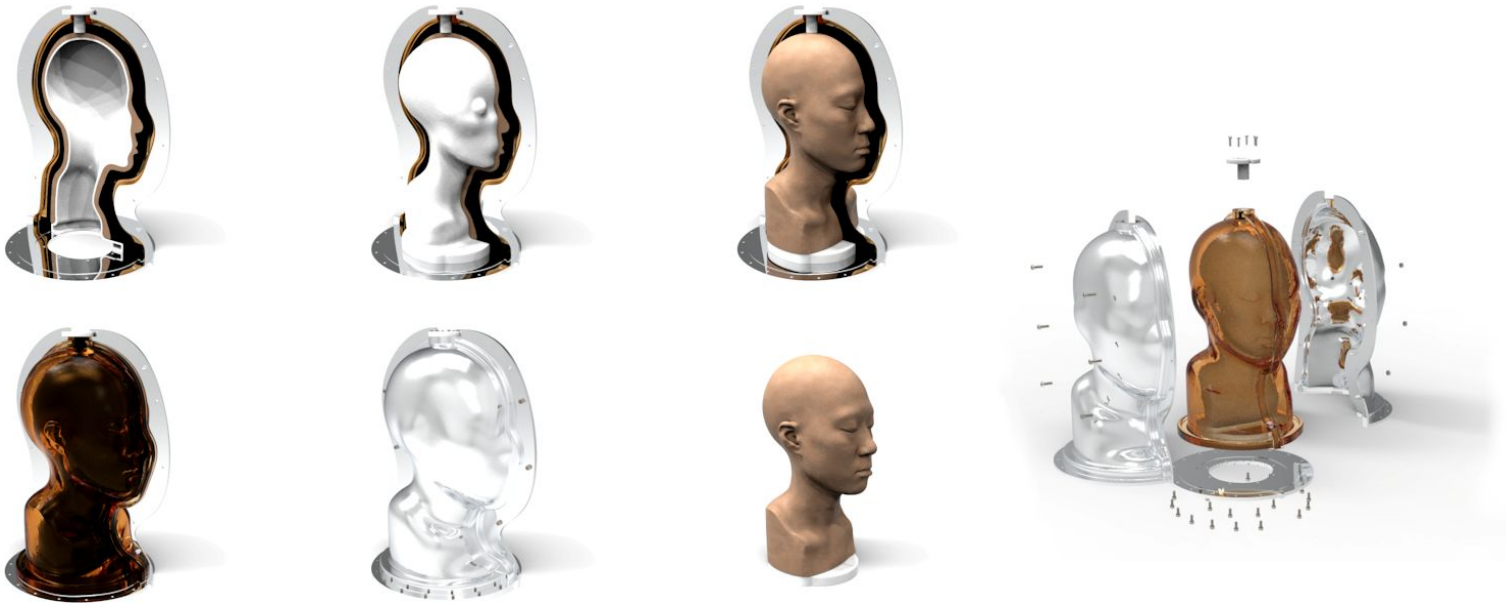
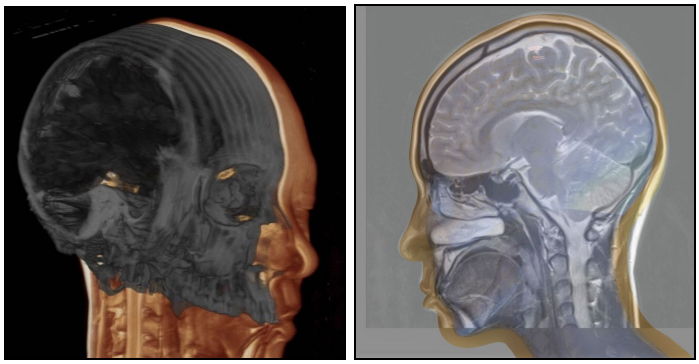


Figure 3: Blanket mold design (Rendered in Keyshot)

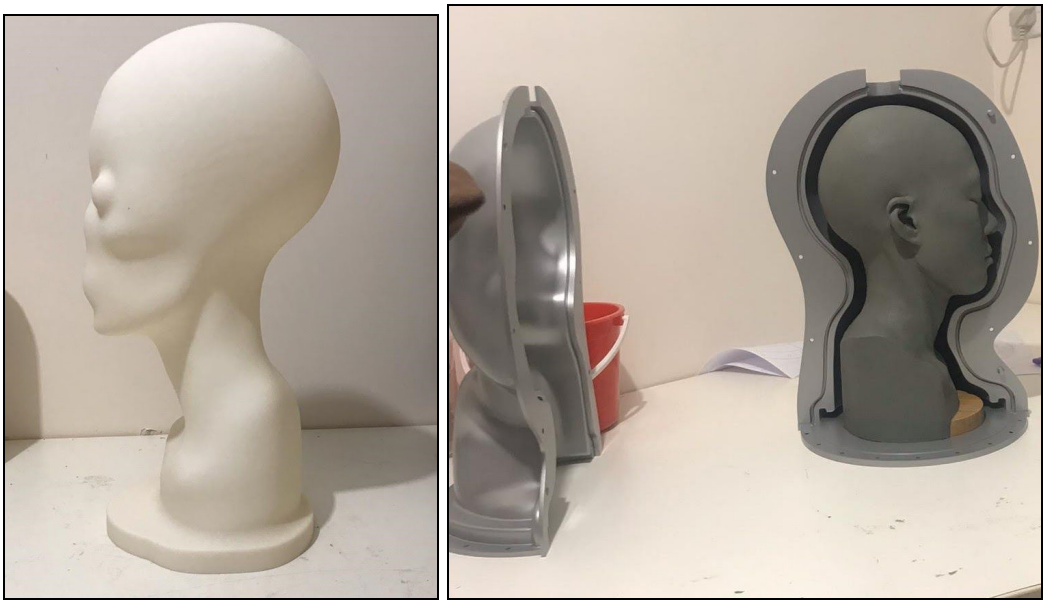
One of the most important points of this project was for the skin thickness to be anatomically correct. To achieve this, a medical imaging company took an MRI of the model's head and neck. A 3D model of her soft tissue and skeletal structure was then created from the MRI data. The tissue thickness map extracted from the MRI was then used to create the topology of the mold core.



Figures 4&5: MRI skull reconstruction (Rendered in Slicer Medical Viewer)

Figure 6: CAD model of mold core (Rendered in Keyshot)

The mold core was 3D printed from Nylon using the printing process of Selective Laser Sintering, along with the small plug that goes on top of the mold. The average thickness of the 3D printed mold core was 4 millimeters. The Mold Shell parts were cut out of ABS plastic using CNC milling. The average thickness of each shell piece was 5 millimeters.



Figures 7&8: Physical models of the mold core and mother mold shell.

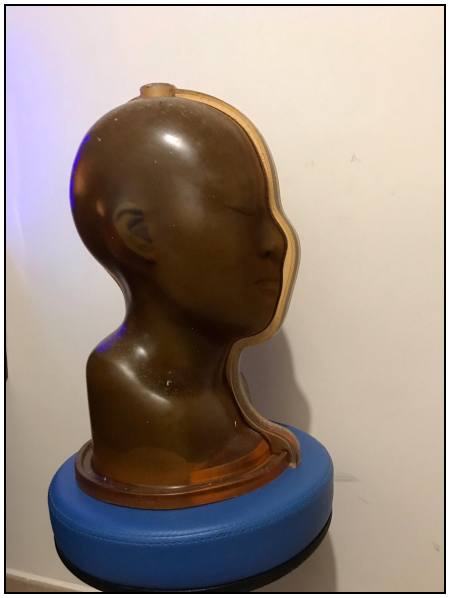
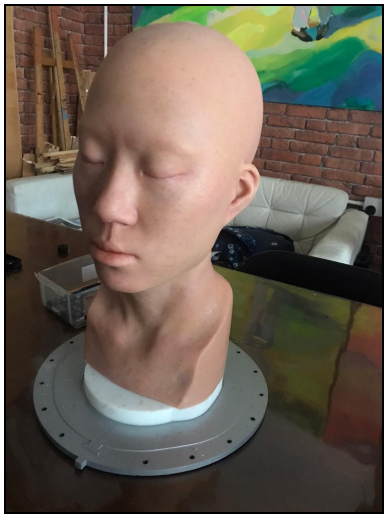


Figure 9: Physical polyurethane blanket mold.

A blanket mold was then cast using polyurethane rubber.
After that the clay master model was de-molded and the mold was then reassembled with the core inside, ready to cast skins, with a seamless 360 degree profile and anatomically correct skin thickness.

ShoreA 00 silicone rubber was used for the skin, which was then turned into a foam by using a foaming agent and running it through an industrial low density concrete foam generator. Then after being foamed, the silicone was injected with a large plunger tube into the small hole in the top of the mold.



Figures 10&11: Physical model of the silicone skin of the head.

For the mechanical design the head and neck has 36 actuators. All the degrees of motion are actuated using rigid linkages attached to the back of the skin with snaps and magnets. The skull design, the size of the teeth, and dental arches are all based on the MRI model, in the same way as the mold core.

Figure 12: CAD model of the skin and skull (Rendered in Keyshot)

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