let's talk about the designs for our machine.

In our initial design, we start with a rigid aluminum frame and add four four-bar linkages. Each linkage had its own servo to drive it, which helps compress the wheels against the cylinder. Then, a motor drives the whole robot to climb up the cylinder.

However, this design had two big problems. First, it was really heavy, meaning the servos need a huge amount of torque to compress the wheels. Second, it was too big to manufacture easily and too slow for us to iterate on quickly.

So, here's our second design. For this one, we decide to use synchronous belts powered by motors to grab onto the cylinder. The robot itself has two main parts: a lower section and an upper section. Each section has its own synchronous belt and motor.

Connecting the two sections is a four-bar linkage driven by a servo, along with two linear guideways. This setup allows the distance between the two sections to change as the servo rotates. The idea is as follows: when the lower belt is fastened and the upper belt loosened, the lower section will push the upper section upward. Once the distance between the sections is maximized, the upper belt will fasten, the lower belt will loosen, and the servo will then pull the lower section up. By alternating these steps, the robot was supposed to climb up the cylinder.

However, this design also runs into a few problems. First, there is too much friction. The belt sticks to the cylinder, preventing the servo from pulling the lower section up. Plus, when one belt is fastened and the other loose, the machine tilts, creating even more friction.

And now, for our newest design!

In this design, we're using an elastic belt to compress several small 'cars' onto the cylinder. Each of these driving cars has its own motor. The compression force is strong enough to ensure the cars grip on the cylinder tightly and drives upward.

To meet the requirements, we designed a rigid frame that ensures all the cars maintain a consistent height. This frame also supports the electrical boards. The cars act like sliders relative to the frame, allowing the robot to adapt well to different cylinder sizes.

For material selection, we chose acrylic board for the outer frame because it's both light and strong. The car structures are 3D printed with PLA – which gives us lightweight parts and a lot of design freedom. And the guideways are carbon fiber tubes, which are super strong and light.

Beyond just material choice, structural design is super important. It lets us achieve stiff structures with minimal material. This picture shows an example of how we use stiffeners to make thin boards stronger. They help prevent the boards from fracturing.

In the right picture, you can see two large boards that are very thin, just three millimeters thick. But by giving them an I-beam-like structure, they become incredibly strong and can withstand significant force."