



Figure 8b. Detailed functional modeling of microscrew handling and insertion solution

3.3.7. Additional ideas resulting from functional modeling

In this case, further examination of the functional model for the biological phenomenon provides insight into the engineering solution. Specifically, the regulation of hormones, nutrient and water, central to the abscission phenomenon suggests that parameters must also be regulated in the microassembly solution. Indeed, while verifying that the polypropylene rod incorporated as described above can be used to manipulate the microscrew into position, it was found that the temperature of the heating plate is the most crucial parameter. At too low of a temperature, the rod is not sufficiently melted, and the bond between the rod and screw is not strong enough for successful tightening of the screw in the substrate. At too high of a temperature, the melted polypropylene flows into additional features in the screw such that the increased torque once the screw is fully tightened is not enough to separate the rod from the screw – an additional pull force must be applied.

The functional model for the biological phenomenon also suggests the possibility of a suction-based approach. Instead of regulating the flow of nutrient/water, an engineered solution could regulate flow of a gas, e.g., use suction to retrieve and possibly orient a microobject, and reverse pressure to release. In addition, an electromagnetic approach can be used on microobjects that can be magnetically polarized, where the magnetic field of the tool could be reversed to separate tool from microobject.

4 SUMMARY

This paper explored combining existing and proven methodologies in functional modeling and biomimetic design. Observed benefits of applying functional modeling to biomimetic design include a more complete, systematic modeling that reveals additional aspects of biological phenomena to be exploited. Incorporating biological phenomena into a function-based design repository requires that multiple facets of solution be presented, possibly including a natural-language description of the biological phenomenon, the strategy derived from the phenomenon, example implementation of the strategy in engineered solutions, and functional modeling of both biological and engineered systems.

This paper illustrated the functional modeling of a single biological phenomenon: the shedding of diseased or dead leaves by plants at multiple levels of biological organization (organism/organ and cellular/molecular). This single phenomenon led to solutions for previous case studies. Examining functional models of the biological or engineered solutions for these examples led to more complete exploitation of biological phenomena, which suggests the need for more complete representation of stimulus when including biological phenomena in a design repository.

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