PUNCHING OUT A BETTER TABLET

Analysis helps to prevent dietary supplements from being too big to swallow.

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Since the establishment of the Japanese brewing industry, the Asahi name has been associated with delivering innovative beverage products to the ever-expanding tastes of its customers both at home and internationally. Among the company's products, its pre-eminent brand, ASAHI SUPER DRY, recently won the Champion Beer Award (top prize, keg lager division) at the 2011 Brewing Industry International Awards held in London, known as the world's oldest international beer competition.

LEVERAGING TECHNOLOGY

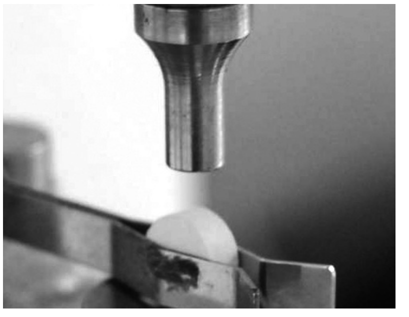
To maintain customer satisfaction and to develop a basis for further growth, the group is making larger investments into food science. Asahi's research organization has gained a highly regarded technical background from developing fermentation technologies for specialty beer production, and now the company is leveraging that position in the development of dietary supplement products. In this industry, researchers need to consider a number of factors, including the product's safety, effectiveness of the active ingredient and manufacturing efficiency. Beyond those factors, though, is the product's usability: Because dietary supplements are usually consumed in tablet form, they must be easy to swallow.

Compared to pharmaceutical tablets — whose volume often contains only a tiny fraction of active ingredients, so they can be smaller in size — food dietary supplements are made of edible constituents and tend to be bigger, which can make them more difficult to swallow. To receive the full benefit of the supplement, an adult must take several of these tablets per day. Customers simply will not use larger tablets on a regular basis if the tablets get stuck during swallowing, or if they cause excessive throat strain or irritation.

A supplement tablet's shape is mostly determined by diameter, thickness and radius of curvature. Evaluation ratings from human test subjects indicate that, in general, the smaller the radius of curvature — that is, the more round a tablet becomes — the easier it is to swallow. However, a smaller radius of curvature also means that the hardness of the tablet (based on a measurement of how much pressure will cause it to crack) will be decreased, and that tablet punching equipment will deteriorate more quickly. The punch machine operates by compressing powder material in a special die under an extremely high mechanical pressure load. Repetitive high stress levels on the equipment sometimes cause mechanical failure in any situation. Additionally, reducing the radius of curvature to obtain a tablet that is easier to swallow requires the punch-head shape to be sharper at the edges. This reduces punch-head durability.

USING SIMULATION

When developing a new supplement product, Asahi staff needed to answer the question of how all of these characteristics — ease of swallowing, tablet hardness and machine durability — can coexist in reasonable balance. At its Research Laboratories for Fundamental Technology of Food, one scientist incorporated ANSYS structural simulation software to further that goal. Previously, Asahi had conducted repetitive experiments to make such evaluations, though researchers realized the limitations of this approach in quantifying all of the complexities. In Asahi's view, engineering simulation represented a powerful solution, and the organization selected ANSYS Mechanical software to be a part of its computational toolbox.



Pharmaceutical and food industries define tablet hardness as the load from one direction that is required to break a tablet.

The process of tablet formation begins when powdered raw material is fed into the punch hole from below. The punch presses down into the hole and compacts powder into the cavity, under pressure, to harden it into a tablet. After depressurization, the punch head lifts up, and the device ejects the tablet.

The most challenging part of the structural analysis was how to specify the Young's modulus of the tablet. The Asahi researcher understood that the reaction force over the area of the punch head should be equal to the tablet's Young's modulus. ANSYS Mechanical simulation of the punch's strength allowed a calculation of this reaction force. Initial assumptions of a uniform Young's modulus throughout the tablet, however, were not valid, as evidenced by a wide gap between experimental values and simulation results. Asahi then determined that the best way forward was to divide the punch head and tablet structures into sections and compute the reaction force on the punch head at each section. In this way, the researcher derived the reaction force for each punch section and, therefore, a realistic variable Young's modulus for the corresponding tablet sections.

After a series of simulations to determine the optimal number of tablet and punch-head sections, the researcher concluded that dividing the tablet and punch head into four sections gave predictions that were most consistent with experimental values. To characterize the load capacity of the punch required a nonlinear analysis, as the load on the punch and the resulting stress inside it did not display a proportional relationship. Observations of the punch head slipping over the tablet during powder compression led the researcher to define boundary conditions to account for frictionless sliding. Asahi finally determined the load capacity by repeatedly computing the stress inside the punch until it reached an allowable stress value.

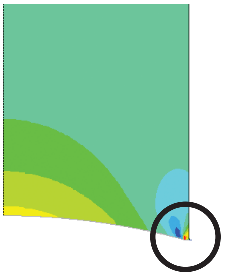
STREAMLINING THE PROCESS

With this background, Asahi's researcher had established a process through which the company could analyze the strength of a particular tablet shape by first calculating the reaction force on the punch head and then determining the tablet's variable Young's modulus. However, in seeking to evaluate many such tablet shapes, Asahi turned to Cybernet Systems, the ANSYS channel partner in Japan, to build a simulation solution using ANSYS Mechanical APDL that would automate the process by simply defining the size of a tablet.

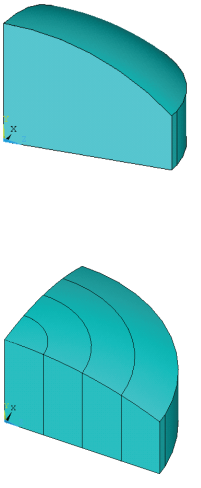
Streamlining computational tasks in this way enabled the researcher to concentrate efforts on studying the results from the overall analysis. For example, he discovered that tablet hardness was not evenly distributed. This characterization could not be visually determined, but the ANSYS post-processing features represented the stress distributions in a contour plot. These graphical displays provided a powerful method to communicate study achievements, not only within the research laboratories but across the larger umbrella of the Asahi Group and beyond.

The final results showed a good association between simulation predictions and experimental data related to a tablet's hardness, which has given Asahi confidence in the process for future tablet design. Experimentally characterizing the hardness of each and every tablet shape would have been impractical, as that would have required evaluating an extremely large number of variations. At a cost of approximately $400 (¥30,000) for each mortar and punch set, simulation could save the company hundreds of thousands of dollars (tens of millions of yen) in material costs alone.

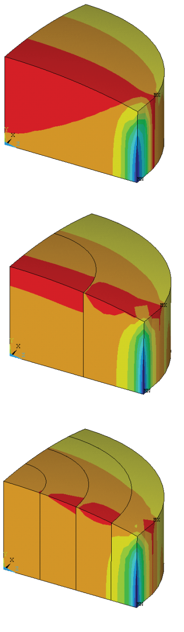
The Asahi Group is encouraged that cutting-edge simulation from ANSYS enables visualization of more and more phenomena that once were a complete mystery to its product designers. Representing the relationship between the reaction force on the punch and the tablet's hardness as an approximated curve was a breakthrough; it allowed Asahi to conclude that the curve is an accurate representation of the properties of a powder material. Computer-aided engineering (CAE) is not the company's focus, but through cooperation with simulation providers at ANSYS, and with support from specialists at Cybernet Systems, Asahi now believes in the high potential of CAE. Organizations with sharp insight into the needs of their customers see much value in using the full pantheon of CAE technology to make new discoveries, allowing them to carry forward the promise of their products, which Asahi has seen as an indispensable benefit.



A 2-D axisymmetric model shows contours of equivalent stress on punch head during contact with tablet. The red area at lower edge corresponds well with experimental results indicating the location where the punch head is most likely to break down.



Structural model of representative tablet shape with a constant Young's modulus (top); tablet that has been divided into four sections (bottom), in which the variable Young's modulus is transcribed for each section by computed reaction force on the punch head. Both models employ symmetry to speed up calculations.



Contour plots showing maximum principal stress on tablet when load is imposed at lower right edge (blue and green colors): model with one section (top), two sections (center) and four sections (bottom)