ON THE BALL

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F inite element analysis helps to improve golf ball rebound velocity by 5 percent, resulting in longer drives in a game measured in inches.

In the highly competitive golf and cycling sectors, differences of just a few percentage points in equipment performance can make the difference between a successful product and an also-ran. Advanced International Multitech Co., Ltd., is a leading producer of golf balls, golf clubs and biking equipment. The company uses ANSYS LS-DYNA software to evaluate a wide range of club head and golf ball designs to improve equipment performance. For example, the business optimized a new line of clubs to make the heads thinner but just as strong as the previous version. By improving both club heads and balls, the company has improved rebound velocity in its current line of products by 5 percent. The resulting improvement in driving distance contributed to a successful product launch, which in turn helped the company to achieve nearly 40 percent sales growth in its recently completed fiscal year.

Advanced International Multitech produces balls for many world-famous brands. The company produced approximately 36 million golf balls last year for Callaway, its largest customer. Advanced International Multitech began operation of an $11 million (U.S.) plant in southern Taiwan in 2010. It is currently running one ball production line in the new plant, increasing capacity from 100 million to 125 million balls per year. Once fully equipped, the plant will provide the capacity to vault the firm into position as the number-one golf ball manufacturer in the world.

EVALUATING DESIGNS

Over the last several decades, substantial improvements have been made in drivers and other golf clubs so that they hit the ball farther and do not require a perfectly on-center strike to achieve good results. To limit the distance that a golf ball can travel, the United States Golf Association (USGA) has placed limitations on the coefficient of restitution (COR), a number between 0 and 1 that represents the percentage of energy transferred from the club to the ball during impact. A COR of 1 represents a perfectly elastic collision, with all of the club's energy being transferred to the ball. A COR of 0, on the other hand, means that none of the energy in the club is transferred to the ball. The USGA limits COR to 0.830. The most comprehensive method of measuring COR is to use an air cannon to fire the golf ball at a club head and measure the ball's before-and-after velocity.

This USGA restriction has forced manufacturers of balls and clubs to re-evaluate designs and determine methods of optimizing performance within these constraints. Golf is a game of inches, so tiny differences in performance between different balls and clubs can make the difference between winning and losing a match — and between success and failure in the marketplace. Physical testing is the gold standard for determining performance differences. But it is expensive and time consuming, as it requires building a prototype of every potential design of interest. Achieving a superior design in today's highly competitive market often requires evaluating thousands of potential designs, so physical testing is not a practical approach for early design stages when many different alternatives are being considered. Of course, physical testing is still essential in the later stages of the design process, when the choice has been narrowed down to a few options.

APPLYING SIMULATION

Golf equipment manufacturers have begun using simulation as their go-to design tool. But the impact of a club head hitting a golf ball is a challenging simulation task because it produces extreme changes in loading conditions and severe deformations in a very short period of time. The most popular finite element analysis software programs use the implicit method, which has difficulty in accurately predicting extremely nonlinear events. The explicit method, on the other hand, captures the physics of short-duration events for products that undergo highly nonlinear, transient events. Algorithms based on first principles accurately predict complex responses, such as large material deformations and interactions between bodies and fluids with rapidly changing surfaces.

ANSYS LS-DYNA is a leading explicit finite element analysis program for the simulation of short-duration events. It has been used in most of the pioneering research aimed at simulating golf ball and club head impacts by most golf equipment companies. The value of this software package has been increased by incorporating it within the ANSYS Workbench environment, which reduces the time required to perform analysis through bidirectional CAD connectivity, geometry cleanup tools, automatic meshing, and quick and simple definition of initial and boundary conditions.

Advanced International Multitech engineers recently used ANSYS LS-DYNA to design a new club head and golf ball. Engineers began by performing physical testing to evaluate the properties of the different materials that were being considered for use in the ball. They modeled the ball as a three-piece system — cover, mantel and core — with Mooney-Rivlin hyperelastic properties and about 10,000 hexahedral elements. The team modeled the club head as titanium alloy plate with about 250,000 tetrahedral elements. The speeds used for the initial club velocity were representative of typical male swing speeds, ranging from about 40 to 50 meters per second (90 to 110 miles per hour).

The analysis investigated different dimensions and material properties for the ball's cover, mantle and core. The same analysis was used to look at the effects of club head geometry. The model took about one hour to run. Advanced International Multitech engineers ran parametric analyses over a wide range of geometries and boundary conditions. The simulation results showed ball velocity at a few inches past the point of impact, the same point at which ball velocity is measured in physical testing. This made it very convenient to evaluate the accuracy of the simulation

by comparing the results with experiments. The simulation predictions closely matched physical testing.

INCREASING DISTANCE

By evaluating a wide range of ball materials and club head geometries, Advanced International Multitech engineers increased the rebound velocity of the ball by about 5 percent. This improvement

By evaluating a wide range of ball materials and club head geometries, Advanced International Multitech engineers significantly increased the travel distance of its golf ball.
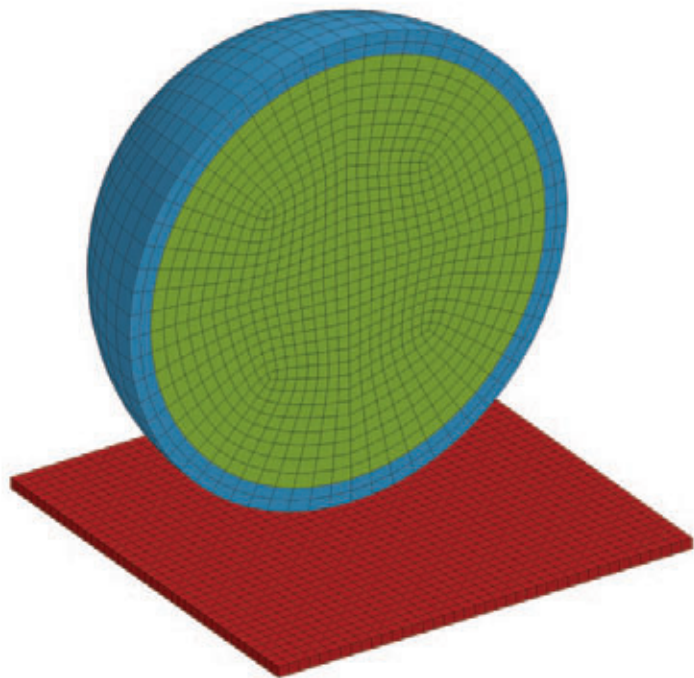
Finite element model of golf ball, with core in green and cover in blue
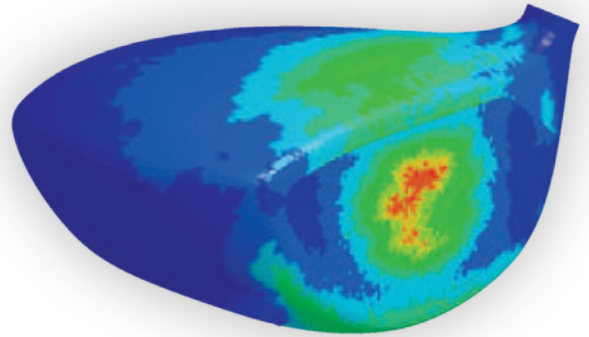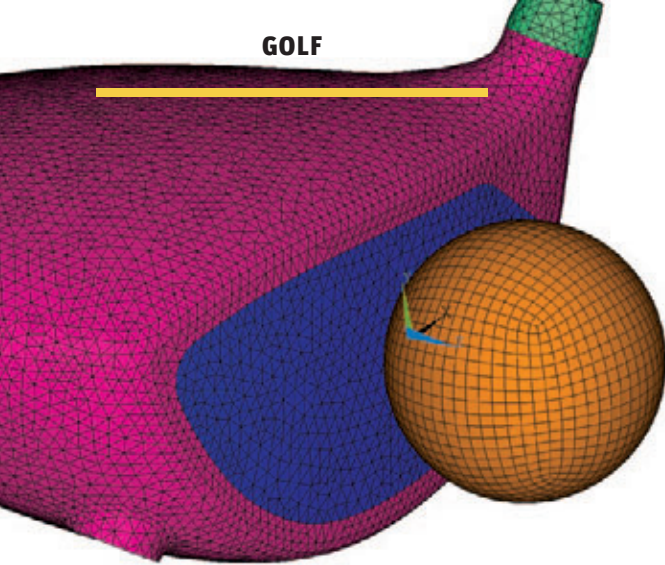
Simulation of impact of club head with ball in ANSYS LS-DYNA

Stress analysis results on club head

Explicit analysis with ANSYS tools has helped the company provide market-leading equipment performance and has played a major role in the company's rapid increase in market share.

directly translates into a significant increase in the distance traveled by the ball for a given club head velocity. Explicit analysis with ANSYS LS-DYNA has helped the company provide market-leading performance for its golf balls and club heads and has played a major role in the company's rapid increase in market share over the past decade.

Advanced International Multitech also uses ANSYS Structural software, which is based upon the implicit method, to optimize the design of bike frames and other composite structural components. Typically, the objective is to minimize the weight of components while providing enough strength to meet safety requirements. The company's engineers use ANSYS Structural to evaluate stresses and deformations of alternative structural component designs by varying part geometry and ply layout; they then iterate to an optimized design that weighs approximately 10 percent less than the previous generation while providing the same level of strength.

Using simulation to gain insight into the way materials respond during complex or severe loading, Advanced International Multitech gained a competitive advantage and improved its products' design. ∧
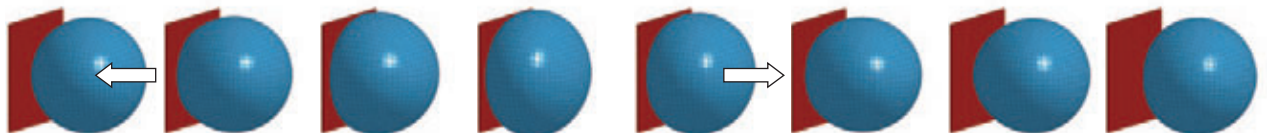
Golf ball impact analysis with initial velocity of 45 meters per second