LONG SHOT

Designing drivers for golf involves trade-offs. Drivers with large clubfaces and deep center-of-gravity (CG) positions have a high moment of inertia and are thus more forgiving of mishits, while smaller clubfaces and geometries can lower drag for faster club speed and longer shots. PING used ANSYS fluid simulation to design unique aerodynamic features in its new drivers that reduce drag and enable the large clubface and deep CG to deliver longer shots while remaining stable on off-center hits.

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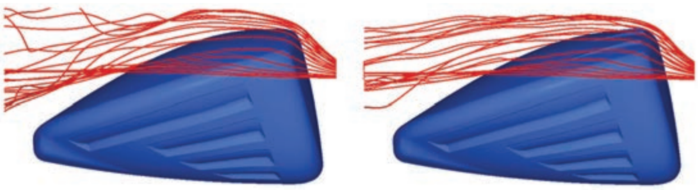
For over 50 years, PING, Inc. has been developing golf clubs that assist both amateur and professional golfers in reaching their potential. Because of constant innovation and design expertise, many champion golfers have used PING clubs. Maintaining this pace of innovation requires engineers to use every tool available to achieve design goals. Engineers at PING employ ANSYS computational fluid dynamics (CFD) solutions to improve the aerodynamics of clubs.

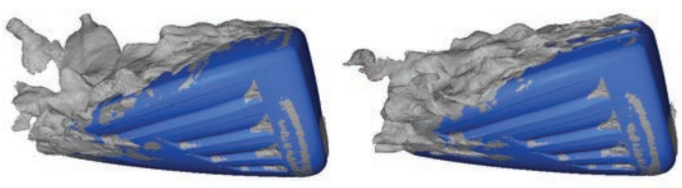
The clubface of a golf driver is usually designed to be as large as the rules allow, with its mass distributed away from its center as much as possible. This increases the moment of inertia of the club, which is a measure of the club's resistance to angular acceleration. So when the clubface contacts the ball away from the center of the clubface, it resists twisting more than a club with a lower moment of inertia. Big clubfaces enlarge the effective sweet spot of the club in all directions, which makes it easier to hit the ball straight.

But large clubfaces and mass distributions centered far from the face typically generate high levels of drag that are mostly caused by pressure differences in the front and rear of the club. This is because the flow around

Turbulators are shown on top of clubhead of new PING G driver.



^ CFD simulation of clubheads without (left) and with (right) turbulators shows how the new design delays flow separation and reduces drag.



^ Side view of simulation without (left) and with (right) turbulators shows that wake is smaller with turbulators.

a blunt body separates from the body and forms a separated or recirculating region in the rear of the body. The flow exerts more pressure on the front of the body than the separated region exerts on the rear of the body. This difference in pressure generates drag that reduces the speed at which the golfer can deliver the clubhead to the ball, which in turn reduces the ball speed and the distance of the drive.

PING used ANSYS CFD software to create and optimize the design of aerodynamic features on the clubhead that excite the flow near the surface of the club and promote a turbulent boundary layer transition that delays the formation of the separated region toward the rear of the clubhead. This reduces the size of the turbulent wake, which in turn increases the pressure on the rear of the clubhead and thus reduces the drag. The resulting PING G30, and other new G drivers, enable top professionals like Bubba Watson to generate up to 10 additional yards in driving distance while providing smaller but still significant gains to average golfers.

SIMULATING A GOLF SWING

PING engineers set out to study clubface aerodynamics to reduce drag without sacrificing the moment of inertia and other mass properties that also have a great impact on driver performance. They began by importing a PTC Creo® computer aided design (CAD) model of their existing clubhead design into ANSYS Workbench. They used ANSYS Meshing to automatically generate a grid consisting of a mixture of tetrahedral and hexahedral elements. Hexahedral elements are preferred for higher accuracy around the boundary layer between the clubhead and the airstream, so engineers added 10 inflation layers consisting of hexahedral elements around the clubhead to accurately capture the high velocity gradients in these areas. Moving away from the clubface, each inflation layer was sized at 1.2 times the thickness of the adjacent layer.

The velocity and angle of attack of the clubhead with respect to air flow are constantly changing during the downswing, so PING engineers developed a series of models with different velocities and angles of attack to separately address each segment of the downswing.

UNDERSTANDING THE PHYSICS

The simulation provided a fundamental understanding of the physics that occurs when air flows over the previous-model driver. It showed that the flow separates at the leading edge of the clubhead, resulting in a large wake in the rear of the clubhead. This insight gave the engineers an idea. Would adding ridges (which PING calls turbulators) to the top surface of the clubhead generate turbulence to delay flow separation toward the rear of the clubhead and reduce the size of the wake area and drag? A small ridge size would have only a very small effect on the mass properties of the club.

PING engineers modified the CFD model to add the ridges, and, when they performed the simulation again, they observed a significant reduction in drag. The team ran a series of simulations with different numbers of

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turbulators, each having different widths, lengths and angles with respect to the clubhead. Each of these clubhead designs was created in the Creo CAD program and then exported to ANSYS Workbench. Engineers simulated these models at a number of different speeds to evaluate how each design would perform for players of different levels. They converged on a turbulator configuration that provides the greatest possible delay in flow separation and the lowest possible drag.

PHYSICAL TESTING VALIDATES SIMULATION

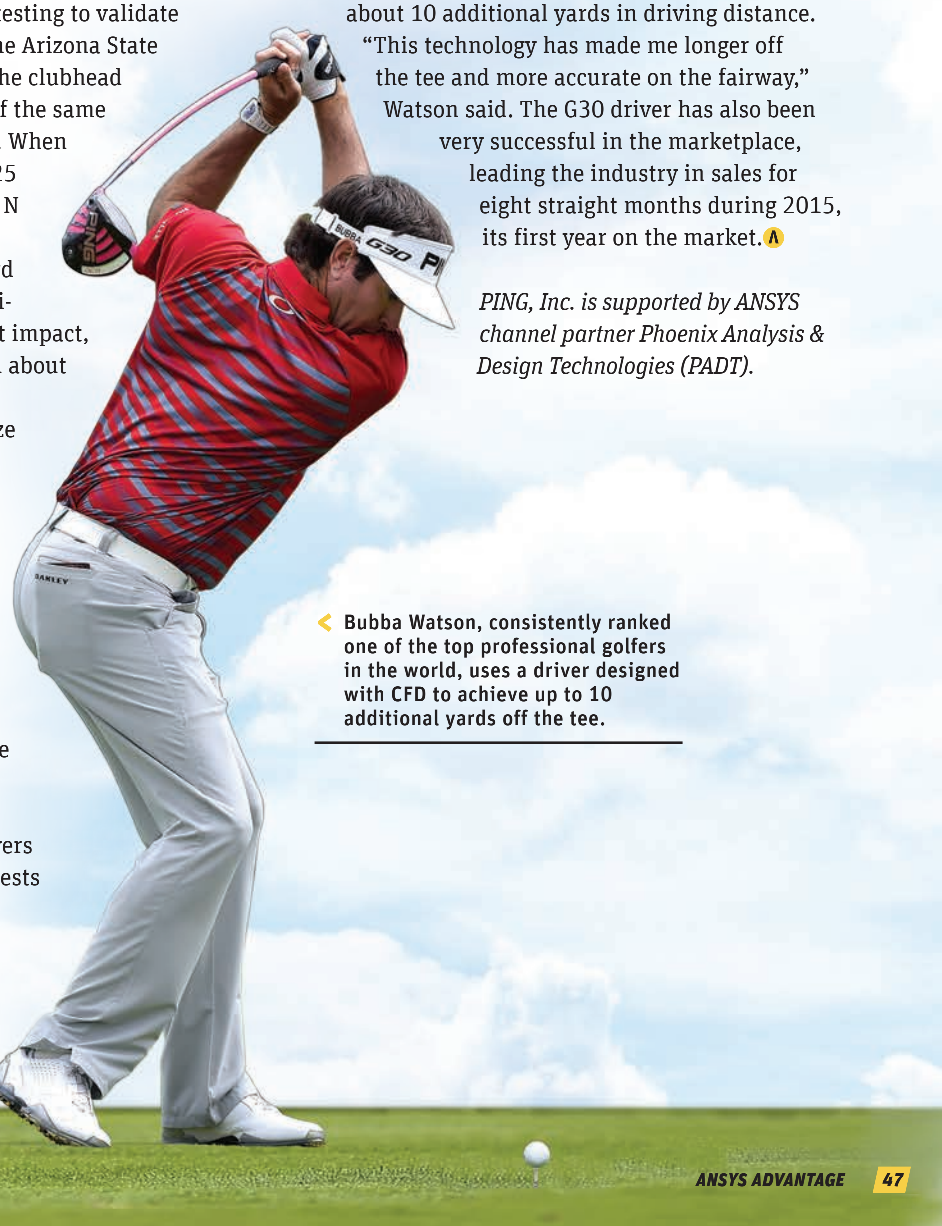
The next step was to perform physical testing to validate the CFD results. PING engineers used the Arizona State University wind tunnel facility to test the clubhead with and without turbulators at some of the same angles and speeds that were simulated. When the driver was square to the airflow, a 25 percent reduction in drag from 9 to 6.7 N was observed for the driver with turbulators when compared with the standard driver. While the standard driver experienced a little over 1.5 N of downforce at impact, the driver with turbulators experienced about 0.5 N of lift.

A smoke stream was used to visualize the flow in the tunnel. Photographs of the smoke showed laminar separation of flow over the standard head at the leading edge of the crown in the driver head without turbulators. In the driver head with the turbulators, flow separation was significantly delayed. The reduction in drag force and delay in flow separation seen in physical testing correlated well with the flow simulations.

Player tests were also conducted to compare the clubhead speed of the drivers with and without the turbulators. The tests showed that average clubhead speed increased by about 1 mph — from 105 mph with the standard clubhead to 106 mph for the clubhead with turbulators. The ratio of ball speed to clubhead speed is typically between 1.3 and 1.5, which indicates that the increase in ball speed could reach 1.5 mph.

The addition of turbulators to the G30 and G drivers allow them to combine some of the highest moments of inertia of any driver on the market with a high level of aerodynamic efficiency. When Bubba Watson first tested the G30 driver with turbulators, he picked up 2 mph in clubhead speed and 4 mph in ball speed, resulting in about 10 additional yards in driving distance. “This technology has made me longer off the tee and more accurate on the fairway,” Watson said. The G30 driver has also been very successful in the marketplace, leading the industry in sales for eight straight months during 2015, its first year on the market. Λ

PING, Inc. is supported by ANSYS channel partner Phoenix Analysis & Design Technologies (PADT).



Bubba Watson, consistently ranked one of the top professional golfers in the world, uses a driver designed with CFD to achieve up to 10 additional yards off the tee.