Sky Science

S.S. White Provides Twisting, Turning Power Transmission with Flexible Shafts

Matthew Jaster, Associate Editor

The flexible shaft is a power transmission device that provides rotary motion around bends and corners. It can be routed over, under and around obstacles that would make using a solid shaft impractical. Flexible shaft assemblies can be used in everything from 747s to children's toys. They have incredibly long lives and are not affected by continuous operation at speeds up to 50,000 rpm and temperatures as high as 1,000 degrees F and as low as -300. Though they are often confused with tension cables—both look the same from the outside—the dynamics of the wires inside flexible shafts are very different.

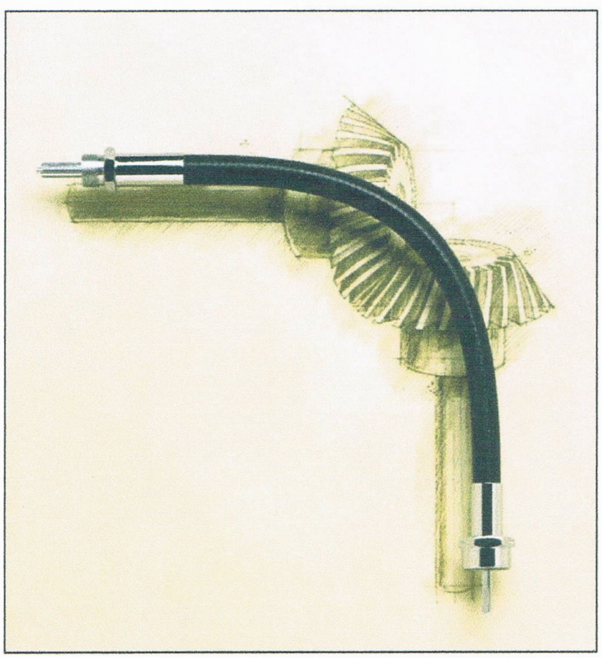
Photo courtesy of Airbus

The Anatomy of the Flexible Shaft

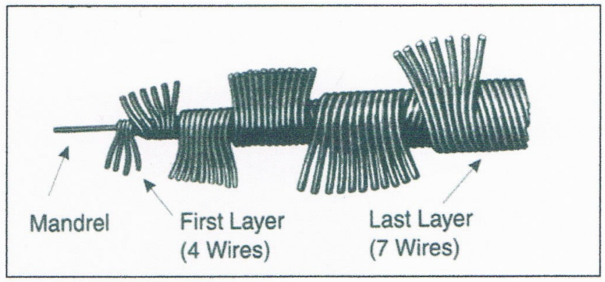
"Essentially, the flexible shaft consists of layers of wires with opposing pitch angles. You're basically applying a twisting motion to the shaft that would make the outer layer tighten down on itself while the layer underneath will be opening up, creating interference and high torsional stiffness," says Brian Parlato, vice president, sales and marketing at S.S. White Technologies. "It's the dynamics of these opposing forces that creates the magic behind flexible shafts."

The ability to twist and turn through obstacles like a pretzel is really what makes the flexible shaft unique. "This is a key consideration in designing and developing these for aerospace applications. It is never straight or just a simple radius; there's always a series of bends," Parlato says. "The flexible shaft takes a snakelike route through the aircraft in order to link actuators together, for example. The path is critical. It's important we're involved at the earliest stage of the system design to try to get the most beneficial path for the flex shafts. Just changing the bend radius by a couple of inches can increase the endurance life significantly."

S.S. White's engineers can maximize the shaft's torque carrying capability while retaining optimum performance characteristics of other key parameters. This is achieved with a proprietary computer modeling software program, called *Perflexion*, that can optimize the performance of any flexible shaft. *Perflexion* allows the design engineer to statistically capture and balance all of the properties of torsional strength, bending flexibility, torsional deflection, point of helix and others without compromising performance. *Perflexion* was conceived by taking S.S. White's own Dr. Adam Black's thesis on flexible shafts and essentially transforming it into a computer program.



This is a typical flexible shaft overlaid on a drawing of right angle spiral bevel gears. It shows how a flexible shaft can achieve the same outcome, but less expensively and more simply.



The construction of a typical flexible shaft starts with a single mandrel and then builds up layers of multiple wires wound at opposing pitch angles. S.S. White varies the size of the wires, the number of wires per layer, and the number of layers per overall diameter to achieve the specific performance requirements.

"Every application has its own unique routing path so no two applications are the same as a result," Parlato says. "Through the application of *Perflexion,* torsional strength can be increased by as much as 25 percent."

Another key innovation for flexible shafts in aerospace applications is a lubrication system known as Flexcellent. Developed exclusively by S.S. White, this system reduces the time-consuming and labor intensive removal and re-greasing of wire wound flexible cores at regular "C-check" intervals. Flexcellent reduces maintenance time, contamination and overall service costs. "Many of our flexible shafts run within hydraulic lines, but in other applications outside of hydraulics, they run inside a casing. Without proper lubrication, the shaft can overheat, wear, or fatigue. We've come up with a couple of interesting ways to lubricate the shaft," Parlato says.

Opportunities in Aerospace

The aerospace industry utilizes flexible shafts in thrust reversers, flaps and slats, cargo doors, rudder controls, etc. "A flexible shaft is responsible for providing power or synchronizing actuators on the aircraft," Parlato says. "Every application is custom. Essentially, you want the shaft to provide maximum torsional strength along with maximum bending flexibility. Then other factors like torsional deflection and point of helix come into play. Today, you'll find flexible shaft on almost every fixed and rotary aircraft on the market."

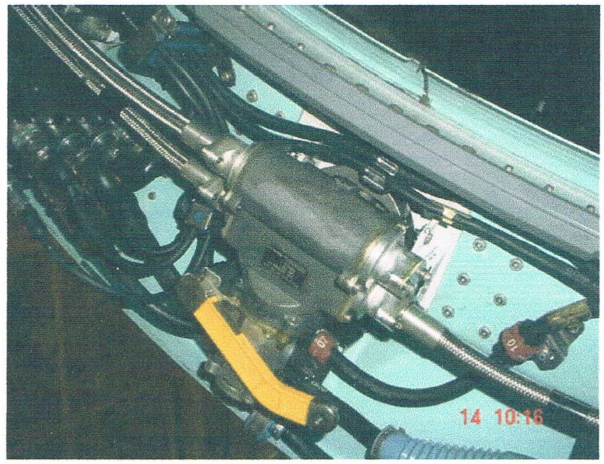
Two key applications for S.S. White in the aerospace industry are found in thrust reverser actuation systems (TRAS) and flaps and slats.

Thrust Reverser. The thrust reverser is used in aircraft engines to slow down the plane after landing. Flexible shafts provide power and also synchronize and connect the actuators that open and close both halves of the thrust reverser. "On smaller jet engines the thrust reverser basically consists of two large deflector plates coming together at the back of the engine to form a wedge. When the thrust hits the deflector plates it is redirected forward, slowing the aircraft down," Parlato says. "These two plates have actuators that move them back and forth. There's a motor and it drives the flexible shaft which drives the ball screw actuator." Larger, turbo fan engines use nacelle bypass ducts which are also actuated in a similar way by flexible shafts.

S.S. White provides flexible shafts for several thrust reverser systems. These flexible shafts can be ten feet long in some cases. Flexible shafts from S.S. White were utilized in the Rolls-Royce Trent XWB for a recent engine test flight of the soon to be launched newest member of the Airbus fleet, the A350. They have also been used in Airbus' A320 and A380 as well as Boeing's 787, 747, and 737.

When a major aerospace manufacturing firm needed flexible shafts for a thrust reverser system, they turned to S.S. White. The A380 Airbus was the first jet to include an electronic thrust reverser actuation system instead of a hydraulic or pneumatic powered system . "S.S. White has been extremely responsive to our needs," says a senior product support manager with 32 years experience in the aerospace industry. "They've been the main supplier of our flexible shafts for many years. They're willing to work with us and provide the quality support that's necessary in these high precision engineering applications."

Flaps and Slats. Flaps are hinged surfaces mounted on the trailing edges of an aircraft wing that help reduce the speed of an aircraft while landing. Slats are the surfaces on the front edge of the aircraft wing that improve airflow at high angles and also for landing. A leading motion and control technology firm provides the hydraulic motors (standard and custom) for flap and slat drive systems. S.S. White, in turn, provides a series of flexible shafts along the wing that drive the actuators that enable the flaps and slats to extend and retract. "A typical system would include five flexible shafts for a flap and five for a slat per plane, 10 flex shafts total," Parlato says. "These are found on regional jets like the Embraer ERJ 145 and Bombardier RJ200, typically seating not more than 50 passengers."



This is the center of an actuator which feeds power to the two adjacent actuators. So one shaft comes in and powers the center actuator and two shafts leave to power the adjacent actuators.

Engineering Challenges

One of the greatest challenges for S.S. White is being brought in late during the design stage. "Many companies that work with us for the first time think we can just come in and route the flexible shaft around everything else. While this is absolutely true, it becomes a much longer process if we're not

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involved at the beginning of the project. We can address all the variables that come into play if we're involved early in the design and development of the system. The shaft development can be very challenging otherwise," Parlato says.

While many industries have to deal with strict lead times for components, this is not a typical problem where commercial aircrafts are concerned. "Aircraft design and engineering is deliberate and time consuming, as it should be," Parlato says. "Every aerospace engineer is incredibly careful about what they're putting into the aircraft and they take their time to make sure it is right."

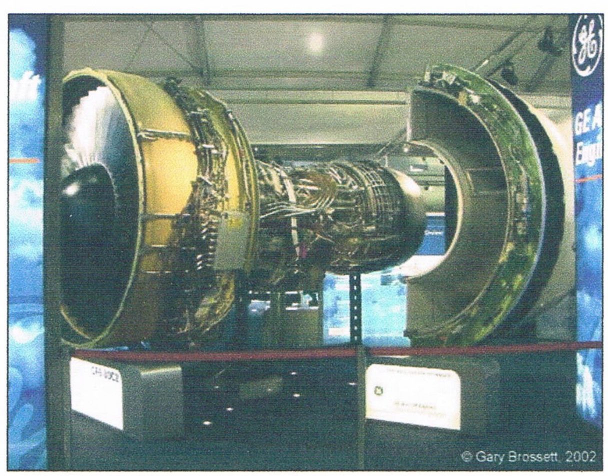
It could typically take more than two years to bring an aerospace system to market and this includes testing. For smaller planes, most of the development work can be accomplished in a year. Still, when dealing with components for aircraft applications, safety is a top priority and one that no one wants to put a timetable on.

"If the thrust reversers, for example, don't work properly, the plane won't stop at the end of the runway and things could get ugly," Parlato says.

Another challenge is quality control. S.S. White has put in an enormous amount of time and effort to ensure the company keeps up with the stringent requirements. "Quality is part of our culture. We are quality certified to both ISO 9001 and AS 9100 revC," Parlato says. "We can trace a wire back to the raw material we used to draw that wire. This is your ticket to entry in both the aerospace and medical environments."

Beyond Flexible Shafts

In order to gain new business in other industries, S.S. White purchased the surgical orthopedic division of Snap-On Inc. in 1999. S.S. White engineers now create state-of-the-art hand-held surgical instrumentation for the removal of orthopedic implants. "We took this business and grew it significantly," Parlato says. "In fact, the high quality demands of aerospace applications are just as significant in medical applications. You have to document everything you've discussed or even thought about in this industry. The regulations are very strict when it comes to surgical components and procedures. Our emphasis



The right hand side of this photo shows the flexible shafts ringing the nacelle and attaching to the actuators.

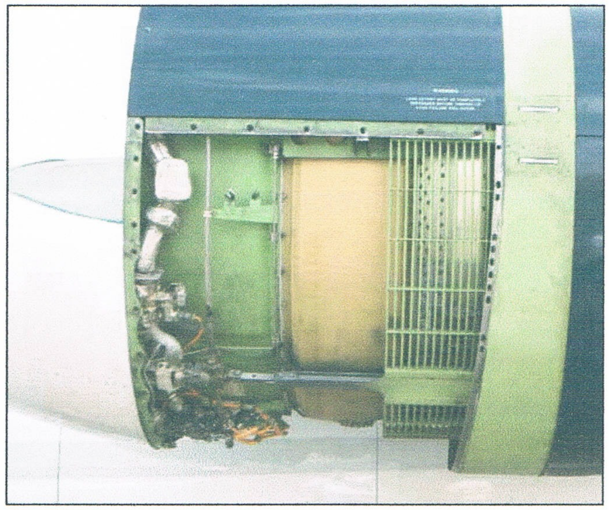
on quality in aerospace applications has certainly helped."

Parlato says that S.S. White also provides CNC components for various aerospace applications including valves and manifolds. "We plan to turn our attention to systems work in the future. It just makes sense to start getting involved in the design and development of the actual actuation systems." The company currently is focused on four areas including aerospace, medical, automotive, and CNC machining.

"We have 30+ CNC machines in our facilities and we've been providing all the machining for aerospace parts since 2005. This is an area we're looking to expand. There's currently a huge push in the Asia market and we think we can become a major player in that market in the future."

Still, the bread and butter at S.S. White can be found 30,000 feet above ground where each and every aircraft utilizes flexible shafts.

"Our claim to fame is that we understand the science behind flexible shafts," Parlato says. "We've defined the terminology and we've built the test equipment. It helps that we really speak the language of aerospace and have essentially become an aircraft company."



The Bombardier RJ200 plane with GERJ34 engines. The flexible shaft is visible going into one of the actuators which make up the Thrust Reverser Actuation System (TRAS).

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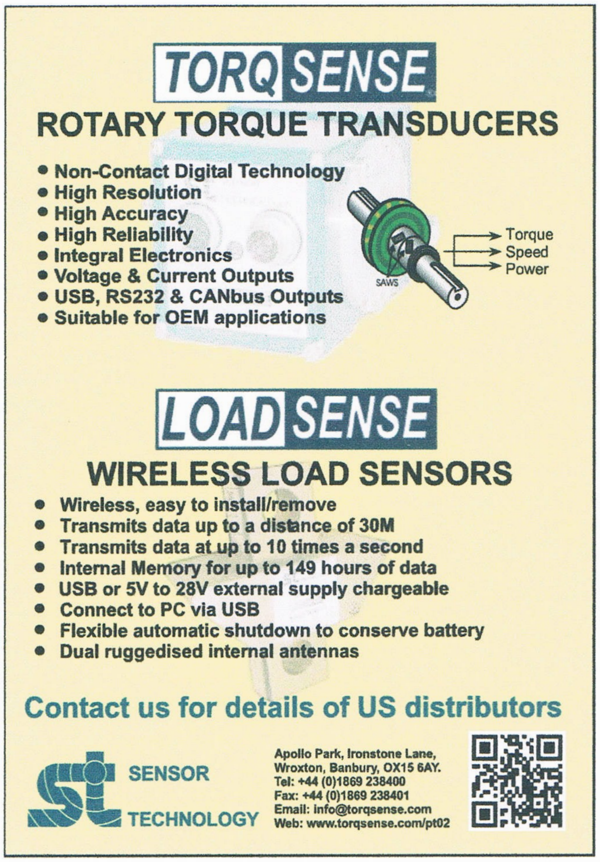

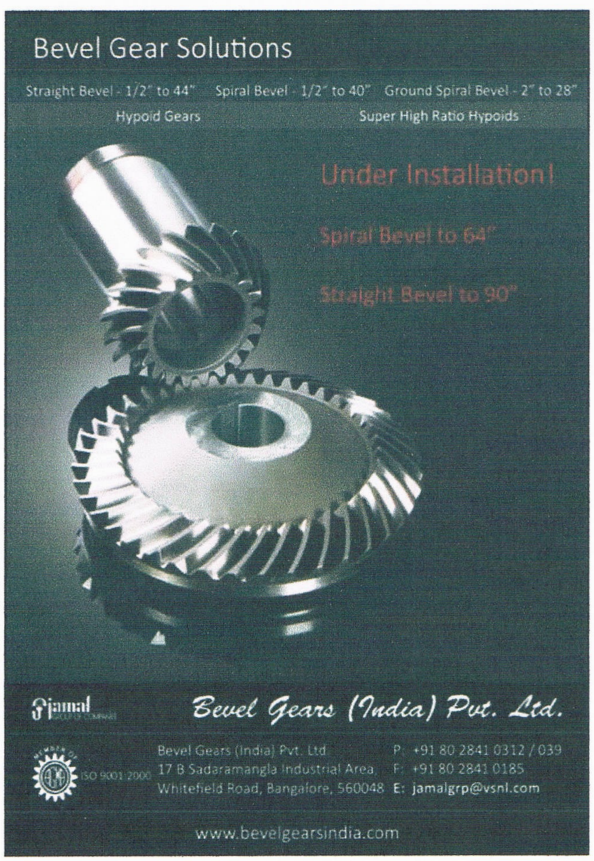

From Teeth to Air Fleets

The history of the flexible shaft is a fascinating one that began in 1844. After setting up his own tooth factory in an attic in Philadelphia, Samuel Stockton White would spend decades building the largest dental manufacturing company in the world with sales offices in New York, Boston and Chicago. One of his employees, Dr. Eli Starr was an inventor with more than ten patents and the man responsible for introducing high speed flexible shafts in S.S. White dental engines.

By 1881, the company took its flexible shaft into the industrial market. It replaced the drive links in speedometers found in automobiles like the Ford Model T (1915) and ended up in aircraft assemblies for the U.S. military (1941). "By World War II, engineers had come up with all sorts of interesting applications for the flexible shaft in the aerospace industry," says Brian Parlato, vice president, sales and marketing at S.S. White Technologies.

In 1972, the S.S. White Industrial Division relocated to its present day location in Piscataway, New Jersey and severed its ties with its sister company S.S. White Dental Manufacturing. The following year a young engineer named Rahul Shukla joined the company. Even though Shukla held three engineering degrees he had never heard of the term "flexible shaft". He spent the rest of the 1970s on tireless calculations, countless experiments, and lengthy research studies on the flexible shaft.

In 1984, senior research engineer Adam Black III joined S.S. White. After five years of field work on flexible shaft mechanics, Black submitted a doctoral thesis to The Stevens Institute of Technology. In 1987, a doctoral degree was awarded to Black for his research. Shukla purchased the company and became CEO in 1988. He changed the name from S.S. White Industrial Division to S.S. White Technologies, Inc.

Today, the company focuses on aerospace, medical, automotive and CNC machining with facilities in the United States, United Kingdom and India. For more information, visit *www.sswhite.net.*