Plastic Replacing Metal in Coupling Applications

Tobias Wolf and Andrew Lechner

Tobias Wolf *is a product engineer with R+W Antriebselemente GmbH.*

Andrew Lechner *is product manager for R+W America.*

Introduction

When it comes to selecting a connecting element between a drive motor and a pump unit, engineers most often choose an elastomeric coupling because of its failure protection and its vibration damping capabilities. Elastomeric couplings, traditionally manufactured with metallic hubs, feature a rugged and robust design noted for its simplicity. Even in the event that the flexible element fails due to overload or other unforeseen factors, this design of couplings adds the security of durable, interlocking jaws, which can continue to hold loads and transmit torque.

Conventional elastomeric couplings use a hub made of aluminium, steel or cast iron, with a flexible element made of resilient material—usually some type of plastic or rubber. The flexible element provides vibration damping while transferring the power from one shaft to the other.

The pump and aggregate industries have used couplings with hubs made of die-cast aluminium or grey cast iron for more than 70 years. Cast materials offer the benefits of moderate durability and low manufacturing costs versus machined metal. When these types of couplings were first designed—and for many years thereafter—metal was the only choice for the hub material.

Despite the fact that this type of coupling has served the industry well, there exists substantial room for improvement in the areas of noise, backlash, weight and corrosion resistance. Traditionally, improving any of the above attributes would require relatively costly alternatives.

But R+W development engineers have spent the last two years in an effort to eliminate those disadvantages, while maintaining all of the existing benefits in a new, standard design. Their primary goals have been to maintain the required rigidity under impact stress as well as the economic advantage of large-quantity production.

Today, thanks to modern materials, analysis techniques and manufacturing methods, these couplings are being manufactured entirely out of plastic (Fig. 1).

Structure and Properties of the Plastic

Thermoplastics were chosen because they can be injection molded quickly and inexpensively. Also, modern thermoplastics offer the required structural properties and thermal stability, as well as the ability to be manipulated into compounds that are extremely durable.

The engineers chose a standard engineering resin based on a semi-crystalline thermoplastic. Since the maximum operating temperature for applications requiring this type of coupling was 150°C, no high-temperature resins were required. In order to provide higher strength and improved elastic modulus, a glass-reinforced material was chosen.

Inner Structure of the Hub

The inner structure of the plastic hub was developed in close cooperation between Universität Bayreuth in Germany and R+W engineers. Initially, they used simulations based on 3-D calculation software to determine the hub geometry best suited to redistribute torsional stress around the outer "shell" of the coupling. Then, various proposals were tested in the field. The research resulted in three basic hub structures created to accommodate three subsets of possible bore diameters for each coupling size.

For accelerated life testing, coupling hubs were placed in an environmental chamber and subjected to 100% humidity and high levels of UV radiation, occurring intermittently, for four-hour periods over the course of one year. These tests were designed to mimic the results of 15 years of exposure to the elements. Complete saturation of coupling hubs yielded a maximum change of +/–1% in critical coupling dimensions.

Also, the couplings were subjected to 40,000,000 load reversals (four times published coupling life) at peak torque. No degradation of the coupling material was detected, even though the steel key used to mount the coupling to the test shaft had sustained significant damage (Figs. 2–3).

After evaluating all of the data, a German patent for the resulting symmetrical structures was applied for in May 2005. This structure's design optimizes transmission of the tangentially applied force, taking the maximum torsional rigidity into account by precisely selecting the angle, location and radius of cross-points of the individual cross-pieces (Fig. 4).

The shrinkage of the component during cooling was also considered in the design of the inner structure. As the surface of the individual hollow spaces is even, very few temperature differences exist within the hub when it cools down. This serves to reduce deformation subsequent to removal from the mold.

Finally, to address coupling balance issues, hubs were tested on dynamic balancing equipment to guarantee smooth rotation at relatively high speeds (6,000–10,000 rpm, depending on size); these speeds were well over the 1,750 rpm at which most industrial motors run. Because of the very light weight of the material as well

continued

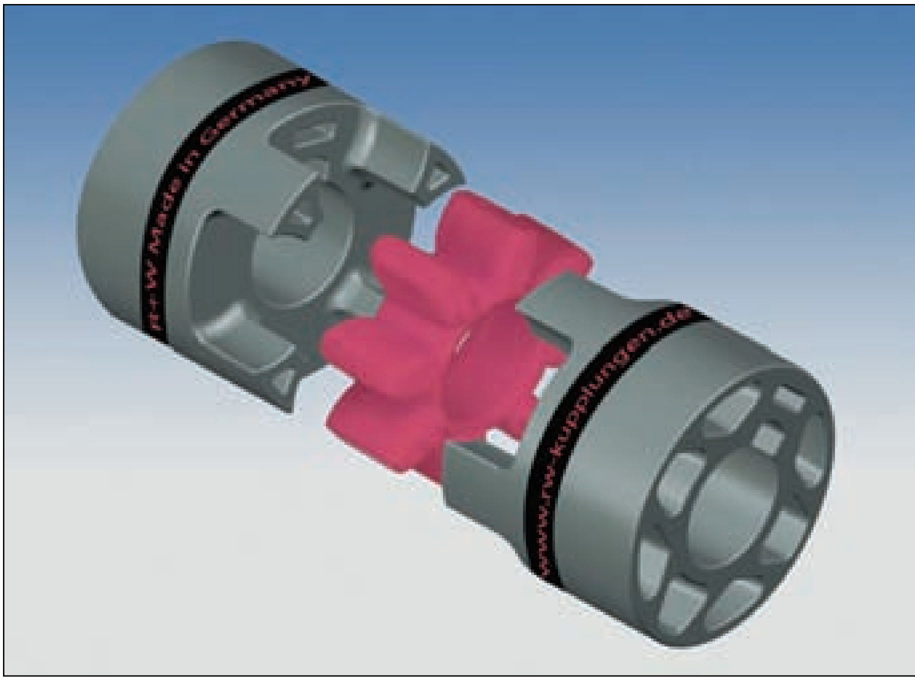

Figure 1—Model series TX1, available for applications with torque up to 810 Nm, is made entirely of plastic.

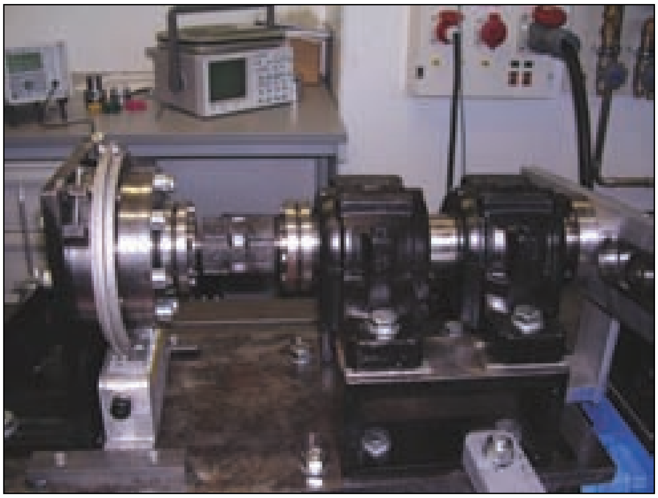

Figure 2—During development, couplings were subjected to 40,000,000 cycles at peak load on a test rig at the Universität Bayreuth in Germany.

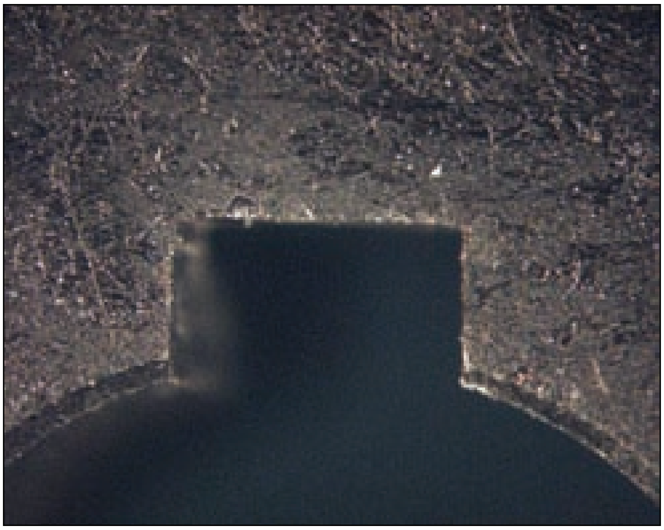

Figure 3—The couplings' keyways exhibited no damage after 40,000,000 cycles at peak load, even though the steel key had sustained significant damage.

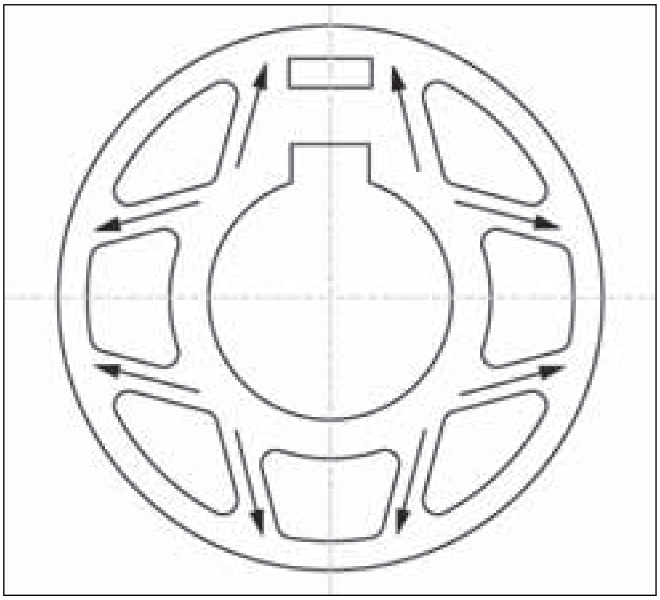

Figure 4—Cross-section of the hub, showing how the design distributes applied force for maximum hub strength.

as the high level of symmetry in the design, the imbalance caused by the keyway is negligible at the rated speeds.

Injection Molding

The mechanical properties of the couplings depend on injection parameters such as the injection time, injection pressure, injection speed, holding pressure time, cooling time, and back pressure.

A *Moldflow* analysis (Fig. 5) was performed to determine the best possible combination of parameters for each sampling.

Options

Elastomer inserts (spiders) not only have to transmit torque, but also must compensate for lateral, angular, and axial misalignments between linked shafts. In mechanical engineering, two fields of application are generally distinguished.

Servo-drive technology requires a precise transmission of the torque and position, and at the same time, it implies a minimum offset between the input side and the output side of the coupling. For this purpose, the long-proven elastomer insert comes in three different shore hardness categories. The zero-backlash of the vibration-damping element is achieved by preload between the insert and the jaw geometry.

The second field of application for elastomer couplings is the pump and compressor technology. Here, not only the transmission of torque is required, but also a high degree of offset compensation. Offsets are caused by the structural situation in industrial pump plants, for example. Specifically for this purpose, R+W has designed and begun manufacturing a new spider which exhibits backlash. The abrasion and wear of the traditional spider have been reduced by an increased level of surface area contact between each jaw and the insert as a result of geometrical changes.

Summary

The first series of fiber-reinforced plastic spider couplings uses a keyway and set screw connection, and covers a torque range of up to 810 Nm (597 lbs-ft) and a bore diameter of up to 45 mm. They can be used within a temperature range of –20°C to –100°C.

For more information:

R+W America
1120 Tower Lane
Bensenville, IL 60106
Phone: (888) 479-8728
E-mail: *info@rw-america.com*
Internet: *www.rw-america.com*

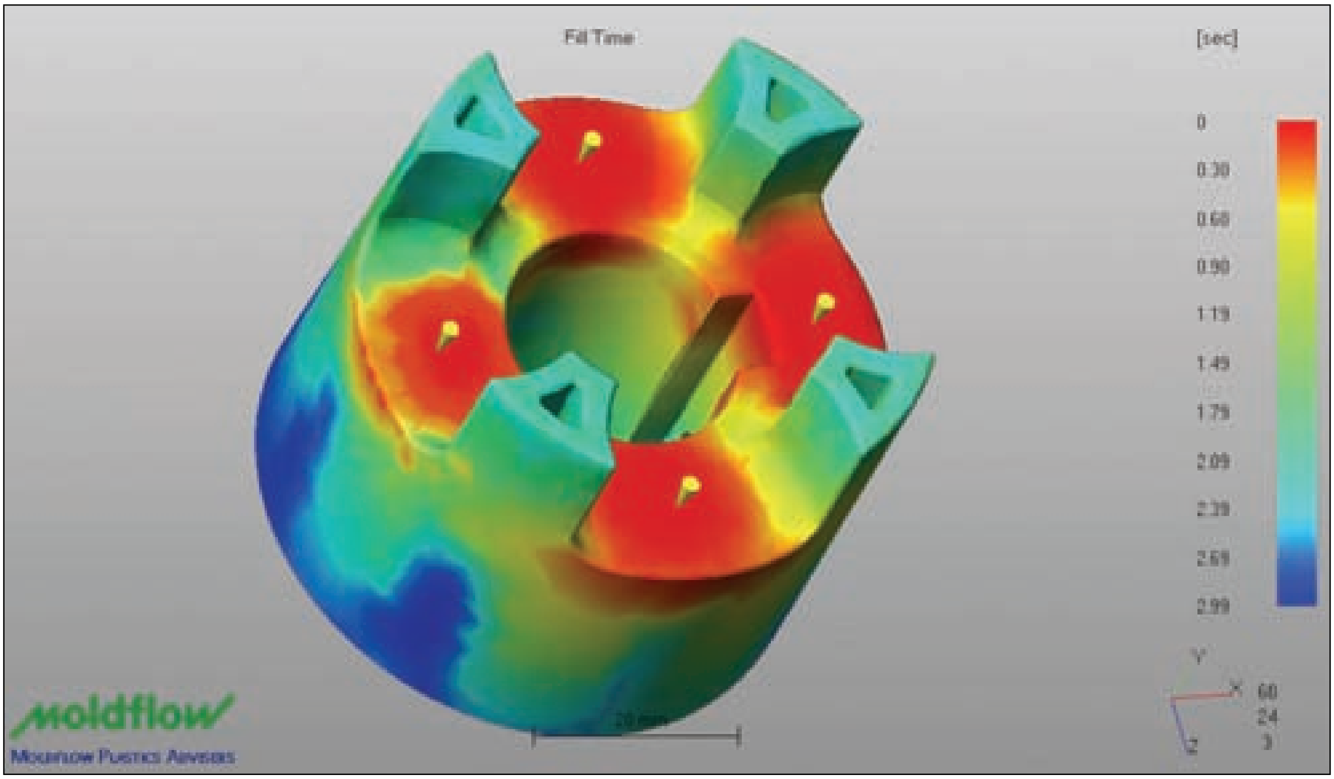

Figure 5—Engineers conducted a *Moldflow* analysis of rheological properties to optimize the injection molding process.

The Promise of Plastics

Spider couplings are used in a wide variety of fields, including the beverage, food, dairy, semiconductor manufacturing, textile, aggregate manufacturing, compressor manufacturing, biotechnology and water treatment industries. Despite this large variety of industries, the main requirements for the couplings are similar, if not comparable. Many of these industries could benefit from plastic couplings.

Coupling Requirement	Improvement Using Plastic Coupling
The total weight of the coupling should be as low as possible, so its moment of inertia does not affect the dynamics of the mechanical system.	Weight reduction of up to 89% compared to conventional couplings.
The noise emission needs be as low as possible.	Noise is damped by the plastic, as sound waves are transmitted far less readily than by metal, if at all.
Torque impacts occur if the rotational direction or speed is changed. So, the coupling needs to be strong enough to avoid breaking of the jaws.	Since the fibers are cross-linked, the material is much more resistant to impacts than cast material.
The required torque must be transmitted while maintaining the dimensions of the coupling.	The dimensions of the hub remain the same as with conventional spider couplings.
In dynamic applications, the hubs must have a certain balancing quality.	Thanks to the injection mold, the required balancing quality can easily be achieved with standard parts.