Interchangeable collector rings

Charles L. Riccitello, Gary D. Law, and R. Greg Robertson

A new design for collector rings on synchronous motors can speed the process of changing rings and reduce downtime.

Throughout the years, the paper industry has been striving to obtain optimum life from large high value synchronous motors. A basic philosophy of yesteryear was to "run them till they fail." A great deal of this philosophy was attributed to and dictated by the demands of the industry. In the long run, this attitude proved to be costly to paper manufacturers in terms of motor repair cost, peripheral equipment repair, and production loss. As recently as five years ago, in the Union Camp Savannah mill, paper machine electric downtime attributed to motor failures was 40% of the total electric downtime in the paper mill. The yearly motor repair costs exceeded US$ 1.5 million.

Later philosophies in motor optimization have shown that periodic motor preventive maintenance, good repair procedures, and tracking failure trends can reduce downtime attributed to motor failure or problems or both.

Background

At the Union Camp Savannah mill, paper machine downtime caused by motor problems or failures was reduced during 1990 from 25% to 12%, or a 48% reduction. As production is optimized, profitability increases come in the form of expense reduction.

Great progress has been made at the Savannah Union Camp mill over the past five years in the area of motor repair specifications. This progress includes motor vendor qualifications, winding insulation systems, and systems to track cause and type of failures.

One area our new failure tracking system uncovered was collector ring failures on synchronous motors. Synchronous motors are used in many applications throughout the paper industry. The collector rings are the weakest link on these motors. These rings have a tendency to wear unevenly. They also have ground problems due to carbon contamination and fail due to control problems. This article describes the authors' work to design and develop an interchangeable set of collector rings. This new design will enable paper mills to change collector rings in an expedient manner without pulling the motor.

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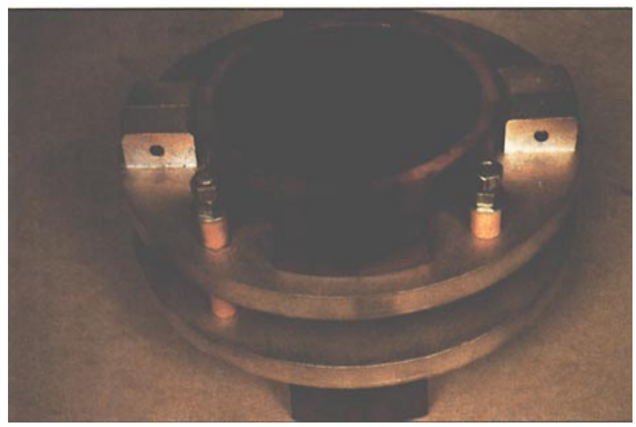
1. Prototype rings showing first design of clamping system used on Textilite hub



Design process

The majority of the lower to medium horsepower synchronous motors are designed with collector rings that are attached to the rotor shaft with an interference fit. This design makes it very difficult to change a set of rings while the motor is in place. Our challenge was to come up with a collector ring that could be removed while the motor was still in place and still maintain concentricity. Some motors take as long as 24 h to change. This time frame can be very costly in lost production.

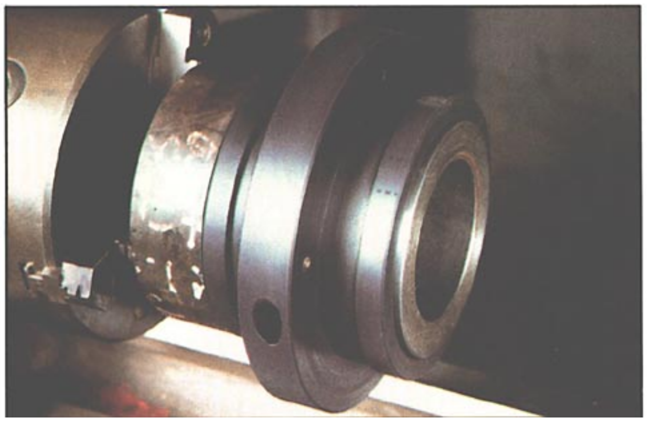
Our first thought was to see what was already available on the market. A survey of motor manufacturers and aftermarket vendors indicated that nothing was available. It became apparent that we would have to design our own ring concept.

Shrink ring collectors are normally designed with a steel shell insulated on the OD and two brass, steel, or stainless steel rings shrunk on the insulated portion of the steel shell. The rings are attached to the rotor and then machined true. To make the rings interchangeable, the hub and rings have to be of a two-piece design and still maintain concentricity and insulation integrity.

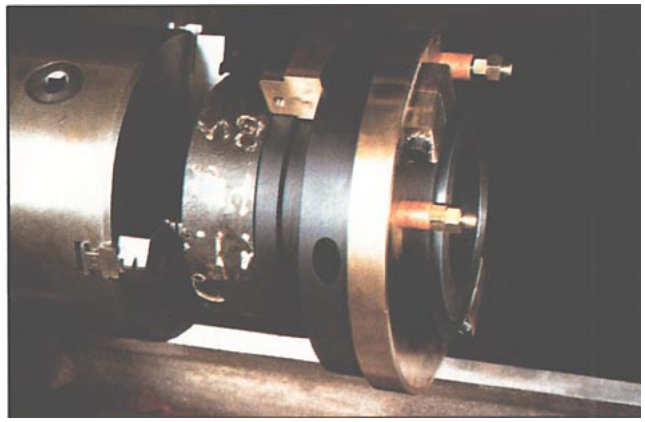
The design process was broken down into the following steps:

1. Hub material selection
2. Hub design
3. Ring design
4. Assembly process.

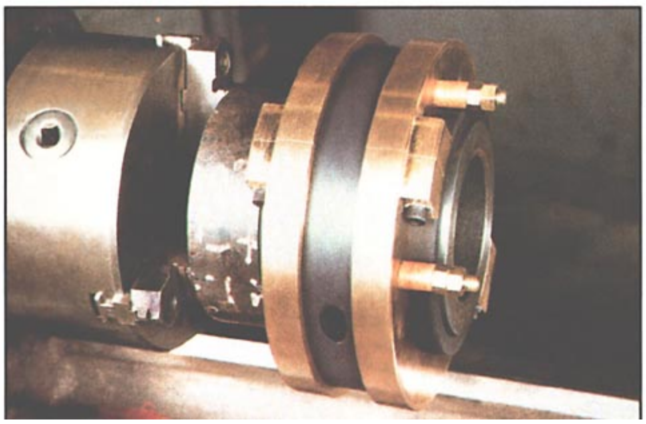
2. Existing hub design using polymer material with new clamping system



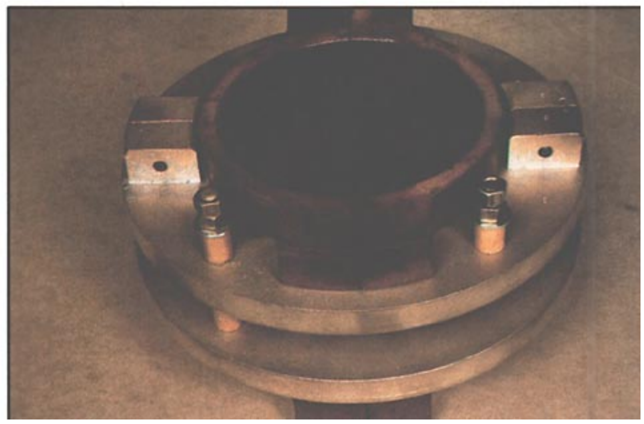
3. Hub assembly showing recessed ring grooves and one ring attached



4. Complete assembly with rings attached and connection studs in place



5. Prototype rings showing tabs silver soldered and pinned in place



Hub material

As we mentioned earlier, the rings must be insulated from the rotor shaft. The original steel hub is insulated with a glass-impregnated tape that is cured to the hub, then machined to the dimension required. The problem we encountered when we split the hub after the tape was applied was that the tape would fall off, no matter what we tried. A new nonconductive material had to be found for the hub assembly.

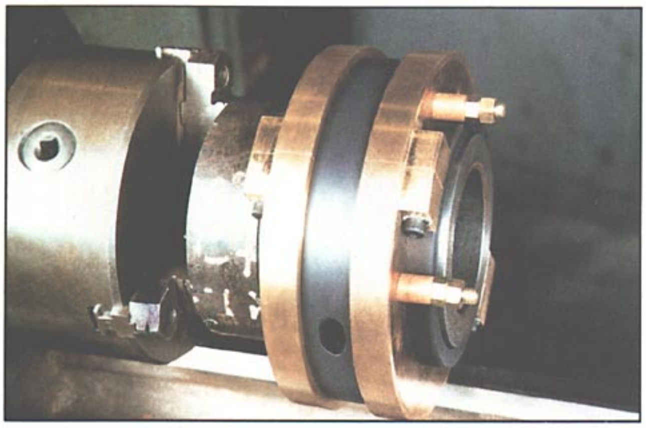
The first material we tried was Textilite, a laminated material that offered good machinability, reasonable dielectric strength, and high temperature resistance. The dielectric strength of Textilite enabled us to machine the shape we needed without adding to the dimension of the insulated collar which supports the slip rings.

The prototype set of rings used the Textilite material. Some of the problems we found were:

1. After the surface of the Textilite was machined, the rings had a tendency to collect moisture. The first attempt to solve this problem was to dip the hub assembly in baking varnish, leaving only the bore to machine. After the baking cycle, we found the hub would stress relieve. To solve this problem, we would machine the hub one hundred thousandths of an inch (0.00001 in.) on all fits. The hub would then be dipped varnish and baked. The final machining would be completed after the dip and bake cycle.
2. Low megger readings were discovered between the ID of the rings and the shaft. This problem was solved by increasing the web thickness on the hub between the ring fit and the shaft.
3. The threaded holes that held the rings together were drilled to the proper tap drill size, then tapped. We found that the threads in the Textilite would not hold. Machined inserts were used and tapped to the required size. This approach to the thread problem worked well.

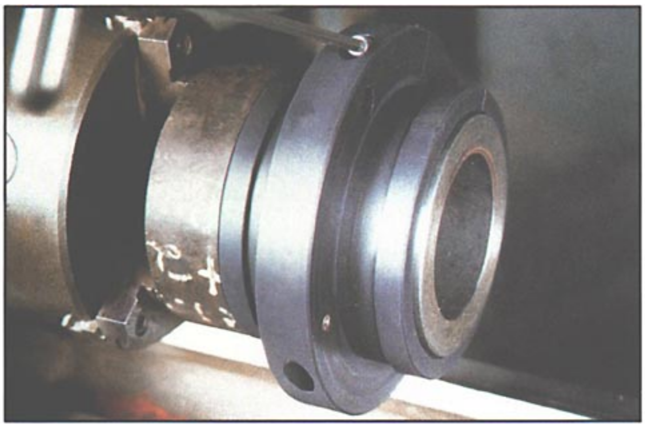
The prototype rings were put into operation and run for six months while their performance was monitored. The assembly held up well, and no problems were uncovered. During this six-month period, we looked for an alternative hub material. Textilite required too many operations and processes to be an efficient material. We began to consider a high temperature polymer plastic which has been used by General Electric's Large Motor and Generator Department to manufacture some collector rings. This material had better machinability, and moisture was not a problem. It had very good dielectric strength and enabled us to machine the hub in two setups. Manufacturing efficiency was improved because the dipping and baking

6. Final design of rings showing holding tabs machined into rings

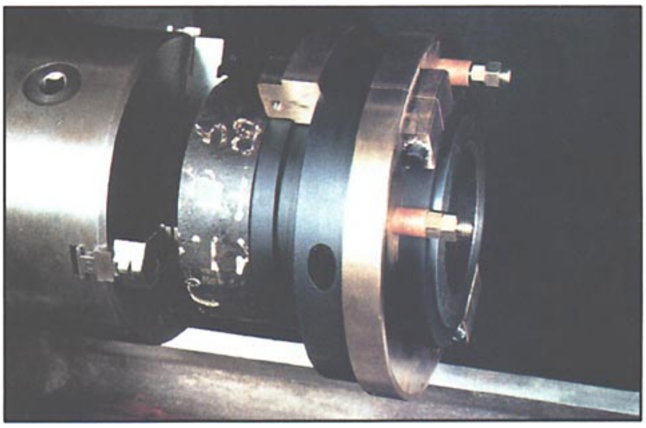


7. Stainless steel rings showing clamping tabs welded to the rings

8. First step in assembling hub to rotor shaft



9. Second step in assembling; the ring closest to rotor must be attached first



cycle was eliminated. We have standardized this product to be used on all slip rings assembled.

Hub design

The hub and rings had to be of an interlocking design to give the assembly strength. The hub was designed to split from 0° to 180°, and the rings would split from 90° to 270°.

Deciding how the clamping tabs would look as a finished product took some time and thought. The prototype rings had two tabs on both ends of the hub, as shown in **Fig. 1.** We had some problems with this system during assembly, especially when the rings were assembled on site. It did give good holding strength.

Because the polymer product is stronger than Textilite, we were able to eliminate the large locking tabs. **Figure 2** shows the approach now used to clamp the hub assembly together. The final locking system makes assembly much easier and reduces the amount of material required to manufacture the hub assembly. Design clearances became our next task. The original solid rings had an interference fit between the shaft and hub of 0.001-0.003 in. This same concept was to be used on the prototype set until we found that the hub could not be closed completely. This made it impossible for the rings to come fully together. We finally decided to machine the ID of the hub to the same size as the shaft. The ID of the rings was machined with an interference fit to give the assembly its interlocking feature.

The rings are positioned on the hub in two recessed grooves, as shown in **Fig. 3.** The grooves are a design feature to make sure the rings are always positioned in the same place during the assembly operation. **Figure 4** shows the complete assembly.

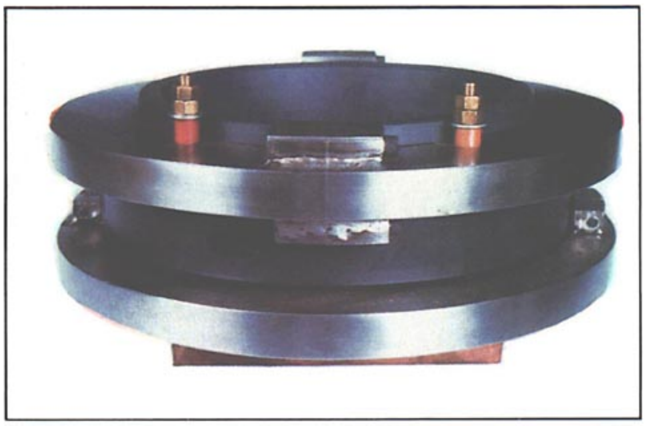
Ring design

The ring portion of this project was probably the easiest part to design. The material used on the prototype set of rings was Collector Ring Brass. As mentioned above, the ID of the rings is machined with a small shrink fit to the hub. The shrink fit locks the whole system together.

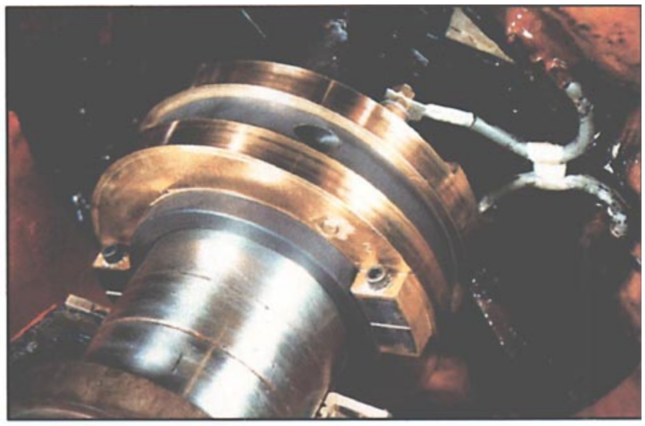
The first rings made had two tabs, silver soldered at each side of the split and doweled, as shown in **Fig. 5.** The rings were attached at the tabs with a threaded screw, and the ID was machined to the required size. The rings were then attached to the hub assembly, and the OD was machined to the corrected dimension.

The strength of the silver soldered joint that held the tab in place was of some concern. As a result, we decided to use ring stock wide enough so the tab could be machined into the ring, not soldered on. **Figure 6** shows the final design of the rings.

10. Completed assembly showing proper method of attaching connection studs



11. Completed ring assembly installed in an 800 hp motor



Steel and stainless rings do not have the tabs machined into them. The tabs are separate pieces that are welded to the ring as the first step in the operation. Carbon steel or stainless steel offers the user the ability to weld the pieces together, which saves time as well as material cost. **Figure 7** shows the clamping tabs welded to the rings.

The connection studs are attached to the rings through a hole in the hub. The stud connecting the second ring is insulated using Micarta Tubing.

One advantage that came from this new ring design is the ability to true up the surface of the rings after they have been in service. In the past, a turning fixture had to be assembled to the motor, and a drive system was required. Now all that is required is to remove the rings, place them in a lathe using the ID as reference point, and turn the ring true.

Assembly process

After the rings have been manufactured, they can be assembled on the motor. This operation can be performed when the motor is out for overhaul or still in place during a shutdown.

The easiest time to assemble the new split rings is when the motor is out for overhaul. The old rings can be removed by a number of methods. The rotor should be completely cleaned and varnish treated before the rings are assembled. The new rings should be assembled in the same location as the old ones.

The first piece to be assembled is the hub. It has the same dimensions as the shaft and may move on the shaft during assembly. The assembly of hub to shaft is illustrated in **Fig. 8**. The back ring goes on first, since the stud must pass through the first ring as well as the hub. This part of the assembly is shown in **Fig. 9**. The two pieces are then bolted together but not tightened, as shown in **Fig. 10**. The front ring is then assembled. With the back ring stud in place, the two pieces are screwed together. At this time, the whole assembly should be tightened. Finally, the motor should be checked to make sure the assembly is tight on the shaft and the rotor has an adequate megger reading. A completed ring assembly installed on a motor is shown in **Fig. 11**.

The on-site assembly process is a little more complicated. The endbell must be removed from the collector assembly end. In some cases, only the top half of the endbell will have to be removed. The collector ring fit should be checked to be sure it is the proper size for the rings being used. The old rings can be removed with any form of grinder. Any stray chips or grinding dust should be collected. After the old rings are removed, any paint or old varnish left on the shaft where the new rings will be installed should be removed. The assembly process with the motor in place is the same as previously described for in-shop installation.

Care should be taken to make sure there is adequate clearance for the brush rigging.

Conclusion

The new ring assemblies have been in operation at Union Camp and other mills in the Savannah area for the past four years. No operating problems have occurred, and the quick-change benefits have paid off. One example of the benefits of interchangeable collector rings occurred on the No. 7 fan pump at Union Camp. The motor was shut down during a scheduled maintenance day, and full field was applied on startup. The rings failed at the connection studs due to the high current in-rush. The split rings were changed and the motor was back in operation in four hours. Prior to the split ring concept, this motor would have to have been changed and a spare put in its place. This operation would have taken 24 h to complete. The loss in production more than offsets the cost to manufacture two sets of split collector rings.

The effort put forth has paid off in reducing synchronous motor downtime due to collector ring failures. The continuous monitoring of motor failures will uncover other problem areas. A systematic approach to solving these problems, as in the split collector rings, will reduce motor repair costs and increase paper machine uptime.□

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