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Turn-Mill Technology Improves Industrial Motor Performance

By replacing a welding process to create rotor cooling channels with multitasking machining from a solid forging, Siemens Norwood in Ohio has realized improved induction motor vibration qualities and much faster overall rotor production times.

BY DEREK KORN

In some cases, an improvement to a machining process or the addition of a new machining capability leads to improvements in an end product's performance. The latter has been the experience at the Siemens Large Drives motor plant in the production of its Above NEMA horizontal AC induction motors that range to 18,000 horsepower.

This successful line of motors is produced at the company's 119-year-old Norwood manufacturing facility in Cincinnati, Ohio. The motors are used in various industries such as mining, chemical, power generation, pulp and paper, and oil and gas. One key motor component is the rotor shaft that installs a stator. Antonio Lassandro, Siemens Norwood's senior manufacturing engineer, says rotors for these motors range from 5 to 13 feet long and have diameters from 8.5 to 20 inches. Made from steel forgings, these rotors (which the team there has nicknamed "logs") can weigh as much as 6,000 pounds.

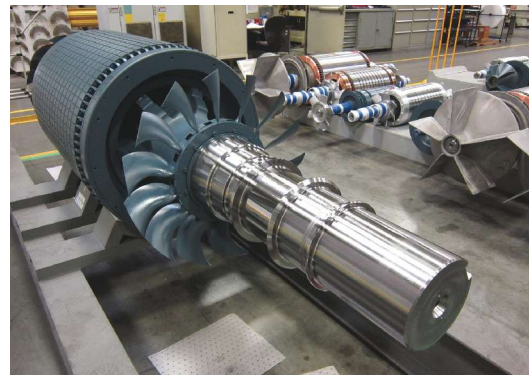
Turn-mill technology enables the Siemens Norwood facility in Cincinnati, Ohio, to more effectively manufacture rotors like this for its large Above NEMA AC induction motors.

A number of machining operations are required to produce a finished rotor from a shaft forging, including rough and finish turning; milling, drilling and tapping; as well as cylindrical grinding and hand diamond burnishing of key surfaces. Stress relieving of rotor shafts and final rotor-assembly-balancing operations are also performed.

Although all of these operations are still required today, it's now possible for Siemens Norwood to complete all the machining work on one multitasking machine in only two setups, rather than sending workpieces across various pieces of equipment, such as lathes and horizontal mills, as it once did. Just as importantly, a manual welding process was eliminated that not only greatly reduced rotor manufacturing time, but improved the vibration characteristics of the company's motors.

"FLUTING," NOT WELDING

In order to cool a stator during motor operation, the section of the rotor inside the stator includes a number of straight, longitudinal channels that serve to direct air through and out of the stator. Initially, Siemens Norwood welded multiple



The Above NEMA motors are used for oil and gas and a range of other industry applications. Motors are available in models ranging to 18,000 horsepower.

rectangular blanks about the periphery of a cylindrical rotor forging to create those cooling channels (see the photo below). Prior to welding, the rotors were rough-turned on a lathe and then sent to a four-axis horizontal mill that machined flats where the blanks would be located for welding.

The manual welding process for each rotor took 50 to 60 hours, and this approach meant other subsequent manufacturing steps also became necessary. For example, the welds required quality inspections to ensure that proper penetration was achieved and that the welds were free from cracks. In addition, a pre-balancing operation for just the shaft was commonly performed prior to balancing the entire rotor assembly. This was necessary because of the natural imbalance that occured due to the inherent variation in resulting weld thickness from one welder to another.

Plus, the heavy welding operations created a good bit of stress inside the rotor. Kris Miller, systems engineering manager, explains that, as a motor heats up during operation, the stresses in rotors with the welded-shaft design change and shift, causing an imbalance that's evident in vibration testing.

Previously, the company created cooling channels by manually welding rectangular blanks to shafts. Not only was this time consuming, but the heavy welds also introduced stresses that required additional rotor balancing work prior to motor assembly.

These issues spurred the decision to adopt a multitask machining process using a large turn-mill machine with a B-axis milling spindle that could mill away the cooling channels from larger-diameter forgings in a process the company now calls "fluting." This technique completes cooling channels on large shafts in what the company describes as substantially less time than the welded design. In addition, the consistency of machining to create channels compared to manual welding has eliminated the need to perform rotor pre-balancing. Good initial rotor balancing characteristics also help eliminate lobing that might otherwise occur during subsequent cylindrical grinding operations, which could extend overall rotor assembly balancing time.

After considering a few turn-mill brands, the company chose an M-80 Millturn from WFL, which is headquartered in Linz, Austria. (WFL's U.S. headquarters is located in Wixom, Michigan, and Siemens Norwood purchased this particular machine through WFL distributor Walker Machinery in Cincinnati, Ohio. This machine was installed in the fall of 2015.)

There are a number of requisite machine

This M-80 Millturn from WFL is the multitasking machine Siemens Norwood chose to perform "fluting" operations to create the rotor cooling channels from a solid, cylindrical steel forging. The turn-mill machine features a 100-horsepower main spindle and 80-horsepower B-axis milling spindle. It can accommodate 20-inch-diameter shafts as long as 236 inches, which Siemens Norwood will take advantage of as it continues to design larger motors.

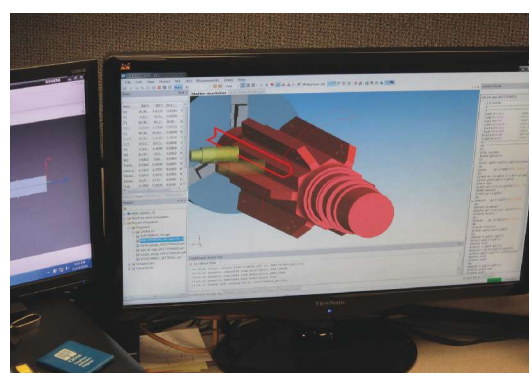
features needed to effectively process these rotors, and size is one. The M-80 with tailstock can swing 39-inch-diameter workpieces with the steady rests removed and accommodate material as long as 236 inches between centers. It also features a 100-horsepower main spindle and an 80-horsepower B-axis milling spindle offering 220 degrees (±110 degrees) rotation. Mr. Lassandro says every one of the automatic toolchanger's 72 stations is used for a range of tools that have a Capto C8 tool interface. The M-80's slant-bed design is important, too, to provide easy operator access to the work area during setups.

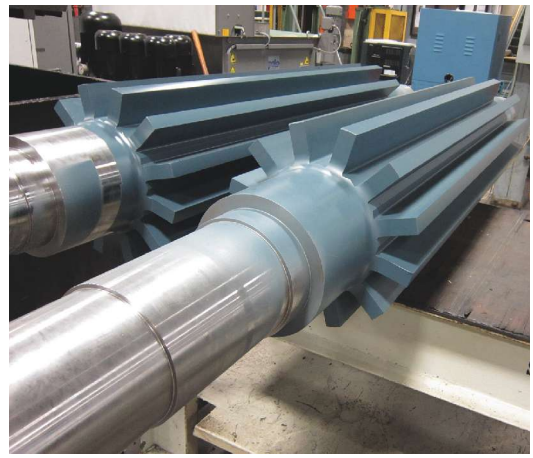
Due to the length of these rotors, programmable steady rests from SMW Autoblok are used to provide additional support. Three steady rests were purchased with the machine (two large and one smaller), although only two are installed on it at any given time. During fluting, the steady rests clamp on diameters on either end of the shaft to provide additional rigidity, minimize vibration during machining and prevent workpiece sag.

Mr. Lassandro says the complexity of the machine presented him with a programming learning curve. This he overcame in part through training at WFL's Linz headquarters. It was also helpful that WFL developed a part program for one rotor model that was machined during runoff test cuts performed in Linz to prove the process. Mr. Lassandro then worked closely with Siemens Norwood's engineering department so it understood the machine's capabilities and with the machine operators so they had a good feel for the new process, machining codes and cycles.

That said, although the rotor models are similar, each often has slight design differences. Plus, rotors are machined in batches of one or two, not hundreds, meaning new programs are developed quite frequently. Therefore, Mr. Lassandro has started to build a library of programs for common rotor styles that he can call up, swap the 3D model for the new job, and then tweak to adjust for different flute depths, bearing diameters, keyway specifications and

Offline simulation is performed for each job to ensure there will be no interferences or collisions during the actual operations. A feature in the Crash Guard Studio software enables Mr. Lassandro to quickly remove workholding elements to get a clearer view of the cutting tool motion.





A face mill is used to create cooling channels when there are only a few flutes, such as the six-flute version above. Conversely, slot cutters are used when there are a larger number of flutes and minimal space between them.

so on, before regenerating a new program.

The type of tool used for fluting depends on how many channels a particular rotor has. For large shafts that have perhaps six flutes, a Sandvik high-feed face mill is used to create the cooling channels, because there is ample space between flutes. For rotors that have many more flutes, a Sandvik 10-inch slot cutter is used (see photo above).

The M-80's capabilities have spurred the facility to use carbide tooling instead of high speed steel as it had traditionally used, too. Mr. Lassandro says the facility takes advantage of the M-80's 1,160-psi through-tool coolant delivery to provide effective chip evacuation while using solid carbide drills. In some cases, it would take several minutes to drill a 4-inch-deep hole on a horizontal mill by pecking with a high speed steel drill. That same hole now takes only 15 seconds to create without pecking using a solid carbide drill and high-pressure through-tool coolant delivery.

In-process part probing also plays a role. Tools can be automatically measured using a WFL tool-setting probe, eliminating the need to perform offline tool measurement or manual touch-offs. An M&H touch-trigger probe is also used primarily to set all machine offsets. For example, after fluting work is completed on a rotor, the rotor's C-axis zero position is determined by probing either side of one flute to ensure that the keyway machined at that location is positioned precisely at the center of that flute.

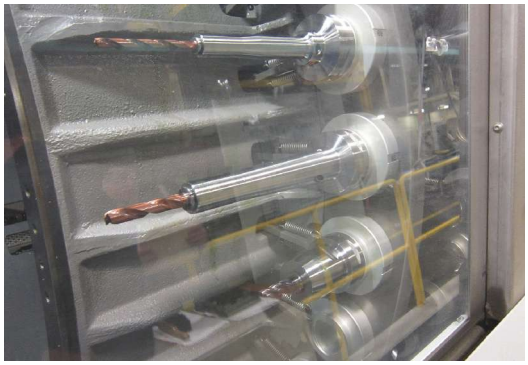
Each part program that is developed is verified through offline Crash Guard Studio simulation software. This software uses CAD models of all machine elements, workholding devices, tooling and so on to ensure there will be no interferences or collisions during the actual operations on the machine. The software includes a helpful feature that enables Mr. Lassandro to quickly remove workholding elements such as the tailstock to get

WFL, call 248-347-9390 or visit wfl.at.

Walker Machinery, call 513-271-3380 or visit walkermachinery.net.

Siemens Norwood, call 513-841-3100 or visit siemens.com.

Sandvik, call 800-726-3845 or visit sandvik.coromant.com.



Tools can be changed out of the ATC magazine without shutting down the machine while it is operating. Solid carbide drills combined with high-pressure coolant enables deep holes to be drilled without pecking.

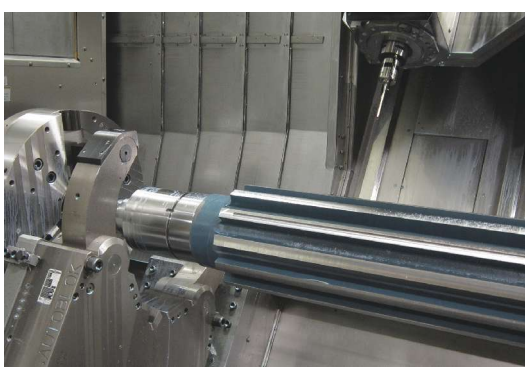
a clearer view of the simulated cutting tool motion down the length of a part. The machine operators can also access Crash Guard from the machine's Siemens 840D control, which shows the motion of machine elements in real time, and prevents accidents from occurring on a new program's first run and initial setup of clamping devices.

WHEN NOT TO MULTITASK

Like most other companies that purchase a turn-mill such as the M-80, Siemens Norwood is able to machine many workpiece features in one clamping. That said, there is often so much fluting work to be done on that machine that the company will use one of its traditional CNC lathes to perform initial rough-turning operations for shafts, rather than tying up the M-80 for that basic work. After rough turning, those shafts are sent back to the turn-mill for fluting. Finish turning might also be completed on the M-80, unless it makes more sense to send the rotor to another lathe for finish turning to enable the turn-mill to start another fluting job.

On the other hand, when there's not so much fluting work scheduled, the shop might run simpler shaft work that doesn't require fluting across the M-80 in order to get most if not all turning and milling work completed in one setup. That eliminates work in process (WIP) when shafts require milling but the horizontal mill is tied up with other work.

Bruce Tillinghast, Walker Machinery president, says Siemens Norwood actually considered adding this type of multitasking equipment platform some 20 years ago, but decided against it. At that time, all the necessary elements—software, hardware, tooling, training and so on—simply didn't jell into the type of repeatable process that's currently possible with today's turn-mill and related machining technologies. The system also wouldn't have been as reliable, he says, which is important given not only the significant investment Siemens Norwood made in its turn-mill machine, but also because it is the only machine in its plant that can perform fluting work.



The machine features touch-trigger probing, which is primarily used to speed setups. For example, probing either side of a flute enables the rotor to be positioned properly in the C axis for milling a critical keyway. Plus, it is possible to park a fully opened large steady rest near the chuck as it is shown here rather than removing it from the machine to enable the milling spindle to access features on short shafts. Otherwise, removing and replacing a steady rest takes time, because it must be properly aligned with the chuck center line.