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Infrared thermography and waveform analysis identify mechanical failure and highlight increased duty cycle concerns in robotic work cell.

Root cause investigation of a single fault on a piece of critical production equipment at Accuride's Henderson, KY, plant uncovered multiple hidden problems. Solving those problems resulted in increased productivity.

The investigation began shortly after an operator noticed a hunting and surfing motion in the work station's Motoman K150 robot as it loaded a press. When excess following error increased and caused the machine to fault regularly, the staff decided to replace the reduction gear assembly on the affected axis.

The manufacturer was asked to send a technician to assist in the assembly replacement. Repairs were made, the axis was exercised with no load, and it showed no apparent faults, noises, or unusual vibration.

The reduction gear was disassembled to locate the cause of the failure, and a badly deteriorated bearing was found.

When the unit was placed in production the next day, setup personnel commented on the extreme heat of the repaired axis servo motor. This open dialogue between the plant's maintenance and production teams allows flexibility in problem solving, which greatly facilitates the company's maintenance objective.

How hot is hot?

When the motor encoder assembly was scanned with a Cincinnati Electronics infrared camera, it showed a temperature 20 deg F above the temperature of the same axis on another K150, Fig. 1. The reduction gear on the hot axis was found to be extremely worn.

The installation of a new unit appeared to correct the extra play or looseness in the system. The motor, which had logged 24,000 hours of production, also was replaced to eliminate concern that it might deserve a rebuild. The robot is in use 24 hours a day, 7 days a week, so testing, troubleshooting, and replacement are done at the expense of production.

Was this a poor repair?

Was the new $8000 reduction gear defective? Was something overlooked, or were there multiple problems? The plant's experience in motion control indicated that the most obvious causes of overheating in pulse-width modulated servo systems are oscillation due to tuning or noise, overload, and phase unbalance.

Duty cycle and load are primary considerations. Because they are typically addressed at the design stage, they were assumed to be satisfactory at this stage of the investigation.

A balanced load on all three phases was quickly verified using a digital multimeter that measured true rms current. Oscillation and following error were stable and there were no major or minor faults. Testing of the cable harness and brake circuit proved inconclusive.

Waveform analysis

The staff continued the investigation of the problem by checking speed and torque curves with a dual trace Fluke 105 Scopemeter. They found that the torque curve was roughly parallel to the speed curve. Ordinarily, torque decays as speed levels off because maintaining speed requires less effort than acceleration or deceleration. Testing before disassembly showed a fairly normal torque curve with no load and abrupt changes to the unusual parallel pattern when a working load was applied.

Two weeks passed before production schedules would allow the time to disassemble any major components. The Motoman technical support technician returned to assist in identifying the cause of excess heat. Oscillation and unbalanced loads were eliminated before he arrived, so it became a matter of disassembling minor mechanical components. One tapered roller bearing out of four on the cantilever arm had disintegrated and parts were wedged between frame members.

After repairs were completed, additional tests showed a very clean speed waveform and rapidly decaying torque curve. This repair appeared to be a resounding success, but new infrared images showed only a small overall decrease in radiant heat. At this point the waveforms were again checked and found to compare favorably to those of another robot doing a similar task.

Further investigation revealed a rapid sequence of torque spikes related to programming procedures. There were more start-stop sequences than needed in cycle programming. Removing three stop-start cycles, and merging two positions, reduced the demand on the robot by 32 full-torque moves per minute and reduced radiated heat 15 deg F.

Because inrush current during startup is 200 percent or more of running current of the axis motor, it is likely that the more efficient program will result in significant reduction in stress to the unit. An unexpected benefit was a 2 second cycle time increase.

Project results

As bottlenecks inhibiting production were resolved, the duty cycle of the machine increased. Continuous improvement of the process and equipment have pushed this unit, one of the more reliable production cells, to the limit. Engineering had recently increased the working speed and position of this material handler; this increase probably precipitated the problem.

What had been the quickest part of the process has now become a concern of reliability and capacity. Yes, the robot can maintain this level of production, and there are still gains to be made. However, programming practices have become more critical, along with the need for more diligence in monitoring the condition of every system. A new opportunity exists to utilize the time gained, increasing productivity with minimum expense.

This investigation illustrates the value of thorough fault analysis. A single fault without clear resolution led to the identification of a series of problems whose resolution produced gains. These gains then may stress other parts of the machine train. Their resolution may then spotlight another opportunity. Continuous improvement resembles a cat chasing its tail: the target keeps moving but the goal remains the same. Collected data may be difficult to interpret without previous experience, but each effort will generate a record for future reference. **MT**

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