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Intelligent Machines 2.0

INTRODUCTION

I was pleased to see Kumar Balan introducing the subject of Artificial Intelligence (known as AI) to the Shot Peener subscribers recently in the Summer 2018 edition ("Emerging Technologies and Blast Machines"). Kumar didn't quite ask if the Shot Peening industry was ready for AI or not, but I'll attempt to crack the door open, exposing some light on current examples that show tremendous possibilities, then try concluding if it is AI.

Wikipedia describes AI as, "Intelligence demonstrated by machines, in contrast to the natural intelligence displayed by animals and humans." The description goes on to say, "The term artificial intelligence is applied when a machine mimics cognitive functions that humans associate with other humans such as learning and problem solving."

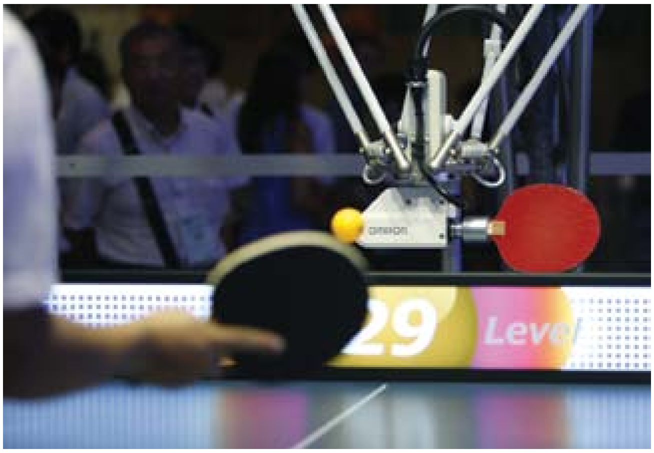
For a device or system to operate in the AI world, sensors must interface with the surroundings or environment with human-like senses including sight/light, touch/force, sound, temperature and smell. All these sensors are already used in common commercial applications and they are just waiting to be adopted by our industry, Shot Peening!

AI Demonstrations and Applications

Here are some fun examples of AI that are out in the human world right now. The Japanese automation/parts maker Omron has demonstrated AI at several trade shows and conferences, much to the amusement of humans. Omron's "Forpheus" is a table-tennis playing robot that has done well with all levels of challengers to the point that now it can return the table-tennis ball within 50 mm of the destination and can rank its human opponents as beginner all the way to expert.

Budweiser and OTTO have driven a transport truck, filled with cases of beer, on a 120-mile (200 km) delivery with the driver in the cab but not driving the truck. The driver guides the transport to the highway and then engages the AI. The truck drives the route without any further driver intervention until the truck exits the highway near the delivery location. YouTube has a great video of this demonstration. As another example, early in 2018, Starsky Robotics demonstrated their AI abilities with a completely driverless vehicle over a 7-mile (11 km) route. Wow.

I'm sure we've all seen television car commercials where a car parallel parks itself perfectly with the driver in the car but not touching the steering wheel. This feature was designed by Toyota in 1999 and it is called the Intelligent Parking Assist System (IPAS). Now you can find this convenience on several cars around the world. The system works by the driver finding a parking spot they like and driving just past it. The IPAS is activated, and the car begins to back into the chosen parking spot. Perfect!



Omron has developed a table-tennis playing robot named "Forpheus."

Author's note: *I recently rented a car with this feature, but I wasn't brave enough to give it a try by wedging between two unsuspecting parked cars that I didn't own. I'm sure everything would have worked out fine, but I didn't want to leave windshield notes for new friends that I'd met by accident.*

Shot Peening Example

Recently, Progressive Surface had the privilege to design and commission a shot peening version of IPAS. I describe this system like an IPAS feature simply because we still require the operator to select the feature to be peened, and once the shot peener controller is engaged, the part feature is located, checked, confirmed and processed. Just like parallel parking!

The shot peening industry has struggled to peen small diameter oil holes in Low Pressure Turbine shafts (LPT shafts) for decades. The LPT shaft oil holes were once considered too small to peen by entering the bore. The shot peening industry answered this problem with the development of very small rotating deflector nozzles or lance nozzles. Accurate and repeatable shot flow control has been available for over 30 years; however, accurate control of very low media flows were developed to meet the need. At this point, shot peen operators could now access the oil hole bores by inserting very small diameter lance nozzles and the media control was reliable enough that small lances didn't become plugged with media. Great!

The next problem to overcome was getting the small lance into the oil hole bore on a production basis without damaging the LPT shaft or the carbide lance. This process required the shot peen operator to enter the peening cabinet, get their face and eyes very close to the target and line-up the lance and bore with very little margin for error. The operator/visual alignment process was hampered since the operator was forced to view these two components—the hole and lance—from the side and not directly overhead.

Two planes of view would be helpful, three planes of view would be perfect, and neither is possible with the operator alignment method. This is due to the physical size of the lance nozzle rotating device and the length of the LPT shaft. Perfect alignment proved to be difficult and misalignment would cause contact.

The following are application-specific parameters for the LPT shaft.

- Hole Size – 4 mm dia x 12 mm depth (0.156" dia x 0.50" thick)
- Shaft Diameter – ranges between 80 mm to 155 mm
- Number of Holes – depending on the part, holes range from 4 to 16 on a single shaft.
- Lance Size – 3.0 mm OD (0.122" OD)

Our customer no longer wanted the operators to be responsible for the lance-to-hole alignment and the consequences if the alignment wasn't perfect. Our customer also stated they wanted us to apply the "maximum automation" required to solve this problem.

Our first step was to fabricate metal tubes that represented the LPT shaft with oil holes. We then fabricated a set of precision rollers, added motion control, and then placed a test robot adjacent to the test stand. Bravely we purchased a precision industrial camera, mounted it over the shaft and proceeded to fail miserably locating the oil holes!

We learned a hard lesson on locating a small diameter hole on the surface of a cylindrical part. Perpendicularity was paramount. Basically, if the hole wasn't 100% perpendicular to the lance, the hole opening appeared reduced in area for the approach of the lance. A tight clearance situation now became tighter!

We quickly realized how difficult this application was. The following few weeks saw a flurry of e-mails back and forth with vision companies and specialists, only to find that we had exhausted the current state of technology. If the hole was located on a very thin metal cross-section, the angular error wouldn't be too bad, but in this application the hole diameter to length ratio was 3:1. If the shaft was misaligned by 5 degrees, the lance would collide with the part.

The camera technology could easily find a dot on a shaft with no problem. If the hole was tapered—smaller at the far end—the camera could align the two circles concentrically within each other and provide perfect alignment. We asked the customer if the operator could apply a mask over the hole with a larger cut-out that the camera could identify as

Loading a low-pressure turbine shaft for peening.

two circles. An aiming device if you will. "No, maximum automation" was the reply.

OK, stay calm and march on. We concentrated on camera imaging, trying to find a way to enhance the observed image to the point that we found the machined shaft surface caused the built-in camera lighting to create nasty reflections, distorting the feature image we're trying to locate. Our project success was starting to look pretty bleak, or maybe even dark.

Then a breakthrough and as Bob Dylan once sang, "the darkest hour is right before the dawn." Our engineering team realized the light reflections could be used to locate the hole. With some advanced programing, we could rotate the shaft clockwise or counter-clockwise to align the hole image with the reflections.

The original intent was to have the camera mounted in the peening cabinet, but once we realized how important the lighting, reflections and stand-off were, we decided to mount the camera to the robot.

We added additional sensors to the shot peen cabinet and they act as digital micrometers to ensure the lance and clearance probe are not damaged. The gauging system also checks the geometry of the robot tools to ensure they are correctly located within very tight tolerances.

The final feature was a wall-mounted Almen strip holder with a shaded-strip mask, representing the exact hole dimensions being peened. Once the Almen strip test is confirmed, the hole peening program is commenced and the shot peening system continues and operates in complete automation.

I don't think the above described system operates much different than the IPAS parking assist. Both systems depend on the driver, or as in the shot peening example, the operator, to get the unit near the intended location. Then with several drives, sensors, feedback and software all working in concert, they complete a human task with 100% accuracy without human intervention. Is this AI you ask? I think it's pretty darn close.

Conclusion

It's my opinion that our Shot Peening industry lives in a zone between two powerful forces—on one side we have a fairly traditional, show-me type industry that hangs on to Almen strips with all the misgivings and opportunity for errors. And on the other side, we have a sensor and control industry that shows so much promise with critical gauges, controllers, sensors, and even 3D scanners that create point cloud images of complex parts. This technology could possibly perform all the part programming for shot peening in the future.

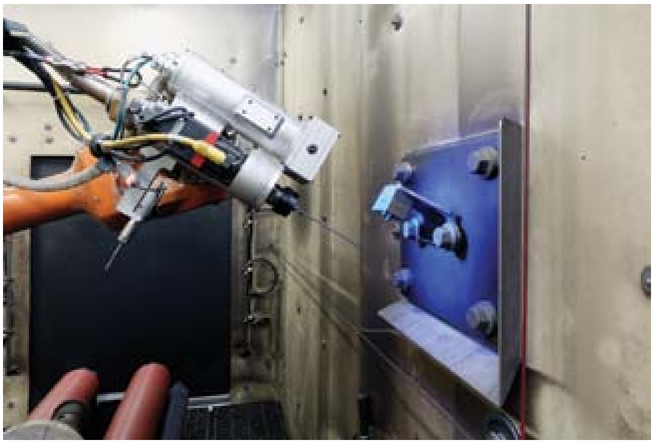
I don't believe it's too great of a stretch to think that powerful software packages could take a 3D model file and apply the correct peening intensity and coverage requirements to achieve the best shot peening benefits for that part. Who knows, maybe there's a University Ph.D. Student working on this solution right now.

As I look back on a 40-year career in shot peening, I remember working with crude analog gauges, cumbersome fixtures that were actual parts with many Almen strip holder blocks and making saturation curves on graph paper using a french curve template. I can see how far we've come. The practice of shot peening has never been so accurate, repeatable and well defined as it is in the current state using modern tools and intelligent equipment.

I'm encouraged as a participant in the latest series of sensor-based and flexible shot peening systems, that they will someday be the industry norm.

Does AI have a place in shot peening? I believe it's just around the corner and frankly, I can't wait!

Author's note: The end user and part owner wished to remain anonymous; therefore, we have not shown the actual LPT shaft and shot peening machine.



Camera locating the simulative hole in an Almen strip holder.

Rotary lance entering the hole of a shaded Almen strip.