Machine Vision Improves Surgical Tubing Quality

Jerry Fireman

Surgical tubing is extruded at rates on the order of 600 feet per minute. It's critical to detect inclusions and other flaws that can cause blockages in the tubing. A laser inspection system was used in the past but the tubing manufacturer was concerned that it was missing many inclusions. The manufacturer evaluated the Integro Anaconda tube inspection system which is based on Cognex [1] machine vision technology and provides very sensitive flaw detection at production speeds. When the machine vision system was first installed on a trial basis, it generated alarms every few minutes.

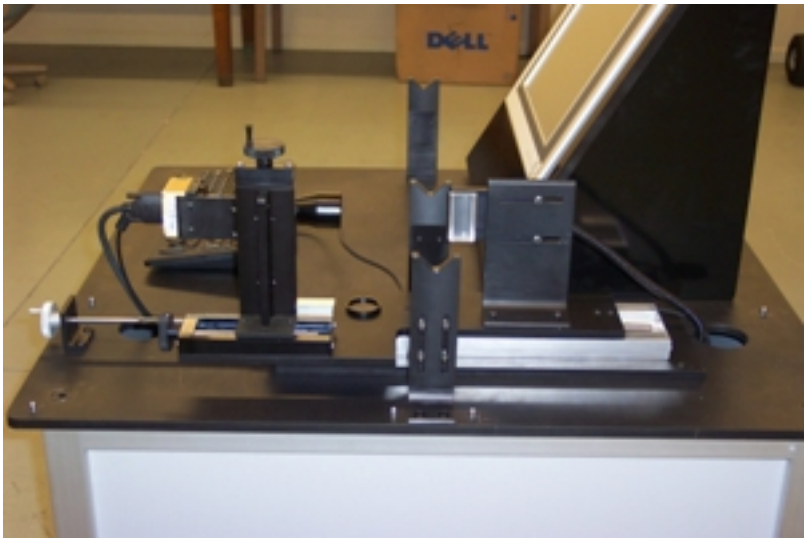
The Integro Anaconda tube inspection system installed.

At first the manufacturer thought there was a problem with the inspection system, but manual inspection of the tubing showed that each alarm represented an inclusion that had been overlooked by the laser inspection system. "The vision system showed that the old inspection system had been missing many inclusions," said Shawn Campion, Vice President, Integro Technologies. "The tubing manufacturer decided to convert their manufacturing process to vision inspection. The system allowed them to implement an active cutting process that removes the bad material and starts a new run from that point. Quality has been dramatically improved. To the best of our knowledge, the machine vision system has not missed a single flaw."

Surgical tubing inspection challenges

The production of surgical tubing begins when plastic pellets or chips are heated and then pushed under pressure by a screw through a die that forces the molten plastic into the shape of the finished tube. The extruded tube is cooled in a vat of water and wound onto drums. Surgical tubing requires the most stringent quality control during the production process but the high rate at which surgical tubes are extruded places enormous demands on any in-line inspection system.

In the past, the tubing manufacturing used a laser scanning inspection process in which the object to be measured is scanned with two parallel laser beams that cross the measuring field at a right angle to each others. The shadow cast by the laser beams produces a light/dark signal that is acquired by a measuring head and analyzed to determine the shadow cast by the extruded material in order to measure inside and outside diameter. While this method is capable of accurate measure of product dimensions it has only limited ability to detect flaws such as inclusions.



The top plate of the Anaconda system.

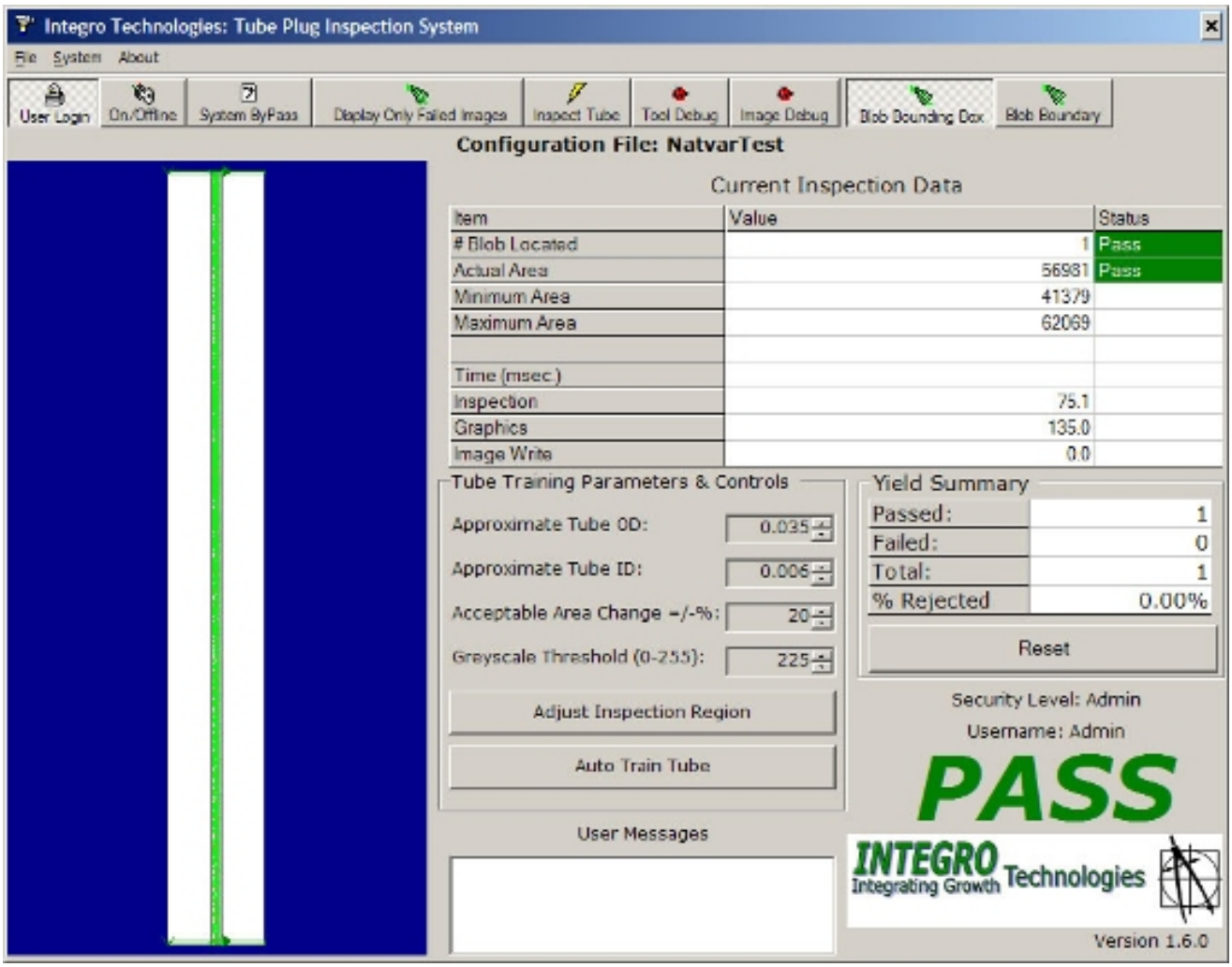
Laser-based inspection is currently the standard method used in the surgical tubing industry but the tubing manufacturer was concerned about its ability to detect product flaws. For this reason, the tubing manufacturer invited Integro Technologies to demonstrate its tubing inspection system which uses machine vision to provide product measurement as well as flaw detection. While machine vision systems are inherently more sensitive than the much simpler laser method, the challenge in applying machine vision to this application has long been the need to keep up with the exceptionally high production speeds used to produce surgical tubing.

Achieving high speed vision inspection

Integro engineers addressed the challenge of keeping up with the high speeds at which surgical tubing is produced through a unique combination of hardware and software. Integro engineers paired a high speed camera with the Cognex MVS-8602e digital frame grabber which supports the Camera Link communications protocol that allows machine vision frame grabbers and cameras to exchange data

at very high speeds. The MVS-8602e supports two independent image acquisition channels that allow the connection of two area scan, line scan or a combination of both types of Camera Link cameras in Base configuration. Alternatively, one area scan or line scan camera can be used in Medium configuration. The frame grabber uses the PCI Express (PCIe) x4 bus which utilizes four 250 MB/s PCIe bus links to quickly transfer image data from the frame grabber to the host memory. The frame grabber also features Direct Memory Access (DMA) channels, pipelined process and on-board image buffers to allow images to be transferred while the system is acquiring new images.

Integro engineers generated further speed improvements by partitioning the vision processing code into different sections of code called threads that run in parallel on the separate cores of a four-core workstation. The engineers developed the multi-threaded vision processing routines using Cognex VisionPro software which automatically creates separate threads for image acquisition and vision processing. VisionPro is a suite of machine vision software tools that supports the Microsoft Visual Studio® .NET programming environment.



The Anaconda HMI; a screen capture from an Anaconda inspection.

In addition to application-level optimization, the machine vision tools are also

optimized by parallelizing their algorithms so they use multiple cores simultaneously. Parallelization is most helpful for image processing filters and other vision tools that run local operations on small regions of the image such as median Gaussian and morphology operations. The image is divided into different pieces and each one is assigned to a different thread. The results from each thread are then combined to produce the final results. The final speedup depends on the algorithm and the number of cores. Overhead creates small inefficiencies so even well optimized vision tools do not run four times faster on a four core workstation.

The vision platform also adapts to the number of cores in the system which is important since the number of cores available may change over time. This allows applications such as Integro's, which was written for a four-core workstation, to run efficiently on an eight-core workstation without touching the source code or recompiling. Downstream maintenance savings are provided while offering the capability to upgrade performance simply by deploying the system on a workstation with more cores.

An image from an Anaconda inspection showing tube occulsions and gels.

Integro engineers used the Cognex VisionPro tool library to provide 100% inspection of the product's inside and outside dimensions and flaw detection at production speeds up to 1000 feet per minute. The system provides process data comparable to laser systems and also provides storage of failed images for utilization in troubleshooting and process refinements. The system is configured to track defects and provide time-based delays to fire outputs for active cutting. Integro engineers took advantage of the flexibility of the machine vision platform to write an application that automatically determines the key characteristics of a tube that is placed in front of the camera and sets itself up with inspection thresholds. Users with sufficient privileges can modify parameters for the given product to optimize system performance and sensitivity.

Substantial quality improvements

In the past, the surgical tubing manufacturer produced a drum with 1000 feet of material that was cut to the size of the customer's order after the fact. The problem is that there was no way to guarantee the quality of each order. Now, when the much more sensitive vision system detects a flaw, the vision system fires an output and a section three feet long centered on the flaw is cut out and discarded. If the flaw is in the middle of a customer order of 25 feet, for example, then a new 25 foot

section is run after the section is cut out. This approach makes it possible to provide each customer with a certificate that their order has been inspected with a vision system and found to be free of defects. The tubing manufacturer's customers have been so happy with the improvements in quality that the manufacturer has been able to deliver using this approach that several of them have rewritten their purchasing specification to require that vision inspection be used on all of their surgical tubing orders.

"The system has dramatically improved the quality of the surgical tubing manufacturer's product," Campion concluded. "To the best of my knowledge, the vision system has never missed a defect. The higher sensitivity of the machine vision system has also provided feedback that has helped the tubing manufacturer substantially reduce the number of defects. The cost of the vision system is higher than laser inspection but feedback from the tubing manufacturer indicates that the system quickly paid for itself through quality improvements."

Jerry Fireman is the President of Structured Information *[2] and has spent 30 years writing about nearly every type of technology. To date, he has written more than 9,000 articles that have been published in over 3,000 trade journals, technical journals and mass media around the world.*

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