Fully-Connected
Remote Visual Inspection (RVI)

GE Inspection Technologies

Abstract.

Remote Visual Inspection or RVI has evolved very rapidly over the past several years with a particular focus on digital connectivity and workflow productivity. This paper will address the current state-of-the-art of video borescope technology and how digital data is viewed, captured, stored and analyzed. Additionally, we will cover future trends for improving the RVI process though menu-directed inspection (MDI) protocols.

Introduction

Video borescopes are used in various industry segments to visually inspect the condition of equipment internals, perform measurement if necessary, and possibly save digital images for subsequent viewing or re-measuring. With current and previous generations of RVI equipment, inspection practices have been primarily a data capturing process. In recent years, advances in technology have enabled borescope inspectors to save digital, full-motion video in the video borescopes, typically using a CD, DVD, CompactFlash™ or other solid-state memory card. These flash media cards plug into the instrument to record the desired image or video and can be removed to transfer the files to a PC. This hand carrying of data from the video borescope to a networked PC came to be fondly known as the portable 'sneakernet' solution. The 'sneakernet' system works, but in the information era, data flow is slow or isolated, and data sharing although better than years past, is cumbersome compared to networked solutions. Also, current inspection processes and results are heavily dependent upon the experience and expertise of the inspector and don't take advantage of today's more advanced software solutions.

Data Management

As RVI moves forward with the digital revolution, video borescopy is evolving from the days of simple data capture into the data management era. We continue to view and save images of interest for documentation but the process no longer has to end at the inspection step, disconnected from the information workflow. By leveraging burgeoning software features, RVI can now be a fully integrated data capture and data management tool. Rather than walking a floppy disk or memory card from a video borescope unit to a PC to share information, (Figure 1) the inspector can use integral and intuitive image management software to create folders, organize and delete files, and even create reports which automatically integrate saved images into the document. These reports or isolated images can be exported directly from the video borescope via email, or may be uploaded to a company network or Worldwide Web for remote viewing, where they may be in turn downloaded and viewed, printed, burned to CD/DVD, and/or saved to a digital archive. In short, today's computing power and network connectivity are harnessed within video borescopes and greatly increase inspection productivity by keeping the workflow driven entirely at the borescope workstation (Figure 2). From initial inspection through creation and submission of the final report, this technology has significant advantage over the two-step "sneakernet" model.

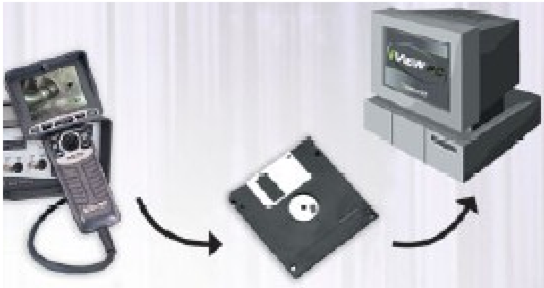

Figure 1. "Sneakernet" data management

Figure 2. XLG3 VideoProbe™ as self-sufficient workstation

Elements of data managment

The first step in any effective data management workflow begins with quality input data. In the case of RVI, this means excellent imaging quality so that the still images and video recordings show true and clearly visible conditions. Secondly, it is important to have adequate computer processing power in order to perform real-time video compression or other demanding video processing. Generally a PC-based operating system is the most efficient means to accomplish these tasks. Application-specific software helps organize the data and makes it more meaningful. Finally, robust network connectivity gets the data moving to where it needs to go.

In addition to the photographic characteristics of the camera imager, proper illumination is also critical to a high quality, usable image. More light means sharper images, less digital noise, and greater scene depth-of-field.

Image processing is equally important. Today's video borescope equipment utilizes analog imagers. In order to move the data into the digital realm, analog video signals must be converted to a digital video stream. With each conversion there is a slight degradation in the image quality so minimizing these analog-to-digital conversions is important. . Typically a video processing system employs one or more digital image processors to perform compression or image enhancement in real-time. Due to the higher processing power in today's most recent borescope system these conversions are limited to one.

Finally, the system's video output display is a critical element so that the operator can properly evaluate the data. A compromise in any one of these elements causes loss of resolution of the image (Figure 3), which could mean failure to detect a small but critical defect.

Figure 3. Disparity in image quality as a result of compromised element(s) of data management

Connectivity

In RVI, connectivity allows the transmission of inspection data to the next step of the workflow. Since technology currently offers an increasingly large number of data transmission methods, it is important that the video borescope provide flexibility in connection devices. Multiple elements of input and output connectivity are important to RVI. Video and audio input are necessary to fully document an inspection by combining input for text overlay and voice annotation with the imaging data. Multiple video stream outputs allow for simultaneous viewing by multiple parties. USB-2 outputs provide fast data transfer to portable memory devices, and Ethernet connections enable hardware and software to connect both to open Internet lines and support private network protocols.

Processing Power

High-resolution image management requires significant processing power. High-end video borescope systems can generate enhanced imaging features such as contrast images, these inverse video format (negative image) is another tool for identifying edges and defects in difficult scenes.

Another daunting video process is exporting video from a video borescope, as in live video streaming or capturing video to memory. Since one second of live video typically contains as many as thirty frames of image data, file sizes are too enormous to manage in the raw state. In order to transmit this data, it must first be compressed to a manageable bandwidth. It is important however to set the data rate high to minimize compression loss, as compression algorithms are designed to delete redundant or otherwise non-value-added data in order to render a smaller file size.

The MPEG-2 compression format offers a good balance between data rate (transfers the data quickly) and data loss (keeps loss minimal, preserving much of the original image resolution). MPEG-2, however, features an adjustable output bit rate that requires extremely powerful processing speed and power. The GE Inspection Technologies XLG3 VideoProbe™ is well-suited for such an intensive processing task, as its CPU features an Intel Pentium® M processor and multiple video processors. Finally at a bit rate of 1 MB per second, today's most advanced video borescope can record over an hour of real-time digital video simultaneously onto a 4 GB flash device and DVD while delivering outstanding image quality.

Since the cameras used within video borescopes are typically VGA-standard devices, the best resolution possible is full VGA (640 x 480 total pixels). It makes no sense to scale video or display on monitors with higher pixel counts as you are then 'making up information'. The goal is to deliver the most realistic and accurate scene possible.

PC Operating System

With a PC operating system integrated into a video borescope, the user can run application software, browse the web and communicate through email and other electronic methods. Application software helps to organize the inspection and data collection process. Running a standard Web browser and supporting network software for Internet connection allow an inspector to search for necessary information or pull down manuals from remote locations. (Figure 4). Once connected to the Internet, the user has access to third-party e-mail services. Even internal company e-mail is possible for enhanced communication from the job-site.

Figure 4. Integral Internet browser, email application, etc

Application-specific software

The “connected” video borescope is a fantastic data-generating and distribution instrument, capable of pumping megabytes of high quality video per second out into ether-space. But information quickly turns into overload unless it is managed. Inspection data needs to be organized data so that the reviewer knows exactly what is being examined and proper archiving can be performed for future reference.

To this end, software that has been customized specifically for the application has been developed to manage this information. Functions of an application-specific software can include, for example: organization of the images with meaningful names; standardization of inspection process so that comparable information is generated and less dependence is placed on the expertise of the inspector; streamlining the inspection to check *only* what is necessary; error-proofing the inspection to check *always* what is necessary; creation of a filing structure for future information recall;
provides a means to categorize data for analysis.

Menu-directed inspection (MDI)

One such application-specific software program is called Menu-directed Inspection (MDI). MDI is application software that runs on the Everest XLG3 VideoProbe™ system and guides the inspector during specific inspections. To use the example of a gas turbine inspection, the user first selects the turbine from a drop-down menu listing such as; *Gas Turbine, Steam Turbine, Control Valve, Coolant Pump.* The inspector then inputs data for that day’s work—information that must appear on the final report such as study details, customer name and site, serial number, inspector name, inspection time and date. The next step is to begin the inspection by selecting the borescope entry port suggested by the graphical user interface (Figure 5).

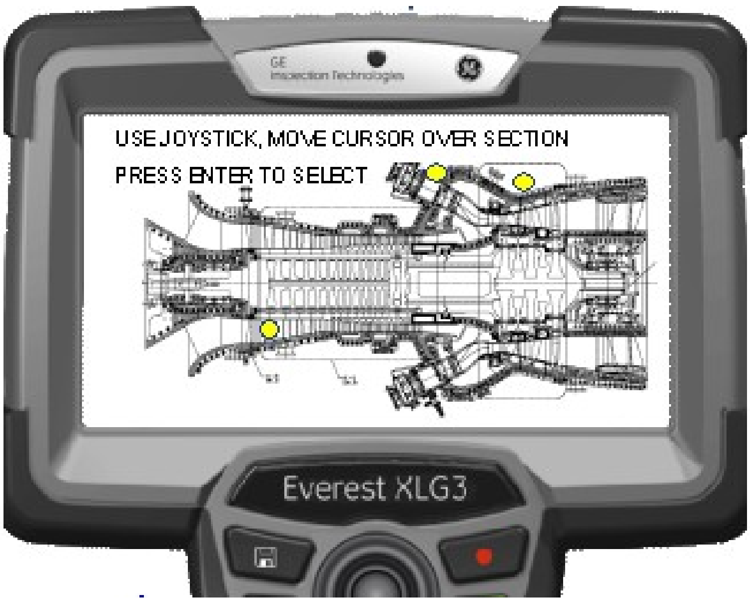

Figure 5

MDI software is pre-programmed to know which areas of the turbine may be accessed from that port. After selecting down to the final level, the inspector selects the specific item within that targeted area to inspect such as, (*stage 1 blade, leading edge*). The purpose of the selection processes is so that the software can identify and tag images for later reporting.

MDI software may be written to allow only images with items of interest (for a more efficient inspection), or to require images of all necessary parts (to ensure a comprehensive inspection). The inspector may be driven step-by-step through each component until the inspection is complete.

Once the user has selected the specific item (stage 1 blade—leading edge, *tip*), the software provides tags for elements that are necessary to inspect. If the inspector notices something else noteworthy, he or she can also save those images. Once the item is identified, the inspector then captures an image. That image file is then tagged with all relevant data and filed within the borescope system. Steps are repeated as required until the inspection is complete.

In addition to simple location tags, images may also be tagged with pre-defined defect tags. This is an important paradigm change for RVI. Visual inspection data today is simply an image—a saved photograph. The analysis of that image is not imbedded in the image, but happens externally, when a person looks at the image and makes an interpretation. The interpretation or analysis is then written down next to the image in a report, or otherwise communicated to make a determination of equipment readiness for service. Then the report is filed away.

Trend analysis is a manual and difficult process of reading sequential reports. When defects are categorized, and quantified, and then tagged or associated with the image, and stored in an electronic database, the manual process can be automated—and this is the real power and benefit of MDI. Visual inspection data can become part of the information flow. Once all images are captured and tagged, the inspector is finished. Paper reports are automatically generated and data can be fed into a data warehouse or saved as individual files. Rhythm™ software is one data warehouse approach.

Share data using Rhythm™ archive

In 2005, GE Inspection Technologies launched Rhythm™, a new software platform offering users the capability to share rich data sets of inspection images and data. Since the database is based on an industry standard, networks comprised of various devices are allowed to cooperatively share inspection image data over a TCP/IP network. The data can be shared either via a common, central database for large-volume, long-term storage; image archive solutions like optical media jukeboxes; or direct review station-to-review station workflow. Workflow could even be set up, for example, to automatically route an image and information for a part with an unusual defect from a local review station to a Level III at a remote site for full review and analysis. Moreover, the first inspector could manipulate and annotate the shared image to highlight the area in question before transmission.

Conclusion

Current technology has ushered the Remote Visual Inspection industry into the digital data management era. Fully digital data streams and improved optical and illumination technology mean better overall imaging quality, which translates to higher probability of flaw detection. Supporting this, enhanced data acquisition methods yield higher quality inspections; the video-borescope-as-workstation model of networked inspection vastly improves data sharing; better and easier data analysis improves decision-making; and improved archiving methods increase efficiency and planning, all of which culminates in real value for the end user.