PMI Technology and its assistance to manufacturing

The non-destructive form of positive material identification can be a shortcut to uncovering the root cause of defective welds, part failure, mixed materials sorting, compliance verification and more. It can be an effective way to verify on-specification conditions in your equipment and systems.

By Michael Porfilio, Quality, Business and Nuclear Systems Lead Auditor, Trident Quality Systems, LLC

Introduction

A maintenance manager at a Midwestern water treatment plant was confronted with a wet floor in the facilities pump room, leaving his crew perplexed. The team could see that a cracked pump housing was the culprit and knew they could repair it with a repair weld. What they didn't know was the type of material that had been used in the manufacturing of the pumps housing – key information that would let them select the proper weld filler material. After a brief discussion, the next step was obvious: perform PMI to determine and verify the material grade used in the pump.

Defining PMI

Materials testing laboratories and industry use a process called "positive material identification" (PMI) to determine the makeup of metallic alloys. As in crime scene investigations, where a number of tools are used to help unravel mysteries, PMI is one means of tracing a material back to its original Material Test Report (MTR), which is a certified chemical analysis that identifies metallic elemental composition. Originally, PMI was a destructive technique performed using wet chemical analysis methods for comparison to material-grade compositional requirements. The process was highly accurate – but labor-intensive, time consuming and costly.

As technology has progressed, advances in technology and electronics have led to portable, hand held X-ray analyzers that are capable of providing valuable chemical information that was previously only with available using fixed laboratory equipment. Portable X-ray fluorescence (XRF), for example, provides a fast, easy, non-destructive analysis with minimal capital investment. Originally designed as a means of identifying high-alloyed corrosion-resistant materials used in the petroleum industry, this technology has demonstrated the ability to provide analysis for most metallic engineering materials used across industry today.

Technique

XRF analyzers work by exposing a material sample to a beam of X-rays generated from an internal source. The X-rays interact with the sample surface, locally exciting atoms that emit energy after excitation. This emitted energy is characteristic of the elements present in the sample and is identifiable as a characteristic energy level. The intensity of these unique energy levels represents the relative concentrations of each element of interest that is collected on a solid-state detector. This approach can gather qualitative and often quantitative information. Modern software packages have the ability to identify hundreds of commercially recognizable alloy grades.

PMI using XRF analysis has become an important tool for quality assurance applications in nearly all areas of industry, but especially in petroleum processing, nuclear building materials, foundry and scrap. Quality systems are increasingly demanding complete traceability for all materials used in production. This can mean that at any point in the design, manufacture or assembly of components into a final product, material traceability may be required on demand. When traceability for production machinery is required and not available, material validation using portable XRF may indicate to provide a PMI link to the original MTR.

Photograph 1. PMI inspection of a cast stainless steel part verifying chemical analysis prior to shipping of product.

Most modern instruments are designed to permit spot analysis for applications. This is ideal for limited-access and for inventory control and material-sorting processes that are based on the differences in chemistry. Material validation of incoming stock and final assemblies demonstrate that proper materials are being used. And while the XRF_PMI technique is best suited for high-alloy carbon steels, stainless steel, nickel and cobalt materials, it can analyze other materials also. Rapid quantification with reliable results are possible with minimum sample preparation such as a light surface abrasion.

XRF techniques can also be used to recreate lost information, such as stock-traceability paperwork. The

instruments used in this type of PMI can provide comparisons to hundreds of alloy grades and material families. Industry-accepted procedures and work instructions for PMI using portable XRF devices define acceptance and rejection criteria and aspects to the testing requirements. These considerations include minimum required radiation safety training and safe practices to be used when operating this equipment.

XRF limitations and successes

PMI using portable XRF has broad applications – but has some limitations. These include the inability to provide analysis of light elements such as Carbon. This is an issue in analysis of carbon steel, where carbon may be the only element separating grades of material, allowing for identification of the alloy family of results. Other light elements including Mg, Al, Si, P and S, suffer from poor limits of quantification, which may impose further restrictions on the effective application of the technique for some materials.

Still, XRF-PMI remains a highly effective to verify most materials, as many successes prove. Here are a few of the many mysteries that have been solved by XRF-PMI.

Next Generation Analyzer – LIBS

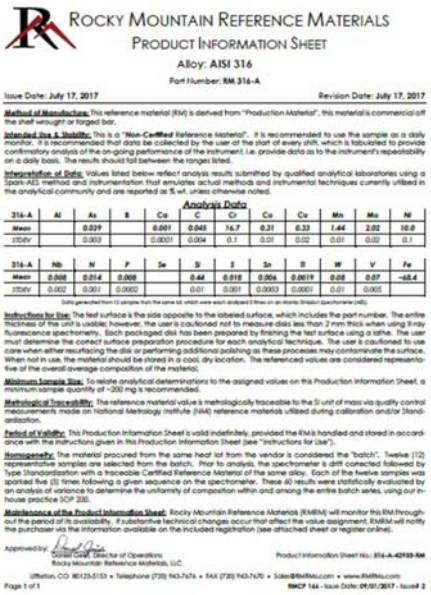
XRF-PMI has been the standard of the industry since the early 1970's. Newer technologies are in production and available currently. The most widely accepted new technology to perform PMI is LIBS; Laser-Induced Breakdown Spectroscopy. This technique uses a form of atomic emission spectroscopy employing a highly energized laser pulse as the excitation source. The laser is focused and creates a plasma, which atomizes and excites samples.

LIBS technology is typically performed on metallic solid samples. This is accomplished that a laser in close contact with the subject piece is energized and ablates the surface in a rastering, bar code like pattern collecting light intensities which are turned into elemental percentages.

The advantages of LIBS technique compared to portable XRF is that there is a broad spectrum of elements that includes C, S, H, O, Li, Bi, Na and Mg to name a few that are able to be analyzed. The ability to measure the lighter elements accurately is the primary advantage over portable XRF as well as a very quick analysis time.

Certified Reference Materials for PMI

To capture the power of the flexibility of PMI the use of certified reference materials (CRMs) is vital to XRF or LIBS accuracy and validation. In the past decade entire sets of alloy families have had CRMs developed. These analytical sets are most important to allow to have the entire applicable analytical spectrum to be represented. 300 series stainless steel, alloyed steels like 4140 or 8630, to bronze alloys all have a full compliment of CRM sets available. Newer material families' such as duplex stainless steel and many casting grades are in development to supplement the existing sets. This is a sector of quantitative and qualitative analysis that will assist and be very useful for the future and growing technology.



ROCKY MOUNTAIN REFERENCE MATERIALS
PRODUCT INFORMATION SHEET
Alloy: AISI 316
Part Number: RM 316-A
Issue Date: July 17, 2017 Revision Date: July 17, 2017
Analysis Data

316-A	Al	As	B	Co	C	Cr	Cu	Cv	Mn	Mo	Ni
Mean		0.029		0.001	0.045	16.7	0.31	0.33	1.44	2.02	10.0
STDEV		0.003		0.0001	0.004	0.1	0.01	0.02	0.01	0.02	0.1

316-A	Nb	N	P	Se	Si	S	Sn	Ti	W	V	Fe
Mean	0.008	0.014	0.008		0.44	0.018	0.006	0.0019	0.08	0.07	~68.4
STDEV	0.002	0.001	0.0002		0.01	0.001	0.0003	0.0001	0.01	0.005	

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Photograph 2. Above is a grade 316 CRM certification. This CRM was produced to specific elemental ranges and validated by numerous accredited independent laboratories.

Photograph 3. A set of high alloy CRMs of stainless steel and nickel based alloys made specifically for XRF-PMI applications.

Case Studies

Case Study 1 - Leaky water valve

Let's return to the water treatment plants pump problem. In this case, the crew removed the pump and took it to the materials testing laboratory to verify the weld material around the footing and the inner surface of the cover for filler-material compatibility to the base material. PMI testing techniques showed the housing to be Nickel-based Inconel 825. The analysis also showed the wrong weld filler had been used originally, which caused corrosion and the subsequent leak after just a few years in service. Because the characteristics of Inconel 825 prevented making a repair weld without heat treatment – which the crew couldn't perform – the plant had to purchase a replacement pump.

Case Study 2 - Critical pressure vessel situation

In preparation to go online, a new coal plant needed to ensure that its critical components had been built/fabricated to specific requirements – which included verification of the base materials and weld fillers. Of particular interest was a fabricated meter housing body with more than 30 fabrication sections and welds. Because this critical component would be in daily operations and in severe conditions, management ordered a quick, on-site PMI analysis. Each panel and every six inches of weld material was verified to ensure compliance. After the analysis confirmed that the unit passed all requirements, the plant was able to put it into service immediately.

Case Study 3 - A suspected mixed-material of flat stock

When aftermarket performance-motorcycle fabrication shop was having trouble making bends in formed metal components, a lab was called in to check for mixed materials in the stick room. The lab assisted in restoring traceability of two mixed lots of steel. The material intended for the work was alloy steel 4130 (UNS G41300), which

contains numerous elements, including 0.80% to 1.10% chromium. Because XRF analysis can detect chromium, as well as nickel and molybdenum, in significant quantities, the process enabled the lab to sort the shops materials using this element alone. It determined that some stock contained very low levels of chromium than required (0.03% to 0.05%), and was set aside for other uses.

Case Study 4 – Incoming melt stock mix

A local foundry had received charge material of Ferro-Molybdenum. Standard Ferro-Molybdenum is 36% Molybdenum with the balance being Iron. A 50,000 pound heat was what was to be poured. When the material was received by the foundry it was transferred into barrels but this was where traceability was lost. The barrels were mixed in the foundries metal stores with other prime materials. XRF sorting of all of the barrels in the metal stores was able to create order by accurately sorting the charge materials prior to them being mixed and off analysis conditions existing.

Compliance stance

PMI continues to be a common practice to approve project and high specification work. It is quite common for purchasing contracts to stipulate that PMI is required prior to shipment of products. It is also a common requirement to verify on site that the chemical make-up of the delivered product meets the required specifications. Third party source inspectors many times are witness to the PMI operations. Companies such as Exxon, Mobil, Shell, Bechtel, NAVSEA US Naval work commonly are heavy users to this type of activity. Developed procedures and work instructions follow all of these projects and are very complicated and thorough. It is my opinion that this type of compliance to specification with dedication to PMI will only continue to be referenced on orders and contracts.

Conclusion – Applying PMI to work in your operations

Whether monitoring incoming and outgoing materials, reverse engineering, contact satisfaction or product repair, portable XRF or LIBS provides the ability to quickly verify material-grade composition using non-destructive testing. As an indisputable value-add in an era of high-quality expectations, counterfeit parts and product traceability, this type of PMI could easily become one of your favorite investigative tools. When you look for setting your budgets for next year think to what you could use PMI in your facility. It could make your production more reliable, safer and addressing risks.

About Michael Porfilio

Michael has been in and servicing the foundry industry since 1985. His background is in the fields of Metallurgy, Quality Management, Sales and Marketing as well as Operations Management. He currently is a Certified Nuclear Quality Systems Auditor and NDT Level III. He is employed at Stainless Foundry & Engineering, Inc. as the Director of Quality.