When results matter

A WHITE PAPER FROM
SPECTRO ANALYTICAL INSTRUMENTS

High-Precision Analysis of Small Parts for Aerospace and Automotive Applications

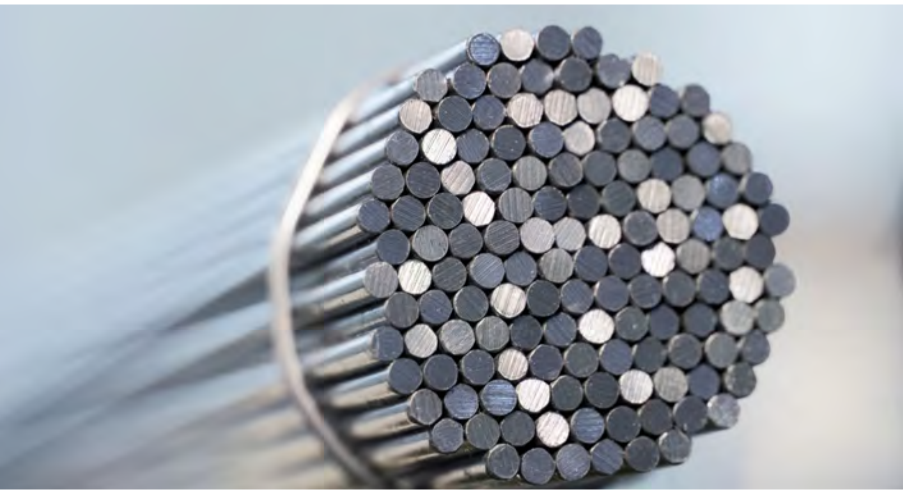
Introduction

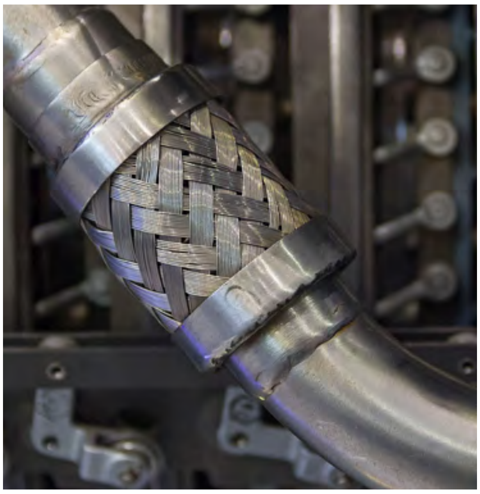
For quality control (QC) and production managers of metalworking manufacturers, small parts can present a real challenge. Customers – particularly in aerospace, automotive, and other critical industries and applications – demand tight QC at every step of the supply chain. So every part must meet every specification, all along the line.

However, metal wires, rods, or screws and other fasteners less than approximately 6 centimeters (2.3 inches) in their greatest dimension, as well as thin metal plates or sheets, are notoriously hard to analyze. So suppliers performing inspection of incoming or outgoing materials may find it difficult or impossible to determine – and document – exactly what elements went into their composition.

That can lead to real problems when it comes to these safety-related components. Negative outcomes may include regulatory penalties, reworking of parts, finished product recalls, or even more catastrophic consequences. To protect their organizations against the risks of losing time, money, reputation, projects, or customers, metalworking managers must be sure.

This paper surveys the benefits and drawbacks of existing approaches. It also describes two instruments available from SPECTRO Analytical Instruments that provide reliable, state-of-the-art solutions for precise analysis of many types of small parts.





ANALYTICAL CHALLENGES

Different analytical technologies suffer varying difficulties in attempting to test small-part samples. For example, arc/spark OES analyzers maintain a sealed argon atmosphere in the measurement chamber to prevent contamination. But if a given sample is too small to be properly positioned so it completely covers the spark stand opening, oxygen (O) from ambient air enters the chamber and bonds with any sample element possessing a high oxygen affinity, ruining the measurement. Or a sample such as an unusually thin metal plate will burn through due to the heat of plasma excitation. XRF analyzers face a different problem: a too-small sample can't be bombarded by a sufficient quantity of X-rays to provide a successful measurement. (See "Superior analyzer solutions" below for further details on these technologies and how they can offer successful small-parts performance.)

In addition, older analyzers may have been adequate for measuring the chemical elements typically encountered in the past. However, recent metals industries developments have presented a number of fresh challenges for analyzing parts of any size:

Zinc

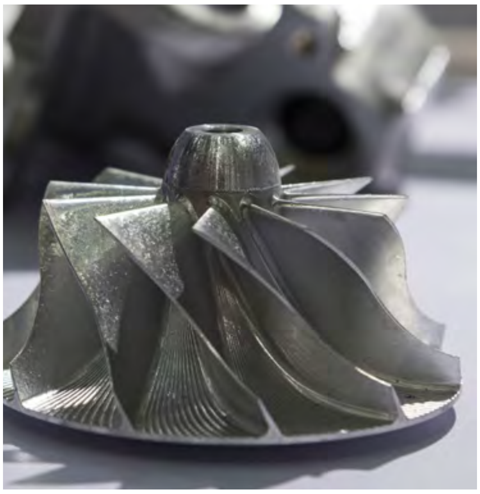
With the growth of recycling, metal materials in the supply chain may now contain higher and higher proportions of reused materials. So products containing nickel, which is fairly easy to analyze, can possess significant concentrations of zinc (Zn) – which challenges analyzers currently used in many metalworking plants.

Tungsten

Producers in the former Soviet bloc had difficulties obtaining enough chromium and cobalt to formulate certain grades of steel. They often substituted more readily available tungsten (W), for its somewhat similar properties. So this element is now found in many metals recycling and supply chains, particularly in Europe. However, accurate determination of tungsten content may be beyond the capabilities of many installed analyzers.

Counterfeiting

In the metals industries, falsification of parts and materials – and/or of their documentation – has led to an increasing number of scandals both major and minor in recent years. This increases the pressure on metal-



working company managers to analyze early and often.

Rare earths

Rare earths pose another increasingly important challenge. Elements like cerium (Ce), neodymium (Nd), and praseodymium (Pr) are often present in magnesium-based ore, and thus in less common magnesium-alloys. However, they are now showing up also as elements of interest in more frequently encountered aluminum-based and nickel-based alloys. In some metals, rare earths are desirable components used for increasing structural strength. In others, they are unwanted contaminants. Wherever used, they present difficulties for less advanced stationary analyzers.

Wide elemental ranges

Finally, as shown above, today's ideal analyzer for small parts in aerospace, automotive, or other applications may be called upon to precisely analyze a considerably wider variety of elements than in previous years. These could include the following:

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Table 1: Aerospace Alloys and Elements of Interest

	Fe-Base	Aerospace Common Grades
	Cr-Cr/Ni-steel	Aerospace Alloys
C	0.0015--2.5	17-4
Si	0.005--4.2	15-5
Mn	0.001--15.2	304
P	0.001--0.14	316
S	0.001--0.4	Haynes 90,92
Cr	0.001--32	13-8Mo
Mo	0.001--7	Aeromet 100
Ni	0.0015--43.5	A286
Al	0.001--2.8	310
Co	0.002--21	410
Cu	0.0005--7.2	422
Nb	0.004--3	321
Ti	0.0005--3.2	347
V	0.0005--10	Kovar
W	0.007--6.1	Invar
Pb	0.002--0.11	20Cb3
Sn	0.0005--0.2	
As	0.002--0.12	
Ca	0.0001--0.012	
Sb	0.002--0.23	
Se	0.002--0.3	
Ta	0.02--0.76	
B	0.0002--0.02	
N	0.001--0.5	

	Ni-Base	Aerospace Common Grades
	Ni-Orientation	Aerospace Alloys
C	0.001--1.1	Hastelloy
Si	0.001--5	Inconel 600
Mn	0.0005--4	Inconel 625
P	0.001--2	
S	0.001--0.35	
Cr	0.001--35	Inconel 718
Fe	0.001--54	Alloy 690
Mo	0.0015--34	Alloy X750
V	0.0005--1.1	Waspalloys
Cu	0.0005--41	MarM 247
W	0.005--13	Alloy 713
Co	0.003--21	Alloy 800
Nb	0.003--8	
Al	0.001--7	
Ti	0.001--6.2	
Zr	0.001--0.3	
Sn	0.001--16	
B	0.0001--0.03	
Mg	0.0005--0.75	
Pb	0.001--0.07	
Ta	0.005--11.7	
Hf	0.01--3.0	
Re	0.1-6.4	
N	0.001--0.33	

	Co-Base	Aerospace Common Grades	Al	Ti
	Co-Orientation	Aerospace Alloys		
C	0.001--2.8		7050	6Al 4V
Si	0.001--3.2	Stellite 6B	7075	
Mn	0.0005--1.9	Elgiloy	6061	
P	0.001--0.046	MPN 35		
S	0.0005--0.05		356	
Cr	0.001--34			
Ni	0.0035--28			
Mo	0.0025--10			
Fe	0.003--50.3			
W	0.005--16.2			
V	0.001--9.1			
Al	0.0005--0.96			
Cu	0.0005--0.094			
Nb	0.001--4.2			
Sn	0.001--0.11			
Ta	0.04--10.3			
Ti	0.001--2.4			
B	0.0001--0.077			
Pb	0.0025--0.025			
La	0.0003--0.05			
N	0.01--0.17			

CONVENTIONAL ANALYSIS METHODS

Currently, different suppliers of metal components to the aerospace and automotive industries turn to a number of solutions for small-parts elemental analysis.

Send them out

When a company has no appropriate analysis equipment onsite, samples may be shipped to third-party laboratories for testing. But while most results may be accurate, mix-ups or handling errors can multiply. This method also adds extra costs and QC efforts. And of course, it increases delays by orders of magnitude. Results are delivered in days, instead of seconds or minutes.

Retask other analyzers

Some metalworking facilities may address small-parts testing via onsite combustion analyzers and wet chemical analyzers already used for other tasks. Unfortunately, preparation and processing of small metal samples with these technologies are extremely time-consuming, and fairly expensive.

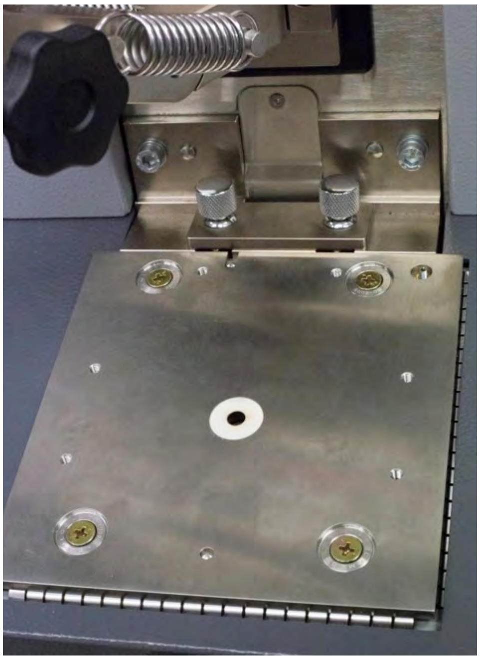

Figure 1: Analysis with ceramic insert

Figure 2: Analysis of foils

Remelt and analyze via OES or XRF

Plants making parts for aerospace or automotive use often have standard OES or XRF metal analyzers on hand to test elemental concentrations in regular sized samples. When these instruments lack dedicated small-part analysis methods, users may remelt or press a small wire, rod, or fastener until it's large enough to fit on a spark stand for analysis. However, remelting can easily cause a portion of the original sample to disappear, as some elements in the sample — such as sulfur (S) or phosphorus (P) — reach their relatively low vaporization temperatures. So the resulting reading fails to reflect the true concentration levels of the original sample.

SUPERIOR ANALYZER SOLUTIONS

The latest models of two types of instruments may fulfill many or all of the analytical needs and avoid the problems described above: stationary OES and handheld XRF.

Stationary OES

An advanced analyzer based on arc/spark optical emission spectrometry (OES) has become the instrument of choice for the most precise small parts inspection in the metalworking world.

For example, the SPECTROMAXx stationary metal analyzer from SPECTRO Analytical Instruments provides both routine and precise analysis of incoming/outgoing materials, including ultra-accurate "mill cert" inspection. With adapters, it can correctly position metal samples as small as 0.8 mm. SPECTROMAXx is a mainstay of foundry analyses and may well be the market leader in its class. With technologies refined over seven instrument generations, it's also widely used by metalworking suppliers for aerospace, automotive, and other critical applications.

It handles 10 matrices, 65 methods, and 54 elements, covering the main components found in today's iron-based and aluminum-based alloys, and more. In addition to the rare earths already mentioned, as well as the zinc and tungsten concentrations now appearing in the supply chain, SPECTROMAXx can measure even trace amounts of other elements frequently encountered in small parts. These include sulfur and phosphorus, as well as carbon (C), nitrogen (N), aluminum (Al), silicon (Si), magnesium, lithium (Li), beryllium (Be), and boron (B), plus the remaining elements listed in Table 1.

Along with high precision and stability, the analyzer's other advantages include minimal measuring times, maximized productivity, ensured ease of use, low operating costs, and low maintenance requirements. Users can save up to 30 minutes per day via its simple standardization using only one sample, based on SPECTRO's iCAL intelligent ca-libration logic software. Finally, its Results Manager analysis archive software provides full archiving, storing, and reporting of results, plus easy connectivity via standard protocols.

Handheld XRF

When a grade analysis is needed or an alloy type must be verified (see table 1 for popular grades to be verified for a quick alloy check), but trace analysis is not required, a handheld energy-dispersive X-ray fluorescence (ED-XRF) analyzer produces satisfactory results.

This kind of "XRF gun" may also be chosen for outgoing and final inspections where finished pieces must present an unmarred appearance. Unlike OES analysis, XRF inspection leaves no visible indication (such as a "burn mark") on metal surfaces.

For example, advanced SPECTRO xSORT handheld ED-XRF spectrometers are designed for many high-throughput elemental testing and analysis tasks — including fast, reliable alloy verification — found in the aerospace and automotive industries. Robust, affordable, highly portable tools, they deliver dependable results in the plant, warehouse, or field for samples as small as 1 mm.

The top xSORT model provides metal grade analysis in only 2 seconds for most iron-based alloys, and identifies alloys based on light elements such as aluminum, magnesium, silicon, phosphorus, and sulfur in 7 seconds. Equipped with SPECTRO iCAL, its standard calibration captures alloys and metals for 16 matrices with 46 elements. An optional integrated video camera offers exact sample positioning and documentation of a measured spot. And the unit provides simultaneous result storage in various formats.

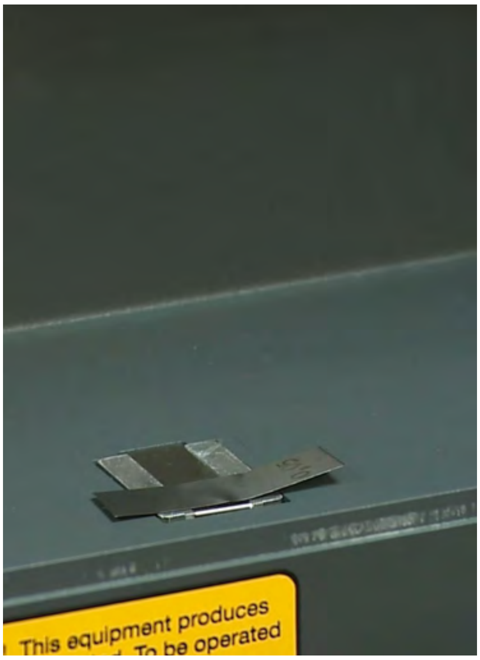

Figure 3: Small part in docking station – xSORT

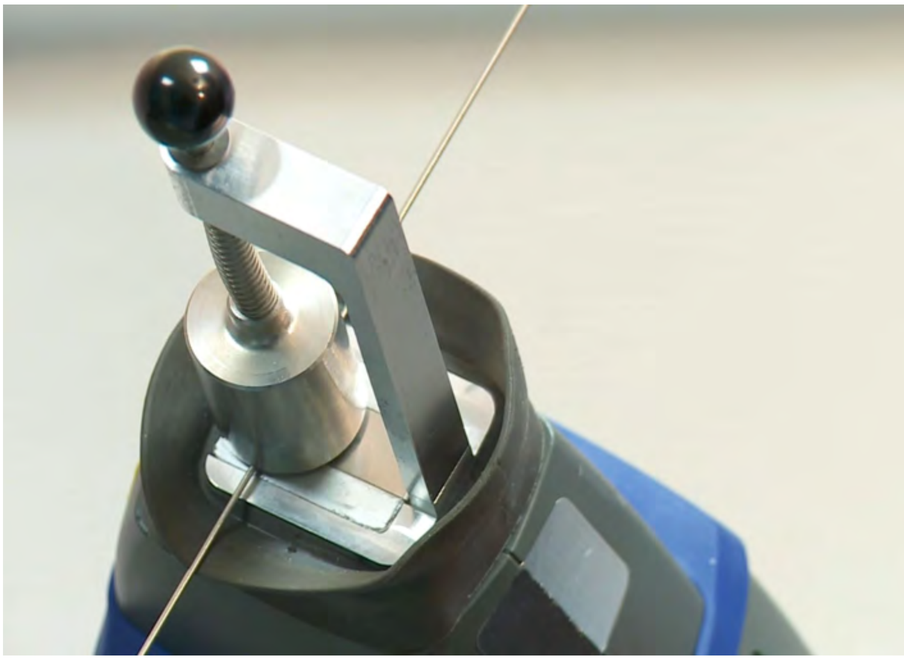

Figure 4: xSORT with small parts adapter and wire

CRITICAL: SAMPLE POSITIONING

Spectrometer suppliers have adopted varying approaches to the challenge of analyzing small metal parts. Some tacitly acknowledge they just can't test such parts in their original condition, instead recommending elaborate sample preparation techniques such as remelting. Others attempt to modify their electrode design so as to focus on a smaller spot. All can face significant difficulties as users struggle to analyze real-world samples in a wide variety of smaller shapes and sizes.

Instead, experience shows that the most fruitful approach is to establish precise control of sample positioning.

Maximum precision and accuracy lie in the ability to carefully control the location of the discharge that travels from electrode to sample. Thus it's critical to place the sample in the right position on the spark stand — directly over the center of the electrode.

SPECTRO has determined that the best way to achieve this is by way of adapters. These engineered pieces accept given ranges of sample sizes and shapes for measurement by the analyzer. The adapter will lock a given sample into place over the spark stand in the optimum position for precise analysis.

For example, as well as various adapters to position wires optimally for top- or side-excitation, kits may include an extra-durable disk of aluminum oxide (Al_20_3) ceramic to reduce the spark stand opening size, and/or a copper block to press and hold a thin-sheet sample securely in place while conducting away heat to further protect it. With almost 40 years of continuous improvement, SPECTRO has developed what's probably the industry's widest array of adapter kits. As a result, an instrument like SPECTROMAXx can deliver precise, accurate analysis of wires, rods, fasteners, thin plates or sheets, and almost any other small pieces — down to sample sizes as low as 0.8 mm.

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CRUCIAL: CALIBRATION AND STANDARDS

A large standards library helps ensure an analyzer's analytical "headroom," or power to achieve excellent analytical performance. The calculation of the analyzer's mathematical calibration curve is based on the measurement of all standards. The measurements of unknown samples are then compared with reference measurements from the standards library for each covered element. The standards define the function of energy intensity emitted by a sample that indicates a given concentration of a certain element.

The more standards an instrument can reference, the higher the likelihood of superior accuracy. SPECTRO Analytical Instruments is believed to lead the metals analyzer industry in this regard. Factory calibrations for analyzers such as SPECTROMAXx are based on 2,648 standards to date. These cover all common and a number of uncommon alloys that might be found during a metalworking facility's small-samples QC analyses.

CONCLUSION

When metalworking managers must conduct QC analyses of small parts for aerospace, automotive, and other critical applications, careful consideration of topics such as elemental range, sample positioning precision, and wide reference standards can suggest the right spectrometric analyzer for the job.

SELECTING A SMALL-PARTS METAL ANALYZER

For the fullest QC features set and mill cert precision, consider an OES metal analyzer. When only alloy verification or outgoing inspection is required, a handheld XRF analyzer can be a good alternative. However, not all OES or XRF models can accommodate the small parts found in today's metalworking supply chain. Look for an analyzer with the following features:

Market leadership.

An analyzer performing well in the widest variety of metalworking plants has the best chance to succeed in yours. With almost 40 years' experience and instruments such as SPECTROMAXx and SPECTRO xSORT, SPECTRO is the acknowledged market leader according to Strategic Directions International (SDi).

Easy calibration.

Some devices demand frequent recalibration. By contrast, the iCAL 2.0 logic system in SPECTROMAXx permits one-time, one-sample standardization in less than 5 minutes. SPECTRO xSORT uses a dual-purpose protective shutter as its iCAL sample for a similar process.

Wide wavelength range.

Since materials, specifications, or applications may change, look for an instrument that covers all the elements you may want to analyze — today or tomorrow.

Adaptability.

Small metal parts come in myriad shapes and sizes. Look for analyzers with the widest range of adapter kits to cover any part you must test.

Large metals database

The largest possible library of prepackaged methods and standards makes for simple setup, easy use, and accurate results. Favor analyzers such as SPECTROMAXx that can handle all the elements found in today's metalworking supply chain — based on a built-in, comprehensive library.

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www.spectro.com

GERMANY
SPECTRO Analytical Instruments GmbH
Boschstrasse 10
D-47533 Kleve
Tel: +49.2821.892.0
Fax: +49.2821.892.2202
spectro.sales@ametek.com

U.S.A.
SPECTRO Analytical Instruments Inc.
91 McKee Drive
Mahwah, NJ 07430
Tel: +1.800.548.5809
+1.201.642.3000
Fax: +1.201.642.3091
spectro-usa.sales@ametek.com

CHINA
AMETEK Commercial
Enterprise (Shanghai) CO., LTD.
Part A1, A4 2nd Floor Building No.1 Plot Section
No.526 Fute 3rd Road East; Pilot Free Trade Zone
200131 Shanghai
Tel.: +86.400.100.3885, +86.400.189.7733
Fax: +86.21.586.609.69
spectro-china.sales@ametek.com

Subsidiaries: ▸**FRANCE:** Tel +33.1.3068.8970, Fax +33.1.3068.8999, spectro-france.sales@ametek.com, ▸**GREAT BRITAIN:** Tel +44.1162.462.950, Fax +44.1162.740.160, spectro-uk.sales@ametek.com, ▸**INDIA:** Tel +91.22.6196 8200, Fax +91.22.2836 3613, sales.spectroindia@ametek.com, ▸**ITALY:** Tel +39.02.94693.1, Fax +39.02.94693.650, spectro-italy.sales@ametek.com, ▸**JAPAN:** Tel +81.3.6809.2405, Fax +81.3.6809.2410, spectro-japan.info@ametek.co.jp, ▸**SOUTH AFRICA:** Tel +27.11.979.4241, Fax +27.11.979.3564, spectro-za.sales@ametek.com, ▸**SWEDEN:** Tel +46.8.5190.6031, Fax+46.8.5190.6034, spectro-nordic.info@ametek.com.
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