

Thermo Scientific ARL iSpark Plus Optical Emission Spectrometer

Options for ultra-fast inclusion analysis



Spark-DAT inclusion analysis

For more than two decades, our company has been a pioneer in the ultra-fast analysis of nonmetallic micro-inclusions by spark OES. The Spark-DAT inclusion analysis available today with the Thermo Scientific™ ARL iSpark™ Plus Optical Emission Spectrometer builds on this long experience, and the many improvements and innovations it has enabled. Thermo Scientific's spark OES inclusion analysis solutions are used worldwide by leading steel companies and more and more companies involved in steel, aluminum, and other non-ferrous metals industries use them every year.

The options available for inclusion analysis that include methods, software tools, and application support are presented in this brochure.

Ultra-fast inclusion analysis

The ARL iSpark Plus with Spark-DAT provides unparalleled speed for inclusion analysis. It provides the combined results of elemental and inclusion analysis in a single measurement in approximately the same time as the time required for elemental analysis alone, thus enabling extremely efficient control of metal quality and production process.

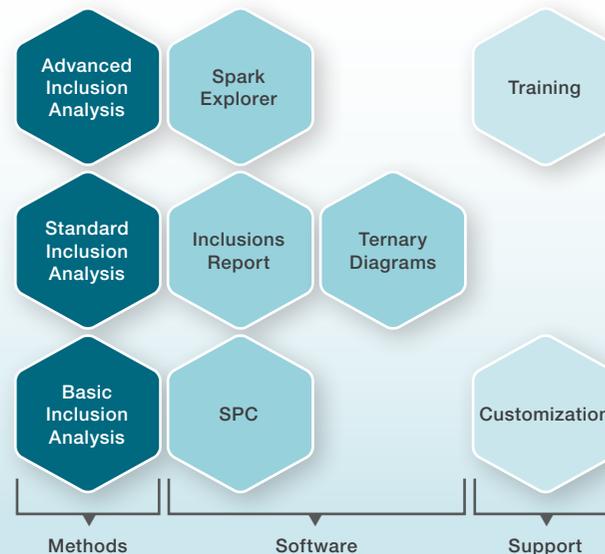
It also means that it is possible to evaluate inclusions in all the samples analyzed in concentration with the OES spectrometer, i.e., in up to several hundred samples per day. Therefore, a wealth of valuable inclusion data can be collected in view of the continuous improvement of product quality and process efficiency.

Key benefits

- Inclusion analysis and elemental analysis combined in a single measurement
- Almost real-time inclusion check in hundreds of samples per day
- Significant cost savings due to a reduced number of costly inclusion problems
- No change in the operation of the ARL iSpark Plus and the sample preparation
- Perfectly adapted for ARL iSpark Plus automated with ARL SMS (Sample Manipulation System)



Options for Spark-DAT inclusion analysis



Inclusion analysis methods

Depending on the metal or alloy of the samples to be analyzed, up to three types of Spark-DAT inclusion analysis methods are optionally available. All these methods, namely Basic Inclusion Analysis, Standard Inclusion Analysis, and Advanced Inclusion Analysis, are combined with elemental analysis. They are delivered ready to use with your ARL iSpark Plus. In many cases, they can also be added to existing elemental analysis methods on the ARL iSpark Plus already in use in your laboratory.

The principal features and specificities of the different inclusion analysis methods are summarized in the table.

Basic Inclusion Analysis

An entry-level method for low-alloy steels, the Basic Inclusion Analysis evaluates the inclusions of some important elements, like Al, Ca, Mg and S (e.g., aluminum oxides, calcium aluminates, and calcium sulfides). Basic Inclusion Analysis also includes a printable one-page report with the inclusion analysis results.

Standard Inclusion Analysis

Available in all metals and alloys analyzable with the ARL iSpark Plus (i.e., Fe, Al, Cu, Ni, Co, Pb, Zn, Sn, Mg, Ti, Ag, Au, Pd and Pt), the Standard Inclusion Analysis method allows evaluating properties of a wide range of inclusions of different compositions.

Advanced Inclusion Analysis

A full-capability method for low-alloy steels, the Advanced Inclusion Analysis allows evaluating the same inclusion properties as the Standard Inclusion Analysis method and, in addition, more advanced ones, like, for example, ESD (equivalent sphere diameter) in μm and inclusion volume fraction.

See the table and Inclusions Report page to learn more on the difference between Basic, Standard, and Advanced Inclusion Analysis.

| | Inclusion analysis method | | |
|---------------------------------|---------------------------|-----------------------|-----------------|
| | Basic | Standard | Advanced |
| Available for | Low alloy steel | All metals and alloys | Low alloy steel |
| Types of inclusions measurable | Main | Many | Many |
| Qualitative/Quantitative data | Qualitative | Qualitative | Both |
| Special feature | Dedicated report | Customizable | Customizable |
| Typical inclusion data obtained | | | |
| Number* | √ | √ | √ |
| SML classification* | √ | √ | √ |
| Size and size distribution* | | | √ |
| Inclusion volume fraction* | | | √ |
| Inclusion concentration* | | | √ |
| Oxygen content | | | In killed steel |
| Available software options | | | |
| Spark Explorer | √ | √ | √ |
| Inclusions Report | | √ | √ |
| Ternary Diagrams | | | √ |
| SPC | √ | √ | √ |

Principal features and specificities of the different inclusion analysis methods.
* by inclusion type

OXSAS analytical software

Where the heart of inclusion analysis beats

OXSAS is the software that controls the ARL iSpark Plus and manages all the aspects of the elemental analysis. OXSAS also includes the full set of Spark-DAT tools needed to run the inclusion analysis method of your choice, from setup to results handling via inclusion data acquisition and processing. It includes, in particular, the fast, statistically-based Spark-DAT algorithms that convert single spark signals into actionable inclusion information.

OXSAS displays the inclusion data with the concentrations of the elements right after the analysis and, like the concentrations, can send them to the statistical process control software or transmit them to a LIMS or another computer.

Quality data in quantity

Spark-DAT methods can generate a huge amount of data on the different types of inclusions (i.e., with different compositions) contained in the sample. This is not a problem for the OXSAS analysis software, which has virtually no limit to the amount of results it can process.

In terms of quality, the inclusion data benefits from the high efficiency of Spark-DAT algorithms, which use specially designed statistical methods and allow an optimal assessment of the composition of the inclusions.

Key features

- Virtually no limitation on the number of inclusion properties
- Efficient discrimination of inclusions of different compositions
- Editor of classes for single spark intensity and size distributions
- Data transmission to statistical process control software, LIMS, or remote computer
- Possibility to recalculate inclusion properties after modification of Spark-DAT algorithms parameters
- Raw data in .txt and .csv formats for use in commercial software

| Parameter | Value |
|-----------------|--------------------------------|
| Task: | ARL |
| Grade: | |
| Type Standard: | |
| Method: | Low Alloy Steel with Inclusion |
| Analysis Date | 24/06/2022 11:11:26 |
| Sample Id1: | sample 1 |
| Sample Id2: | |
| Sample Id3: | |
| Average Mode | Manual averaging |
| Tolerance table | None |

| Element | Units | AVG | SD | SD% | 1 | 2 |
|----------------|----------------------------------|--------|---------|-------|--------|--------|
| N | % | 0.0007 | 0.00003 | 4.27 | 0.0007 | 0.0007 |
| C | % | 0.0792 | 0.00028 | 0.35 | 0.0794 | 0.0790 |
| Mn | % | 1.672 | 0.0108 | 0.65 | 1.680 | 1.664 |
| Si | % | 0.2073 | 0.00062 | 0.30 | 0.2077 | 0.2069 |
| P | % | 0.0127 | 0.00011 | 0.86 | 0.0128 | 0.0126 |
| S | % | 0.0016 | 0.00006 | 3.70 | 0.0015 | 0.0016 |
| Ni | % | 0.0105 | 0.00023 | 2.16 | 0.0103 | 0.0107 |
| Cr | % | 0.2486 | 0.00019 | 0.08 | 0.2484 | 0.2487 |
| Cu | % | 0.0065 | 0.00003 | 0.40 | 0.0065 | 0.0064 |
| Mo | % | 0.0018 | 0.00020 | 10.68 | 0.0017 | 0.0020 |
| V | % | 0.0046 | 0.00002 | 0.36 | 0.0046 | 0.0046 |
| Ti | % | 0.0026 | 0.00001 | 0.42 | 0.0026 | 0.0026 |
| Al | % | 0.0714 | 0.00116 | 1.62 | 0.0722 | 0.0706 |
| Nb | % | 0.0547 | 0.00066 | 1.21 | 0.0552 | 0.0543 |
| W | % | 0.0047 | 0.00027 | 5.73 | 0.0045 | 0.0048 |
| Ca | % | 0.0005 | 0.00009 | 15.92 | 0.0006 | 0.0005 |
| Mg | % | 0.0005 | 0.00004 | 8.09 | 0.0005 | 0.0005 |
| S (Sulfides) | ppm | 0.37 | 0.094 | 25.48 | 0.44 | 0.30 |
| O (Oxides) | ppm | 5.98 | 2.231 | 37.33 | 7.55 | 4.40 |
| Al pc tot | n/mm ³ | 507 | 205 | 40.45 | 652 | 362 |
| Ca pc tot | n/mm ³ | 4048 | 2580 | 63.75 | 5872 | 2223 |
| alumina c | ppm | 1.64 | 0.024 | 1.44 | 1.63 | 1.66 |
| alumina n | n/mm ³ | 72 | 0 | 0.00 | 72 | 72 |
| alumina ESDavg | µm | 5.48 | 0.026 | 0.47 | 5.47 | 5.50 |
| alumina vf | mm ³ /dm ³ | 6.26 | 0.090 | 1.44 | 6.20 | 6.33 |
| Ca aluminate c | ppm | 0.00 | 0.000 | --- | 0.00 | 0.00 |
| Ca aluminate n | n/mm ³ | 0 | 0 | --- | 0 | 0 |

Result display of a two-run advanced inclusion analysis combined with elemental analysis of a low alloy steel sample.

Software tools for inclusion analysis

Spark Explorer

Understand what lies beyond numbers

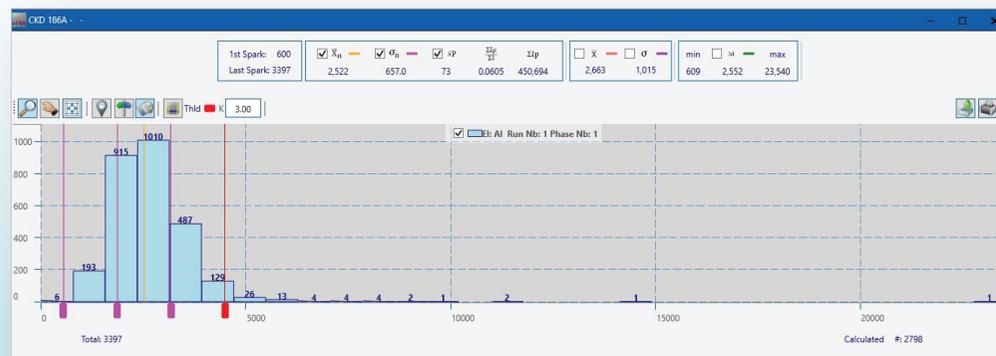
Exploration of the raw inclusion data becomes important when you need to better understand some inclusion analysis results or want to optimize your method. Spark-DAT Explorer was conceived for this and will help you to work efficiently with the so-called single spark signals used in the inclusion analysis.

It offers a large number of useful functionalities and several ways to visualize and compare the signals corresponding to inclusions on different element channels, or in different samples.

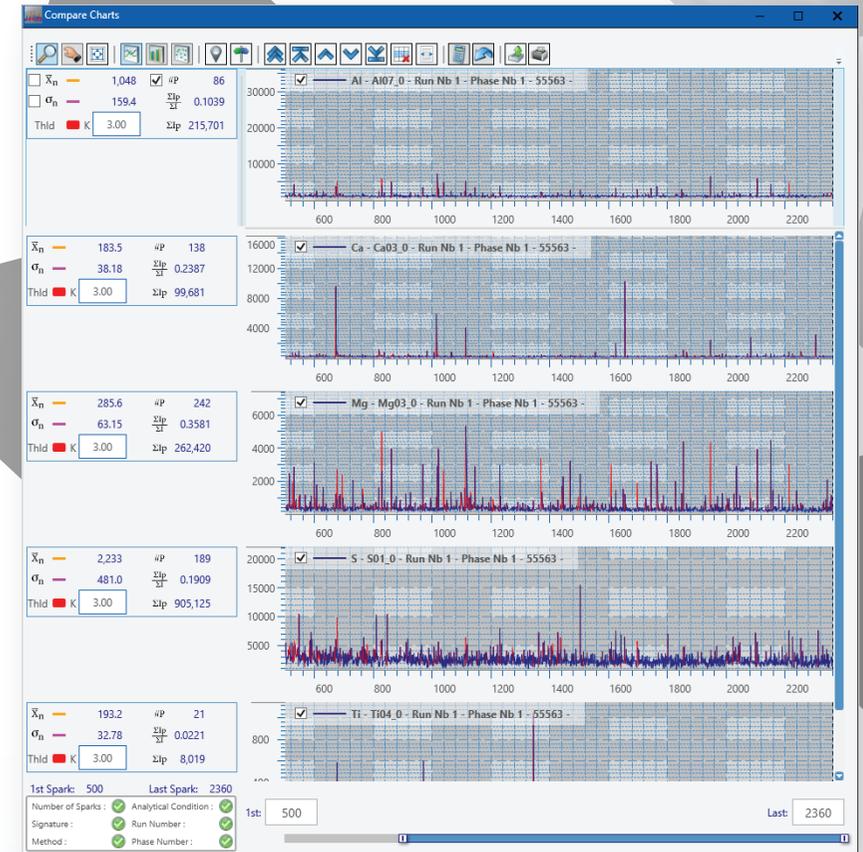
Spark Explorer allows to interactively adjust the parameters of methods and algorithms for an optimal ultra-fast inclusion analysis. Useful applications include, for example, investigating and documenting in case of an issue with the product quality or production problems.

Key features

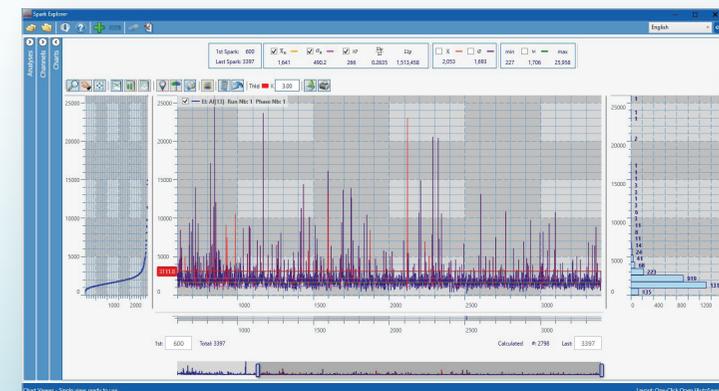
- Display single spark run charts for an unlimited number of elements, samples, and runs
- Graphical adjustment of detection threshold of inclusion signals (intensity peaks)
- Interactive computation of statistical data and other key inclusion figures, e.g., peak counts and insoluble ratio
- Simultaneous display of run chart, histogram, and S-chart of the single spark intensity signals
- Distribution histograms
- Printout of reports and exports of charts to image files



Distribution histogram of Al single spark intensities in a low alloy steel sample.



Comparison of single spark signals of Al, Ca, Mg, S and Ti in a low alloy steel sample.



Display of S-chart, run chart and histogram of Al single spark signals in a low alloy steel sample.

Software tools for inclusion analysis

Inclusions Report

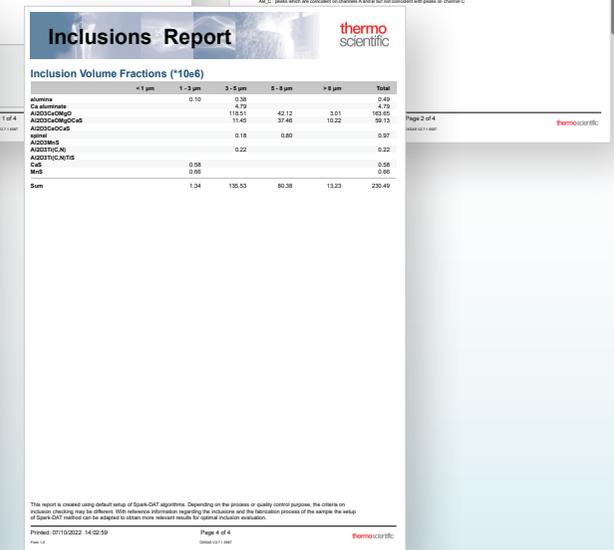
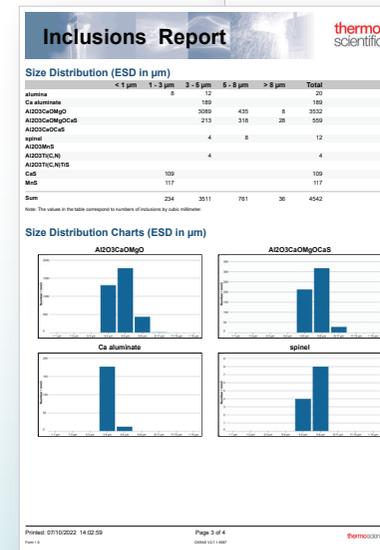
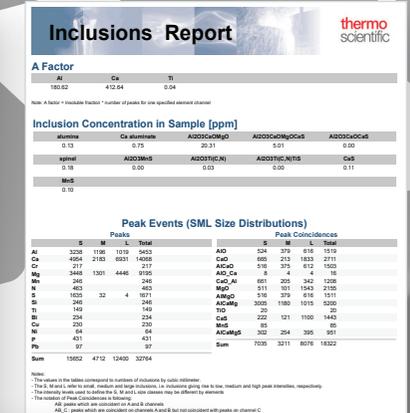
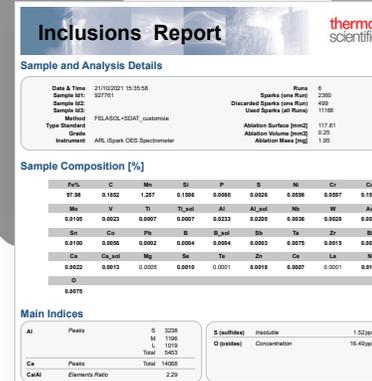
A digest of the inclusion data

The Inclusions Report option compiles all the data and information relevant for the inclusion evaluation in a single dedicated document. Inclusions Report is the tool of choice for studying inclusion analysis results in detail, documenting and archiving results, or transmitting data to specialists in the functions or departments of the company concerned with inclusion issues (e.g., defectology and process specialists).

The document is configurable and includes sections and contents that depend on the inclusion analysis method selected.

Key features

- Contents available with both Standard and Advanced Inclusion Analysis
 - Surface, volume and mass of evaluated sample material
 - Elemental composition of the sample
 - User-defined main inclusion indices
 - Inclusion counts and relative size distribution (SML classification)
- Additionally, contents available with Advanced Inclusion Analysis
 - Size distribution (in μm)
 - Inclusions concentrations (in ppm)
 - Inclusion volume fractions (in mm^3/dm^3)
 - Determination of low oxygen concentrations in killed steels
 - Ternary Diagrams (option)
- Concentration of soluble/insoluble fractions of elements (e.g., Al, B, and Ti) if option selected



Example of an inclusion analysis report of a low alloy steel sample measured with Advanced Inclusion Analysis method.

Software tools for inclusion analysis

Ternary Diagrams

Snapshots of the inclusion population

Ternary diagrams show the composition and size distribution of the inclusions composed of one to three chemical components, e.g., $\text{Al}_2\text{O}_3\text{-CaO-MgO}$ or $\text{Al}_2\text{O}_3\text{-CaO-MnS}$. They provide a snapshot of the inclusion population, typically at a specific point of the manufacturing process.

Ternary diagrams allow, for example, to follow the modification of the aluminum oxides during calcium treatment. They are generated with the Ternary Diagrams software module available as an option for Advanced Inclusion Analysis in low alloy steel and Inclusions Report.

Key features

- Size classes in μm
- Inclusions per mm^3 , by size class
- Average inclusion composition in % and represented by a dot on the diagram

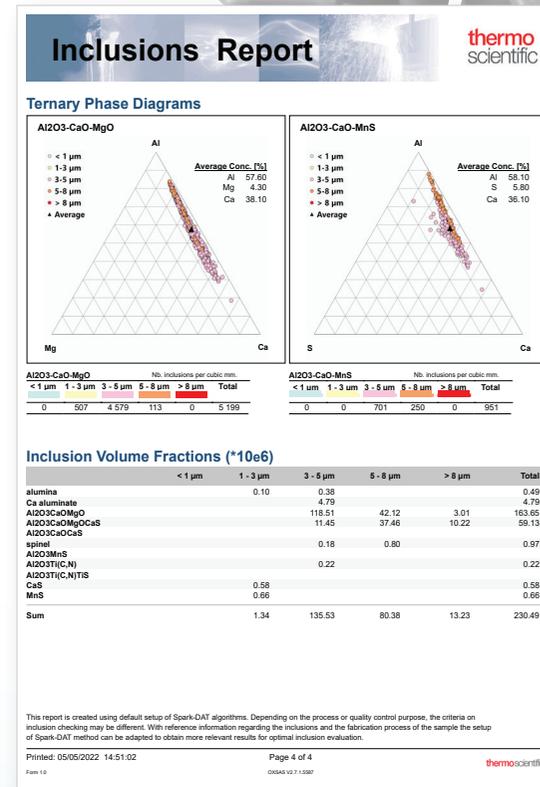
SPC

A most effective way for inclusion control

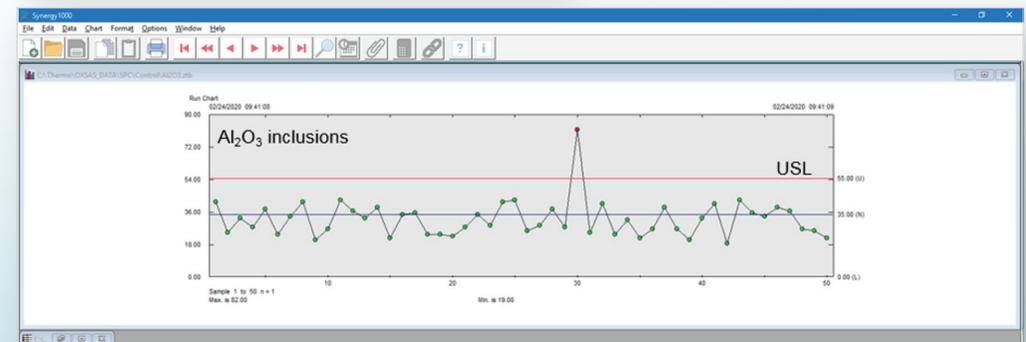
Inclusion data measured with the ARL iSpark Plus can be exported by OXSAS to SPC (statistical process control) software, allowing for simple, virtually online inclusion control. SPC software is a perfect option for companies that want to minimize issues due to inclusions, minimize non-compliant products, rework and scrap.

Key features

- User-defined Upper Specification Limit (USL)
- Trend notifications (e.g., upward drift in the number of inclusions) and incident warnings (typically, when the specification limit is exceeded)
- Can be used simultaneously for element concentrations and inclusion data



Examples of ternary diagrams in an inclusion analysis report.



SPC run chart of aluminum oxides in 50 steel production samples. Number of inclusions in sample 30 is above USL, which signifies that its inclusion content is not compliant.

Application support

Several support options by experienced Thermo Fisher Scientific specialists are available for customizing your methods to your specific materials analysis needs and staff training.

Customization

The inclusion content, especially the type of inclusions, in your samples can vary greatly depending on the metal quality and the manufacturing process. The configuration of the Spark-DAT method (Standard Inclusion Analysis or Advanced Inclusion Analysis) is, therefore, particularly important. Our application specialists will be happy to discuss with you in order to configure the Spark-DAT analysis during the manufacturing of your ARL iSpark Plus as closely as possible to your needs.

Some options are also available when finer adjustments to the methods are needed. Particularly useful and appreciated is the option of coming to our premises in Ecublens, Switzerland, to customize the method with our specialists before shipping your ARL iSpark Plus.

Training

A training course is recommended for those who are new to Spark-DAT inclusion analysis and intend to optimize their method or create new ones by themselves. Several options exist for training from one of our regional application laboratories or in remote web sessions.

Are you interested in Spark-DAT inclusion analysis? Do not hesitate to contact your local Thermo Fisher Scientific sales representative for more information on inclusion analysis methods, software and application support, or a demo.



Learn more at thermofisher.com/isparkplus