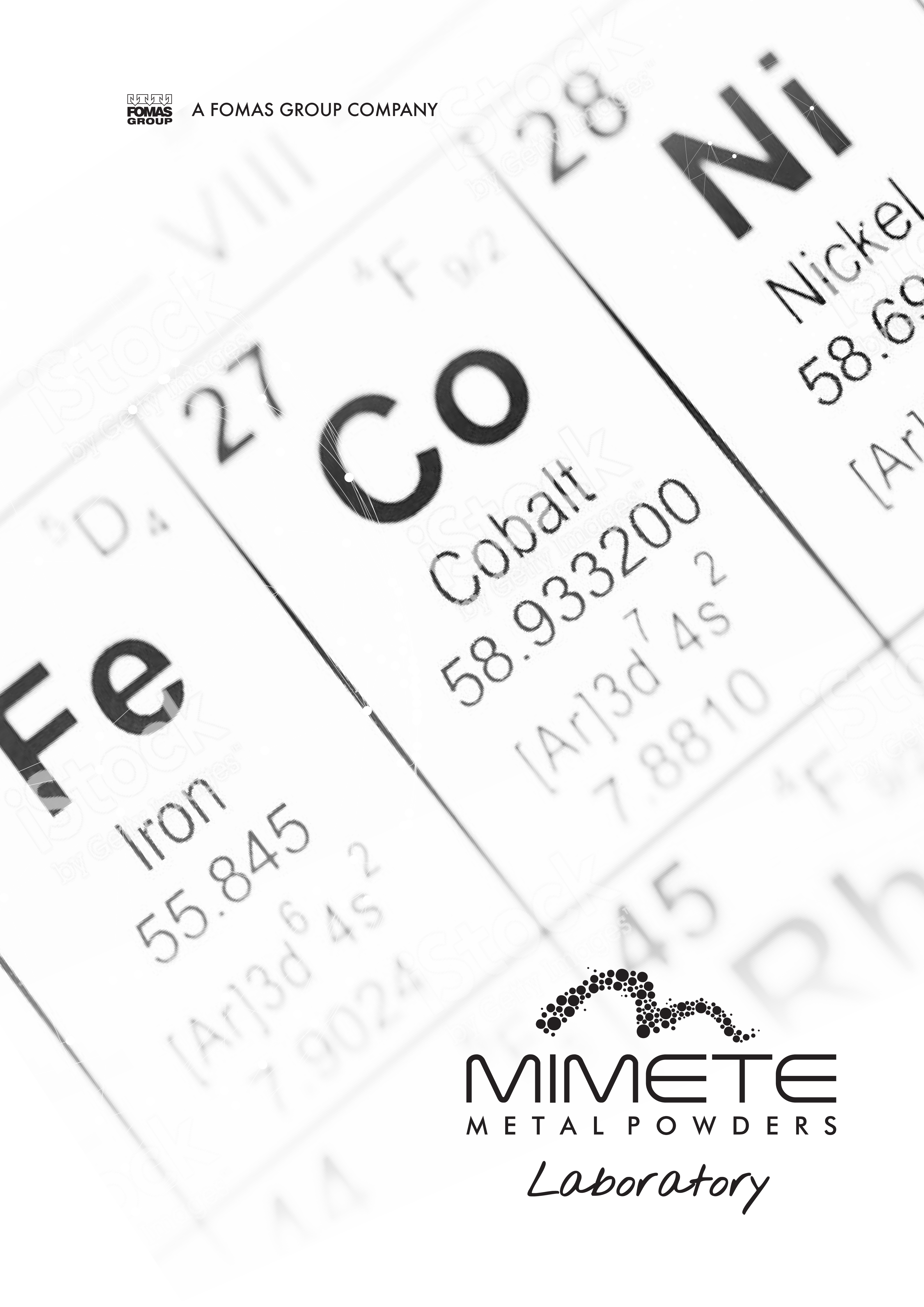


A FOMAS GROUP COMPANY

MIMETE METAL POWDERS

Laboratory

LABORATORY

Our in-house laboratory can offer a wide range of services on standard and custom powders or directly on final products.
Our dedicated technicians carry out all the required tests ensuring that metal powder complies with specifications.

Our Laboratory is available for third party analyses, both for powder customers and also for any other application and industry

TYPE OF ANALYSIS	TEST	REFERENCE STANDARD	EQUIPMENT
Chemical	XRF	ASTM E1621 ASTM E572 ASTM E2465	Wavelength Dispersive X-ray Spectrometer
	ICP-OES	ASTM E1479 ASTM E2594	Inductively Coupled Plasma Optical Emission Spectrometer
	ONH	ASTM E1019	Oxygen, Nitrogen and Hydrogen Analyzer
	CS	ASTM E1019	Carbon and Sulfur Analyzer
	PMI	ASTM E1476	Handheld XRF
Morphological	PSD	ASTM B822 ISO 13320-1	Particle size analyzer
	SIEVE ANALYSIS	ASTM B214	Mechanical Sieve Shaker
	SEM		Scanning Electron Microscope
Physical	FLOWABILITY	ASTM B213	Hall Flowmeter Funnel
	APPARENT DENSITY	ASTM B212	Apparent density kit
	TAP DENSITY	ASTM B527	Tapping Apparatus
Metallography	OM	ASTM E3 ASTM E407	Optical Microscope
Mechanical	TENSION AT ROOM TEMPERATURE	ASTM A370 ASTM E8/8M	Tensile test machine
	TENSION AT ELEVATED TEMPERATURE	ASTM A370 ASTM E21	Tensile test machine and furnace
	IMPACT	ASTM A370 ASTM E23 ISO 148-1	Charpy impact machine
	HARDNESS	ASTM A370 ASTM E10 ASTM E92 ASTM E18	Brinell, Vickers, Rockwell hardness test machines (also portable)
	STRESS-RUPTURE	ASTM E139 ASTM E292	Creep test machine

CHEMICAL ANALYSIS

Chemical composition is the main parameter that determines properties of final components, in terms of thermophysical, mechanical, corrosion and oxidation behaviour. Moreover, specific chemical elements or their combinations can potentially cause cracks during manufacturing, cooling or finishing of parts. The relevance of metal powder chemical analysis detection stems from the fact that they are directly transformed into metal components. Therefore, identification of potential contaminants is mandatory. To guarantee full control of chemical composition, MIMETE laboratory is equipped with different instruments dedicated to specific elements or samples.

WD- XRF | Wavelength dispersive X-ray Spectrometer

USE: this instrument has been selected due to its ability to evaluate chemical composition of both bulk material and powder. This allows MIMETE to monitor its products from the beginning of the process to the end.

BASIC PRINCIPLE: when materials are exposed to X-rays, ionization of their component atoms may take place. The removal of an electron in this way makes the electronic structure of the atom unstable, and electrons in higher orbitals "fall" into the lower ones: thus, the material emits radiation, which has energy characteristic of the atoms present. By measuring the energy intensity for each frequence, it is possible to calculate the concentration of each element within the sample.

PROS/CONS: XRF allows to identify the main chemical elements of a product giving a general and complete spectrum of the sample, even if quantitative determination might be accurate just for main alloying elements.

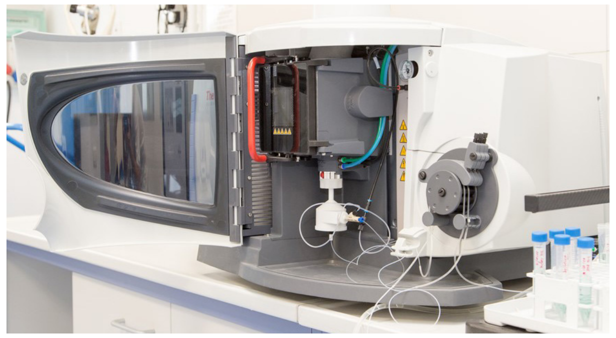
STANDARDS: ASTM E572 & ASTM E1621, ASTM E2465.

However, XRF is not able to detect trace elements. For this reason, MIMETE integrates the results obtained by this first analysis with a second instrument: the Inductively coupled plasma optical emission Spectrometer.

ICP-OES | Inductively coupled plasma optical emission Spectrometer

USE: this instrument has been selected due to its ability to detect trace elements. This allows MIMETE to guarantee full detailed chemical analysis monitoring also traces and undesired elements.

BASIC PRINCIPLE: an acid solution of the material is nebulized and introduced directly inside plasma flame. The flame excites atoms and ions, which emit electromagnetic radiation at wavelengths characteristic of a particular element. The intensity of this emission is indicative of the concentration of the element



within the sample.

PROS/CONS: ICP-OES takes quite long time and very careful sample preparation, but is the only instrument that is able to identify every single element of the product even in very low percentage.

STANDARDS: ASTM E1479, ASTM E2594

CS | Carbon and Sulphur Analyzer

USE: this instrument is used to measure simultaneously the amount of carbon and sulfur within the sample, both bulk material and metal powder.

BASIC PRINCIPLE: A very limited quantity of the sample is prepared in a ceramic crucible and melted in a high frequency induction furnace in a pure oxygen atmosphere, causing sulfur to react to sulfur dioxide (SO_2) and carbon to carbon dioxide (CO_2). The released gases are detected by infrared cells, which convert intensity of electric signals in content of S and C respectively.

PROS/CONS: CS analyzer is able to perform a rapid and precise analysis, but it is important to pay close attention to sample preparation to avoid absorption of organic contaminants.

STANDARDS: ASTM E1019

ONH | Oxygen, Nitrogen and Hydrogen Analyzer

USE: this instrument is used for the simultaneous measurement the amount of oxygen, nitrogen and hydrogen within a sample, both bulk material and metal powder.

BASIC PRINCIPLE: a very limited quantity of sample is fused in a graphite crucible at high temperature in a carrier gas flow and the evolved gases are transported through the detectors. Carbon monoxide is produced by the reaction of carbon in the graphite crucible and oxygen of the sample. Nitrogen and hydrogen are released in its elemental form. The system is equipped with a nondispersive infrared sensor and with a thermal conductivity cell able to convert intensity of electric signals in content of N, O and H respectively.

PROS/CONS: NOH analyzer is able to perform a rapid and precise analysis, but it is important to pay close attention to sample preparation to avoid absorption of humidity or other contaminants.

STANDARDS: ASTM E1019.

PSD (PARTICLE SIZE DISTRIBUTION)

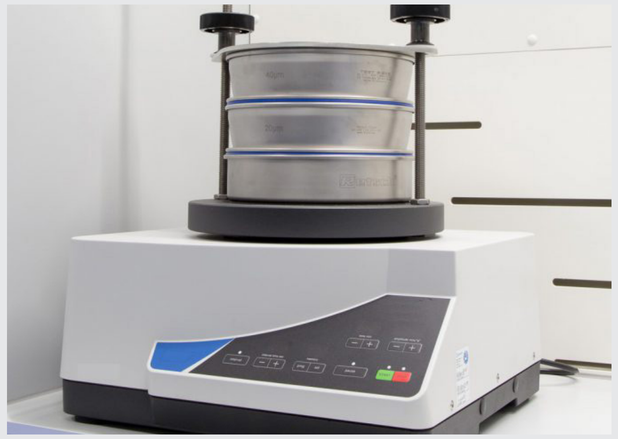
Particle size distribution is the key feature to differentiate powders because it influences flowability, reactivity with oxygen and humidity, user's process parameters, final component properties (mechanical resistance, microstructure, density, surface roughness, …).
Considering high impact on end product quality, MIMETE monitors powder PSD along the whole production process. Two different instruments are used.

Mechanical Sieve Shaker

USE: It is the optimal instrument to measure and classify coarse particles.

BASIC PRINCIPLE: PSD is reported as the weight percentage of powder retained by each mesh of a series of standard sieves of decreasing size. A sieve shaker is used in order to impart to the set of sieves a rotary motion and a tapping action of uniform speed. The sample of dry powder is screened and divided into the different fractions, that are weighted to evaluate discrete particle size distribution.

PROS/CONS: it is a direct measurement which can process large samples, being statistically



very representative. However, it is not applicable to measure particles below 45 μm and it is time expensive.

STANDARDS: ASTM B214

Laser diffractometer

USE: to obtain the complete semi-Gaussian or cumulative curve that represents PSD of any powder sample, the simplest and most accepted technique is laser diffractometer. The instrument evaluates PSD by light scattering.

BASIC PRINCIPLE: based on Fraunhofer Diffraction or Mie Scattering (or a combination of both light scattering analysis techniques), the instrument measures angular distribution of light scattering generated by a laser beam going through dispersed particles (in dry condition). The angular distribution is then mathematically converted into PSD as volume percent of powder sample calculating the equivalent diameter of the spherical particle that determines each specific diffraction angle.

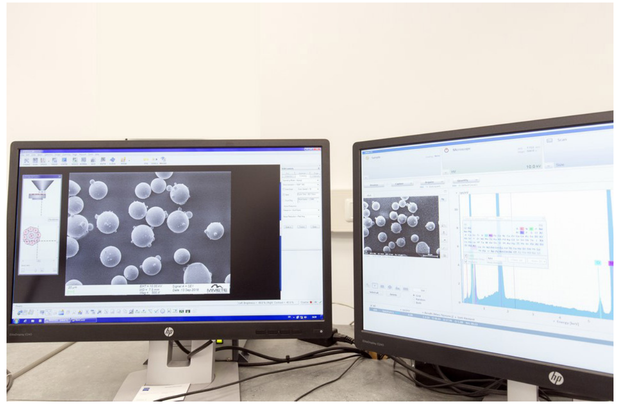
PROS/CONS: it is an indirect measurement which can process limited samples, being statistically less representative but useful for expensive powders. This analysis provides detailed and repeatable analysis of the whole PSD in a very short time, but it is based on rigid assumptions such as particles sphericity.

STANDARDS: ASTM B822 and ISO 13320-1

MORPHOLOGICAL

MORPHOLOGICAL CHARACTERIZATION

SEM | Scanning Electron Microscope



USE: it is the perfect instrument to characterize powder morphology in terms of detect particles shape, dimension and defects such as satellites, caps, agglomerates, surface oxidation.

BASIC PRINCIPLES: produces images and qualitative chemical analysis of a sample by scanning the surface with a focused beam of electrons and collecting:

- Secondary electrons (SE) emitted from very close to the specimen surface, producing very high-resolution images of sample morphology;
- Back-scattered electrons (BSE) emerging from deeper locations within the specimen that consequently can provide information about the distribution, but not the identity, of different elements in the sample;
- Characteristic X-rays emitted when the electron beam removes an inner shell electron from the sample, causing a higher-energy electron to fill the shell and release energy. The energy or wavelength of these characteristic X-rays can be measured by Energy-dispersive X-ray spectroscopy (EDAX or EDS) and used to identify and qualitatively measure the content of elements in the sample and map their distribution.

PROS/CONS: it provides clear high resolution images in a limited time, but the analysis is limited to a small quantity of powder.

STANDARD: there is no a reference standard because it is a qualitative analysis.

OM | Optical Microscope

USE: it is the only technique that allows to detect porosity and inclusions. Coupled with image analysis, can give interesting statistical information.

BASIC PRINCIPLES: it is a qualitative analysis commonly used for metallographic investigation. The surface of a specimen (eventually embedded in polymer resin) is prepared by various methods of grinding, polishing, and etching. After preparation, it is analyzed using optical microscopy to identify morphology, different phases and predict material properties.

PROS/CONS: it provides clear images, but sample preparation is quite complex and time consuming and the analysis is limited to a small quantity of powder.

STANDARD: ASTM E3 and ASTM E407

TECHNOLOGICAL PROPERTIES

FLOWABILITY

The ability of powder to flow is considered one of the most important property for powders to be used in Additive Manufacturing. In fact, high flowability ensures uniformity among layers, thus having meaningful effect on density and homogeneity of final component.

Hall Flowmeter Funnel

USE: it is used to measure the ability of powder to flow through a calibrated orifice just under the force of gravity.

BASIC PRINCIPLE: a fixed quantity of powder flows through a calibrated orifice and the total time is measured, in order to evaluate the flowability rate. The best flowability is obtained with spherical, dense particles in completely dry conditions.

PROS/CONS: it is an easy and quick test for quality check of different powder properties (i.e. particles shape, satellites, surface interactions, humidity) affecting the behaviour in Additive Manufacturing equipment. However, it is considered a "good" indicator until more representative and reliable parameters will be validated.

STANDARDS: ASTM B213

DENSITY

Metal powder is characterised by different type of densities: apparent density and tap density are the most interesting ones, also in relation to each other.

Hall Flowmeter Funnel

USE: it is used to measure the density of powder prior to be packed ("Apparent density").
BASIC PRINCIPLE: a density cup is used to hold a fixed amount of free-flowing metal powders, coming from the flowmeter funnel. The apparent density is calculated as the ratio between the mass of powder in a dedicated cylindrical container and the volume of the cup itself.
PROS/CONS: it is an easy and quick test, but the result is not very indicative of powder behaviour.
STANDARDS: ASTM B212

Tapping apparatus

USE: it is implied to measure the density of powder after being packed ("Tap density").
BASIC PRINCIPLE: Tap density is measured as the ratio between the mass of powder and its volume after standardized tapping procedure applied to guarantee reproducibility of results. To pack the metal powder a tapping apparatus is used.
PROS/CONS: the automated tapping apparatus guarantees reproducibility of testing conditions, but the result might be not really indicative of powder behaviour.
STANDARD: ASTM B527

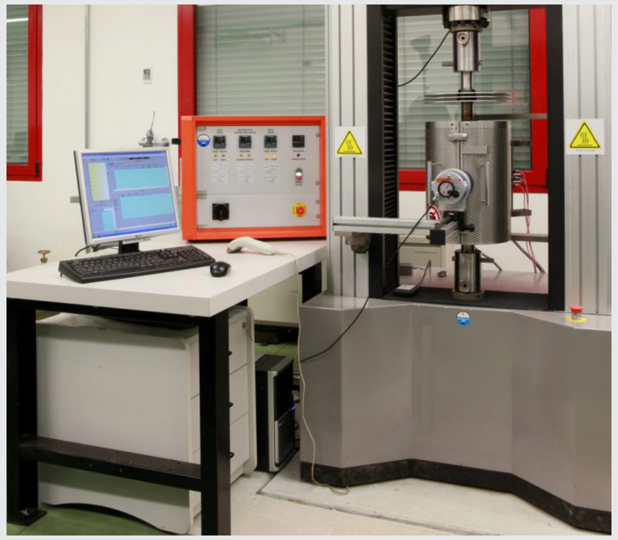
MECHANICAL PROPERTIES

Mechanical tests can be performed in our parent company, 15 km far from MIMETE. FOMAS laboratory has a long history and it evolved in order to accomplish new technology and customers' requirements. Since power generation, nuclear and oil & gas industries represent FOMAS main markets, the imperative to be able to supply to its customers certified products has always been part of the company's mission. For this reason, FOMAS has an ISO/IEC 17025 accredited laboratory.

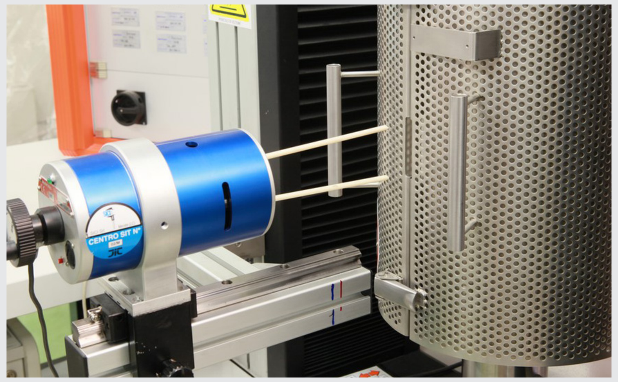
TENSILE TEST

Tension at room temperature

USE: a robotized machine is used to measure ultimate tensile strength, yield strength, maximum elongation and reduction in area at room temperature.
BASIC PRINCIPLE: a sample machined according to international standards is subjected to a controlled tension until failure.
EQUIPMENT CAPABILITIES: 250 kN equipped with computerized electronic data acquisition.
STANDARD: ASTM A370 and ASTM E8/8M



Tension at elevated temperature



USE: the 250 kN machine is equipped with a small electric furnace to measure metals tensile properties (ultimate and yield strength, maximum elongation and reduction in area) at elevated temperature.
BASIC PRINCIPLE: it is the same as tensile test at room temperature, but the sample is positioned into a small furnace and fixed on the machine. The ASTM standard establishes the dimension of a standardized opening of the furnace in which the electronic extensometer goes through thus getting in contact with the sample and being able to measure its progressive deformation.
EQUIPMENT CAPABILITIES: testing temperature up to 1000 °C.
STANDARDS: ASTM A370 and ASTM E21

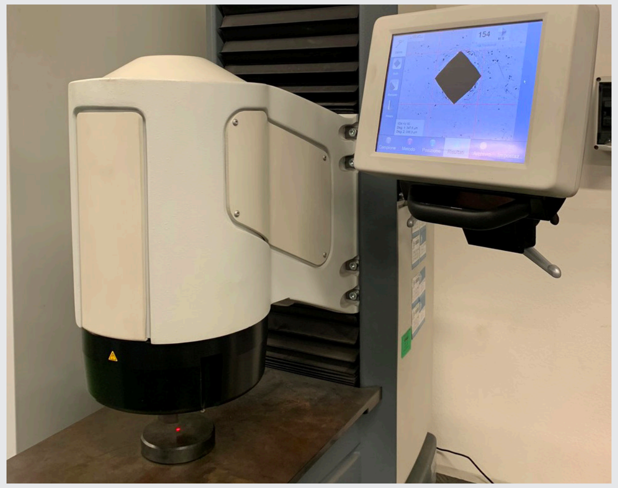
IMPACT TEST

USE: the impact test is also known as Charpy test and determines the amount of energy absorbed by a material during fracture. The absorbed energy allows to study temperature-dependent ductile-brittle transition.
BASIC PRINCIPLE: the instrument is a pendulum characterized by defined mass and arm length that is dropped from a known height to impact a notched sample. The energy transferred to the material is defined as the difference in the height of the hammer before and after the fracture. Looking at the broken sample, it is possible to evaluate also fracture appearance and lateral expansion.
EQUIPMENT CAPABILITIES: FOMAS lab offers 4 different pendulum, 2 (one of 450 J and one of 300 J) standardized according to

ASTM and 2 (one of 450 J and one of 300 J) according to ISO.
Testing temperatures from -196°C to +300 °C.
STANDARDS: ASTM A370 and ASTM E23 and ISO 148-1

HARDNESS

Brinell test (HB)



USE: it measures the macro-hardness of metals by indirect evaluation of penetration of a specific indenter.
BASIC PRINCIPLE: a 10 mm diameter steel ball is used as an indenter. At the end of standardized time, the diameter of the imprint is measured.
PROS/CONS: it is a highly reproducible and quick test, but cannot measure very small areas
STANDARD: ASTM A370 and ASTM E10

Vickers test (HV)

USE: it measures the macro and micro-hardness of any material by indirect evaluation of penetration of a specific indenter. It can be used for all metals and has one of the widest scales among hardness tests.
BASIC PRINCIPLE: the indenter is in the form of a square-based pyramid where the top angle is 136°: this shape makes the indenter resistant to all materials. At the end of standardized time, the diagonals of the imprint is measured.
PROS/CONS: it allows to measure hardness of different phases present in the sample, but the surface preparation must be executed accurately.
STANDARD: ASTM E92

Rockwell test (HRC)

USE: it measures the macro-hardness of metals by direct evaluation of penetration depth of a specific indenter.
BASIC PRINCIPLE: it does not require optical readings, but it directly measures the depth of penetration of an indenter under a large load compared to the penetration made by a minor load. There are different scales, denoted by a single letter, that use different loads or indenters.
PROS/CONS: the advantage of Rockwell test is its ability to display hardness values directly, without calculations.
STANDARDS: ASTM E370 and ASTM E18

STRESS RUPTURE

USE: it measures the tendency of a material to deform subjected to high levels of mechanical and thermal stresses, changing its geometry in relation to time.
BASIC PRINCIPLE: A constant load is applied and, at the same time, temperature increases. The test ends when the sample breaks, which can require many weeks; final elongation and reduction of area are measured.
EQUIPMENT CAPABILITIES: FOMAS lab offers 6 creep machines (4 up to 900°C; 2 up to 1000°C).
STANDARD: ASTM E139 and ASTM E292

MIMETE
METAL POWDERS

MIMETE S.R.L.
Via Padania, 10 20853 Biassono MB Italy
+39 039 99811 info@mimete.com
www.mimete.com