ELTRA®
ELEMENTAL ANALYZERS

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O/N/H ANALYSIS IN RAW MATERIALS FOR AIRCRAFT COMPONENTS

Combustion Analysis provides rapid and reliable results

INTRODUCTION

An airplane is a complex means of transportation which must fulfil many requirements. First, it should be safe for passengers, pilots and all people working in and around it. The materials used should be low-wear and robust against different climate conditions. Additionally, the mechanical load capacity of the whole airplane must be high enough for a large number of starting and landing procedures.

Beside the safety aspects, economic factors also come into play. Fuel consumption, for instance, should be as low as possible and in general, the acquisition costs should be in an affordable range.

All factors taken into account, a mix of construction materials is used which ensures both safety and longevity but also an economically reasonable expenditure.

To give an example, the following materials are used to build a Boeing 787 airplane: [1]

Material	Used in % by weight
Composites	50
Aluminium	20
Titanium	15
Steel	10
Other	5

Table 1: Materials used for aircraft construction

To verify the requested material properties and ensure maximum safety, each component is submitted to thorough testing. Part of the quality control process involves testing of mechanical properties, like tensile strength, or elasticity but also the **determination of the chemical composition**. One important part of chemical analysis of materials used in the aerospace industry is always the measurement of the gases oxygen (O), nitrogen (N) and hydrogen (H) which have a significant influence on the material properties.

The O/N/H analysis of aluminium, titanium and steel is stipulated in several international standards like ASTM or DIN/EN/ISO:

Matrix	Element	Standard
Aluminium	H	ASTM E 2792
Titanium	O/N/H	ASTM E 1447; ASTM E 1409 ISO 22963; DIN EN 3976
Steel	O/N	ASTM 1019; ISO 17053 DIN EN ISO 15351 // 10720

Table 2: Standards for oxygen, nitrogen, hydrogen analysis

This article will focus mainly on the matrix titanium which, compared to aluminium, possesses better fracture toughness, higher tensile strength and is also easier weldable. This makes it increasingly interesting for aircraft construction, especially in combination with **carbon-fibre-reinforced plastics (CFRP)** [2].

MATERIAL GRADE OF TITANIUM

Metals like copper and iron are well-known and widely used in many products, although they occur less frequently on earth than the less-known metal titanium which is the tenth most frequent element on earth. One reason for its lower usage is its price. Titanium is spread widely in the environment which makes it difficult to exploit and expensive to process [3]. It occurs, for instance, bound in the minerals illmenite ($FeTiO_3$), perovskite ($CaTiO_3$) and mainly in rutile (TiO_2). To generate pure titanium metal, TiO_2 is converted into $TiCl_4$, which has to be led over liquid magnesium at temperatures of 800 - 900 °C (Kroll process). This process makes of titanium and its alloys an expensive material grade.

The mechanical properties of titanium and its alloys are advantageous for aircraft construction. First, the density is 60 % lower in comparison to steel which makes it a light material. The low weight leads to reduced fuel consumption. Second, good resistance against heat and corrosion ensures a long lifetime and engine safety. Third, low embrittlement and low thermal expansion allows to combine titanium and its alloys with CFRP (Carbon Fibre Reinforced Plastics) [1], [4].

Titanium and titanium alloys are mainly used in technically critical parts of an airplane like airframes, or engines [4.]

Alloy	Component
Ti 6Al 4V	Cockpit window frame, wing box, fastener
Ti 3Al 2.5V	Hydraulic pipe
Ti 10V 2Fe 3Al	Landing gear, Track beam
Ti 6Al 2Sn 4Zr 2Mo	Exhaust, Tail cone
Ti 15V 3Cr 3Sn 3 Al	Duct

Table 3: Titanium alloys used in aircraft components

Despite all these advantages, it needs to be considered that **the gases oxygen, nitrogen and hydrogen can affect the mechanical properties of titanium in a negative way**. An additional risk is the high affinity of liquid titanium to these gases during the preparation process. Therefore, it is necessary to work with an evacuated furnace [5]. For most titanium alloys a maximum content for oxygen, nitrogen and hydrogen is defined, for grade 2 titanium, for example, the allowed maximum values are oxygen is 0.4 % , nitrogen 0.05% and hydrogen 0.015 % . For Ti_6A_4V the maximum oxygen content allowed is even lower with 0.25 %.

Oxygen is like poison for titanium and its alloys. With increasing oxygen concentration, the material becomes harder and more susceptible to cracks [6]. An additional hydrogen concentration can further impact the product quality due to hydrogen embrittlement [7]. With increasing hydrogen content, the titanium first loses its ductility which can be followed by spalling of the titanium surface.

QUALITY CONTROL USING COMBUSTION ANALYSIS

Fig. 1: ELEMENTRAC ONH-p

Due to the big impact the O/N/H concentrations have on material properties of titanium and its alloys, a reliable measurement of these elements is indispensable for the quality control of titanium-based products.

ELTRA's O/N/H analyzer ELEMENTRAC ONH-p (Fig. 1) uses inert gas fusion to measure the requested gases in a wide concentration range from the low ppm level up to 2%. The electrode furnace, which is also called impulse furnace, of the ONH-p melts the titanium sample at temperatures up to 3000 °C and measures the released hydrogen and nitrogen in their elemental form and oxygen as carbon dioxide. The carbon dioxide is formed by reaction of the oxygen from the titanium sample with the carbon of a graphite crucible. To assure a reliable measurement of O/N/H, fluxes like nickel or tin are added to the sample. These reduce the melting point and ensure a complete release of the embedded gases and a good repeatability of the O/N/H measurements. The ELEMENTRAC ONH-p complies with all international standards and is easy to use for academic and non-academic staff alike.

The ELEMENTRAC ONH-p processes samples of any solid shape like powder, granulate, wires or small plates. Typical sample weights are approx. 100 mg. The sample amount can be increased up to 1000 mg for steel and iron-based samples for which no fluxes are required.

TYPICAL MEASUREMENT RESULTS OF THE ELEMENTRAC ONH-P

A) O / N / H concentrations in titanium samples

TYPICAL RESULTS

91205-1001 Titanium Standard (LOT 114 C)

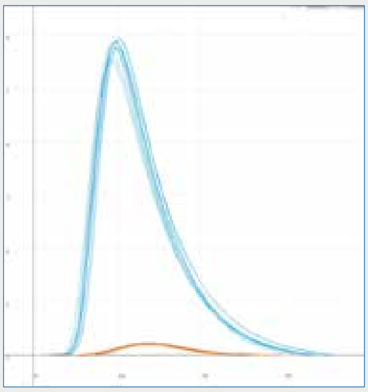
Weight (mg)	ppm H
101.6	10.2
101	11.1
100.8	10.1
101.8	9.9
102	9.3
100.5	12
102.1	11.3
104.7	9.5
103.7	10.9
103.9	10.5
Average values	
	10.480
Deviation / Relative deviation (%)	
	0.847 / 8.08 %

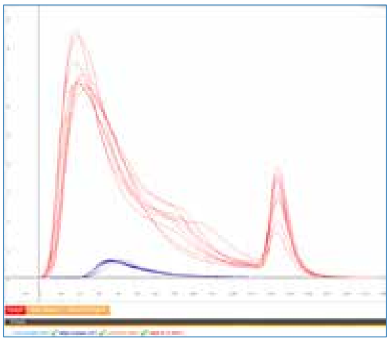
TYPICAL RESULTS

LECO 502-891[2)]

Weight (mg)	Oxygen (ppm)	Nitrogen (ppm)
119.4	1150.6	95.8
115.7	1114.3	86.5
117.8	1159.5	104.7
123.1	1149.7	98.9
116.4	1205.1	97.7
116.4	1206.7	105.1
112.4	1183.0	101.5
118.5	1180.6	106.0
116.3	1120.3	93.8
118.0	1171.1	107.4
Mean value		
	1171.1	100.4
Deviation / Rel. deviation (%)		
	37.9/3.2 %	6.6/6.6 %

[2)] certified values: O: 1170 ppm ± 90 ppm; N: 100 ppm ± 10 ppm





TYPICAL RESULTS

ALFA AESAR TiH2 1-3 Micron powder

Weight (mg)	% Hydrogen	% Oxygen
31.34	4.027	2.42
31.04	4.023	2.50
31.10	4.021	2.44
25.15	4.013	2.39
26.62	4.026	2.41
29.14	4.015	2.44
25.61	4.031	2.41
26.47	4.010	2.43
28.64	4.031	2.39
27.66	4.028	2.49
Mean value		
	4.023	2.43
Deviation / Rel. deviation (%)		
	± 0.0076 (0.2%)	± 0.03 (1.5%)

B) O / N / H concentrations in steel samples

TYPICAL RESULTS

Steel ELTRA 91400-1003 (LOT 812 C)

Weight (mg)	ppm H
1010.2	6.5
1004.3	6.4
1004.5	6.1
1005.6	6.0
1005.9	5.7
1004.3	6.3
1003.6	5.8
1012.1	5.8
1004.1	5.8
1003.9	5.6
Average values	
	6.0
Deviation	
	0.3 / 4.9 %

TYPICAL RESULTS

Euronorm ZRM 194-2[2)]

Weight (mg)	ppm O	ppm N
1001.7	113.9	32.9
1000.1	119.0	32.6
1006.7	115.3	32.4
1016.4	122.0	32.0
998.1	109.5	32.1
1017.1	115.3	31.7
1018.7	114.3	31.9
989.5	115.4	32.0
991.0	116.4	33.3
1019.8	126.2	32.6
Average values		
	116.7	32.3
Deviation / Relative deviation (%)		
	± 3.4 / 2.9 %	± 0.52 / 1.6 %

[2)] certified: ppm O : -
ppm N : 31.9 (± 2.4 / 7.5 %)

CONCLUSION

Due the big impact the oxygen, nitrogen and hydrogen content of a raw material has on safety-relevant parts in an aircraft, reliable measurement of element concentrations is indispensable.

ELTRA's ELEMENTRAC ONH-p combustion analyzer with its powerful electrode furnace and wide range detectors is perfectly suited for measuring these gases in low, medium and high concentrations in steel and titanium samples.

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