



Material and Failure Analysis
Scope of work TAF1

Scope of work

Laboratory service

The service packages below will be arranged in accordance to an analysis schedule in correspondence to the client's request.

1 Sample preparation

1.1 Preparative work (machining and factory)

Transportation and disassembling of the test items including using of crane and lift truck on the IABG premises in Ottobrunn, Use and provision of machine tools and separating tools, Cutting of modules / test items including skilled staff.

1.2 Preparative work (laboratory)

Use and provision of laboratory equipment and resources. This apply to cutting services for sampling, installation of laboratory experiments, customer and project tailored services.

2 Macroscopic documentation

2.1 Macro documentation

Macroscopic analysis of test items, macro-documentation with macrolens and digital camera, analysis with a stereo microscope up to a magnification of 100 : 1, integration of the pictures in our Image Access database.

3 Metallographic investigation

3.1 Metallographic specimen incl. basic documentation

Include the preparation for micro or macro section of the extracted sample, the standard contrasting, and the light microscopy documentation of the structure with a maximum of 5 pictures. The evaluation of the micro hardness according to Vickers of the core structure with 5 single measurements and averaging.

- Maximum size of the (imbedded) test items Ø 50mm / 35 x 65 mm
- 50% additional charge for materials with a strength of more than 1,000 MPa for high alloyed steels, special metals, coats, ceramics

3.2 Metallographic specimen without documentation

Include the preparation for micro or macro section of the extracted sample including the standard contrasting.

- Maximum size of the (imbedded) test items Ø 50mm / 35 x 65 mm
- 50% additional charge for materials with a strength of more more than 1,000 MPa for high alloyed steels, special metals, coats, ceramics

3.3 Light microscopy

Documentation of micro structures with the light microscope.

Range of magnification 12.8 x - 1,200 x

3.4 Standard analysis materialography

Accredited tests including test certificate for the structure analysis below:

- ☐ Grain size according to DIN ISO 643, ASTM E112
- ☐ Coat thickness of metal and oxide coats, microscopic procedure according to DIN EN ISO 1463
- ☐ Examination of non-metallic, carbidically and sulfidic inclusions according to DIN 50 602 (Procedure M), ASTM E 45, SEP 1520, SEP 1615
- ☐ Microstructure of cast iron according to DIN EN ISO 945 (analysis surface up to 80 mm²)
- ☐ Porosity analysis according to VDG recommendation P201E, VW5009, PV6097 (test surface up to 80 mm²)
- ☐ Particle analysis (statistical analysis / classification of maximum 3 light microscopy or REM-pictures)

4 Scanning electron microscope investigation

4.1 Sample vaporization with gold

Vaporization with gold (Au) per REM-specimens for non-conducting materials as plastics, biological specimens and ceramics.

4.2 Scanning electron microscope investigation including EDX

Provision and use of the scanning electron microscope (REM) with an energy dispersive x-ray microanalysis (EDX).

- ☐ Fractrography – analysis of the fracture surface for determination of the failure mechanism
- ☐ Qualitative and semi-quantitatively microanalysis (EDX)
- ☐ Point, integral, line and object analysis, spatially resolved microanalysis (mapping)
- ☐ Customized analysis/examinations

5 Mechanical technological analysis

5.1 Macrohardness (HB, HR, HV, HL)

Accredited test according with calibrated hardness tester including test report (5 single measurements, averaging) for each of the following test methods:

- ☐ Brinell (DIN EN ISO 6506-1, ASTM E10)
- ☐ Rockwell (DIN EN ISO 6508-1, ASTM E18b)
- ☐ Vickers (DIN EN ISO 6507-1, ASTM E92)
- ☐ Mobile Hardness test according to Leeb (HL-C, -D, -G, DIN50156-1)

5.2 Low load and microhardness (HV1 down to HV 0.01)

Accredited test according to Vickers (DIN EN ISO 6507-1, ASTM E92) with calibrated hardness tester including test report (5 single measurements, averaging).

5.3 Hardness profile (DS, CHD (Eht), Nht)

Accredited test according to Vickers (HV1 down to HV 0.01, DIN EN ISO 6507-1, ASTM E92) with calibrated hardness tester including test report and graphical illustration of the hardness profile. Evaluation of the hardness profile with a maximum of 20 single measurements for each of the following tests:

- Case depth according to DIN 50 190-2, DIN EN ISO 2639 and DIN EN 10328
- Decarburization depth according to DIN EN ISO 3887
- Effective nitrided case depth according to DIN 50190-3
- Fusion hardening depth and fusion depth according to DIN 50190-4

5.4 Hardness profile (welded joints)

Accredited weld hardness testing according to DIN EN 1043-1 or DIN EN 1043-2 with calibrated hardness tester including test protocol.

5.5 Hardness test on plastics and rubber

Accredited hardness testing according to Shore A and D (DIN EN ISO 868) and IRHD (DIN EN 48) on plastic and rubber material including test protocol.

5.6 Tensile test - sample manufacturing

Manufacturing of a round or flat standard specimen at nominal diameter/size. The sample manufacturing occurs according to the resource availability at the IABG or a qualified subcontractor of the IABG.

5.7 Tensile test – testing

Implementation of an accredited tensile test on calibrated testing machines with precision strain measurement and determination of characteristic values (R_p , R_m and A_5) including test report.

The testing occurs according to the resource availability at the IABG laboratory or at a certified accredited subcontractor of the IABG.

5.8 Charpy impact test – sample manufacturing

Production of 3 samples (V-notch) according to ISO 148/EN10045-1. The production occurs at a qualified subcontractor of the IABG.

5.9 Charpy impact test – testing

Implementation of the impact test and determination of the impact energy including test report of 3 samples. The testing occurs according to the resource availability at the IABG laboratory or at a certified accredited subcontractor of the IABG.

6 Analytics

6.1 Chemical material analysis

Quantitative emission spectroscopic analysis by a certified and accredited subcontractor of the IABG including test report.

6.2 Remelting

Remelting of small samples into compact analytical samples (Fe, Cu, Al-base) or cast iron samples into a white solidified state. The service is provided by a certified and accredited subcontractor of the IABG.

6.3 Quantitative analysis of C, N, O, S

Quantitative determination of one of the following elements by a certified and accredited subcontractor of the IABG.

- ☐ Carbon (C)
- ☐ Nitrogen (N)
- ☐ Oxygen (O)
- ☐ Sulfur (S)

6.4 Residual stress

Radiographic determination of the residual stress at the material surface in both 0° and 90° direction by a qualified subcontractor of the IABG. Generation of depth paths from the material surface until a depth of approx. 3 mm by single step measurement. Defined electrolytic removal of material to reach customer requested material depth steps.

6.5 Thermogravimetric analysis (TGA)

Thermogravimetric measuring system with automatic measuring cycles for the determination of humidity, fiber and resin share of plastics and fiber-reinforced plastics. Possibility of multiple analysis with high weights until 5 grams and up to 1,000 °C.

The determination of fiber volume contents occur by determination of the density according to the buoyancy method to DIN EN ISO 1183-1 (procedure A) and the thermogravimetric analysis by macro TGA as agreed. For the analysis of the fiber and resin volume share the density of both the fiber and resin must be known, otherwise it is only possible to evaluate the mass share of each component.

6.6 Dynamic differential calorimetry (DDC)

With the dynamic differential thermoanalysis the glass transition temperature and the reaction enthalpy of plastics according to the specifications ISO 11357-2/-3 is to be determined. The temperature range can be chosen by the customer and must be within – 90°C until + 450°C. For each sample a heating curve within a standard heating rate of 10 K/min. will be established.

For determination of the degree of cure at resin compounds the reaction enthalpy (ΔH_{100}) of the fresh material and the resin mass share of the cured specimen must be known. Alternatively the determination of the enthalpy values of the curing will be analyzed.

The analysis will be carried out at a certified and accredited subcontractor of the IABG.

6.7 Dynamic mechanical analysis (DMA)

The dynamic mechanical analysis will be executed at fiber reinforced plastics (FRP) according to the specification DIN 65583 as a single bending fatigue test (single cantilever). The glass transition temperature will be determined by the temperature dependence of the elastic modulus. The storage modulus or loss modulus will be evaluated as well.

The test will be standardly performed with a heating rate of 5 K/min., a frequency of 1 Hz and an amplitude of 15 microns. The temperature range can be chosen by the customer and must be within + 40°C until + 270°C max. The minimum sample geometry is 35 mm x 10 mm x 1 mm, while the thickness must not exceed 2 millimeters due to stiffness. The specimens will be dried for 7 days at 105°C prior to test.

The analysis will be carried out at a certified and accredited subcontractor of the IABG.

7 Nondestructive tests

7.1 Visual testing – VT

The visual testing contains the implementation of the test for macroscopic visible damages or inhomogeneity's. Documentation in form of a test protocol including the evaluation will be provided.

7.2 Borescope testing

The borescope testing of cavities, pipes, or at difficult-to-access areas of components will be carried out by the means of a video borescope. Documentation in form of a test protocol including the evaluation will be provided.

7.3 Penetrant testing – PT

The penetrant testing will be applied to detect surface opened defects at test items conducted by an according to DIN EN 4179 or DIN EN ISO 9712 qualified and approved test staff. Documentation in form of a test protocol including the evaluation will be provided. The testing will be carried out within the IABG laboratory or on-site.

☐ Testing of the surface according to the red-white or fluorescence procedure.

7.4 Ultrasonic testing – UT

To detect inner defects within component volumes an ultrasonic testing will be conducted by an according to DIN EN 4179 or DIN EN ISO 9712 qualified and approved test staff. Documentation in form of a test protocol including the evaluation will be provided. The testing will be carried out within the IABG laboratory or on-site.

☐ Testing with a pulse-echo contact technic by use of a mobile hand held equipment.

7.5 Phased-Array Ultrasonic testing – PAUT

Composite materials will be tested by phased-array technology. In addition to the classic ultrasonic testing an evaluation of the A-, B-, or S, scans in form of pictures as well as additional documentation and analysis functions are available. Documentation in form of a test protocol including the evaluation will be provided. The testing will be carried out within the IABG laboratory or on-site.

7.6 Eddy-current testing – ET

By the use of an eddy-current testing method, surface or close to surface located defects will be detected at electrically conductive test items such as metals. The test will be conducted by an according to DIN EN 4179 or DIN EN ISO 9712 qualified and approved test staff. Documentation in form of a test protocol including the evaluation will be provided. The testing will be carried out within the IABG laboratory or on-site.

7.7 Magnetic particle examination – MT

With the magnetic particle testing method, surface or close to surface located defects will be detected at electrically conductive test items such as metals. The test will be conducted by an according to DIN EN 4179 or DIN EN ISO 9712 qualified and approved test staff. Documentation in form of a test protocol including the evaluation will be provided. The testing will be carried out within the IABG laboratory or on-site.

7.8 X-ray testing – 2 dimensional

Both for NDT testing and failure analysis the 2 dimensional x-ray analysis with a 180 kV microfocus x-ray tube will be carried out within a digital x-ray device. The sample can be moved in X, Y, Z and R direction in order to detect inner structures and defects, which are displayed at a monitor in live modus. With the enlargement of the detector/sample distance a magnification of structures up to max. 2000:1 is possible. Documentation in the form of pictures will be provided. Customer attendance at investigation is possible.

7.9 X-ray testing μ CT– 3 dimensional

Performance of a 3D X-ray testing with a 180 kV microfocus X-ray tube within a digital x-ray device. After sampling appropriate scan parameters will be defined by the operator. The sample will rotate by 360° while cross sectional images are taken. Subsequent a volume will be reconstructed using appropriate algorithms. Depending on the sample size the maximum reachable scan resolution is 3 microns. The testing occurs in the IABG laboratory or in cooperation at a qualified subcontractor of the IABG, depending on the availability of the system.

☐ For data analysis and evaluation the work package 7.10 must be considered.

7.10 X-ray testing μ CT – data analysis and evaluation

This operation consists of the analysis regarding the shape, size and location of detected defects or inhomogeneities (lengths, areas, volumes). Furthermore the nominal/actual value comparison of outer and inner geometries is available. The real geometry data extracted from the volume scan will be provided as STL-dataset. All analysis will be carried out by the means of a volume graphics software system (VGL).

☐ Generated pictures, videos and measurements as well as the VGL viewer software will be provided to the customer.

8 Reporting and consulting

8.1 Material and failure analytical services

All relevant results of the analysis will be summarized in an IABG report. It includes the diagnosis and evaluation of the damages (failure mechanism), the discharge of conclusions (root cause) and suggestions for improvement (failure prevention) according to the VDI- guideline 3822 (basics and implementation of failure analysis).

Creation of test protocols or test reports for the realized material analysis, evaluation of results, transcription of customized needs and requirements.

8.2 Material and failure analytical expertises

Integration of internal and/or external experts for customer challenges.

9 On-site service

9.1 Ambulant metallography / On-site expertise of failures

Ambulant metallography including the equipment and on-site-expertise of failures on request.

I. General

1. All agreements with respect to the performance of the contractual services are included in writing in this contract. The IABG General Terms and Conditions shall apply exclusively. Deviations in conditions shall not apply unless IABG has agreed expressly to these in writing. This shall also be the case when, aware of deviations or contrasting conditions, services are rendered without reservation.
2. IABG reserves the right of ownership and copyright in respect of all its documents/handed over information and particularly in respect of technical drawings drawn up by IABG in connection with an offer. The afore-mentioned documents shall not be made accessible to third parties without the prior written consent of IABG.
3. IABG and the customer shall observe secrecy with respect to all confidential information made known to them.
4. IABG shall be entitled to interrupt contractual services if
 - a) the customer wholly or partially, despite due date and warnings, unauthorized fails to make the agreed payment
 - b) the customer does not fully or timely fulfil obligations which are accepted by him or obligations incumbent upon him
 - c) IABG realizes that the articles provided by the customer constitute a definite risk to persons or property.

In such cases, the customer shall reimburse the additional expenditure incurred by IABG as a result of the interruption of the contractual task. The right of IABG to assert additional claims remains unaffected hereof.

5. Contractual rights of the customer shall, without the prior consent in writing of IABG, be neither transferable nor assignable.

II. Period of Performance / Duties of Cooperation

The pre-requisite for compliance with the agreed deadlines is that the customer fulfils promptly all obligations incumbent upon him. Obligations incumbent upon the customer are primary obligations. The customer in particular has to supply IABG with information, objects and documents required for the correct and complete performance of the order. Moreover the customer has to point out special risks to IABG which can occur to it or its employees as a result of the nature of its properties or objects.

III. Remuneration, Payment

1. The remuneration for performance / part performance by IABG will be invoiced on a monthly or quarterly basis or in accordance with the payments plan agreed and is due for payment without deductions 14 days after the date of the invoice in as far as delivery of the invoice did not occur more than three days after the date of the invoice. In the latter case, the 14-day period commences from the date of receipt of the invoice.
2. In addition to the agreed remuneration, the valid statutory rate of value added tax (VAT) has to be paid. The set-off against liabilities not recognised by IABG nor legally established by a court judgment nor ready for decision is excluded.

IV. Guarantee for Purchase and Specific Task Contracts

1. IABG provides a guarantee against quality defects for 12 months. The contractual specifications establish the agreed final status. Supplementary or changing status details only become part of the agreed status if they are expressly declared in writing to be a part of the contract.
2. If the contract goods are demonstrably defective, IABG shall, at its option, within a commensurate period, supply a replacement or effect repairs. The customer has to inform IABG of complaints in writing without delay with a sufficiently detailed statement of the reasons. The customer shall be entitled to cancel the contract (rescission) or to reduce the remuneration or to undertake a replacement if IABG lets a reasonably set deadline elapse without effecting a replacement or without reworking the contractual object or if IABG is neither willing nor capable of correcting the fault or effecting a compensation delivery or if this is unreasonable for the customer. The cost reimbursement in the case of the replacement is restricted to the level necessary, at most up to the respective contractual order total.
3. The guarantee shall lapse if the contractual object is altered by the customer or by third parties unless such changes are not the cause of the faults occurring thereafter.
4. Guarantee statements in the sense of §§ 443, 639 of the German Civil Code only exist if such details have been designated expressly and in writing as guarantee.

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5. In the event of the existence of a legal defect the above-mentioned provisions shall apply accordingly.

V. Liability

1. In case of negligent breach of any material contractual duty, the liability of IABG shall be limited to an amount of € 25,000 or, insofar as 30 % of the order value is greater, to the amount resulting therefrom, up to a maximum of € 150,000. In other respects, the liability of IABG is excluded.
2. The above exclusion of liability shall not apply to personal injury or if the damage caused results from gross negligence or wilful acts or if such is based on liability arising from the Product Liability Law (ProdHaftG), from any guarantee or any other mandatory statutory provisions.
3. In no case shall IABG be liable for non-foreseeable damage, lack of economic success, indirect and consequential damage (in particular financial damage), as well as any damage arising from claims by third parties insofar as such liability is not a mandatory requirement of law, such as in case of wilful acts.
4. The above provisions shall apply accordingly in case of
 - default
 - damages resulting from defects
 - reimbursement for alleged costs and expenses.

5. For negligently caused material damage to specimens and test equipment made available to IABG under the contractual provisions, including test units provided, IABG liability is limited to the extent of the insurance cover concluded by IABG, at most € 2.5 million, in as far as individual values or production costs of the respective specimen and test units do not exceed € 2.5 million (maximum value). Should the maximum value be exceeded, the customer is obliged to inform IABG in writing of the higher total value of the specimens and testing units made available to IABG under the contractual provisions in due time before conclusion of the contract. The parties will in this instance agree the liability/insurance cover individually; if this does not occur, IABG liability for simple negligence is restricted to € 250,000 at most. For infringement of the notification obligation, IABG liability is excluded, in as far as this legally permissible.

VI. Infringement of Industrial Property Rights

1. Should the utilisation of the contract goods by the customer in accordance with the contract result in the infringement of an industrial property right, IABG shall indemnify the customer against all financial obligations that have been declared by final decision of a court of law or that have been arrived at by way of composition proceedings with the prior written consent of IABG. The pre-requisite hereto is that the customer notifies IABG immediately in writing of all claims made against him and gives IABG the authority to conduct litigation and gives IABG comprehensive support. The indemnity obligation of IABG is restricted to those expenses which are necessarily incurred by the customer as a result of or in conjunction with the take-up of the claim by third parties.
2. IABG is entitled, at its own option, to give the customer the right to continue to use the contractual object, to replace the contractual object or to change it to the extent that a property rights infringement no longer exists. If the above-mentioned measures are not feasible for IABG at economically commensurate conditions, IABG is entitled to terminate the contract. In as far as no intentional behaviour exists, claims above and beyond these by the customer are excluded.
3. In as far as the customer is responsible for the infringement of the industrial property rights, he indemnifies IABG against claims by third parties and reimburses the legal defence costs.

VII. Transport

The delivery and removal of the goods or of specimens is undertaken by the customer. Until the handover to IABG and from the return to the customer, the risk of an accidental destruction of the goods / the specimen is the responsibility of the customer. The customer has to obtain all the licenses and approvals from public authorities and others for the transport.

- VIII. German Law shall apply, in particular the German Civil Code, the German Commercial Code and German copyright law. The application of the provisions of the UN Sales Convention is excluded.



General conditions

1. General

Our proposal is issued using the IABG VAT-Reg. No. DE 129383387.

We assume that the value of the test specimen is less than 2.5 Mio. €. In case of a higher value, please inform us, to discuss a respective adaptation.

The responsibility for a secured supply chain in terms of the customs code lies in the hands of the customer.

Please deliver the test specimen to IABG, Einsteinstraße 20; 85521 OTTOBRUNN, GERMANY, dep. FS25 (Logistic Centre), phone +49 (0) 89 6088 2931, for registration. In case of test specimen brought along, please declare at the reception when entering our premises.

2. In addition for our clients based outside of Germany

Our Proposal is based on the assumption that IABG will obtain the official approval from the German Federal Office of Economics and Export Control (BAFA). To apply for the approval, we need all necessary information at least 2 month prior to your order.

All prices are subject to applicability of Reverse-Charge-Practise. If Reverse-Charge-Practise cannot be applied, all prices quoted are plus VAT valid at the time the service is provided.

3. In addition for our clients based outside of the European Union (EU)

To comply with the obligations of pre-declaration in terms of European Customs, all deliveries to IABG from outside the EU have to be announced to IABG at least 24 hours before they leave the country of origin outside the EU. In case of a missing or delayed announcement shipments might be withheld at customs. This could lead to delays and additional cost for which IABG cannot be held responsible.

Prior to delivery of the test specimen to IABG premises we require the pro forma invoice and customs document (copy of ATLAS export declaration or CARNET ATA) for proof of export and in order to request a corresponding import customs procedure in Germany.