

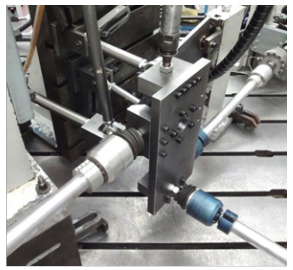
Testing. Understanding. Simulating

Material Characterization Excellence by Nemak Schaffhausen

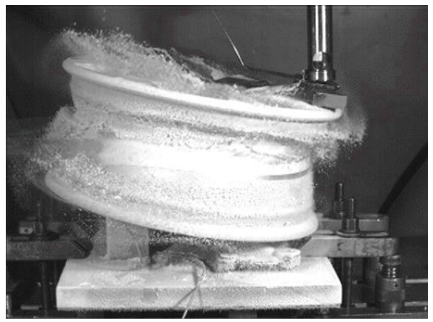
Schaffhausen Lab testing overview

- Certified & accredited testing lab (ISO 9001 / 17025)
- TISAX level 3 certification
- Testing equipment for samples, components & assemblies:
  - Static test (up to 600 kN) & mechanical material characterization
  - Multi-channel cyclic bench test (1-4 channels, up to 320 kN)
  - Impact test (up to 2700 J)
  - Boundary parts (adverse tolerance) testing & requalification of parts from new mould patterns & HPDC dies
- Analytics:
  - Salt spray corrosion test (-40…+70°C, Cap.: 2x1.5x0.7 m^3)
  - Fully-equipped metallography & microscopy
  - Scanning Electron Microscopy (SEM, EDX)
  - Chemical analysis
  - Dilatometry

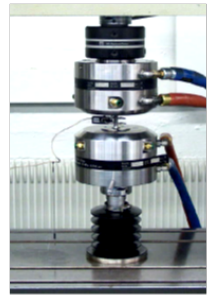




4-channel wheel carrier



Impact test



fatigue curves



Pendulum impact test



3D-scanner



Bending/shear test



Hardness testing machine

A Trusted Partner in Material Characterization

Nemak Schaffhausen offers comprehensive materials testing and characterization services through:

- Certified & accredited testing lab
- One-Stop solution for material and component validation
- Expertise in lightweight metals and casting technologies with experienced materials engineers and specialists
- In-house specimen manufacturing and workshop capabilities
- Advanced testing infrastructure
- Material data for simulation
- Advanced failure analysis
- Reliable external partners, where required



Our Promise

We do not simply deliver test results. We provide reliable engineering data that enables our customers to develop safer, lighter and more durable products with confidence.

Testing Expertise and State-of-the-Art Infrastructure

Nemak
Innovative Lightweighting

Standard tests e.g. for generating data sheets a/o for material specification conformity checks

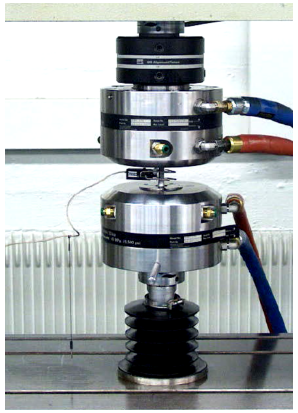
Mechanical Tests

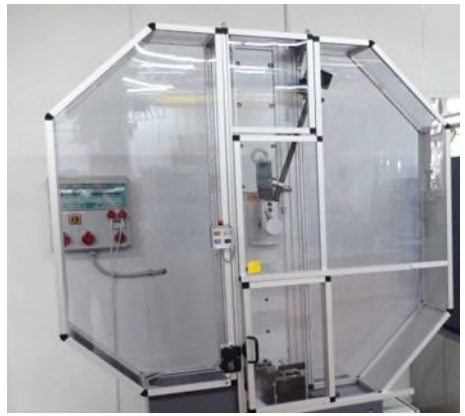
- Tensile tests D5-10mm (RT…950 °C)
- Compression tests
- Bending tests
- Hardness tests Brinell / Vickers / Rockwell
  - Low-load Vickers hardness (e.g. for microstructure homogeneity)
- Pendulum Impact tests 25/75/300 Joule (-50…+100 °C)
- Shear test (e.g. for welded samples)
- Creep-tests (up to 950 °C)

Fatigue Testing

- High-Cycle Fatigue (HCF)
- Low-Cycle Fatigue (LCF)
- Endurance testing
- Lifetime assessment


Tested samples


Fatigue tests


Pendulum impact test


Tensile test


Bending/ shear test


Hardness testing machine

Supporting in-house Workshop

Prototype Machining & Specimen preparation

- Complex geometries, test rig fixtures, material samples
- CAM milling centers (up to 800 x 500mm, 3-/5-axis available)
- Turning machine (dmax = 380mm)
- Grinding machine (working area 420 x 200mm)

Additional know-how and devices

- Assembly / joining (e.g. screws, press-in bearings, welding)
- Heat treatment test capabilities
- Welding for test rigs, metallographic welding evaluation



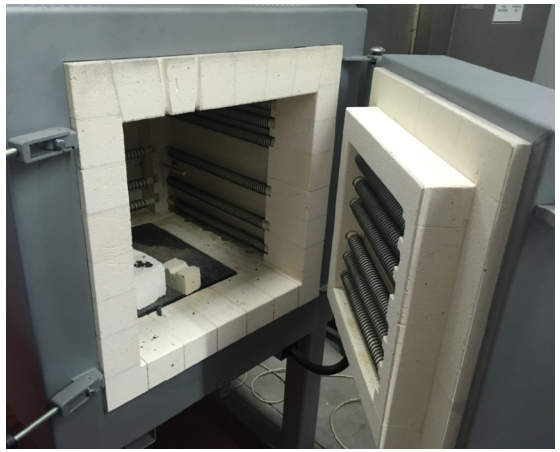
5-axis machining center



Turning machine



Prototype example (e-Housing)



Heat treatment furnace
(available in different sizes)

Testing Competency based on Reliable Data

Helping us understand your challenge to deliver tailored testing solutions and maximize value

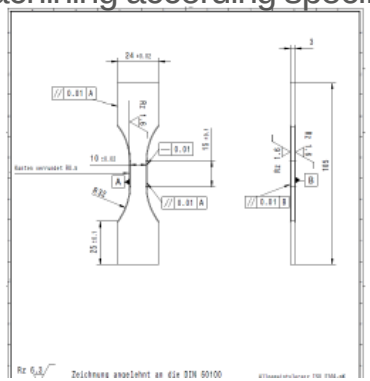
What we need from you

- Component information
  - Parts origin / customer / project
- Material information
  - Material designation and material condition
  - Alloy composition (could be done by the lab)
  - Specification information (real static mechanical properties could be done by the lab)

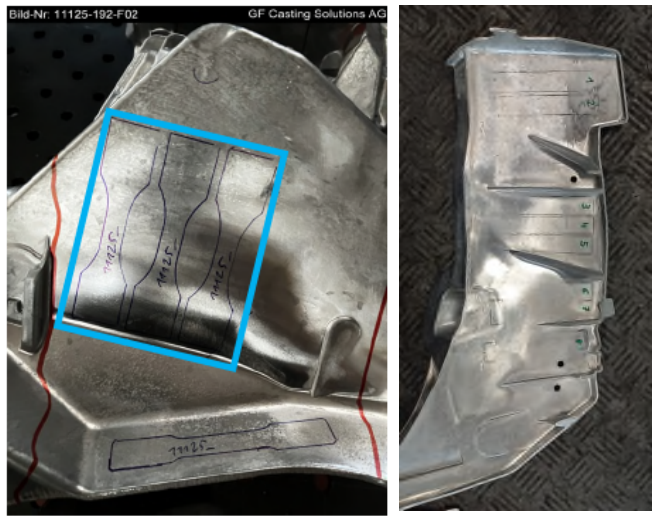
Sampling aligned für Al-HPDC

- Flat component areas (not curved)
- Continuous casting skin / vs machined surfaces
- Uniform thickness, no joints

Sample machining according specifications



Meaningful sampling positions



Static Load Testing

Testing of Fundamental Properties / Quality Control / Safety Verification



Testing machine 100 kN (Zwick Z100)

Software Testexpert II V 3.61

- Tensile test according to DIN EN ISO 6892-1
- Bending test according to DIN EN ISO 7438
- Shear test according to DIN EN 28749
- Test of welded connections



Prüfprotokoll

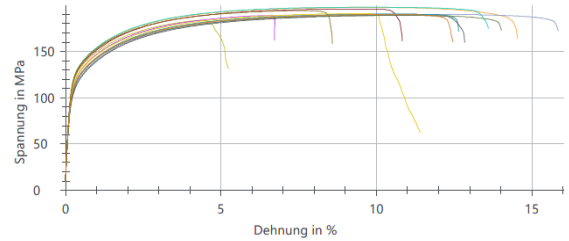
Kunde	: J. Hossinger		Probenentnahme	: M. Schmid
Projektnummer	: 100'112		Prüfer	: F. Edbauer
Auftrags-Nr.	: 100'112_JH_23-11		Datum	:
Prüfnorm	: DIN EN ISO 6892-1		Maschinendaten	: PE 191-05-06
Art und Bezeichnung	: GFPI Salt		Lufttemperatur	: 20.5°C
Werkstoff	: AlSi10MnMg		Luftfeuchtigkeit	: 45.8%
Probentyp	: DIN 50125 E3x8x30		Luftdruck	: 970.1hPa

Prüfgeschwindigkeiten	: Verfahren A(1)	
Vorkraft	: 10	MPa
Geschwindigkeit Streckgrenze	: 0.00025	1/s
Prüfgeschwindigkeit	: 0.0067	1/s

Prüfergebnisse:

Legende	Nr	ZL-Teil-Nr.	a_0 mm	b_0 mm	S_0 mm²	$R_{p0.2}$ MPa	R_m MPa	A_g %	A_{30mm} %	$A_{5,65}$ %	E GPa
	1	11053-08	2.73	8.02	21.89	129.71	197.71	9.37	14.29	14.96	64.29
	2	11053-10	2.73	8.02	21.89	130.01	197.98	9.43	13.36	13.89	67.26
	3	11053-11	2.76	8.03	22.16	127.69	195.99	9.14	10.61	10.80	66.65
	4	11053-21	2.72	8.02	21.81	127.53	183.58	3.99	5.05	5.20	61.53
	5	11053-23	2.67	8.02	21.41	123.18	188.82	6.22	6.48	6.52	64.32
	6	11053-29	2.69	8.02	21.57	129.91	194.12	7.21	8.37	8.54	67.66
	7	11053-06	2.71	8.02	21.73	114.48	190.04	11.49	15.60	16.18	65.99
	8	11053-12	2.71	8.02	21.73	117.29	190.50	10.13	12.41	12.73	67.41
	9	11053-14	2.74	8.02	21.97	113.37	189.16	10.59	12.61	12.89	65.30
	10	11053-17	2.71	8.02	21.73	122.86	190.90	9.05	11.34	11.66	64.87
	11	11053-19	2.69	8.02	21.57	118.00	189.13	10.44	13.77	14.25	65.25
	12	11053-20	2.67	7.97	21.28	118.74	189.99	9.86	12.24	12.61	67.52

Seriengrafik:



Statistik:

Serie n = 12	a_0 mm	b_0 mm	S_0 mm²	$R_{p0.2}$ MPa	R_m MPa	A_g %	A_{30mm} %	$A_{5,65}$ %	E GPa
$\bar{x}$	2.71	8.02	21.73	122.73	191.49	8.91	11.34	11.69	65.67
s	0.03	0.01	0.24	6.22	4.20	2.11	3.20	3.37	1.80

Example tensile test protocol

Static Load Testing

Hardness Measurements for fast Process & Quality Control



Hardness testing machine
EMCO Dura Vision 300

- Brinell (DIN EN ISO 6506)
  (ø2.5 mm, 5 mm and 10 mm)
- Vickers HV30 (DIN EN ISO 6507)
- Rockwell (DIN EN ISO 6508)

Scope of Application

- Incoming inspections, certificates & quality control
- Process monitoring, e.g. quick-check – indication for heat treatment
- Materials characterization, e.g. estimation of tensile strength, support for material cards
- Assessment of wear and service life

Analytics & Further Laboratory Competencies

Chemical Analysis

- LECO combustion analysis for sulphur & carbon content
- OES (Optical Emission Spectrometry)
- X-Ray diffractometry (reactivable)







	DI	Analysis	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Sr	Ca	Na	P	Zr	Pb	V	Mo
			%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
AlSi10MnMg + N_2 & Salz (Serie)	**0.89**	**GFSH**	**9,9**	0,12	0,005	**0,54**	**0,24**	0,01	0,00	0,01	**0,055**	**0,010**	0,001	0,000	0,002	0,010	0,002	0,009	0,002
		Specification range	*9,5-11,5*	*<0,14*	*<0,03*	*0,5-0,8*	*0,26-0,35*	*<0,03*	*<0,03*	*<0,05*	*0,04-0,09*	*0,01-0,02*	*<0,002*			*<0,03*			
AlSi10MnMg + Ar	**0.65**	**GFSH**	**10,3**	0,11	0,004	**0,54**	**0,25**	0,00	0,00	0,01	**0,053**	**0,010**	0,000	0,000	0,002	0,013	0,002	0,008	0,005
		Specification range	*9,5-11,5*	*<0,14*	*<0,03*	*0,5-0,8*	*0,26-0,35*	*<0,03*	*<0,03*	*<0,05*	*0,04-0,09*	*0,01-0,02*	*<0,002*			*<0,03*			
AlSi10MnMg-1Rec Heneken	**0.8**	**GFSH**	**10,0**	**0,21**	0,013	**0,58**	**0,23**	0,01	0,01	0,01	**0,092**	**0,003**	0,000	0,000	0,002	0,005	0,004	0,011	0,000
		Specification range	*9,5-11,5*	*0,18-0,20*	*<0,03*	*0,5-0,8*	*0,26-0,35*	*<0,03*	*<0,03*	*<0,05*	*0,04-0,09*	*0,01-0,02*	*<0,002*			*<0,03*			

Example OES - Analysis

Scope of Application

- Material specification
- Incoming goods inspection
- Supplier Evaluation
- Materials characterization & failure analysis

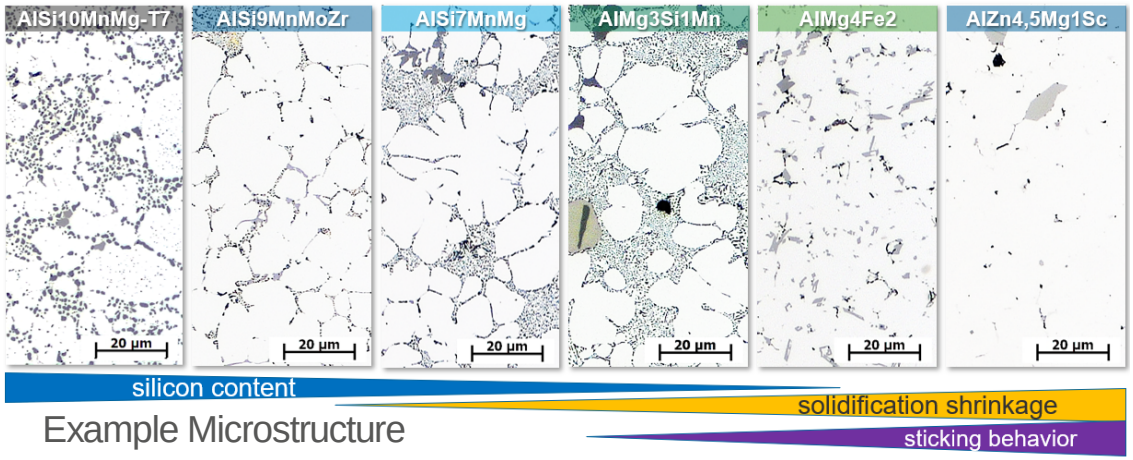
Analytics & Further Laboratory Competencies

Metallography

- Fully equipped sample preparation (cutting, embedding devices, impregnation, etching)
- Grinding/polishing automat
- Zeiss light microscope
- Stereomicroscope, Keyence digital microscope

Scope of Application

- (Fracture) surface investigations
- Microstructure analysis & quantitative evaluation
- Porosity analysis
- Evaluation of heat treatment
- Investigation of intermetallic phases



Example Microstructure





Material Characterization

Documentation – Example: HCF Bench test samples

Fracture locations after testing

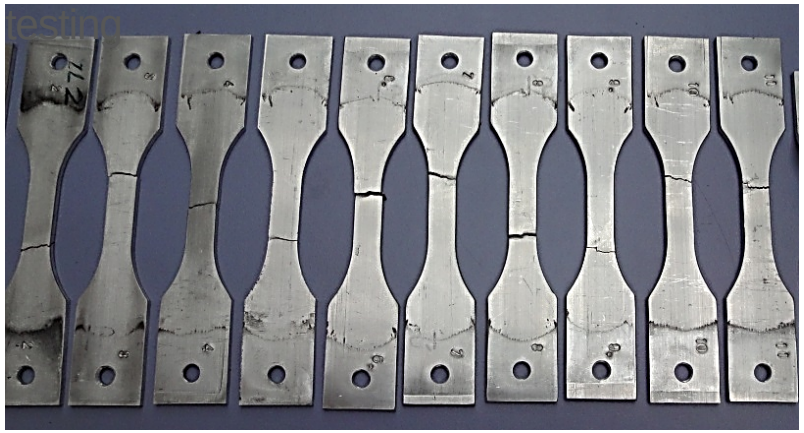
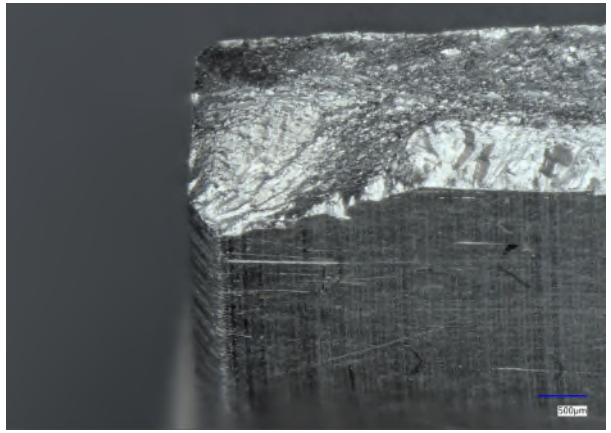


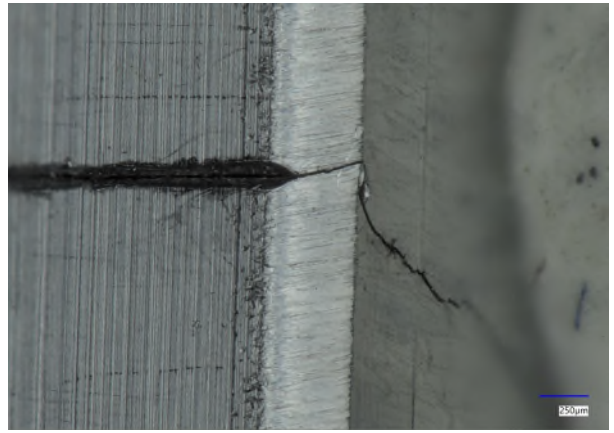
Foto-Documentation

Fracture surface analysis



Stereomicroscopy

Crack propagation assessment

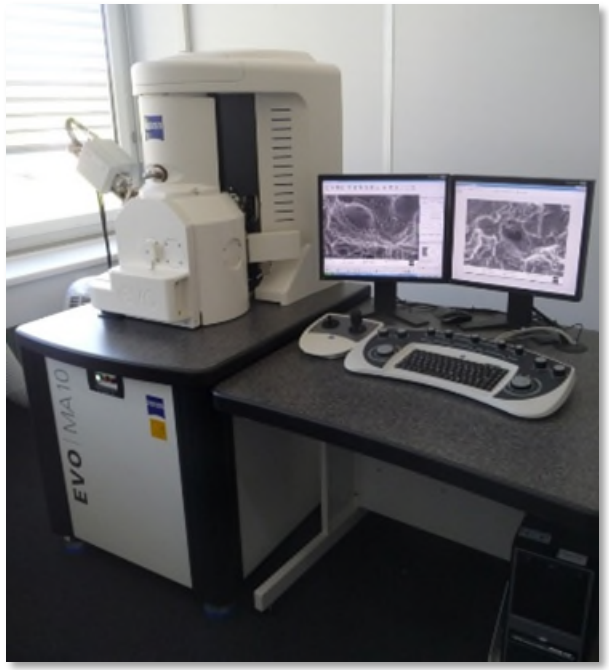


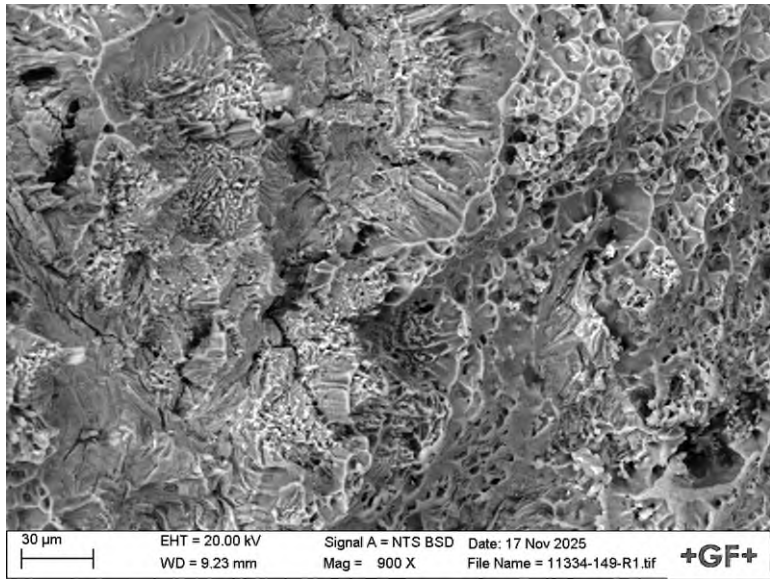
Stereomicroscopy

Material Characterization

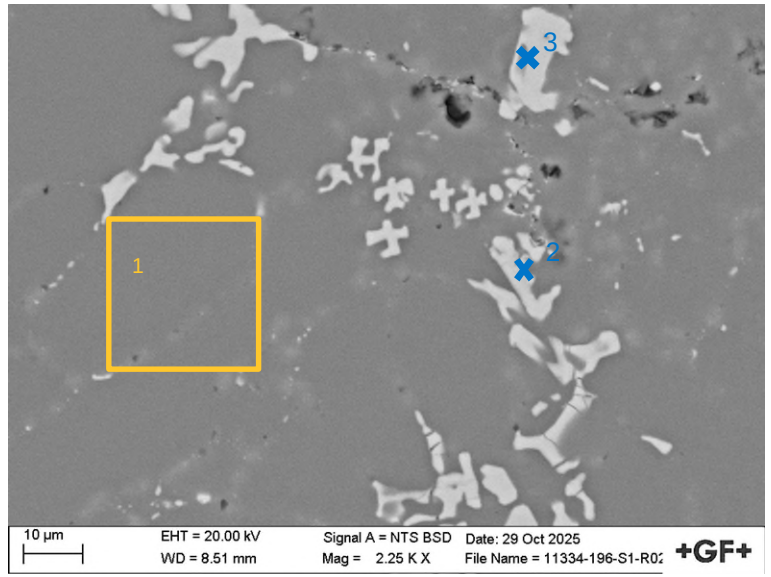
SEM & EDX – Energy Dispersive X-ray Spectroscopy

Zeiss Scanning Electron Microscope with EDX for chemical composition check on microscopic small objects/ defects on surfaces, e.g. for failure analysis of components





Example fracture surface

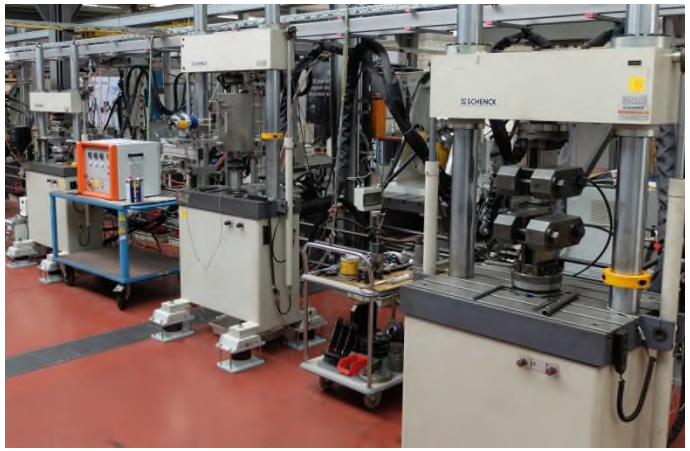


Example phase segregation of a polished sample: EDX-Analysis

Weight -%	C	O	Mg	Al	Si	Mn	Fe
11334-195-S1(1)_pt1	1.48	0.39	0.30	88.83	9.01		
11334-195-S1(1)_pt2	4.84			56.30	9.40	23.50	5.95
11334-195-S1(1)_pt3	7.90			54.35	9.19	23.19	5.38

Servo Hydraulic Test Benches

Determination of Fatigue Strength and S-N Curve Testing for Material Cards

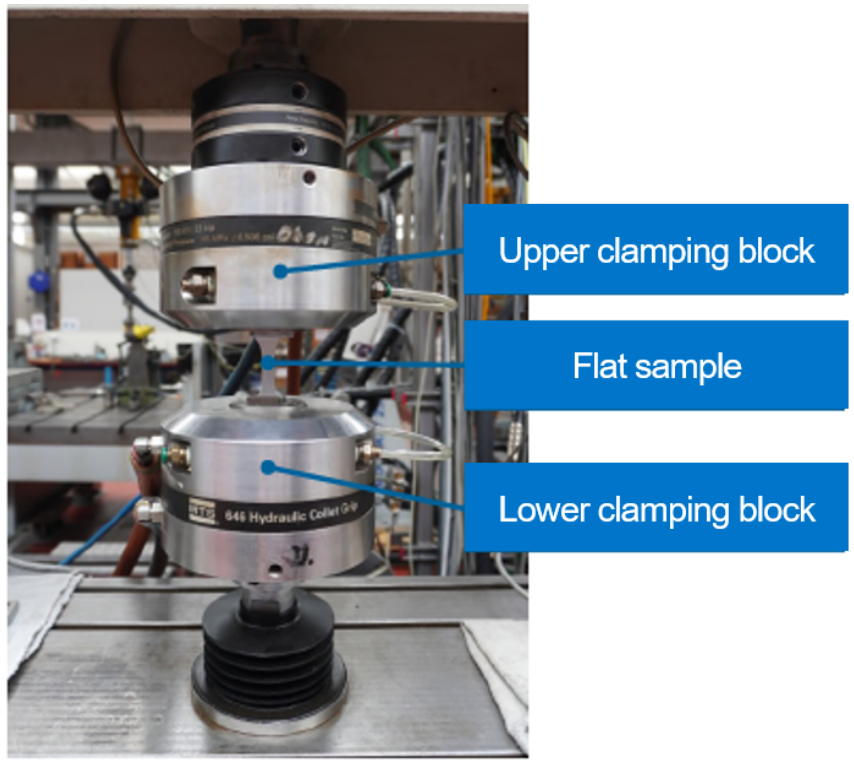


Servo Hydraulic Testing Machine Schenk / IST

Available testing machines:

- 50 kN, 150 kN and 200 kN
- Displacement: ± 50 mm
- Frequency: up to 60 Hz
- LCF testing (Iron castings)

Software: Instron 8800



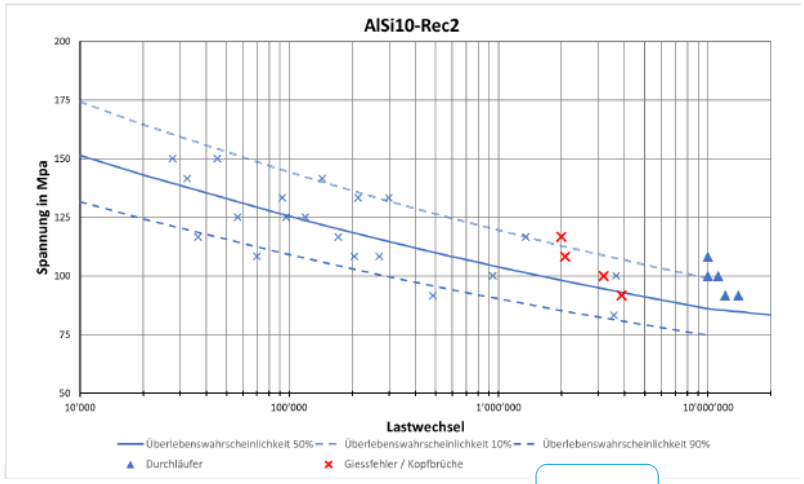
Example HCF-test for AlSi10MnMg

- Clamping of flat-beam specimens using hydraulic clamping chucks
- Sinusoidal load application
- Test frequency 20 – 45 Hz
- Freely selectable stress ratio e.g. R=-1 / R=0 / R=0,1 / notched samples
- Shutdown criterion is a rupture or >10 million load cycles (run-through)
- Fracture location and fracture surface analysis after testing
- List of test equipment and proof of accreditation included with the report

Fatigue Strength and S-N Curve Testing

Parameters and Evaluation

ZL-Nr.	Breite in mm	Dicke in mm	Kraft in kN	Spannung in MPa	Lastwechsel	LOG Sp	LOG LW	D/B	Bemerkung
11125-110.1	10.00	3.00	3.00	100	3'643'532	2.00	6.56	B	Bewerten OK 1
11125-110.2	10.00	3.00	3.25	108	269'169	2.03	5.43	B	Bewerten OK 2
11125-110.3	10.00	3.00	3.50	117	1'345'979	2.07	6.13	B	Bewerten OK 2
11125-111.1	10.00	3.00	4.50	150	45'258	2.18	4.66	B	Bewerten OK 2
11125-111.2	10.00	3.00	4.25	142	32'376	2.15	4.51	B	Bewerten OK 3
11125-111.3	10.00	3.00	4.00	133	298'350	2.12	5.47	B	Bewerten OK 1
11125-112.1	10.00	3.00	3.75	125	96'186	2.10	4.98	B	Bewerten OK 2
11125-112.2	10.00	3.00	4.00	133	92'280	2.12	4.97	B	Bewerten OK 2
11125-112.3	10.00	3.00	4.25	142	143'535	2.15	5.16	B	Bewerten OK 1
11125-113.1	10.00	3.00	3.00	100	937'749	2.00	5.97	B	Bewerten OK 1
11125-113.2	10.00	3.00	3.50	117	171'184	2.07	5.23	B	Bewerten OK 3
11125-113.3	10.00	3.00	2.75	92	14'000'000	1.96	7.15	D	Nicht bewerten
11125-114.1	10.00	3.00	2.75	92	12'108'489	1.96	7.08	D	Nicht bewerten
11125-114.2	10.00	3.00	3.00	100	11'196'783	2.00	7.05	D	Nicht bewerten
11125-114.3	10.00	3.00	3.25	108	10'023'728	2.03	7.00	D	Nicht bewerten
11125-115.1	10.00	3.00	3.75	125	119'043	2.10	5.08	B	Bewerten OK 2
11125-115.2	10.00	3.00	4.50	150	27'539	2.18	4.44	B	Bewerten OK 3
11125-115.3	10.00	3.00	4.00	133	212'805	2.12	5.33	B	Bewerten OK 3
11125-127.1	10.00	3.00	2.50	83	3'562'378	1.92	6.55	B	Bewerten OK 3
11125-127.2	10.00	3.00	2.75	92	485'390	1.96	5.69	B	Bewerten OK 3
11125-127.3	10.00	3.00	3.00	100	3'185'129	2.00	6.50	B	Nicht bewerten KB
11125-128.1	10.00	3.00	3.25	108	69'872	2.03	4.84	B	Bewerten OK 4
11125-128.2	10.00	3.00	2.50	83	10'000'000	1.92	7.00	D	Nicht bewerten
11125-128.3	10.00	3.00	3.25	108	2'083'711	2.03	6.32	B	Nicht bewerten KB
11125-136.1	10.00	3.00	3.50	117	36'548	2.07	4.56	B	Bewerten OK 4
11125-136.2	10.00	3.00	2.75	92	3'880'492	1.96	6.59	B	Nicht bewerten KB
11125-136.3	10.00	3.00	3.50	117	1'993'028	2.07	6.30	B	Nicht bewerten KB
11125-147.1	10.00	3.00	3.75	125	56'346	2.10	4.75	B	Bewerten OK 2
11125-147.2	10.00	3.00	3.25	108	204'456	2.03	5.31	B	Bewerten OK 3
11125-147.3	10.00	3.00	3.00	100	10'000'000	2.00	7.00	D	Nicht bewerten



k = 12.2

Zeitfestigkeitsbereich

$Regressionsgerade\ m = \frac{\log(S)-\log(SD)}{\log(N)-\log(ND)}$ wobei S die Spannungsamplitude und N die Schwingspielzahl sind

Die Regressionsgerade m und der Achsenabschnitt c können in Excel mit den Funktionen «STEIGUNG» bzw. «ACHSENABSCHNITT» berechnet werden.

$Steigung\ k = -\frac{1}{m} = -\frac{1}{\frac{\log(S)-\log(S_D)}{\log(N)-\log(N_D)}} = -\frac{\log(N)-\log(ND)}{\log(S)-\log(SD)}$ wobei m die Regressionsgerade der Wöhler-Kennlinie ist

Dauerfestigkeitsbereich

$Steigung\ k_2 = k * 2 - 1$ wobei k die Steigung im Zeitfestigkeitsbereich ist

Berechnung Überlebenswahrscheinlichkeit 10% / 90%

$$\text{Streuung (Standardabweichung) } s = \left[\frac{1}{(n-1)} * \sum_{i=1}^{n} (\log(N_i) - \log(N_{50\%\ n}))^2\right]^{1/2}$$

wobei n die Anzahl der gültigen geprüften Proben ist



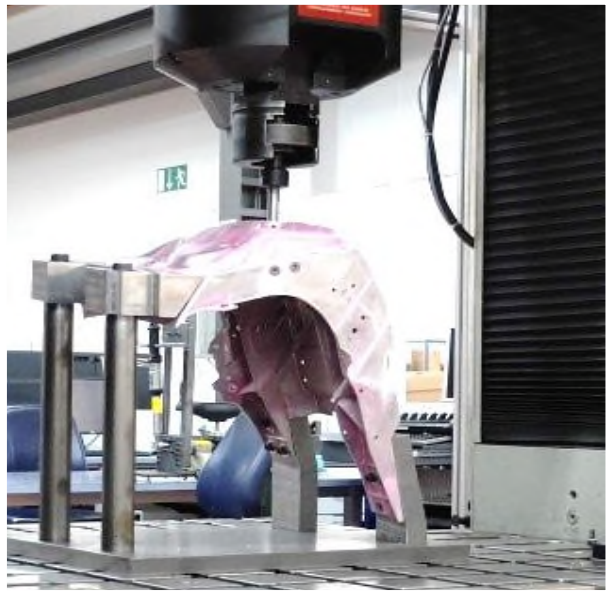
$Streuspanne\ T_N = \frac{1}{10^{2.56*s}}$ wobei s die Streuung (Standardabweichung) ist

Quelle: Prof. Dr.-Ing Erwin Haibach. *Betriebsfähigkeit Verfahren und Daten zur Bauteilberechnung*. VDI-Verlag GmbH

Parts Testing - Static Load Bench Test

Features of available assets:

- Force max. 600 kN, displacement max. 1000 mm
- Realization of bending, shear, push or pull tests
- Documentation of deformation till fracture
- Possibility of test recording by high-speed camera
- Applicable e.g. for quasi-static crash tests on complex parts such as shock towers, battery frames, subframes, A-pillars, support brackets, longitudinal members, pull-out tests on screws

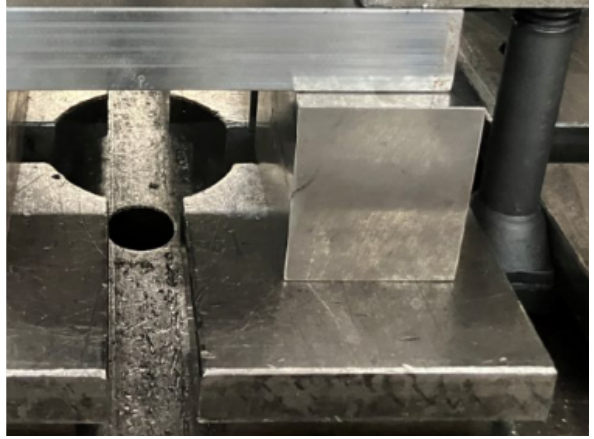












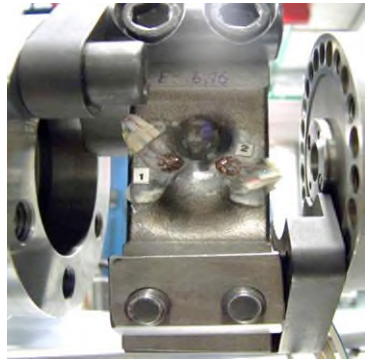
Parts Testing - Cyclic Load Bench Test

Service load collectives including:

- Force max. 320 kN
- Torque max. 500 Nm
- Displacement max. 250 mm
- Frequency max. 60 Hz
- 1-channel endurance bench test
- Fluid pressure test max. 10 bar
- Possibility of recording temperature rise during testing (thermal imaging camera)
- Verification of numerical simulation and validation (depicted below)



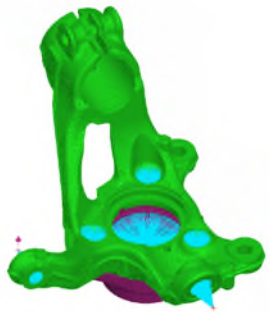
1-channel bench test for chassis parts

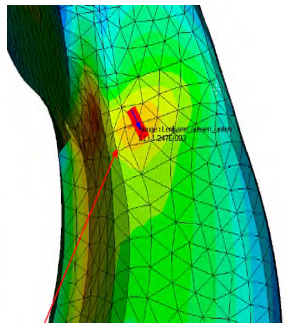


Torque- / spherical test specimen



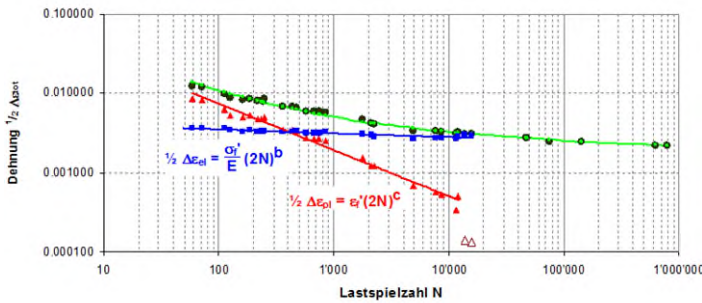
1-channel bench test passenger car knuckles / wheel carriers







Numerical simulation setup of a passenger car front knuckle



E-N- fatigue curves

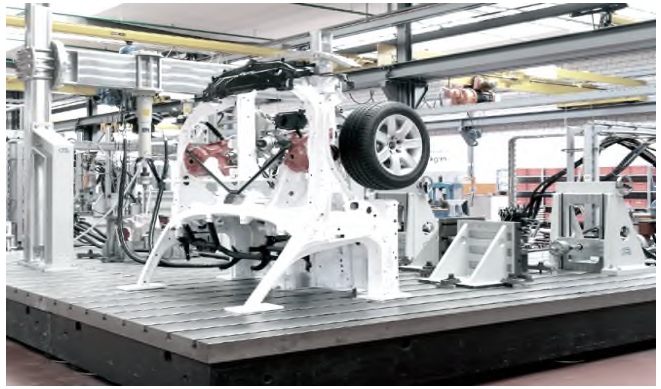
Multi-Channel Cyclic Load Bench Test

Service load collectives including:

- Force max. 400 kN
- Displacement max. 250 mm
- Frequency max. 60 Hz
- System testing
- Component testing
- Sub-component testing
- Environmental test:
  stress corrosion (salt spray)

Multi-channel tests:

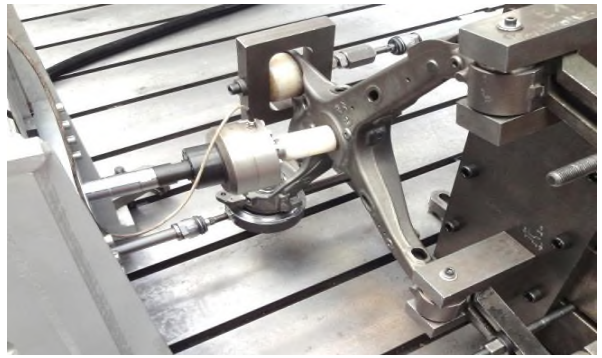
- Up to 4-channels in x/y/z directions
  with varying frequencies



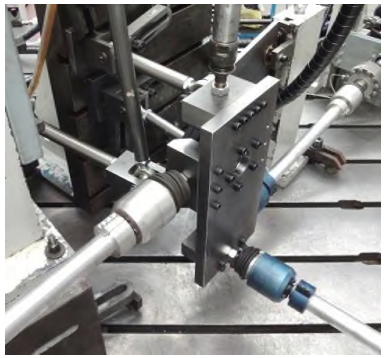
Shock tower system test



4-channel chassis test



Trailing arm 2-channel component test

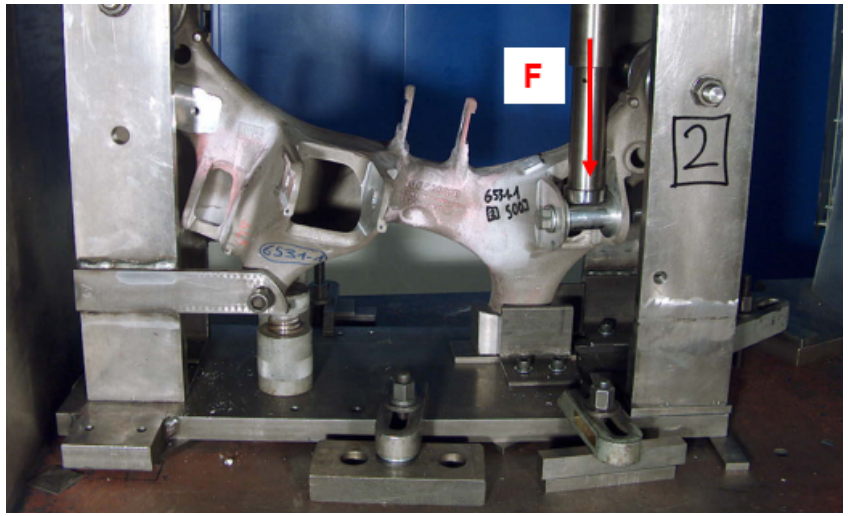


4-channel wheel carrier

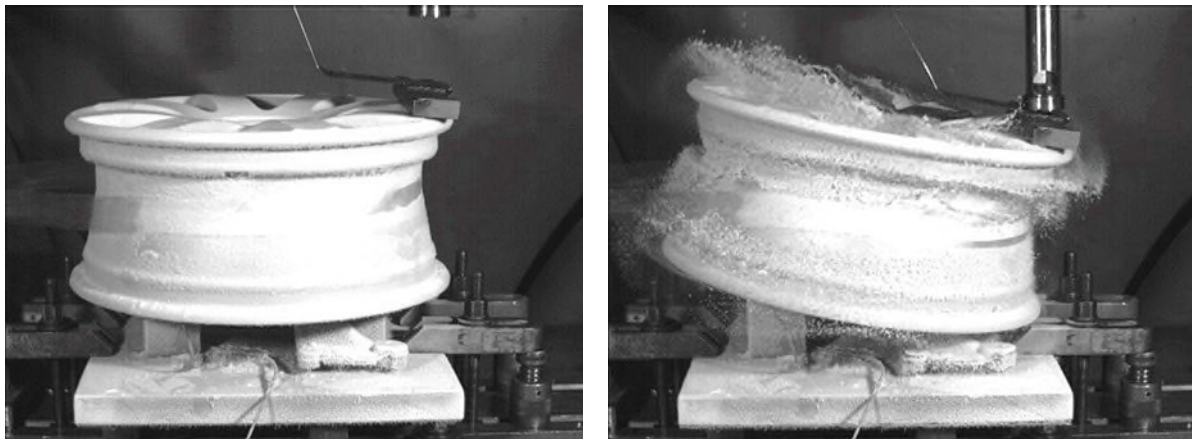
Impact Test

Test framework fits standard samples, segmented / complete components a/o subassemblies

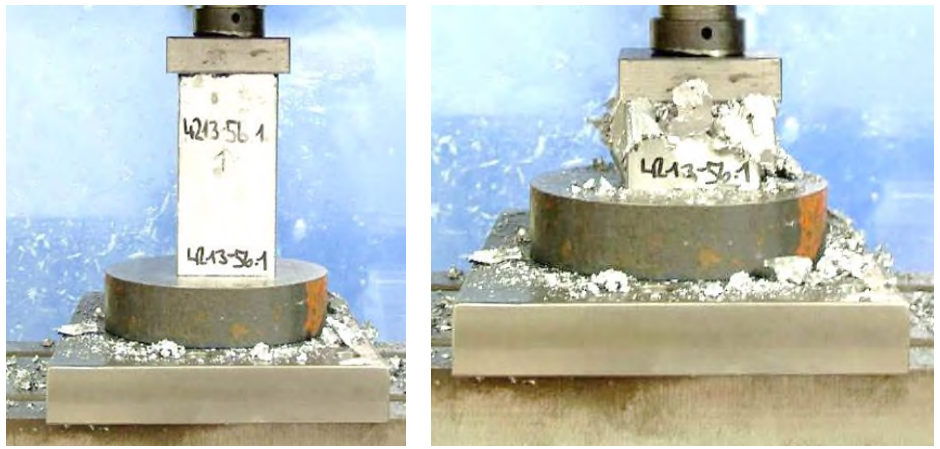
- Simulation of crash load cases → impact energy max. 2700 J
- Load cell 200 kN
- Max. height 2.69 m
- Velocity max. 7.2m / sec
- High speed video recording
- Data recording 100 kHz
- Temperature min. -40° C



Impact test setup for subframe kinematic points



Impact test of aluminum rims mounted on cast iron knuckles



Impact test on standard metal samples

Measurement Technology

Further equipment & applications

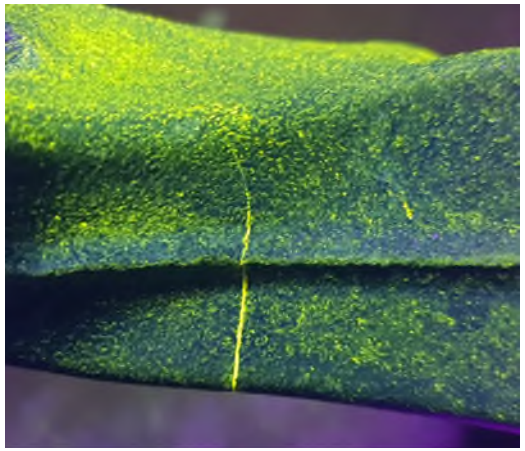
- 3D scanner for e.g. check on deformation after test, results usable for reverse engineering
- Eigen frequency analysis
- Ultrasonic test: Young's Modulus of castings
- Screwing station: test on screwing force, thread fracture force, comparison of differently coated screws
- Roughness measurement
- Light/Scanning Electron Microscope: check for crack-inducing surface/material defects
- Crack test:
  - dye penetrant test
  - magnet particle test



Test setup for screwing test



3D-scanner



Crack test

Further Laboratory Competencies

Salt spray corrosion test

- Capacity: 2,1 m 1,5 m x 0,76 m / 2000 L / 500 kg
- -40…+70°C, varying humidity



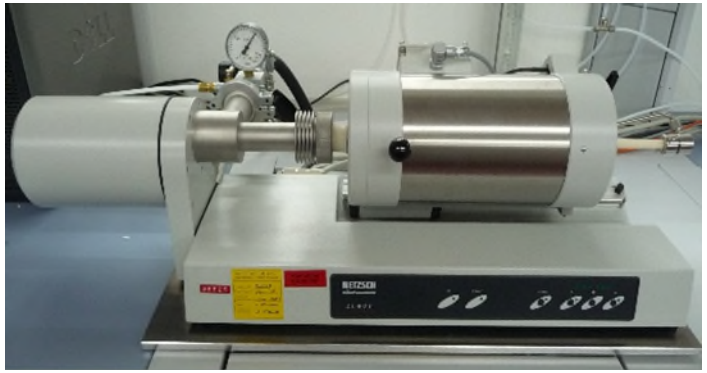
Corrosion chamber



Corrosion test

Dilatometry

- Determination of the coefficient of thermal expansion
- Investigation of material phase transitions (heat treatment verification, check of material specification conformity)
- Determination of characteristic parameters for developing thermal material cards



Dilatometer

Examples of frequent component tests

Recurrent Tests on Prototypes, Pre-Series and Running Serial Parts

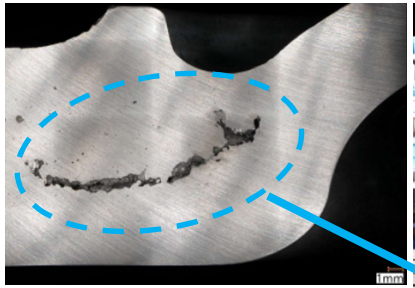
Plant asks for check of accordance to OEM spec. after detected peculiarity during production process

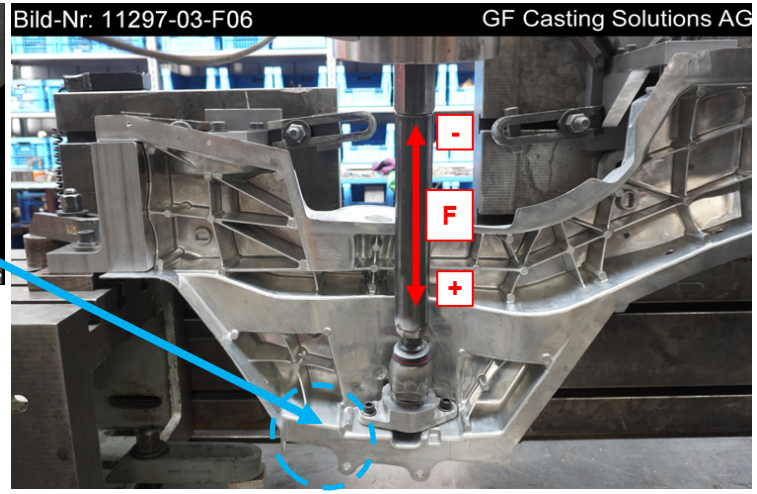
e.g.: X-ray (porosity), dimensional check (bearing tolerances)

Customer mandates re-validation of serial parts from new molds / tools / HPDC dies according to OEM spec.

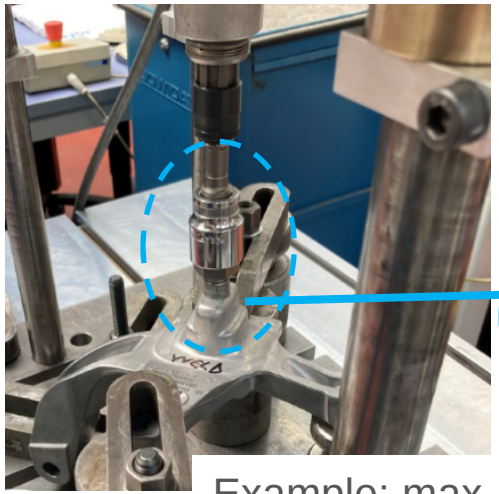
e.g.: in-cast insert tests, material properties, fatigue service tests

Boundary parts control





Requalification





Example: max. load screwing tests on inserts

Organizational Culture
Our foundations



Nemak
Innovative Lightweighting

Our Values
are not just words

CUSTOMER FOCUS
We are the strategic partner for our customers to add value and grow together as we evolve the mobility industry.

INNOVATION
We nurture an innovative mindset across disciplines to address our current and future challenges.

TRUST & COLLABORATION
Our working relationships are based on trust and collaboration, embracing diversity to deliver excellence and achieve our goals.

RESPECT & RESPONSIBILITY
We drive business growth while acting safely and responsibly towards our people, society, and the environment.



Nemak

Innovative Lightweighting

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