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HTR-E

High-Temperature Reactor Components and Systems

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Workpackage 3:
3.1 Experimental Validation

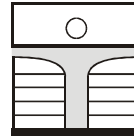
Experimental Test Program

Holger Stegemann

University Zittau/Görlitz

GERMANY

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EXPERIMENTAL TEST PROGRAM

Workpackage 3: The Large Capacity Magnetic Bearings

Task 3.1: Experimental Validation

Zittau, 02/29/2004

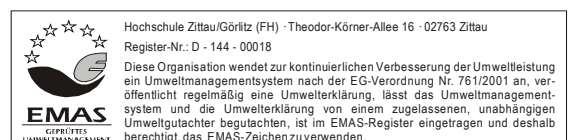
Zu erreichen:

Theodor-Körner-Allee 16 • 02763 Zittau

Tel.: (0 35 83) 61 0

Fax: (0 35 83) 51 06 26

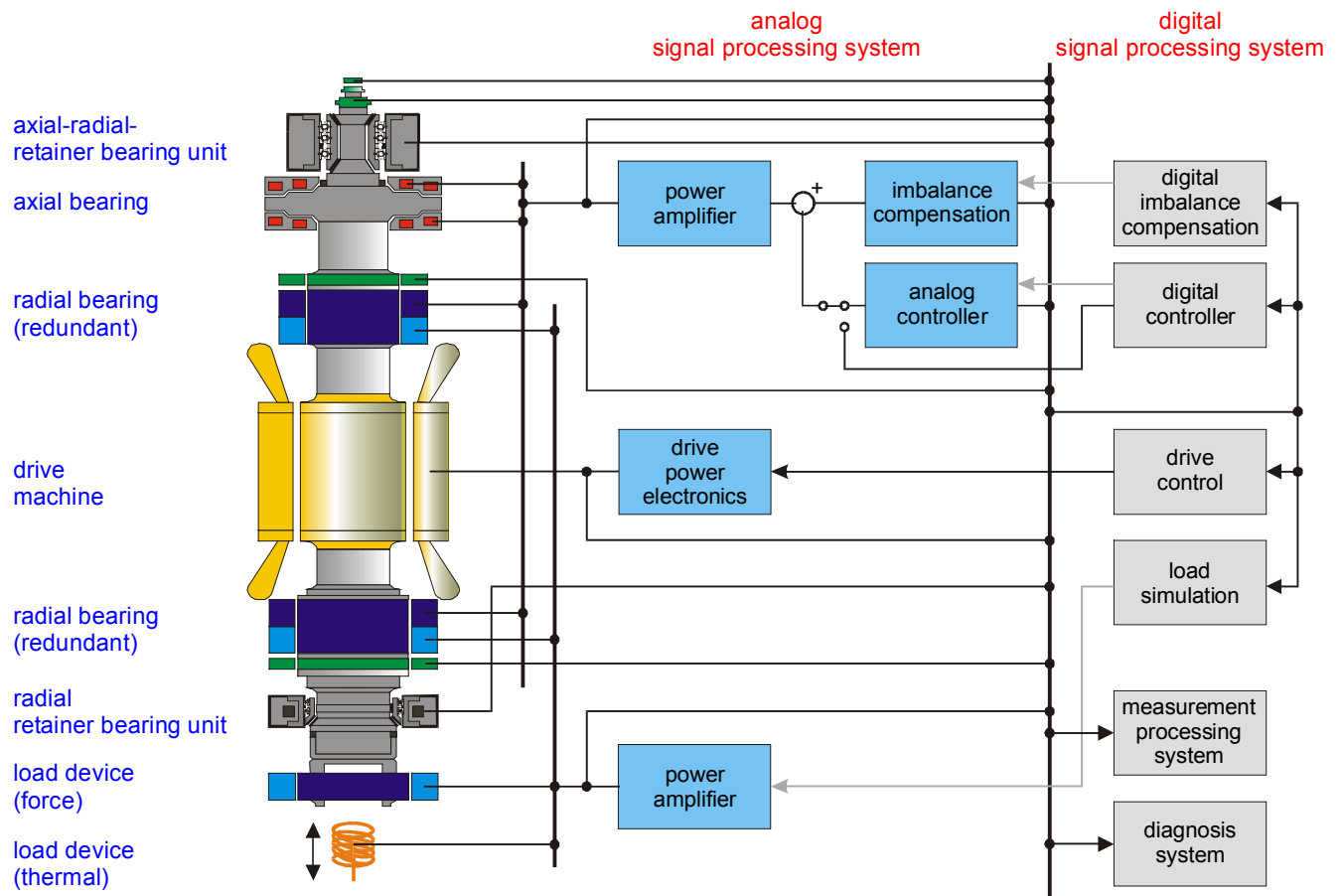
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EXPERIMENTAL TEST PROGRAM FLP500

Aim: Determination of static and dynamic limits of the AMB's with scaled boundary conditions of the HTR turbomachine

Source: Mechanical loads at the turbomachine
Document: HTR-E – AMB and CB – Functional Requirements
HTR-E-02/06-D-3-1-1
Description of the FLP500 (available in SINTER-Network)



Test facility FLP500

Load capacity FLP500:

upper radial AMB (redundant)	$0.6 \times 10^4 \text{ N}$
lower radial AMB (redundant)	$1.0 \times 10^4 \text{ N}$
mechanical load device	$1.0 \times 10^4 \text{ N}$

Load capacity GT-MHR:

radial AMB 1	$6.0 \times 10^4 \text{ N}$
radial AMB 2	$12.0 \times 10^4 \text{ N}$
radial AMB 3	$12.0 \times 10^4 \text{ N}$
radial AMB 4	$6.0 \times 10^4 \text{ N}$
radial AMB 5	$6.0 \times 10^4 \text{ N}$
radial AMB 6	$6.0 \times 10^4 \text{ N}$

Downscaling conditions

radial forces	downscaled 10:1 regarding the load capacity of the radial bearings GT-MHR : FLP500
frequencies:	original

Tests	Requirements GT-MHR	Test Conditions FLP500	Expected Results
1. mechanical loads	– radial forces due to turbomachine rotor unbalance 0.1 G – radial electromagnetic forces caused by eccentricity of the rotor in the generator stator (acting only on radial bearings n° 2 and n°3) 0.85x10⁴ N – resonance frequencies range 0-60 Hz – speed max 3600 rpm – AMB loading assessment (document HTR-E-02/06-D-3-1-1) max. 5.2 x10⁴ N	– radial loads with redundant radial AMB's (acting in primary AMB's level) max 0.6x10⁴ N and 1.0x10⁴ N – radial loads with magnetic load device (acting at lower shaft) max 1.0x10⁴ N – radial loads frequencies 0-60 Hz (static, dynamic, circulating forces) – speed max 7000 rpm	– determination of stability, rotor displacement, vibrations, cut-off frequency, time constants

Tests	Requirements GT-MHR	Test Conditions FLP500	Expected Results
2. test of controller and diagnosis algorithms	– assurance of maximum accuracy of shaft positioning in central position – quick response of AMBs to external impacts	– test of linear and non-linear controller algorithms – test of diagnosis algorithms – operating modes: start up, shut down, speed up to 3600 rpm, unbalances, external loads	CONTROL – stabilisation of rotor position – optimisation of controller parameters for maximal accuracy of shaft – control of stiffness and damping – short rise time and recovery time (quick response to external impacts) DIAGNOSIS – diagnosis of failures in sensors, actuators and controllers – determination of radial and axial forces (loads) internal: caused by unbalances external: caused by drive and driven machine – monitoring of limit values and gradients (rotor position, current) ⇒ verification of ability of tested control and diagnosis algorithms

Single Tests

Test	Condition
1. Mechanical loads	
1.1 static loads	radial load 850N – gradient: step, upper radial AMB (redundant) n=0 rpm PID controller radial load 850N – gradient: step, lower radial AMB (redundant) n=0 rpm PID controller radial load 850N – gradient: step, load device n=0 rpm PID controller radial load 850N – gradient: ramp, upper radial AMB (redundant) n=0 rpm PID controller radial load 850N – gradient: ramp, lower radial AMB (redundant) n=0 rpm PID controller radial load 850N – gradient: ramp, load device n=0 rpm PID controller radial load 850N – gradient: step, upper radial AMB (redundant) n=3600 rpm PID controller radial load 850N – gradient: step, lower radial AMB (redundant) n=3600 rpm PID controller radial load 850N – gradient: step, load device n=3600 rpm PID controller radial load 850N – gradient: ramp, upper radial AMB (redundant) n=3600 rpm PID controller radial load 850N – gradient: ramp, lower radial AMB (redundant) n=3600 rpm PID controller radial load 850N – gradient: ramp, load device n=3600 rpm PID controller

1.2 dynamic loads	
1.2.1 speed and unbalances	speed up n=0-3600 rpm different ramps for speeding up
1.2.2 external dynamic loads	radial load 850N – gradient: sinusoidal, frequency 0-60 Hz upper radial AMB (redundant) n=0 rpm PID controller
	radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, lower radial AMB (redundant) n=0 rpm PID controller
	radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, load device n=0 rpm PID controller
	radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, upper radial AMB (redundant) n=3600 rpm PID controller
	radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, lower radial AMB (redundant) n=3600 rpm PID controller
	radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, load device n=3600 rpm PID controller

2. Test of controller and diagnosis algorithms	
2.1 controller	PID controller start up
	PID controller speed up 0-3600 rpm
	Fuzzy controller start up
	Fuzzy controller speed up 0-3600 rpm
	Fuzzy controller static loads radial load 850N – gradient: step, upper radial AMB (redundant) n=0 rpm
	Fuzzy controller static loads radial load 850N – gradient: step, lower radial AMB (redundant) n=0 rpm
	Fuzzy controller static loads radial load 850N – gradient: step, load device n=0 rpm
	Fuzzy controller static loads radial load 850N – gradient: ramp, upper radial AMB (redundant) n=0 rpm
	Fuzzy controller static loads radial load 850N – gradient: ramp, lower radial AMB (redundant) n=0 rpm
	Fuzzy controller static loads radial load 850N – gradient: ramp, load device n=0 rpm
	Fuzzy controller static loads radial load 850N – gradient: step, upper radial AMB (redundant) n=3600 rpm
	Fuzzy controller static loads radial load 850N – gradient: step, lower radial AMB (redundant) n=3600 rpm
	Fuzzy controller static loads radial load 850N – gradient: step, load device n=3600 rpm

	Fuzzy controller static loads radial load 850N – gradient: ramp, upper radial AMB (redundant) n=3600 rpm
	Fuzzy controller static loads radial load 850N – gradient: ramp, lower radial AMB (redundant) n=3600 rpm
	Fuzzy controller static loads radial load 850N – gradient: ramp, load device n=3600 rpm
	Fuzzy controller dynamic loads radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, lower radial AMB (redundant) n=0 rpm
	Fuzzy controller dynamic loads radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, load device n=0 rpm
	Fuzzy controller dynamic loads radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, upper radial AMB (redundant) n=3600 rpm
	Fuzzy controller dynamic loads radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, lower radial AMB (redundant) n=3600 rpm
	Fuzzy controller dynamic loads radial load 850N – gradient: sinusoidal, frequency 0-60 Hz, load device n=3600 rpm
2.2 diagnosis	
2.2.1 failures	Test of diagnosis system <i>MLDia</i> – Determination of failures failures: gain, offset location: sensors, controllers, actuators
2.2.2 loads	Test of diagnosis system <i>MLDia</i> - Determination of loads loads: radial – internal (caused by unbalances) radial – external (caused by load device)
2.2.3 limits	Test of diagnosis system <i>MLDia</i> – Monitoring of limit values and gradients limits: rotor displacement, currents

Time Schedule

Task	03/ 2004	04/ 2004	05/ 2004	06/ 2004	07/ 2004	08/ 2004	09/ 2004	10/ 2004	11/ 2004	12/ 2004	01/ 2005	02/ 2005	03/ 2005
0. preparation of experiments - simulation of tests (MLDyn) - preparation of FLP500	x	x	x										
1. mechanical loads				x	x	x	x						
2. test of controller and diagnosis algorithms								x	x	x	x	x	x