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Information needs on "Turbine design and operating conditions" for the choice of high temperature materials and experimental tests conditions

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Introduction :

Following the description of Framatome work proposed by B. Riou on the "design use and specification" subtask concerning the turbine discs and blades, this document proposes a list of information that would be needed.

- To define the best candidate materials and the test matrix for blades and discs, in the frame of HTR-M project.
- To define further critical testing that would be needed to ensure an adequate turbine life (tests would be performed in the frame of HTR-M1 or 6th Framework Programme).

These requirements are issued from CEA experience on R&D projects dealing with high temperature properties of aero-turbines. This list should serve as a first basis for HTR turbine requirements, and it is foreseen that preliminary data will be provided in HTR-M (to select the best candidate materials) and more detailed information displayed in the frame of the HTR-E contract.

- **Turbine discs**

Required Information (for all stages)	**Consequences on material selection**
<u>Disc geometry :</u> - Overall dimensions - Disc profile - Bore ϕ (hub) - External ϕ (rim) - Attachments between discs (? bolts) - Required surface roughness - "Disc to shaft" assembly method - "Disc to blade" attachment type	Billet size, manufacturing route machining, drilling can induce a sensitivity to LCF
<u>Service conditions : (to be provided as graphs, plots)</u> - Temperature distribution (nominal speed) - Radial stress distribution (nominal speed) - Tangential stress distribution (nominal speed) - Axial stresses due to thermal gradients - Operating lifetime + life cycles (number of shutdowns, % of lifetime at different speeds, maintenance interval…)	*Disc design is usually limited by high temperature LCF properties of the alloy.* Alloy composition and heat treatment creep-fatigue and Low Cycle Fatigue conditions

- Possible over-temperature or over-speed (accidental conditions) with associated scenario	
<u>Design rules and mechanical criteria</u>	
General life assessment methodology (standards, design rules, 1D, 2D or 3D simulations?)	
List of possible critical defects (bore, hole, metallurgical defect)	critical defect size to control by NDE, metallurgical controls to perform during manufacturing
Critical mechanical criteria for design (? is creep or fatigue (or …) the limiting factor for design)	test matrix definition (more testing with the critical properties)
Minimum required ductility of alloys (non aged and aged conditions)	damage identification and modelling
Vibration analysis (critical speeds, possible failure location due to vibration)	HCF testing need and conditions
Cumulative damage laws needed (linear?)	life time models, remaining life calculation
Are stress relaxation properties important for design	
Fatigue and creep design rules (1% plastic deformation in creep?)	influences the creep tests to be conducted (? rupture tests or not)
How is thermal ageing considered and what is needed to take it into account (experimental tests) ?	
<u>Environment effect</u>	
Impurity level (? carburising or oxidising environment)	definition of the mechanical tests under “representative environment”
Possible plate-out by fission products	possible embrittlement by metallic fission products (Cs, Ag, Te)
Specific design criteria related to environment	
Recommendations on alloy composition (Co) due to plate-out	strong impact since most Ni-based superalloys contain Co

- **Turbine blades (rotating blades)**[1]

Required Information (for all stages)	**Consequences on material selection**
<u>Blade geometry :</u> Blade profile, exit angle Blade height and mass	choice of manufacturing process (casting + machining)
<u>Service conditions :</u> Temperature distribution (nominal speed) Radial stress distribution (nominal speed) Tangential stress distribution (nominal speed) Bending loads due to fluid / blade interactions Operating lifetime + life cycles (number of shut downs, % of lifetime at different speeds, maintenance interval…) Possible over temperature or over speed (accidental conditions) with associated scenario	*Blade design is usually limited by high temperature creep properties of the alloy.* creep-fatigue and LCF testing needs

[1] For turbine vanes (static blades), an evaluation of possible geometry, thermal and hydraulic stresses id needed for material and process selection.

Design rules and mechanical criteria	
General lifing methodology (standards, design rules)	
List of possible critical defects (metallurgical defect, machining)	critical defect size to control by NDE, metallurgical controls to perform during manufacturing
Creep design rules and damage assessment	creep tests conditions
Minimum required ductility of alloys (non aged and aged conditions)	damage identification and modelling
Vibration analysis	need for HCF testing
Environment effect	
Impurity level (? carburising or oxidising environment)	definition of the mechanical tests under "representative environment"
Possible plate-out by fission products	possible embrittlement by metallic fission products (Cs, Ag, Te)
Specific design criteria related to environment	
Recommendations on alloy composition (Co) due to plate-out	strong impact since most Ni-based superalloys contain Co