UT-TBM/BB-He

Task Title: HELIUM COMPONENTS TECHNOLOGY PROBLEMS AND OUTLINES OF SOLUTIONS

INTRODUCTION

For fusion reactors with Helium Cooled Lithium Lead blankets (HCLL concept), helium technology problems have been identified in 2003. Experiments have been proposed in the same fields as those undertaken for fission reactors. In a first step, the fields explored are tribology, thermal insulation, and leak tightness. Also, the circulator technology is experimentally addressed.

The tribometer was the first experimental device designed and started. So some interesting results had already been obtained and described previously in 2004. The new 2005 results are reported.

The thermal barrier experiment called HETHIMO (Helium THermal Insulation Mock-up) and the leak tightness experiment called HETIQ (Helium Tightness Qualification) were built during the first semester of 2004. After technical troubles, the tests have been postponed due to safety problems, which have been solved during 2005. The experiments will start in the beginning of 2006.

A side channel compressor is in operation, and tests, since the end of 2005.

2005 ACTIVITIES

TRIBOLOGY

The “CEA – He tribometer” is a “pins on rail alternative sliding tribometer”.

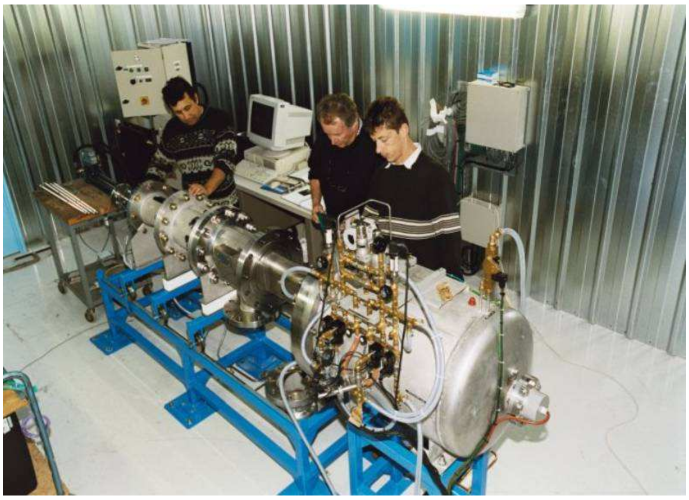


Figure 1: CEA tribometer

Figure 2: Set of bare specimen

The major characteristics of the He tribometer are:

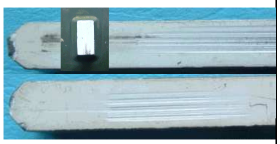
- Plane/plane contact (0,5 cm²),
- Alternative motion,
- Load: 0 – 20 MPa,
- Amplitude: up to 20 mm, Frequency: up to 6 Hz.
- Environment Parameters: temperature (up to 1000°C), steam, impurities

The main objectives of the CEA experimental program on tribology deal with the study of tribological situations in helium at high temperature (in the range of 500°C - 1000°C).

The table 1 reports the new results (in red), and results of former years, for comparison. We will only comment the 2005 results.

For the 75% (ZrO_2-Y_2O_3) + 25% CaF_2 / NiCrAlY coating (Classic plasma spraying): the tests were performed at 900°C and 5 MPa of contact pressure. The wear and the coefficient of friction (μ = 0.3) were low, but thermal dilatation between the coating and the substrate induced delamination of the coating.
The CERMET (Cr_3C_2 – NiCr) test is the only test in which the 5000 required cycles were performed. The tribological behaviour is very good, with a wear rate of 0.008 µm/cycle and a coefficient of friction lower than 0.3.
The SiC coating is too thin and too brittle, and the substrate too soft at 900°C to support the load of 5 MPa. This induced the failure of the coating.

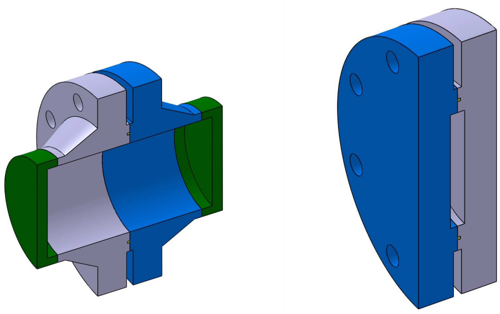
Table 1: Synthesis of the main results obtained during the CEA tribological program

Material	Temperature (°C)	Contact pressure (MPa)	Coefficient of friction	Nb of cycles	Wear	
HR 230	450	5	0,4	2600	-	
ZrO_2-Y_2O_3	800	5	0,6	1500	-	
	800	2	0,55	5000	+	
	1000	2	0,6	1000	- -	
ZrO_2-Y_2O_3+ 25% CAF2	900	5	0.27	1000	+	
LUBODRY	800	2	0,7	1000	- - -	
	500	5	0,5	1000		
	800	0,5	0,5	1000		
Cermet Cr_3C_2-NiCr	700	5	0.28	5000	++	
SiC	900	5	0.28	1000	- - -	

- -: total wear of coating, - -: high wear, -: significative wear, 0: mean wear, +: low wear, results of the year

LEAKTIGHTNESS

The objective of the program on static seals is to deal with two problems: fatigue and creep.
Fatigue tests simulate the effect of normal or incidental transients inducing structure temperature variations. They consist in thermally cycling the elements of the connection, either in phase, or out of phase, to take into account the individual thermal response of the elements, due to their time constants. The greatest effects might be found in flange connections between a valve and a pipe.
Creep tests consist in stabilizing the experimental conditions during a long time, and monitoring the leak rate.
Two tests sections have been built.



Cycling   Creep

Figure 3: Leak tightness experimental devices

The seal tested in 2005 is a 230 mm diameter HELICOFLEX (trade mark) seal, which is appropriate for a DN 200 piping. At the beginning of each test, the gap between the flanges is filled in with He at 40 bar, at room temperature. The system is then heated up to 500°. During the first step at 500°C, the pressure is adjusted to 100 bar. From this time, no addition or taking out of He is done. The seal leak rate is computed by using the pressure reduction rate measurement.
The environment parameters are the following:
Gas: Helium

Cycling:
- Temperature: from 20°C to 500°C,
- Ageing time at max temperature: 2 h and 24 h,
- Number of cycles: 10.

Creep:
- Temperature: 500°C,
- Ageing time: 500 and 5000 h.

The main results can be summarized as follows.

1- The disassembly capability of the seal is bad at the end of the cycling test (adhesion in the groove) and reasonably good for creep tests. A surface treatment may correct this without modifying the main characteristics and results.

2- When the nominal temperature and pressure are reached (500°C, 100 bar), the mean leak rate is typically $1x10^{-5}$ $Pa.m^3.s^{-1}$ and radial displacements induced by creep or thermal cycling do not affect the performances.

SIDE CHANNEL He COMPRESSOR

A side channel technology compressor has been designed for a helium mass flow rate of 150 $g.s^{-1}$ and a compression ratio up to 1.35. It has been built, and installed in a Cadarache loop, for characterization. It is typically the technology of helium compressor to be used in HCS (Helium Coolant System) for helium cooled TBM (Test Blanket Module) in ITER.

Figure 4: Side channel compressor (The He inlet is at the lower left, and the outlet is being fit by the operator)

The tests in progress aims at verifying the performances and at validating the technologies used for designing this compressor:
- side channel compressor stage
- immersed rotor and electrical motor
- synchronous electrical motor
- high pressure penetrations for electrical power and measurements.
- grease life lubricated ceramic ball bearings.

The first results obtained on the DIADEMO helium loop (CEA-Cadarache) during the last weeks of 2005 are very promising.

REPORTS AND PUBLICATIONS

[1] L. Cachon. « Tribomètre He – Frottement homogène de revêtement CERMET Cr_3C_2-NiCr sur sous couche NiCrAlY». CEA Technical report NT DEN/DTN/STPA/LTCG/05-054. Dec. 2005.

[2] G. Laffont al. « Preliminary Testing of Critical Technologies for Helium Technological Ring for High Temperature Gas Cooled System Technology Development». Global 2005.

[3] F. Witters « Report of experiments on helium technology with static benches -year 2005” CEA Technical report NT DEN/DTN/STPA/LTCG/05-076. Dec 2005

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