Cryotribometer

Key words

Tribology, friction, wear, low temperatures, hydrogen embrittlement

Fields of application

Measurement of friction coefficients and characteristic wear data as well as function and endurance tests at components in liquefied gases at temperatures as low as -269 °C, in particular in liquid hydrogen.

Methodology and instrumentation

Tribological model investigations: the test set-up consists of a rotating disc and a fixed pin (or ball) which is pressed against the face of the disc with a defined normal force. During the test the friction force is detected continuously. After the test the wear is measured by profilometry or gravimetry.

Components tests: function and lifetime of simple components (e.g. bearings) can be investigated.

Cooling: the test set-up is located inside an individually constructed, vacuum-superinsulated metal dewar and is cooled directly by a liquid coolant or by means of a heat exchanger.

Items tested

Model test configurations (pin-on-disc), sliding bearings, ball bearings, complete assemblies (e.g. pumps)

Quantities / characteristics tested

Friction coefficient, wear (linear, volumetric, gravimetric), lifetime, failure mechanisms

Uncertainty / reliability of results

Error of the force measurement < ± 1 %, error of the temperature measurement < ± 0.5 K
data scatter (friction coefficient): ± 5 % to ± 50 % depending on the material

Qualification and quality assurance

Both cryotribometers are unique in Europe.

They were designed and in most parts also constructed at BAM.

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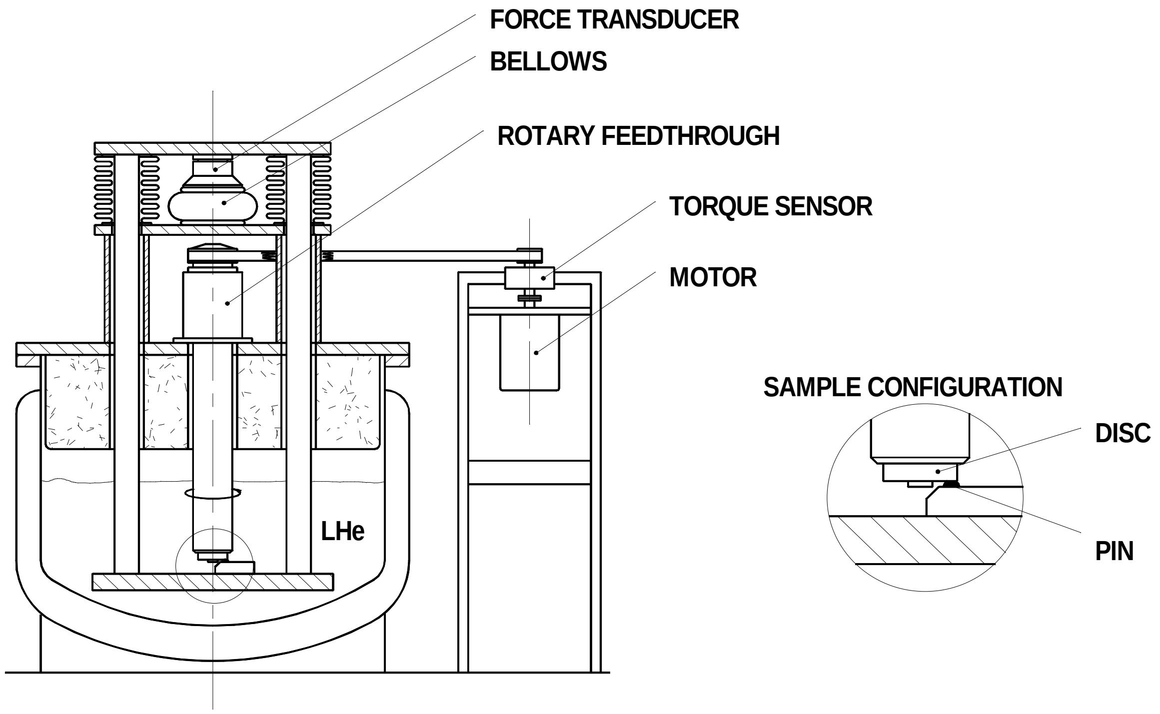
Further information

Cryogenic plants and machines (temperature range below approximately 120 K) often contain tribologically stressed components like bearings, face seals or piston rings. Because no liquid lubricants or greases can be applied at such low temperatures these tribosystems often create undesired heat and experience high wear. To meet such problems, solid lubricants or material combinations with good friction properties in unlubricated service must be employed. For the investigation of such materials special test devices (cryotribometers) and methods of measurement are developed and applied.

Test devices

The Cryotribometer CT 2 provides experimental conditions for tribological model tests in liquid cryogenic media like nitrogen (LN_2), hydrogen (LH_2), or helium (LHe). The test set-up is located inside a vacuum-insulated metal dewar which is operated as a bath-cryostat. Thus the set-up is completely immersed into the coolant and the temperature of the sample is the boiling temperature of the coolant. The normal force is applied by means of a load frame with the fixed sample mounted on his lower beam. This load frame is lifted upward by means of gas pressure applied to a rubber bellows or a lever with dead weight. This results in a mechanically stabile design and allows normal forces up to 500 N, with the drive unit, force and displacement sensors located in the warm part of the test rig. The driving shaft with the rotating sample at its lower edge is sealed by a ferrofluidic rotary feedthrough on the top flange of the cryostat and driven by a motor with a torque sensor via a belt drive.

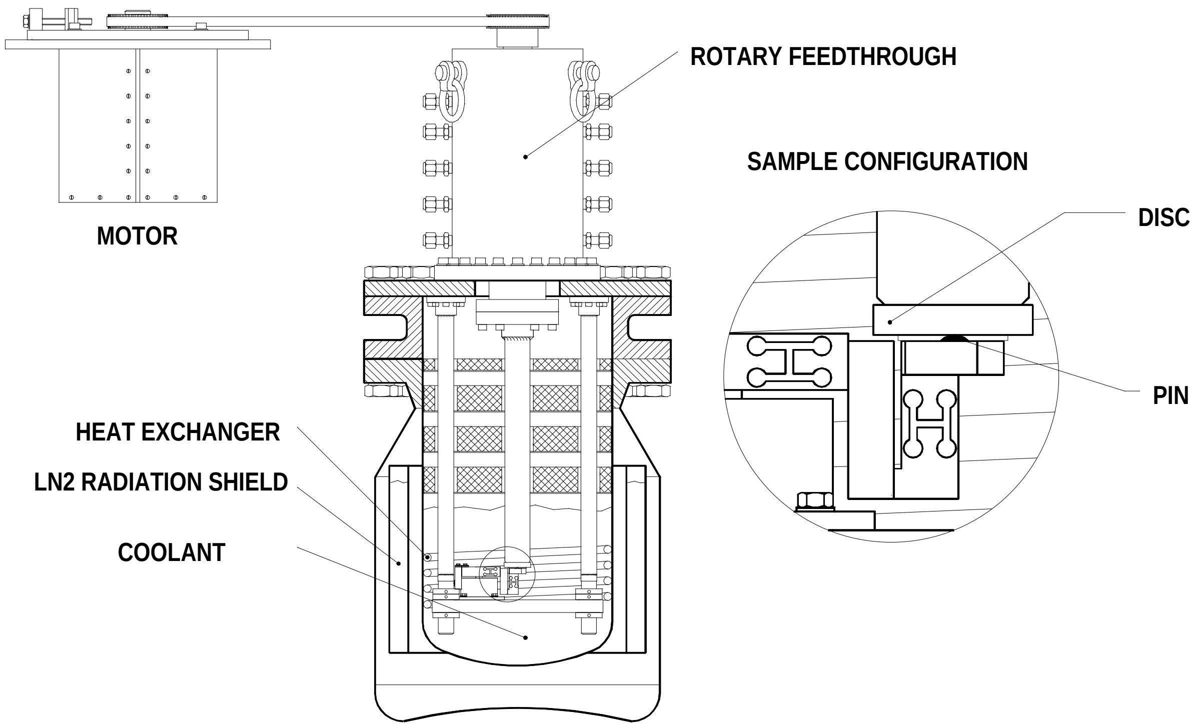


Technical data

sample chamber	geometrical volume: 147 l (max. coolant volume: 70 l) acceptable overpressure: 1 bar
body 1	cylinder or ball; Ø = 3 mm to 10 mm
body 2	disc; Ø = 42 mm
environmental medium	LHe, LH_2, LN_2
temperature	4.2 K; 20 K; 77 K
normal force	≤ 500 N
no. of revolutions	≤ 3000 min^{-1}
sliding velocity	≤ 7 m/s

Cryotribometer CT3 can be employed for tribological model investigations, tests of roller and sliding bearings, and complete components like pumps in a wide temperature and pressure range. The test assembly is located in a pressure resistant, vacuum insulated metal dewar with LN_2-radiation shield. The sample chamber is designed for a pressure range from 10^{-3} mbar to 20 bar. Cooling is provided by a spiral shaped heat exchanger inside the vessel through which the coolant, liquid helium (T = 4.2 K) flows. Therefore, there is no limitation to an equilibrium state on the boiling curve of the coolant as in a bath cryostat. For hydrogen as environmental medium gaseous, liquid, and overcritical states (critical point of H_2: T = 33 K; p = 13 bar) can be adjusted.

For tribological model tests loading is performed by means of helium gas pressure and normal and friction forces are measured by strain gauges located in the cold part of the test rig. The driving shaft for the rotating sample is sealed by a ferrofluidic rotary feedthrough on the top flange of the cryostat and driven via a belt drive.

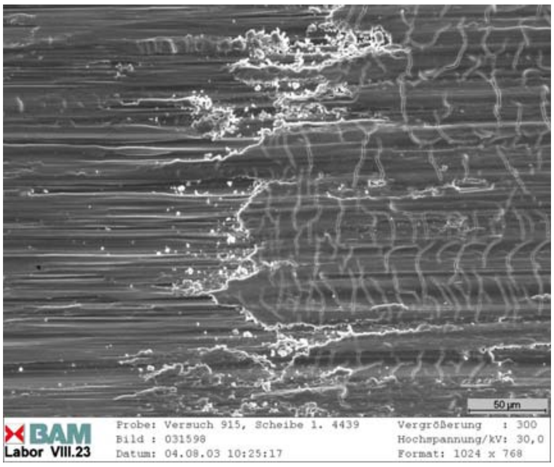


Technical data

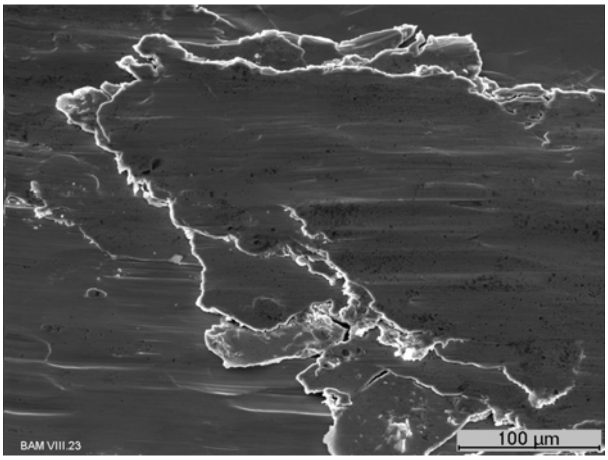
sample chamber	geometrical volume: 39 l pressure range: 10^{-3} mbar to 20 bar
body 1	cylinder or ball; Ø = 3 to 10 mm
body 2	disc; Ø = 42 mm
environmental medium	He-,H_2-, N_2-gas, LH_2, LN_2
temperature	10 K to 300 K
Normal force	≤ 100 N
no. of revolutions	≤ 3000 min^{-1}
sliding velocity	≤ 7 m/s

Example of test results

Austenitic steels are standard materials in cryo- and hydrogen technology, because they are not susceptible for embrittlement at low temperatures and under H_2-influence. However, in tribosystems they experience complex thermal and mechanical stressing which leads to lattice transformations and thus to a loss of these favorable properties.



Liquid hydrogen



Liquid helium

Scanning electron microscope images of wear tracks on austenitic stainless steel in 300fold magnification: crack formation in strongly deformed areas after stressing in liquid hydrogen (right part of the image). After tests in liquid helium no similar effect is noticeable.

Literature

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