Technical Specification

Active Magnetic Bearing Motor Bearing Unit for ESS project

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Technical Specification:
Active Magnetic Bearing Motor Bearing Unit

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Change History

Issue	Date	Initials	Modifications
A	25 Aug 2022	AKM	Original
B			
C			
D			

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References

[1] ESS official webpage: https://europeanspallationsource.se/european-spallation-source
[2] “
[3] “
[4] “

1. Introduction

This document is a short technical specification for a motor bearing unit required to support and drive a centrifugal blower wheel for the ESS Helium cooling requirement [Ref 1].

It is expected that a full specification will be issued but this document should provide the minimum information for discussion with potential suppliers.

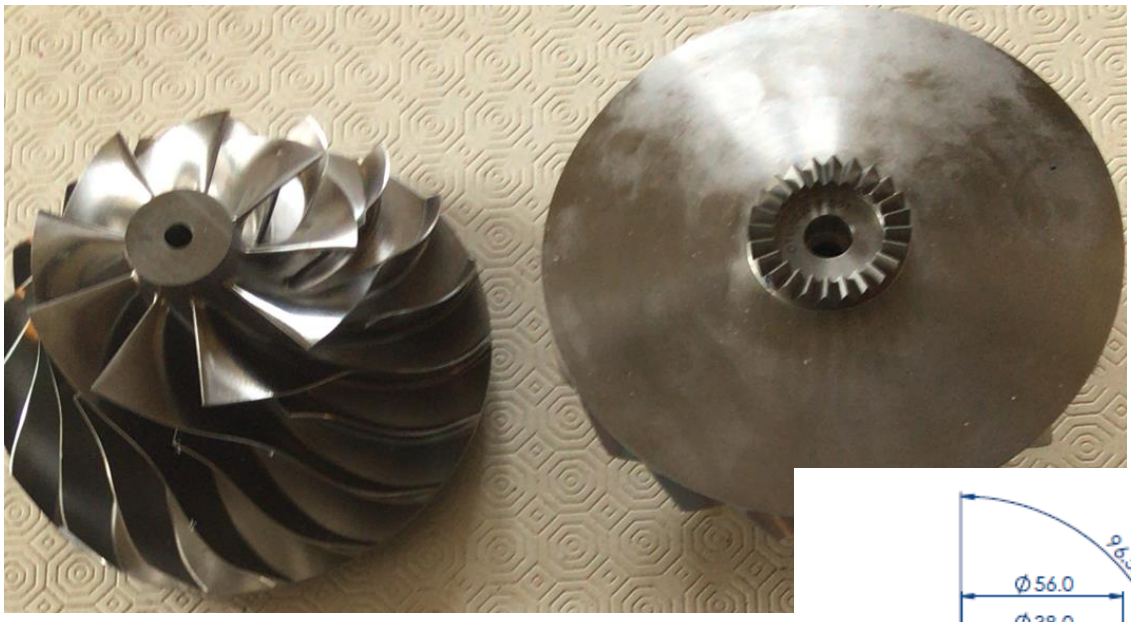
2. Description

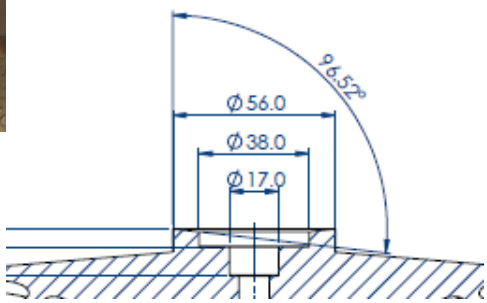
Two identical motor bearing units are required each with the following nominal performance

39 krpm speed
170 kW power to the shaft
Helium process gas at 10 bar inlet, 11.4 bar[1] outlet
Helium gas temperature inlet 20-40 degC

The compressor wheels and volutes exist and have been tested to demonstrate basic fundamental performance. The mounting is a Hirth radial spline machined by Voith – the shaft must have a mating radial spline. Inconel wheel mass ~ 3 kg.

The wheel has a 10 mm hole for a tie bolt to hold in place.

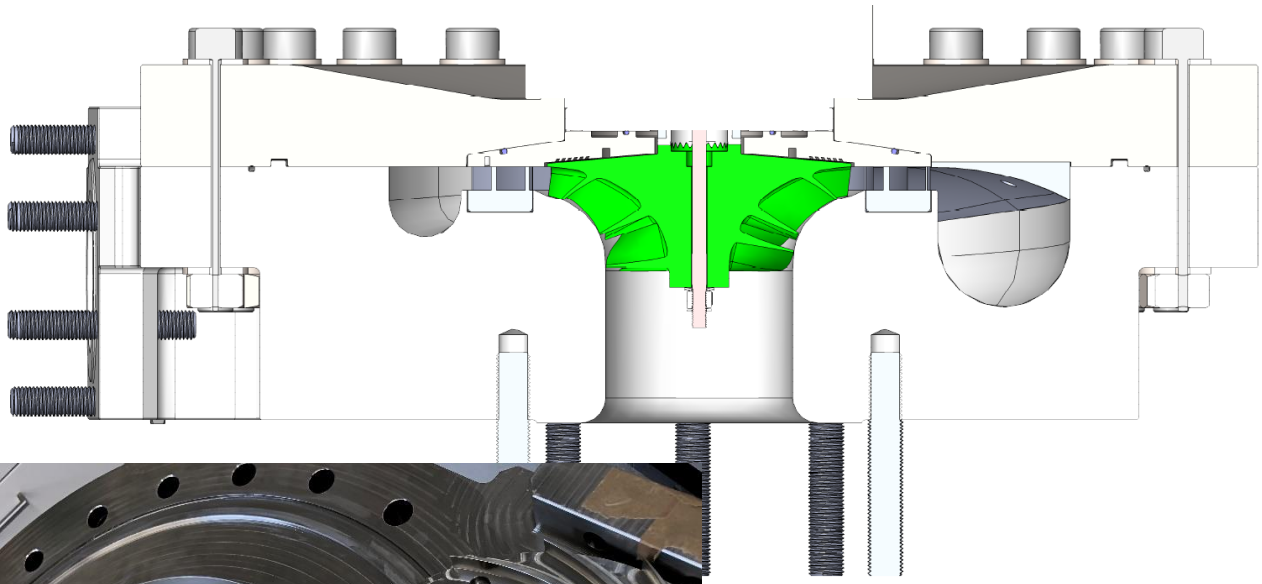


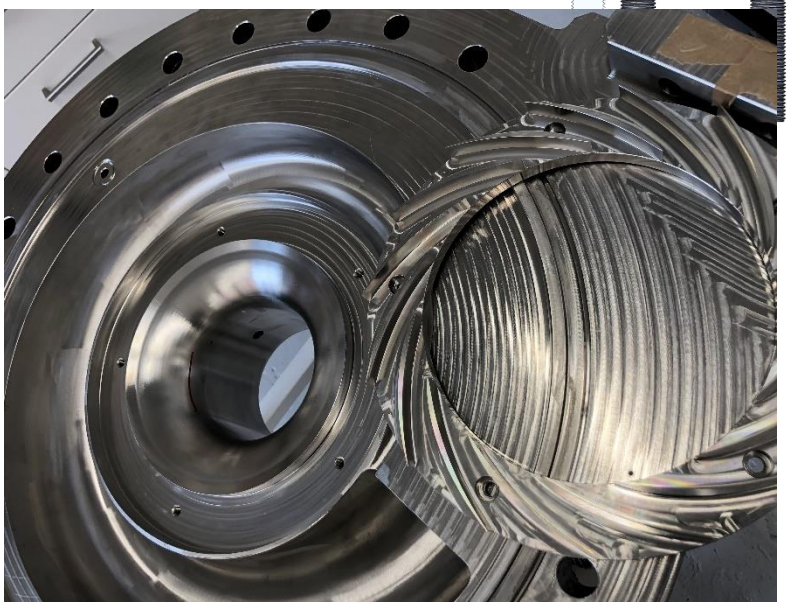


The tie bolt must provide 30 kN axial load to hold the wheel in place – this can be achieved using an Inconel tie bolt and high tensile nut with an M10 thread.

[1] All pressures in this document are absolute.

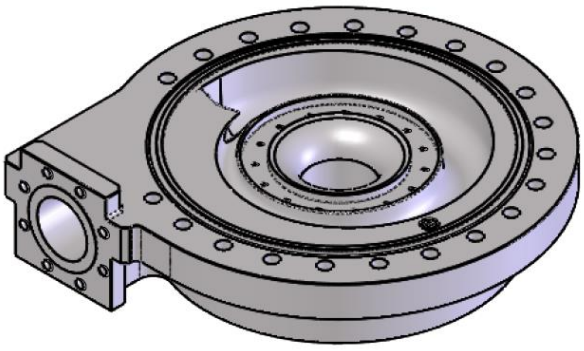
The existing volute and backplate assembly with outlet diffuser guide vanes are shown below with the wheel in place:

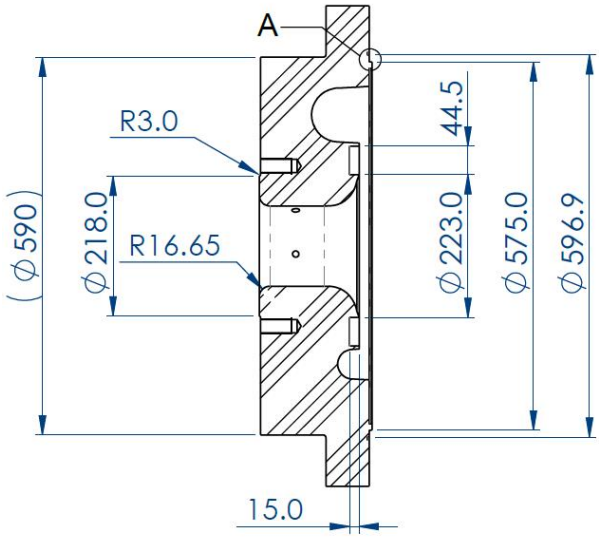


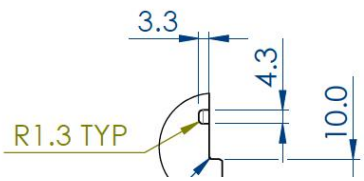


This assembly has a mass around 800 kg.

The photo on the left shows the outlet diffuser vanes and the volute.







The above parts fit into an existing skid which contains flow measuring, valves and process instrumentation. The image below shows the volute mounted on the skid using anti vibration rope mounts.

The Helium gas in the circuit is clean and dry and is filled following a vacuum cycle but over time the Helium gas will contain some very small (0.2nm) radioactive particles.

A clean Helium purge flow is available to keep the motor and bearings clear of these particles (of ~10 g/s).

No oil or grease or other fluids are allowed in the system and the leakage from the circuit is an absolute minimum.

A hermetic design is required based on the Active Magnetic Bearing technology with a 40 year lifetime (with maintenance and replacement parts as necessary during this period). The machines are expected to undergo a relatively small number of start stop cycles (100 per year typically).

Two KEB inverter drives are existing and have been tested. These are the latest KEB F5 inverters including Active Front Ends (AFE) and Sinus Filters to enable motor operation up to 400 V 3ph, 360Amp.

A Profinet control system already created by ESS will control the machine and undertake monitoring and protection functions. This Profinet system exchanges information with the KEB drives to set the exact running speed.

The system is intended to be operated for long periods with minimal personnel in attendance as the Helium gas will contain some very small (0.2nm) radioactive particles.

The mounting method of the motor & bearing units onto the existing backplate needs to be decided in discussion with the client. Possible solutions are bolting or welding. The latter may prove to be simpler to meet the pressure directive. If necessary a new backplate (316L) may have to be manufactured; in this event the client will assume the cost of this component.

2. Scope of Supply

The delivery shall include

- Two Motor & Bearing units suitable for holding the existing compressor wheels in the existing volute assemblies to meet the speed and power requirements as specified in this document.
- Electronics required to drive the Active Magnetic Bearing system.
- Interface software to integrate with the ESS Profinet control system to enable control and safety features.
- Documentation including Installation, Operation, Functional Specification
- Factory Acceptance Test FAT
- Certification where necessary to meet the EU directives.
- Support on site to commission and test the delivery.
- Transport to Prague
- Quality documentation

3. Design Requirements

	Description	Value	Notes
1	Process Gas	Helium	99.9%. The remaining 0,1% consists of oxygen, carbon dioxide and water, hydrogen (including tritium), iodine, tritiated water and tungsten particles. The motor bearing units shall not contaminate the circuit (no oil or grease).
2	Gas pressure inlet	7 bar **10 bar**	Start up condition at 20 degC **Nominal** condition at 40 degC
3	Gas outlet pressure	**11.4 bar**	**Nominal** at 40 degC inlet Note: no requirement at 7 bar inlet during startup
4	Speed range	**39000 rpm** 10,000 rpm 40,000 rpm	**Nominal** condition, 100% duty Minimum speed (power is what is available) Maximum speed (power not exceeding nominal)
5	Motor Power	170 kW	**Nominal** shaft power at 39,000 rpm. This is the power required by each centrifugal wheel.
6	Gas flow rate	2.85 Kg/s	Flowrange required 25-102% Only the 102% flow at the 11.4 bar outlet pressure has to be guaranteed.
7	Helium leak rate	0,15 mbar*l/s	For the supplied parts (volute C seals and graphite pipe flange seals already existing)
8	Vacuum		Units must support vacuum.
9	Machine protection		Communicatoin using Profinet with the ESS control system.
10	Gas temperature	40 degC 20 degC 95 degC 250 degC	**Nominal** - during startup. - 30 mins under emergency condition, 1/year. - system catastrophic failure; the units must maintain safety integrity but the motor bearing unit is not expected to survive in an operational state.
11	Maintenance		Minimal access. Design should enable simple removal and replacement.
12	Lifetime		40 years with maintenance periods as required.
13	Materials		A list of acceptable materials is available. 316L and Inconel are on this acceptable list.
14	Motor rotor stator units	Class H	Ideally a canned motor design and/or an encapsulated stator are suitable.
15	Codes and Standards		- EU Machine Directive 2006/42/EC - Pressure Equipment Directive 97/23/EC - Low Voltage Directive 2006/95/EC - Electromagnetic Compatibility 2004/108/EC
16	Design point for code approval		13 bar pressure 300 degC

			Volute test pressure is 20.3 bar. Fluid Group 1
17	Seismic requirements		The units are mounted on wire rope spring anti vibration mounts which reduce the seismic requirement to normal industrial levels.
18	Space available		Each of the supplied motor bearing units shall fit inside a cylinder 0.7 m diameter, 1.5 m vertical height (possible to extend this). AMB Electronics can be mounted in the adjacent room up to 8 m away.
19	KEB Inverter drives	Each.	Type: F5-R AFE 208KVA. 300AMP Sinus filter included. 16 kHz drive frequency.
20	Motor cooling	Water cooled	Nominal 24 lpm water at 30 degC to each motor (48 lpm total).
21	Purge flow available	0-10g/s	Clean HEPA filtered Helium at 20-40 degC

4. Bearing Design

The ESS control system monitors flow and pressure and prevents operation of the centrifugal wheel in surge conditions.

4.1 Journal Bearings

The shaft is currently mounted vertically such that the only radial loads are out of balance. The rotor should be balanced to better than ISO grade G2.5.

The centrifugal wheel radial clearance is 0.4 mm so the journal bearings must maintain the shaft within this space to avoid contact during rotation. Given the tolerances of manufacture we suggest a maximum radial motion of 0.2 mm during all rotation.

4.2 Thrust bearings

The wheel mass is 3 kg which needs to be added to the mass of the shaft including bearings and motor rotor. The total rotor mass is estimated to be within the 10-20 kg range giving a downward axial load on the thrust bearing up to 200N during all its operation.

The centrifugal wheel load is offset by a labyrinth seal on its back face giving another 100 N axial load.

To support the above loads and allow some overload capacity a thrust bearing with a 1000 N capability in both directions is required.

The axial tip clearance of the centrifugal wheel is 0.4 mm with a 0.5 mm gap behind the wheel so that the total axial movement is ~0.9mm. The AMB thrust bearing must position the wheel to give ~0.4 mm axial tip clearance during all rotation.

The rotor can rest on the centrifugal wheel blades during zero rotation periods.

4.2 Rotordynamics

The bearing design must allow operation from 10,000 to 40,000 rpm without no-go speeds.

5. Sealing

The supplied hardware must be hermetic with seals capable of operation with Helium. Metallic C seals and graphite flange seals are used in the volute. Internal seals may be O rings.

Sealing integrity must survive a catastrophic event where the system reaches 250 degC. It is expected that the motor and bearing systems will need replacing in this event.