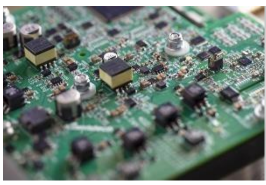
aeristech

WHITE PAPER

HIGH-SPEED E-COMPRESSOR PLATFORM
FOR 150+ KW FUEL CELL INSTALLATIONS

Summary

This paper outlines the development of the Aeristech NovA (Novel Architecture) platform for air compressors, discussing its origins in the APC (Advanced Propulsion Centre) program 'Trident' and the challenges faced during its creation. It covers the testing processes and outlines future steps for technology improvement. The paper concludes by highlighting the practical applications of the NovA platform, such as 150 to 250+kW fuel cell stacks, as well as potential in industrial oil-free air.



INTRODUCTION

Aeristech has been developing high-speed motor and controller technology since 2010, starting with electric turbocharging through to supercharging and now e-compressors. Our latest motor and controller platform, NovA, is the culmination of three years of collaborative development with Cummins Turbo Technologies (Now CEC – Cummins Engine Components) under the Trident APC project. Leveraging our patented motor and controller technologies, we have undertaken substantial enhancements, bolstering the power and maturity of our machines. This progression has produced our platform NovA, representing a new era for Aeristech's future development products.

DEVELOPMENT PROGRAM

Developed over a period of three years the NovA platform looked to develop a turbo compressor for hydrogen fuel cells using Aeristech's patented motor and controller technology. This consists of a 4-pole permanent magnet motor with a current source inverter.

Continuous Electrical Shaft Power	Continuous DC Input Power	Max Speed	Continuous Electrical Shaft Torque	Maximum Axial Thrust Load
kW	*kW*	*kRPM*	*Nm*	*N*
28.43	35.21	100	2.72	220

The market direction for larger fuel cells has driven the need for significantly larger compressors than our previous developments. This platform is designed to provide 2.72Nm at 100krpm and can be configured into single, stage, two stage or turbo compressor type configurations. This allows the platform to be customised to various mass flow and pressure ratio design points for various applications. The platform has also been designed to be oil free through the use of foil air bearings. These foil air bearings are hydrodynamic, using the rotation of the shaft to generate cushions of pressure to deal with both lateral and axial loads.

CHALLENGES

At these power levels and speeds, shaft losses become a significant challenge that called for additional features in the shaft design and motor commutation strategy to enable steady state performance. As the rotor rotates, the magnetic flux path is deformed slightly. This generates eddy currents which contribute to shaft losses. Although these losses are relatively small, the challenge is cooling. Isolation from the main housing causes the heat to build up in this area.

In addition to rotor heating, thrust load was another significant challenge. A combination of rotor speed, desired pressure ratio and thermal design meant that designing a viable thrust solution must account for a lot of competing factors. Several design iterations were undertaken to establish the relationships between these factors which are unique to this specific type of compressor. The result is a highly designed thrust system that can deal with both the anticipated thrust loads and stay within the necessary temperature limits.

DEVELOPMENT STAGES

The NovA platform began with subsystem testing of the e-magnetics. A test rig to enable nose-to-nose testing was developed. By using a proven ball bearing motor, with identical e-magnetics and coupling this to the new motor, motor behaviour and efficiency could be evaluated. The test rig also enabled bearing and electronics subsystem testing to be undertaken.

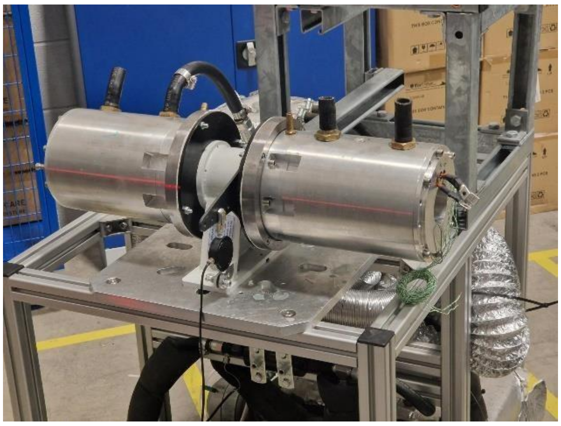


Figure 1: Sub-system testing of e-magnetics. Nose-to-nose motor arrangement with torque arm and load cell.

A first iteration of the design was then produced and evaluated. This included a full compressor and turbine. Although most risks were mitigated in the sub system tests, further challenges were found with the cooling air flow within the unit.

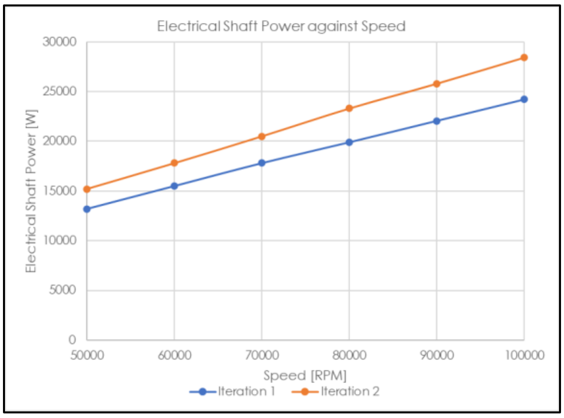


Figure 2. Graph of electrical shaft power capability with iteration improvement.

A second iteration was then developed to address these short comings and has taken us to the power levels we can see today. Development continues to incrementally edge up the speed and torque performance of the motor.

TESTING & VALIDATION

To understand the robustness and longevity of the platform's design, the NovA prototypes were exposed to a range of challenging environments, including temperature extremes, vibration, and water immersion.

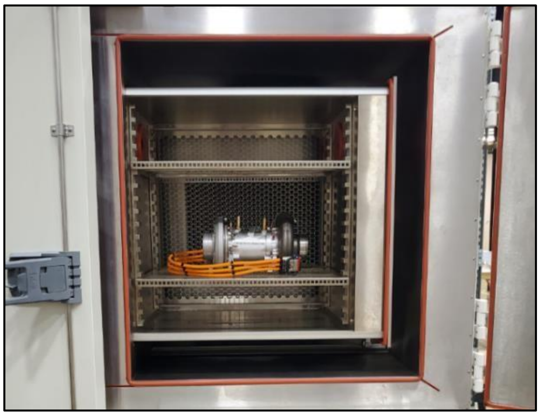


Figure 3: NovA Platform in thermal shock cabinet.

THERMAL SHOCK

Thermal shock testing demonstrated the platform's capability of withstanding repeated rapid changes in environmental conditions. The motor was soaked at temperatures of -40°C and +80°C before being rapidly moved to an environment at the opposite extreme. This cycle was repeated for a total of 100hrs. Continued operation was performed following this test, and a full disassembly showed no degradation to components or performance.

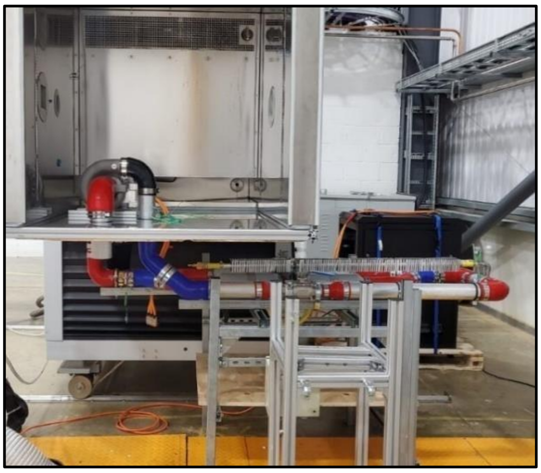


Figure 4: NovA platform in environmental test chamber. Including piping for turbine recovery.

OPERATIONAL EXTREMES

Cold start-up (-40°C) and extended high speed, high temperature operation (+80°C) was verified through operation across a 100hr multitemperature cycle test program. The high humidity conditions also provided the opportunity for an initial assessment of the corrosion resistance of the materials and finishes used within the motor.

The test program also allowed performance of the motor to be checked at the voltage tolerance limits, as combined temperature and voltage extremes are most likely to impact motor operation.

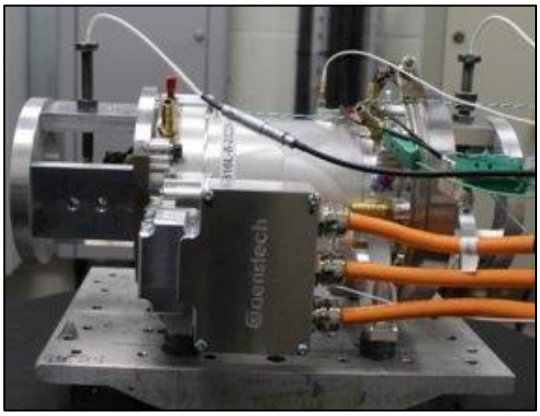


Figure 5: NovA platform on shaker test rig.

VIBRATION TESTING

Resonant frequencies of the rotor were verified during operation and used to define an initial 8hr vibration durability test The Compressor was hard mounted to the shaker table to evaluate shaft movement for given vibration input. This allows us to design the anti-vibration mounts for a given application to allow for acceptable shaft motion.

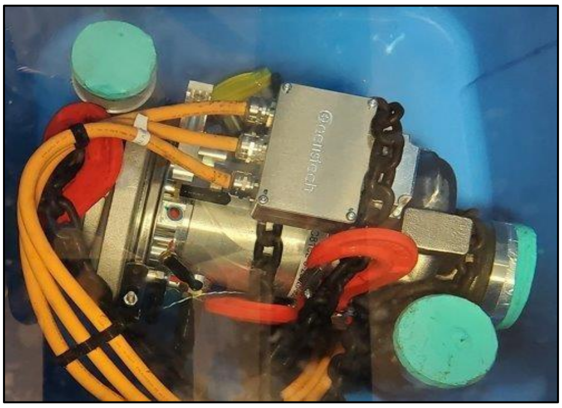


Figure 6: NovA Platform during ingress protection (IP) test.

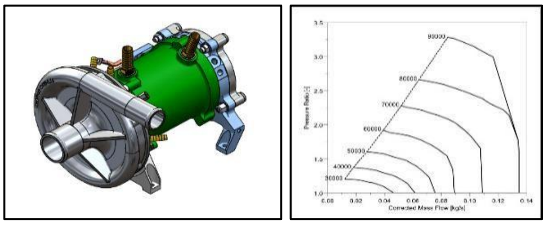
IMMERSION TESTING

The design to IPX7 rating was tested by immersion of the motor in water to a depth of 1 metre for 30 minutes. The results indicated that there were small leaks through compression fittings used for monitoring equipment. With these fittings removed and plugged, the unit was able to pass the immersion test successfully. Further investigation for alternative fixings is underway, though it is anticipated that these can be removed entirely for subsequent prototypes.

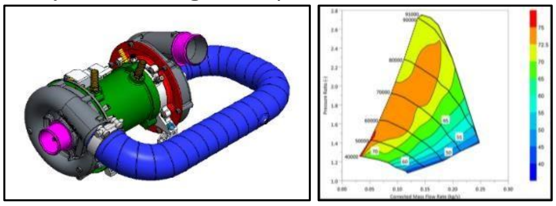
Next Steps

The NovA platform range will be expanded to include a single stage compressor, two stage compressor and a further turbo compressor. These will look to address various fuel cell sizes from 150kW upwards. In addition, a series of compressors to support oil free applications such water treatment and food and pharmaceutical processes.

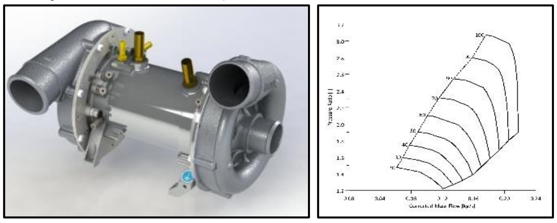
- Single stage Compressor.



- Two Stage Compressor



- Turbo Compressor



CONCLUSION

Aeristech’s NovA platform represents a significant step forward in high-speed ecompressor technology for 150+ kW fuel cell installations. This white paper covers the platform's development, addressing challenges such as e-magnetic design and management of thrust loads. Through iterative improvements and innovative solutions, the NovA platform achieved a substantial increase in total power, showcasing adaptability to various compressor setups. Its potential applications in fuel cell stacks and oil-free air systems highlight its versatility for modern energy and industrial needs. The commitment to further improvement is evident in plans to commission an in-house air bearing test rig.

Rigorous testing, including thermal shock tests, confirm the NovA prototypes' durability in demanding conditions. With the ability to withstand temperature extremes, vibration, and water immersion, the NovA platform proves its suitability for real-world applications.