Fig. 1: The Diamond Light Source particle accelerator in Oxfordshire © 20113

Vacuum compatible maxon motors for extreme conditions.

maxon motor spent several months working alongside Instrument Design Technology (IDT) to customise a small, brushless motor to perform in the extreme vacuum conditions of the synchrotron. This article highlights the challenges in the design.

The Diamond Light Source particle accelerator in Oxfordshire has been used for projects as diverse as analysing the effects of strain on aircraft wings, studying the behaviour of the HIV virus, and even reading ancient letters without opening them. The 45,000m2 synchrotron facility works by accelerating electrons to 3GeV, generating beams of synchrotron light, up to ten billion times brighter than the sun, in order to understand molecular structures. To prevent electrons being lost in collision with air molecules, the whole process is undertaken in a vacuum, around one billion times lower than atmospheric pressure. Clearly, creating scientific instrumentation for such conditions requires greatspecialist knowledge, and Widnes-based Instrument Design Technology (IDT) supplies theworld's leading synchrotron facilities.

Diamond specified that the that the Double Crystal Monochromator for its new X-Ray Spectroscopy Beamline B18 should drive the crucial Bragg rotational axis with a DC motor rather than the usual stepper motor. IDT managing director Paul Murray explains: "The goal was to achieve higher rotation speeds, with a lower motor temperature and smoother drivetrain than the stepper motor we had used previously. Stepper motors are inherently noisy, and often sources of vibration. Eliminating this issue would immediately improve results from the DCM - but the new motor would have to work flawlessly in a vacuum of 10-8 Torr." To help solve the problem IDT enlisted the help of Paul Williams, senior sales engineer at maxon motor UK. With experienced engineers handling the project at every stage, and a long history of customising high-performance motors for applications as demanding as space and surgical robotics, maxon's teams in Britain and Switzerland were eager to rise to the challenge of creating a bespoke solution. Williams says: "Because the vacuum in the synchrotron must not be compromised, each individual aspect of the motor and its construction had to be analysed for possible outgassing. The challenge for us was effectively to create a brushless motor with virtually no glues or plastics, an incredibly high temperature tolerance, and excellent performance."

The starting point for the custom motor was maxon's EC22 Heavy Duty. Although originally developed for sub-sea oil applications, the 22mm brushless motor's laser-welded stainless steel construction and broad temperature range already addressed many of the needs of high vacuum applications - and being a brushless DC motor meant it would immediately be more efficient, quiet and responsive than the previous stepper motor.

When customising the EC22 HD for use in the synchrotron, Maxon accounted for a number of factors. First among these was temperature management. Motors in a vacuum cannot dissipate heat through convection in the normal way, so can be prone to overheating. It is therefore important to choose a motor with high temperature tolerance, stay well within its rated performance in air, and, if possible, position other components in such a way as to spread heat by conduction. A high ratio gearbox was also vital. High vacuums of 10-7 Torr and greater can pull gaseous compounds from materials such as plastics and glues, compromising performance and contaminating the vacuum - a problem known as outgassing.

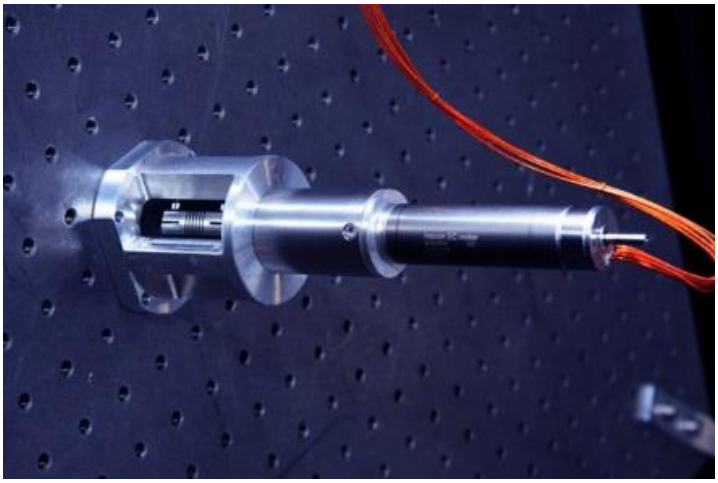

Figure 2: The modified EC 22 HD maxon motor in the particle accelerator ©Diamond Light Source

Each component in the motor was individually tested, and upgraded as necessary. For example, standard PVC cable coating was replaced with a more inert, Kapton version. It was therefore important that the EC22 HD was already substantially made from stainless steel, rather than plastics. Because of the potential for outgassing, the usual glues and epoxies could not be used, and the motor was put together using extensive micro laserwelding. From its work with space and aerospace projects, maxon knew how standard, light greases used on motor bearings are affected in low pressure conditions. It was therefore important to specify an extremely inert lubricant which was also thick enough to avoid giving off vapour under high vacuum - and to account for the effect of this change on the motor's operating characteristics and anticipated life cycle. To finally remove any remaining outgassing threat, motors for controlled vacuum conditions are baked at 120ºC for 24 hours. Already purpose-built for temperatures in excess of 200º C, the EC22 HD proved an ideal starting point.

The Double Crystal Monochromator, incorporating the special maxon DC motor, is now in active service in Diamond Light Source's Beamline B18, playing its role in key experiments on a daily basis. As an example, a group of Italian scientists used Beamline B18 to study dust in snowflakes that fell some 800,000 years ago - about the time of the first hominid life on Earth. Ice cores drilled from the Antarctic are made up of layers of frozen snow, dating back hundreds of thousands of years... and minute dust particles trapped as the snow fell hold key information about the earth's climate, atmosphere and volcanic activity at the time. Using X-Ray Absorption Spectroscopy, the scientists were able to study the mineral composition of the dust, determining its origin, and unlocking clues to the changes in global climate patterns over hundreds of millennia.

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Application report: 5192 characters, 954 words, 3 figures

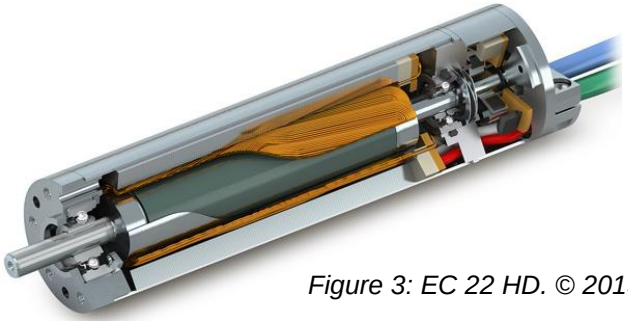

Figure 3: EC 22 HD. © 2013 maxon motor ag

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