Multi-parameter investigation of radiation effects on grease lubricants for use in radiation areas at CERN

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The operation of the particle accelerator complex at the European Laboratory of Particle Physics (CERN) relies on several hundreds of Beam Intercepting Devices (BIDs), some of them containing lubricated mechanical components. These critical pieces of equipment are required to withstand high radiation doses over their lifetime, while retaining exceptional reliability despite the limited possibility of maintenance access. Additional lubrication challenges are brought by high contact pressures, long periods under static loads, followed by small but highly precise movements. Instances of impaired equipment performance have been reported [1] as evidenced by high friction and poor motion control. Most BIDs include movable mechanical components (e.g. roller screws, bearings, wire ropes) and are lubricated by grease, which can be severely degraded by exposure to ionizing radiation.

Lubricating greases typically consist of a base oil, thickener and additives, all of which can exhibit degradation under radiation levels encountered in operation. However, they are difficult to replace as self-lubricating materials or dry lubricants do not offer comparable performance in terms of friction reduction and wear resistance. Knowledge of radiation resistance of readily available commercial greases is needed to provide reliable lubricating solutions for radiation areas, and plan preventive maintenance or re-lubrication before critical lubricant damage occurs. Unfortunately, the existing studies on radiation effects are often outdated, or focus on the evolution of a single physical property, not necessarily reflecting the performance of the lubricant in a specific application.

Our research program studies the effect of controlled irradiation on the chemical, physical and tribological properties of a range of commercial greases. A selection of greases with different chemistries has been irradiated with gamma sources up 10 MGy, and with a neutron-dominated mixed field up to 2.5 MGy [2]. A series of post-irradiation analyses was performed, including physical (viscosity, rheology), chemical (FTIR, TAN, Raman) and tribological testing (friction).

Samples irradiated in controlled conditions exhibit similar degradation patterns as observed in operation [1]. Visual and physical changes can be linked to chemical changes to the grease thickener and base oil components. Significant differences were observed between different grease compositions, indicating the importance of appropriate lubricant selection for irradiated components. Friction coefficient and the condition of lubricated metallic surface depend not only on the lubricant type and absorbed dose, but also on the time of contact between the materials. The work demonstrates the need for a new, multi-parameter and operation-oriented approach in evaluating radiation resistance of grease lubricants.

References:

[1] D. Senajova et al., submitted to Engineering Failure Analysis (2024)
[2] M. Ferrari *et al.*, Phys. Rev. Accel. Beams, **25**, 103001 (2022)