HySurf—Microstructured Hybrid Surface with Improved Friction Properties

K. Vaideeswaran, J. Gobet, S. Biselli, V. Courbat, P. Margraf•, O. Sereda

Nitrocarburisation is a surface hardening technique usually applied to improve the wear resistance of steel surfaces. On the other hand, dry lubricants are utilised to lower the coefficient of friction (COF). Currently, the lifetime of steel components, in many applications using either of these techniques individually, are faced with the limitations of the two techniques: high COF for nitrocarburised surfaces and low wear resistance of dry lubricant coatings. Thus, the current study involves the creation of a hybrid surface using the impregnation of a dry lubricant on to a nitrocarburised surface. The mechanical strength and hardness of Gerster SA's nitrocarburised surfaces accompanied by the impregnation of the porous outermost layer with a solid lubricant creates a "hybrid surface" possessing both outstanding wear resistance and a low COF, with a high adherence to substrate.

The nitrocarburising (NC) process parameters (atmosphere, temperature, dwelling time) were optimised by Gester SA, leader in steel surface treatment in Switzerland, to obtain samples that have a distinct porous surface structure (in terms of size, shape and density) as observed by metallographic and microscopic investigations. The porosity thus obtained is suitable for the impregnation of a dry lubricant. CSEM implemented its know-how in surface engineering and lubrication jointly with Gerster to define and test dry lubricants suitable for such surfaces. Analyses were conducted with multiple commercial lubricants (containing lubricating particles e.g., Polytetrafluoroethylene (PTFE) and MoS_2 in thermoplastic or thermosetting polymer matrix) and upcoming lubricants (e.g., parylene, sol-gel based polysilazanes and thermally diffused zinc) were analysed. The goal was to obtain a void-free interface with the NC surface (hybrid surface). In parallel, metallic samples without nitrocarburisation were coated with the same dry lubricant as a reference (henceforth called non-NC). The tribological analyses were conducted against a quenched steel ball on all surfaces with and without lubrication were also conducted in parallel.

Without any lubricant, the NC surface showed a wear rate 5 times lower than the non-NC surface, although the COF remains >0.6. The best lubricant among the tested ones for both surfaces (NC and non-NC) was found to be a commercial lubricant containing PTFE particles in a thermoplastic polymer matrix with the following remarkable properties:

- Cost effective application by dip coating, results in a suitable thin (<2 µm) impregnating layer (see Figure 1).
- In the presence of a thin film of dry lubricant (<2 µm) and under the application of high loads (~800 MPa, applied force= 0.5 N), the hybrid NC surface retained a CoF <0.2 for over 400 m of sliding (see Figure 2). On the other hand, the COF for the lubricated non-NC increased from ~0.1 to > 0.3 within 120 m.
- Meanwhile, while the steel ball sliding against the lubricated non-NC surface showed heavy wear, the corresponding ball sliding against the hybrid NC surface showed very limited wear.
- Electron microscopy of the sliding tracks in the hybrid NC-surface shows the presence of the NC nodules as well as the lubricant, whereas no traces of the lubricant were found in the sliding track on the non-NC surface.

In this manner, the clear advantage of combining nitrocarburisation with the impregnation of a dry lubricant towards forming a hybrid surface has been demonstrated.

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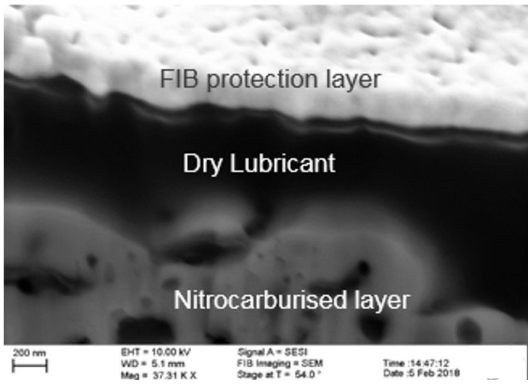

Figure 1: Focused Ion Beam (FIB) section showing the continuous interface between the lubricant and the nitrocarburised layer.

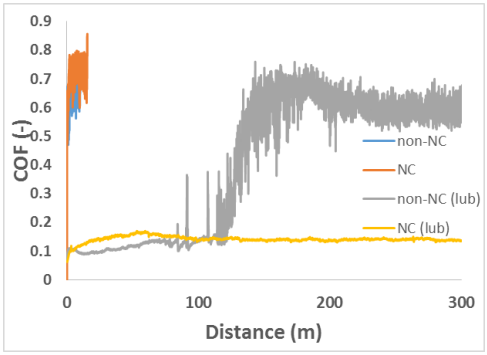

Figure 2: COF evolution (applied force =0.5 N) on non-impregnated NC and non-impregnated non-NC, as well as impregnated NC steel (hybrid surface) compared to impregnated non-NC (reference surface), showing the advantage of the hybrid surface.

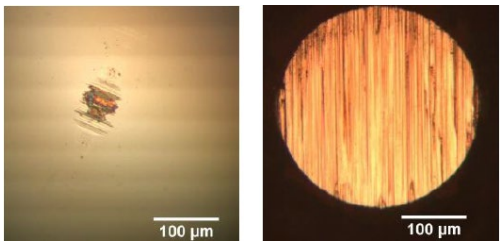

Figure 3: Optical microscope images of the 2 mm diameter steel counter body (load 0.5 N) after 400 m of sliding on the hybrid surface (NC, left) versus the lubricated reference surface (non-NC, right). The hybrid surface reduces drastically the wear of the steel counterpiece.

• Gerster SA, Güterstrasse 3, CH-4622 Egerkingen, Switzerland