ANTI- GALLING TREATEMNT FOR BOLTS AND FASTENERS USING COBLAST

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ABSTRACT

ENBIO have developed a novel, green, ambient temperature blast coating technique known as CoBlast. A co-incident stream of abrasive and coating media simultaneously remove a metal's passivating layer while depositing a lubricious coating on the newly-exposed reactive metal surface. Previously used to apply a black thermal control coating surface, this process can be utilised to deposit various chemistries and textures.

In this work, CoBlast was used to apply a low friction coating onto the surface of M10 and M6 fasteners to inhibit galling. Selective area coverage of just the thread section can be achieved and all materials used are REACH-compliant and VOC free. To determine the performance of the coated fasteners, bolt tension at a specific input tightening torque was measured 10 times using a digital torque wrench and a compressive donut load cell. Bolt materials tested were Grade 5 Titanium and A2-70 Stainless steel. Samples were characterised using microscopy, SEM and cross-sectional microscopy. ENBIO have developed a thin low friction coating for fasteners which ensure repeatable bolt tensions over 10 bolt retightens. In the case of SS A2-70 the performance of the coating exceeds that of the competitor Molykote, while for Ti Grade 5 the bolt tension remains consistent but lower than Molykote.

INTRODUCTION

CoBlast, an abrasive surface treatment technique developed by ENBIO Ltd. has been previously used to apply black thermal control coatings for use on spacecraft [1,2]. However, the same process has been utilised to deposit thin < 5µm, well adhered low-friction, fluoropolymer coatings on super-elastic nitinol [3]. Titanium and Stainless-Steel fasteners are often used in the construction of spacecraft due to their mechanical strength and corrosion resistance properties [4]. This grade of fastener is much more expensive than other metallic fasteners and are prone to galling and cold welding. These issues limit the amount of times a bolt can be reused safely. Currently, Titanium bolts are used 2 to 3 times before they are disposed, resulting in high scrap rates during the building process. A low friction grease or dry film lubricant spray is sometimes applied to improve this but there are often issues about contamination, consistency of application or thick coatings resulting in oversizing of the threads. This work describes the application of a dry lubricant coating onto fasteners using CoBlast as a way to maintain consistent bolt tension during multiple uses and to reduce galling and cold-welding, Fig 1.

Fig. 1. Uncoated (left) and CoBlast coated (right) titanium bolts

The goal is to significantly reduce the cost associated with bolt scrappage and the difficulties associated with applying currently available commercial lubricants, through the application of thin, conformal coatings across the thread section, Fig. 2. A direct comparison with an aerosol-based treatment (Molykote) is explored.

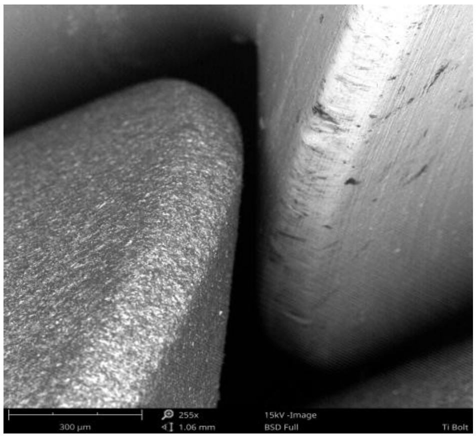

Fig 2. SEM of CoBlast coated (left) uncoated (right) thread section

MATERIALS AND METHODS

2.1. CoBlast Deposition Process

The CoBlast process is described in more detail elsewhere [3,5]. A blend of alumina abrasive, fluoropolymer and low friction wear resistant powders were fed into the blast stream using a suction fed, powder feeder system. The blend is pneumatically conveyed through a nozzle, mounted on a 6-axis robot (Staubli TX60). This robot directs the nozzle/material stream across the material surface in such a way as to ensure an even coverage, Fig. 3. The bolt was rotated at 250 RPM and the nozzle moved along the length of the bolt at a fixed transverse velocity in order to ensure complete coverage.

Fig.3. Titanium Bolt undergoing CoBlast coating

2.2. Bolt Tensioning testing

In order to test the compressive load exerted by a bolt (Gr5 Titanium and SS A2-70) torqued to a specific force, a digital torque wrench and a compression load cell (Futek LTH 500) were utilised, Fig. 4. The bolt and washer arrangement are shown in Fig 5. The same material was used in the bolts, nuts and washers to ensure consistency of the system ISO-16047, 2005 [6].

The digital torque wrench was connected to data acquisition software to capture the peak torque while the load cell was connected to an Advanced Force Gauge (Mecmesin) which subsequently fed the bolt tension signal into Emperor Lite software (Mecmesin). Both the peak torque and the resultant bolt tension achieved were exported into an excel file, averaged and normalised. A minimum of 3 bolts were measured for each condition in order to obtain reliable data.

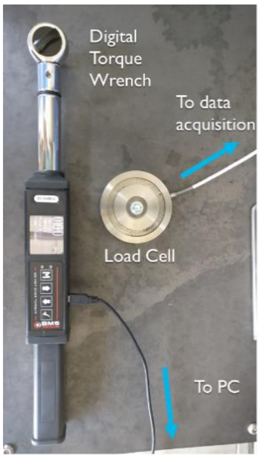

Fig. 4. Digital Torque Wrench and compression donut load cell

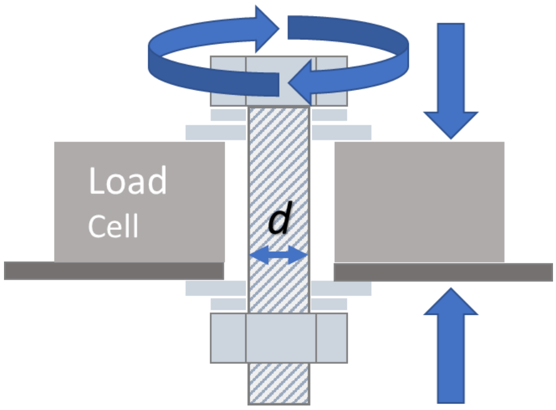

Fig. 5. Schematic of fastener and load cell Experimental configuration

2.3. Scanning Electron Microscopy

Scanning Electron Microscopy (SEM) was carried out using a Phenom XL (Eindhoven, NL). The Phenom XL was used to examine both the surface of the samples before and after testing. Sectioned samples were cold mounted in EpoFix™ resin (Electron Microscopy Sciences Ltd. Hatfield, PA, USA), ground, and polished to a sub-micron finish prior to imaging.

RESULTS AND DISCUSSION

3.1. Proof of Concept

Preliminary proof of concept experiments was conducted using M10 SS A2-70 Bolts. The bolts were torqued to 40 Nm with resultant bolt tension recorded. The coating CoBlast deposited onto the bolt threads was a PTFE mixed with F240 alumina abrasive. The uncoated bolt galled and seized after 3 retightens while the coated bolt was able to undergo 100 retightens with just a 6% reduction in bolt tension over this range, Fig 6.

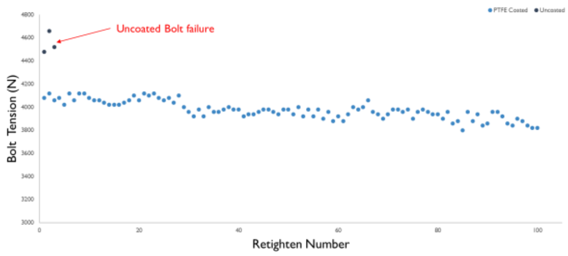

Fig. 6. Uncoated bolt seizing after 3 retightens while the coated bolt was able to undergo 100 with minimal decline in performance

3.2. Comparison against Molykote Aerosol

Having experimentally selected the best performing fluoropolymer and abrasive blend on the SS bolts, the experiment was repeated using M6 Ti bolts and compared to Molykote. The Molykote was applied manually onto a rotating bolt using the same experimental set as outlined for the CoBlast process. The bolts were torqued to 10 Nm due to their reduced size. The untreated, CoBlast and Molykote treated results are presented in Fig. 7. Each result is the average of at least three bolts.

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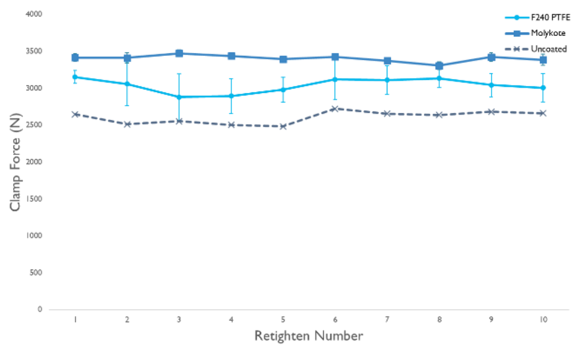

Fig. 7. Repeated clamp force measurements for F240 PTFE blend, Molykote and uncoated M6 Gr5 Titanium bolts

In this experiment, the Molykote outperformed the CoBlast coating in terms of resultant higher clamping force. This higher clamping force is indicative of a more lubricated system as the nut will pass over the threads easier and clamp harder at the same applied torque. However, when the SEM images of a thread section in the nut locking zone of the thread are examined it can be observed that both the Molykote and CoBlast coatings offer enough lubrication that there is less deformation of the thread. In both cases the coating has been stripped due to the shear forces of the nut (Fig. 8.). Significant deformation is observed for the untreated bolt.

Fig. 8. Post 10 retightens (uncoated left, Molykote middle, CoBlast right)

It is postulated that the Molykote performs better than the CoBlast coating in this case due to a number of factors. The Molykote is of a different consistency to the dry CoBlast coating. This softer more aqueous consistency allows the nut to "grab" and smear the coating as it travels along the thread. The method of Molykote deposition also results in thicker coatings than CoBlast with issues such as pooling occurring in the wells of the threads, Fig. 9. These wells, up to 50-80 µm thick in places act as additional reservoirs of lubricant which get distributed up the threads as the nut is manoeuvred on and off the bolt. While a benefit in terms of additional lubrication, it results in a large amount of debris as a result of the 'coating' coming away from the bolt and potentially contaminating the removal area. This does not occur with the CoBlast coating as it is thin and conformal across all the threads

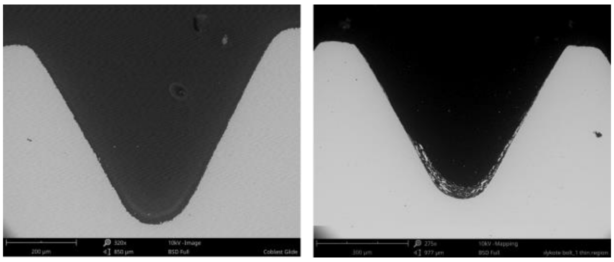

Fig. 9. Cross section SEM of the trough of coated thread sections. CoBlast coating (left) and Molycote (right). Thick coating of Molykote pooling at bottom not observed with CoBlast

3.3. CoBlast Coating Development

The preceding experiments indicated that whilst the CoBlast coating showed promise as a lubricious anti-galling coating for fasteners, more development was needed in order for it to match the clamping force performance of Molykote. For this round of testing the applied torque was reduced from 10 Nm to 4 Nm. This was to ensure that the lubricious performance of just the coatings were evaluated and not influenced by deformation of the underlying bolt material. Numerous rounds of testing looking at multi-dopant blends and various blend ratios were evaluated (not discussed here). The results shown in Figures 10 and 11 compare the results of the best performing (to date) CoBlast coating (CoBlast Glide) and compared it against Molykote for both M6 SS-A2 70 and Titanium Gr 5 bolts respectively.

In the case of the Stainless-Steel bolts, both coatings are comparable to the first 4 retightens showing similar bolt tensions. As the number of retightens increase the Molykote coated bolts drop off while the CoBlast coating remain more consistent holding a relatively steady bolt tension with repeated bolt tightens. It is to be noted that the CoBlast bolt was still able to be hand loosened and removed once the main clamp force was removed. This was not the case for the uncoated bolts. For untreated bolts, although maintaining a lower steady bolt tension, it is more difficult to apply a smooth progressive tightening and loosening torque. They are also not able to be loosened by hand, indicating high friction between the nut and threads caused by deformation and damage.

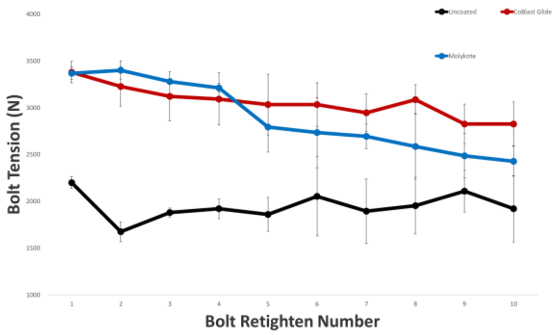

Fig. 10. Repeated clamp force measurements for CoBlast Glide, Molykote and uncoated M6 SS-A2 70 bolts

The Titanium bolts tested show a consistent bolt tension although lower value when compared to Molykote. This higher bolt tension however is not the key determining factor of performance as consistency of retighten tension is much more important during functional use. Further testing is required to investigate and optimise the CoBlast treatment to reduce error and improve performance when compared to Molykote.

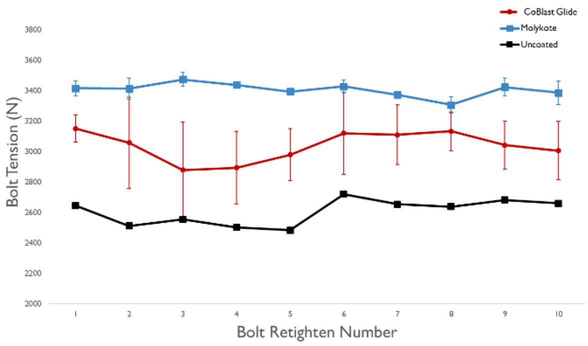

Fig. 11. Repeated clamp force measurements for CoBlast Glide, Molykote and uncoated M6 Gr5 Titanium bolts

CONCLUSIONS

ENBIO have developed a thin low friction coating for fasteners which ensure repeatable bolt tensions over 10 bolt retightens. In the case of SS A2-70 the performance of the coating exceeds that of the competitor Molykote, while for Ti Grade 5 the bolt tension remains consistent but lower than Molykote. Further work is planned with a wider range of bolts in collaboration with end-users.

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