Evaluation of Fastener Treatments for US Marine Corps Ground Vehicles

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ABSTRACT

Treatments for threaded fasteners are regularly used on USMC ground vehicles to prevent seizing as a result of corrosion. Environmental factors such as humidity and the presence of salt spray in addition to material selection, including dissimilar metal contact and the use of coatings, can influence corrosion and seizing of threaded fasteners. Performance of treatment products, designed to reduce fastener corrosion, were evaluated by measuring the weight gain and the torque, required to remove the fastener from aluminum and steel panels, as a function of time in an environmental test chamber. The accelerated atmospheric exposure consisted of a humidity exposure, a salt spray application with a solution containing sodium chloride, calcium chloride, and sodium bicarbonate, and a high temperature drying cycle. At selected exposure times, the fastener assemblies were removed from the environmental chamber and dissembled. The threads of the bolts and the base metal panels were inspected for damage such as thread galling and corrosion. Control samples, without fastener treatments, were also tested to provide a basis for comparison of the thread treatment products. Tests revealed that steel fasteners in steel panels were most prone to seizing compared to steel fasteners in aluminum panels. Both the petroleum-based anti-seize and the polytetrafluoroethylene (PTFE)-based thread treatments effectively prevented seizure and thread damage. Additional anti-seize alternatives are being tested and preliminary results are reported here as well.

Keywords: fastener, corrosion, treatment, seizing, salt spray, anti-seize.

INTRODUCTION

Fastener treatments, regularly used on USMC vehicles including HMMWV and MTVR, are being used to prevent seizure/galling of the threaded fasteners. Typically, fastener seizure/galling results in additional labor, and consequently increased costs, to remove the fastener during routine equipment maintenance. Costs can further be increased if the fastener removal process causes additional damage to vehicle components. It has been previously demonstrated (1,2) that fastener seizure is most likely promoted by corrosion in the thread contact areas and can be accelerated in the presence of interconnected dissimilar metals, such as steel bolts in cast aluminum housings exposed to aggressive environments, such as seawater. There is a vast inventory of treatment products available for corrosion and seizure/galling prevention. For instance, petroleum-based anti-seize products containing graphite and aluminum may act not only as a lubricant but also as a corrosion resistant, protecting galvanically steel fasteners. It is interesting to note that graphite can also act as the nobler component of a galvanic couple, thus exacerbating the corrosion of both steel and aluminum. Likewise, the petroleum-based carriers may also act as water dispersant preventing the ingress of water in the thread contact area, and consequently, corrosion of the threaded components is likely to be minimized. On the other hand, PTFE-based anti-seize products may act as a thread lubricant and may also prevent water accumulation owing to the hydrophobic nature of this component.

The objective of this study was to evaluate the performance of different anti-seize treatments in preventing seizure/galling on various threaded fastener materials exposed to cyclical corrosive environments.

EXPERIMENTAL PROCEDURE

As-received fasteners examined (i.e. washers and bolts 5/16” in diameter and 18 threads per inch) were cadmium-plated steel (Mil-90725), black oxide-coated steel (SAE J429), zinc-plated steel, 316 stainless steel, and ultra corrosion-resistant coated steel. After weighing, the bolts were treated with anti-seize products, including PTFE-based (Tef-Gel®), petroleum-based, Marine Grade, Ni-based (N-5000), and Mo-based (Moly-50) anti-seizes. A set of fasteners were left untreated for control purposes. Then, the fasteners were tightened to as-received base metal panels with an initial torque of 15 ft·lb (20 N·m) using a breakaway or a click-type torque wrench. The base metal panels were 1018 carbon steel and 6061 aluminum alloy drilled and tapped with mating threads. Afterwards, the fastener/base metal assemblies were cleaned with acetone and ethanol to remove any excess residue of anti-seize material and weighed prior to testing.

The assemblies, prepared in triplicate, were placed in a cyclic environmental test chamber and exposed to a salt-water spray cycle of a mixture of NaCl, $CaCl_2$, and $NaHCO_3$, a high temperature drying cycle, and a high humidity cycle in accordance with the GM 9540P standard test protocol (3). Test exposures ranged from 1 to 90 days and were continuous with no intermediate inspection or maintenance. Fig. 1 shows a photograph of the actual experimental setup.

After exposure, the assemblies were lightly rinsed with distilled water to remove any loose deposits and reweighed after drying. After weighting, the assemblies were then placed in a vise in preparation for dismounting. For some of the hardware, particularly the black oxide-coated steel bolts, it was necessary to remove corrosion product buildup from around the bolt head for bolt removal. The procedure for bolt removal started with an initial breakaway torque of 15 ft·lb (20 N·m) comparable to the installation torque. Additional torque in 5 ft·lb (6.8 N·m) increments was applied until the bolt either was removed from the panel or failed and was broken. After bolt removal, the threads of the bolts and the metal panels were inspected for signs of damage. Any galling/seizure of the threads or other thread damages were recorded.

RESULTS AND DISCUSSION

Figs. 2 to 6 show the average weight gain as a function of exposure time for the various treated and untreated bolt materials mounted in steel and aluminum panels. Both treated and untreated fastener assemblies showed an apparent weight increase with exposure time, which may be attributed to the accumulation of corrosion products that were not removed by rinsing. Although the increase in weight is a result of corrosion, the measured weight changes cannot be used to estimate corrosion rates, because the net weight change is the result of both weight gain due to corrosion product accumulation and weight-loss due to spallation of corrosion products, which cannot be accurately measured. The weight increase trends for all bolts examined with and without thread treatments mounted in steel panels were comparable, attaining over a ~3% weight increase for up to a 90-day period, suggesting that the use of thread treatments did not alter the buildup of corrosion products responsible for the increased weight after exposure of the untreated fasteners in steel panels. Similar observations were recorded for the treated and untreated bolts mounted in aluminum reaching <1.5% weight increase for up to a 90-day period. Overall, weight loss measurements of the untreated and treated bolts in aluminum panels were ~10% of the weight increase noted for the steel panel assemblies as a result of the smaller amount of corrosion products deposited on the aluminum compared to those observed on the steel panels. Light corrosion of the aluminum was noted in all cases in the crevice region between the washer and the aluminum panel.

Preliminary exposure tests with fastener assemblies were conducted to determine the breakaway torque required to loosen the bolts prior to atmospheric exposure. For all cases, the breakaway torques were similar to the installation torques. Thus, increase in the breakaway torque after accelerated atmospheric exposure testing can be attributed to galling/seizure of threaded bolts as described next (4).

Figs. 7 to 11 show the results of the breakaway torque as a function of test exposure time for the treated and untreated fastener materials in steel and aluminum alloy panels. For up to 7 days of exposure, the breakaway torques for the cadmium-plated and black oxide-coated steel bolts (Figs. 7 and 8, respectively) were comparable to the respective installation torques, suggesting no significant corrosion or seizing of the threaded components. However, the breakaway torques increased significantly after 28 days for the untreated fastener materials, resulting in component failure as well as galling of the threads in some assemblies as illustrated in Fig. 12. Increased breakaway torques were also noted for the bolts treated with either the petroleum-based or PTFE-based anti-seize after a 28-day exposure, but these torques were smaller than those recorded for the untreated bolts. The increased breakaway torques, more significant for the case of the cadmium-plated steel bolts, can be associated with both corrosion products accumulated on the steel panels and the bolts as exemplified in Fig. 13. Comparable observations have been reported by Brickford (4), Peterson et al (5), and Morrison (6). The smaller breakaway torques observed for the black oxide-coated bolts despite the significant accumulation of corrosion products around the hex of the black oxide-coated bolts can be attributed to extensive cleaning needed prior to removing the fastener, which may have mechanically loosened the fastener. Regardless of the increased breakaway torques, no failures were observed in any of the petroleum-based or PTFE-based treated bolts. Nevertheless, thread galling was noted on all cadmium-plated and black oxide-coated bolts treated with the petroleum based anti-seize after 90 days and with PTFE-based anti-seize after 28 and 90 days of exposure.

Results obtained with the cadmium-plated and black oxide-coated bolts in aluminum alloy panels are shown in Figs. 7 and 8, respectively. For both untreated fastener materials, the breakaway torque slightly increased for up to 28 days and remained nearly constant afterwards, attributed mainly to the relatively low strength of the aluminum panels. Thread galling and thread damage were noted on the untreated cadmium-plated and black oxide-coated bolts exposed for 28 days. In contrast, no significant increase in breakaway torque was noted for fasteners treated with either petroleum-based or PTFE-based anti-seize. Moreover, thread galling was observed in one black oxide-coated bolt treated with petroleum-based anti-seize and no thread galling was noted in any of the PTFE-based treated fastener assemblies.

Supplementary breakaway torque results (see Figs. 7 to 11) are being obtained using an expanded range of fastener materials including cadmium-plated steel, black oxide-coated steel, zinc-plated steel, stainless steel, and ultra corrosion-resistant coated steel, treated with Marine Grade, Ni-based, and Mo-based anti seize components. Preliminary results for up to 64 days revealed extensive thread corrosion damage as well as galling of all untreated fasteners in both steel and aluminum panels except for the stainless steel fastener which showed minor thread corrosion distress but signs of galling/seizing consistent with an increase in the breakaway torque in as early as 14 days of exposure. In contrast, no significant thread galling was noted in any of the treated stainless steel bolts in agreement with the slight increase in the breakaway torque respect to the installation torque. In general, thread treatment effectively minimized galling/seizure in both steel and aluminum even after 64-day exposure. Tests currently underway will reveal product performance for extended exposure periods.

CONCLUSIONS

1. The results of the fastener tests clearly show that the untreated threads are prone to galling/seizing. Removing the fasteners after corrosion has occurred can result in damage to the thread bolts that necessitate replacement or repair. In extreme cases, seizure is severe and the fasteners cannot be removed.

2. Based on the tests conducted, coated steel fasteners in steel panels appear to be more prone to galling or seizing compared to coated steel fasteners in aluminum.
3. Both petroleum-based and PTFE-based anti-seize treatments effectively minimized galling or seizure for the exposure times tested. Major differences in the performance of the two anti-seize products were not observed, however, bolts in steel panels treated with petroleum-based anti seize appeared to have less damage after exposures of 28 and 90 days compared with the fasteners treated with PTFE-based anti seize. In contrast, PTFE-based treatment appeared to be slightly better than petroleum based anti-seize on bolts in aluminum panels.
4. Preliminary results for up to 64 days revealed extensive thread corrosion damage as well as galling of all untreated ultra corrosion resistant and zinc-plated steel bolts mounted in steel or aluminum panels. Untreated stainless steel fasteners mounted in steel or aluminum panels showed minor thread corrosion distress but signs of galling/seizing consistent with an increase in the breakaway torque in as early as 14 days of exposure. In general, thread treatment of zinc, ultra corrosion resistant, and stainless steel bolts effectively minimized galling/seizure in both steel and aluminum even after 64 days of exposure. Tests currently underway will reveal product performance for extended exposure periods.

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REFERENCES

1. B. I. Kostetskii and V. N. Lozovskii. "Factors Determining the Probability of Seizure and Oxidation of Metals in Friction", Materials Science Journal 4 (5), 1971.
2. P. E. White. "Coating of Bolts to Prevent Seizure", Proceedings of the Society of Chemical Industry, Vol 43, pp. 1486-1490, 1964.
3. General Motors. "Accelerated Corrosion Test GM 9540P", General Motors Engineering Standard GM 9540P, 1997.
4. S. Peterson, G. Wechler, and M. Pepi. "The Performance of Three Alternative Coatings to Electroplated Cadmium for Corrosion Protection in Fastener Applications", Army Research Laboratory ARL-TR-1952, 1999.
5. J. Brickford. "An Introduction to the Design and Behavior of Bolted Joints", Marcel Dekker Inc. 3rd Ed., New York, 1995.
6. D. Morrison, C.L. Springfield, and J. Gayle. "Study of Corrosion Protection Methods for GSE Applications at Kennedy Space Center", Report No. MAB 3221-69, Laboratories Division, Florida, 1972.

Fig. 1: Top view of the fastener assemblies inside the atmospheric exposure chamber.

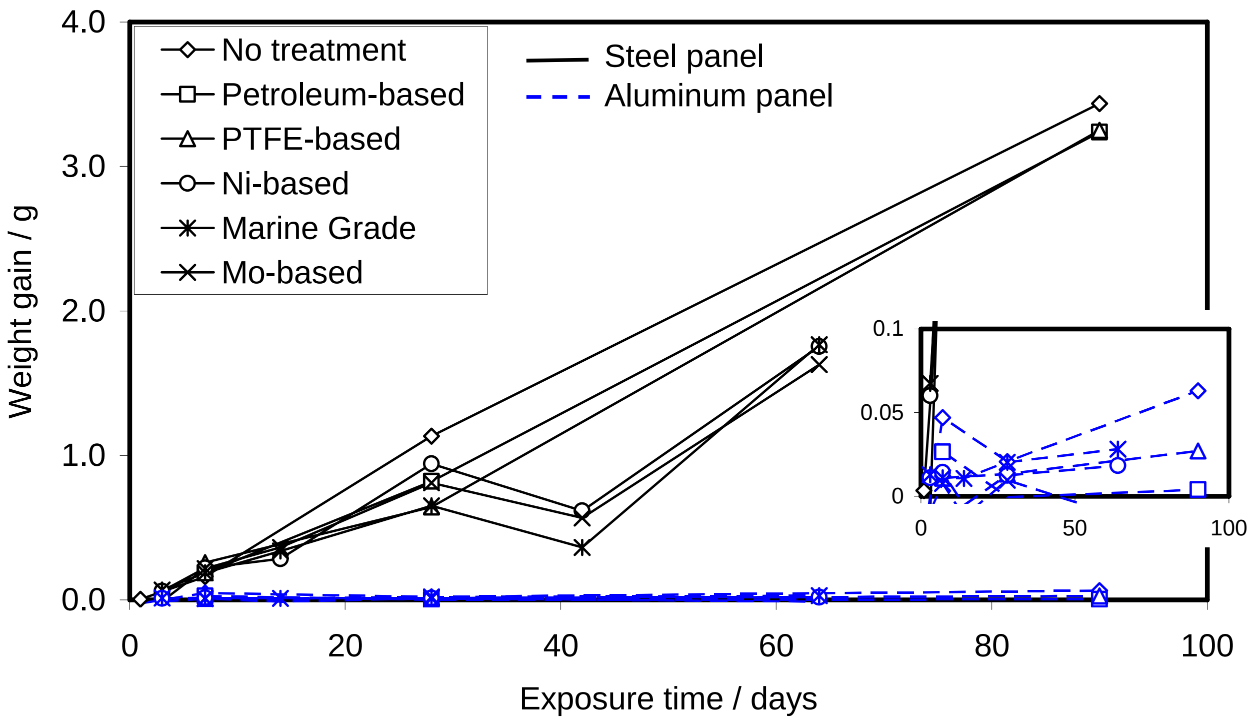

Fig. 2: Weight gain of the cadmium-plated bolts in 1018 steel and 6061 aluminum alloy panels.

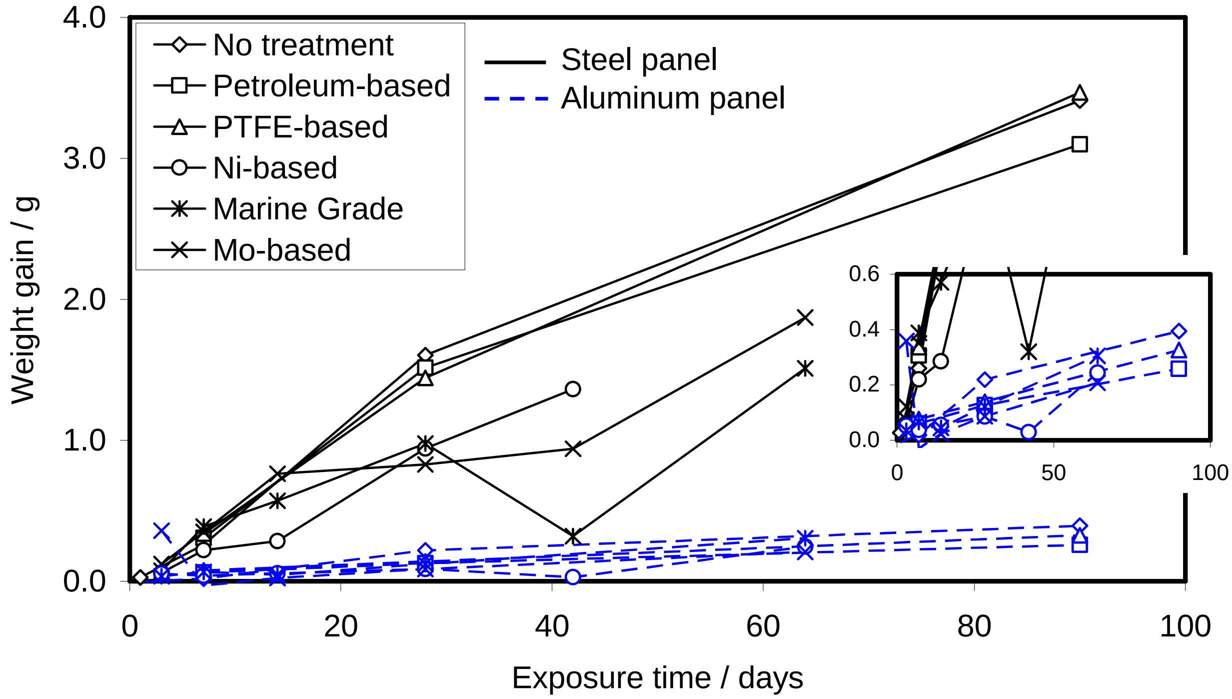

Fig. 3: Weight gain of the black oxide-coated bolts in 1018 steel and 6061 aluminum alloy panels.

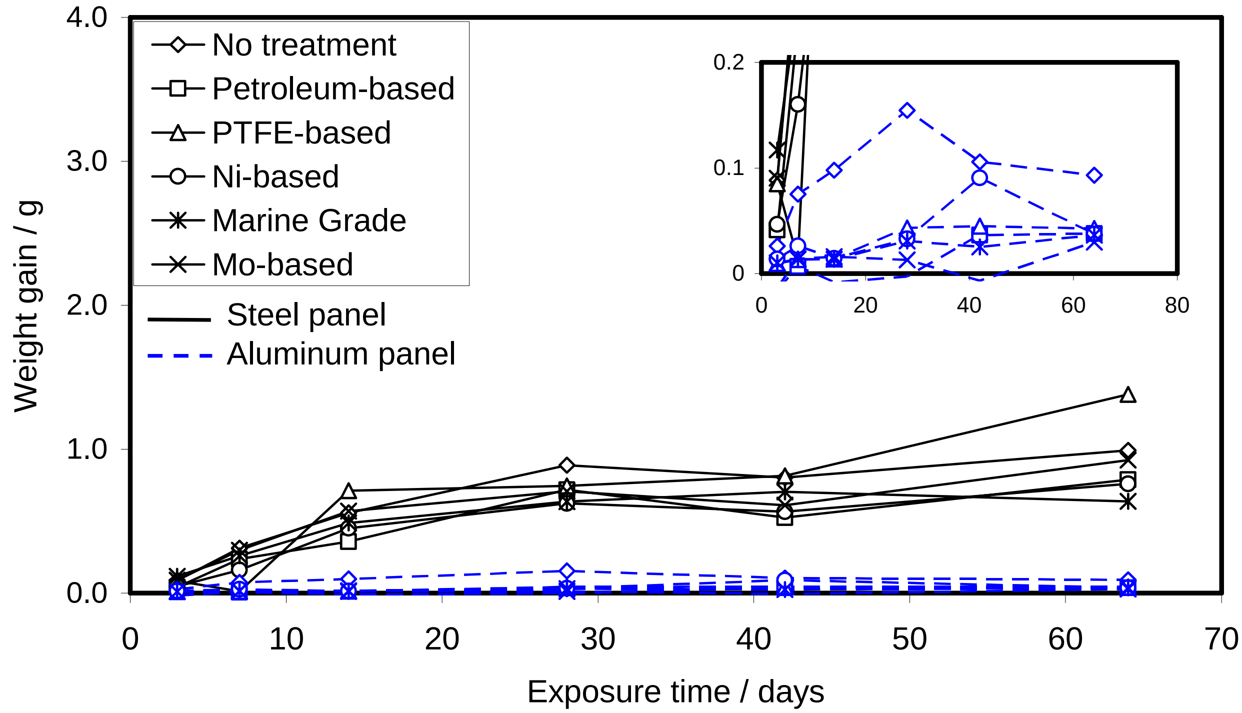

Fig. 4: Weight gain of the 316 stainless steel bolts in 1018 steel and 6061 aluminum alloy panels.

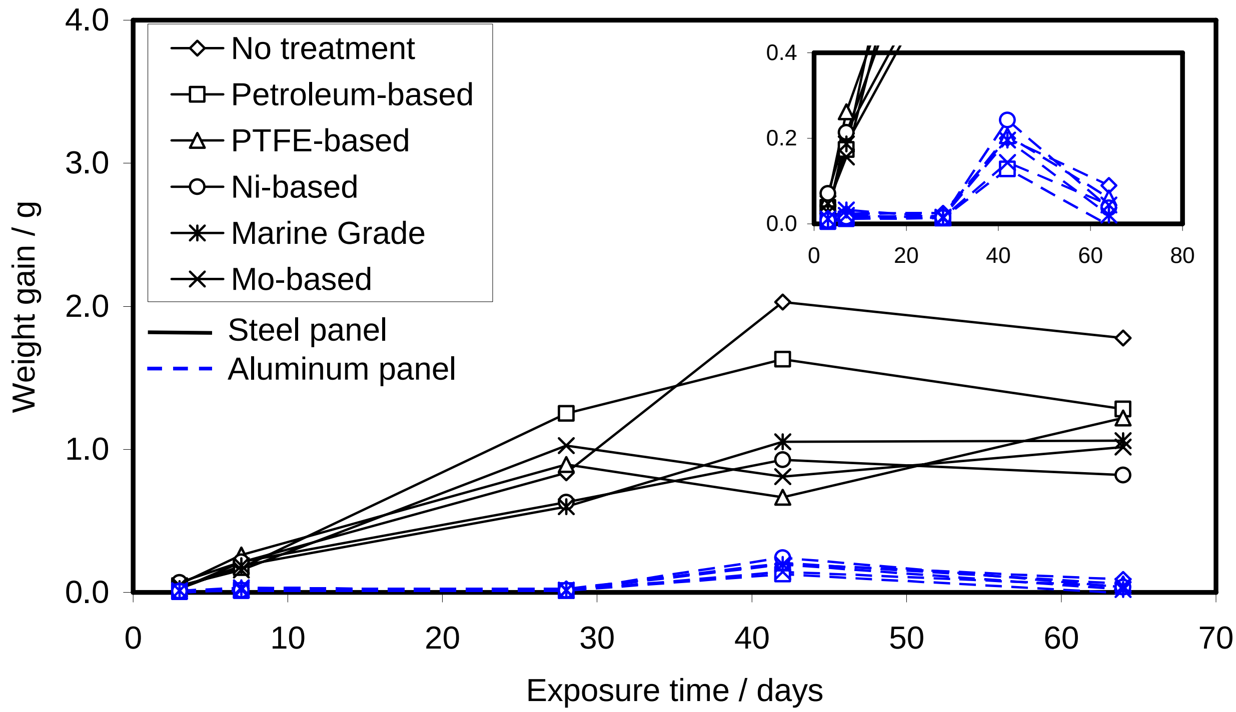

Fig. 5: Weight gain of the ultra corrosion-resistant bolts in 1018 steel and 6061 aluminum alloy panels.

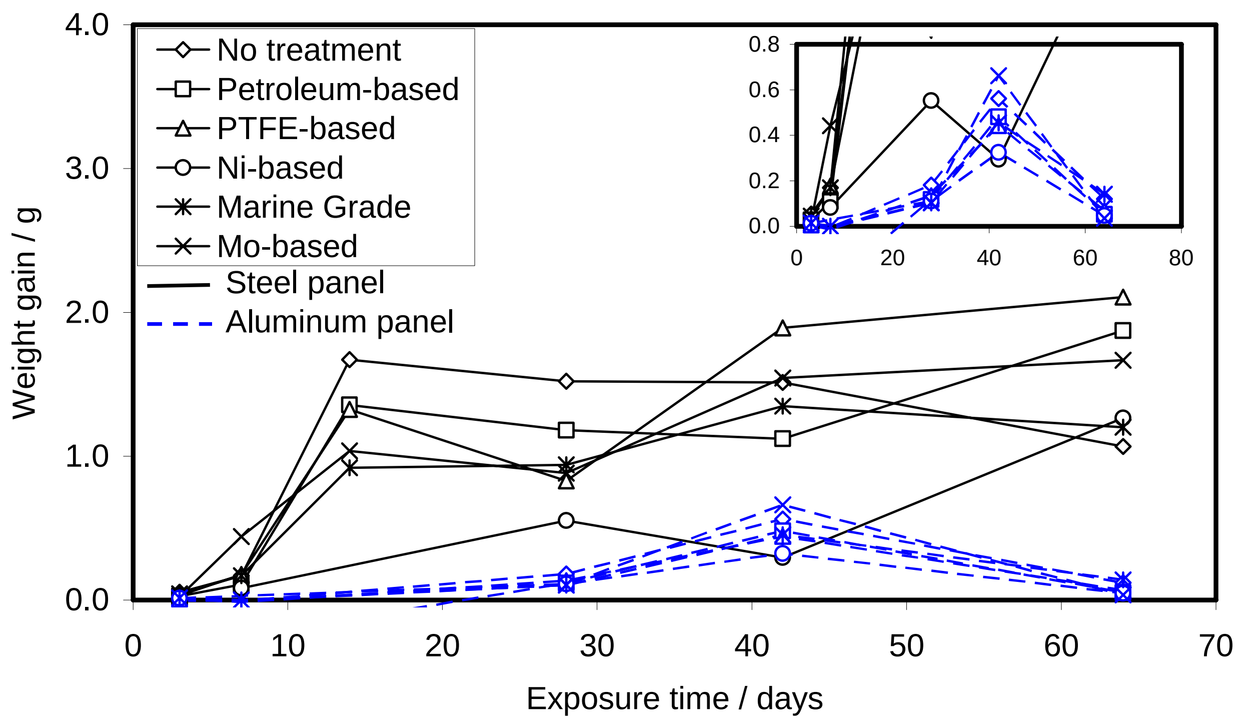

Fig. 6: Weight gain of the zinc-plated bolts in 1018 steel and 6061 aluminum alloy panels.

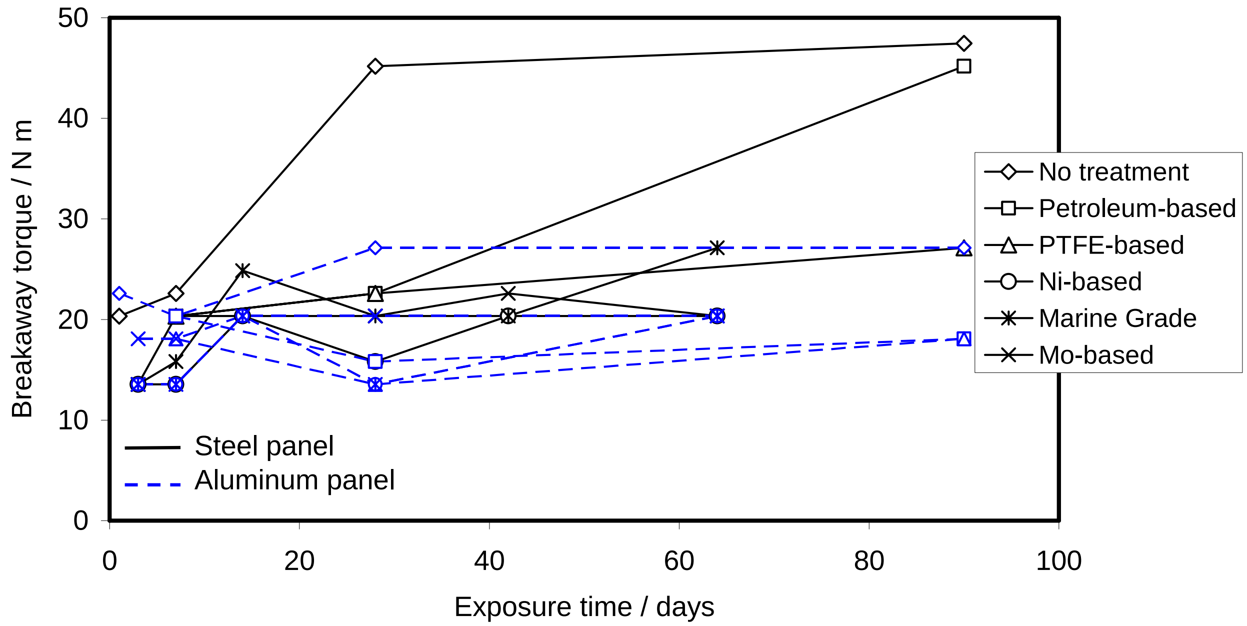

Fig. 7: Torque required for removing cadmium-plated bolts in 1018 steel and in 6061 aluminum alloy panels.

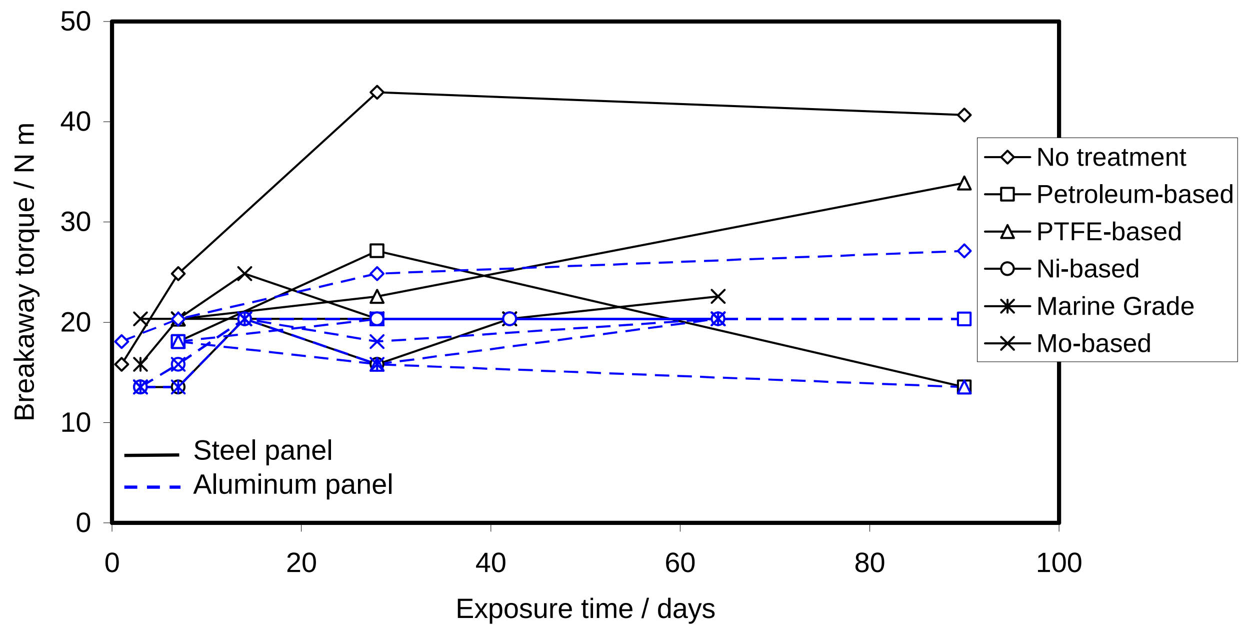

Fig. 8: Torque required for removing black oxide-coated bolts in 1018 steel and in 6061 aluminum alloy panels.

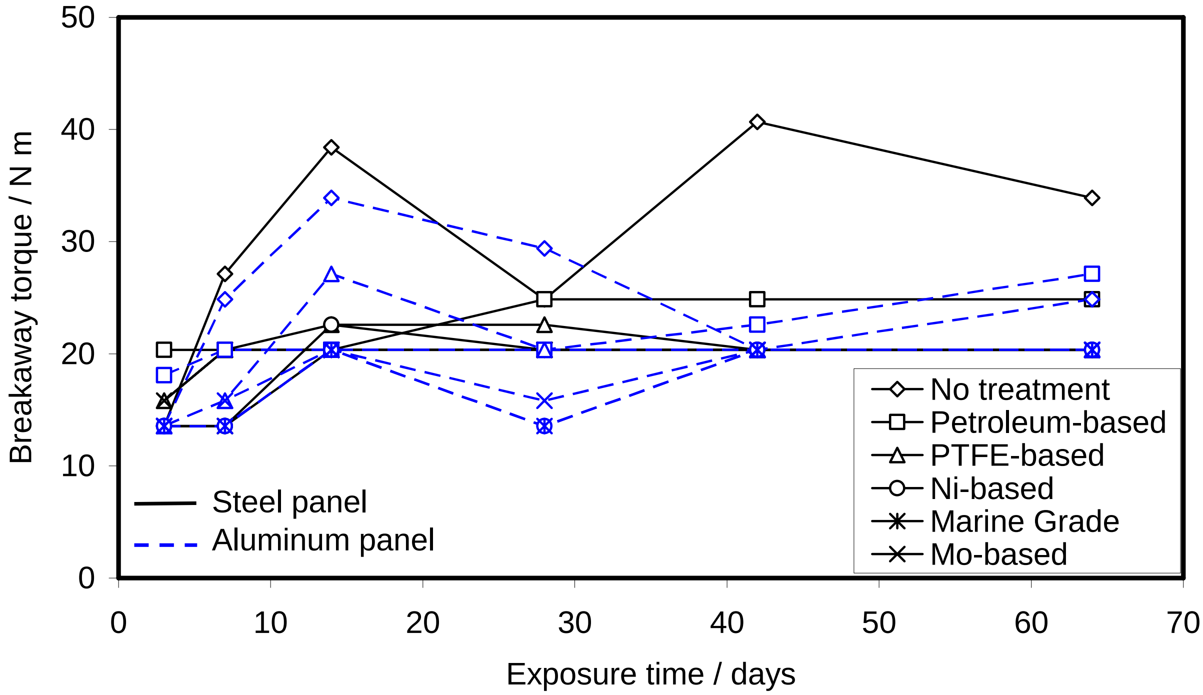

Fig. 9: Torque required for removing stainless steel bolts in 1018 steel and in 6061 aluminum alloy panels.

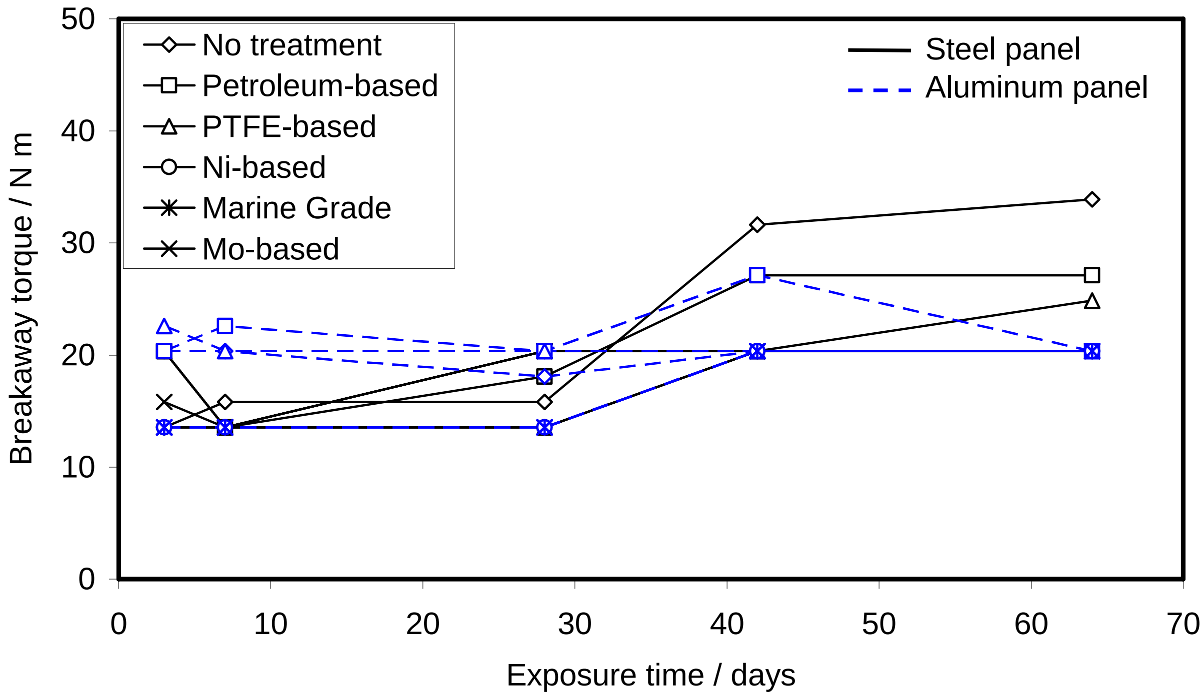

Fig. 10: Torque required for removing ultra corrosion-resistant bolts in 1018 steel and in 6061 aluminum alloy panels.

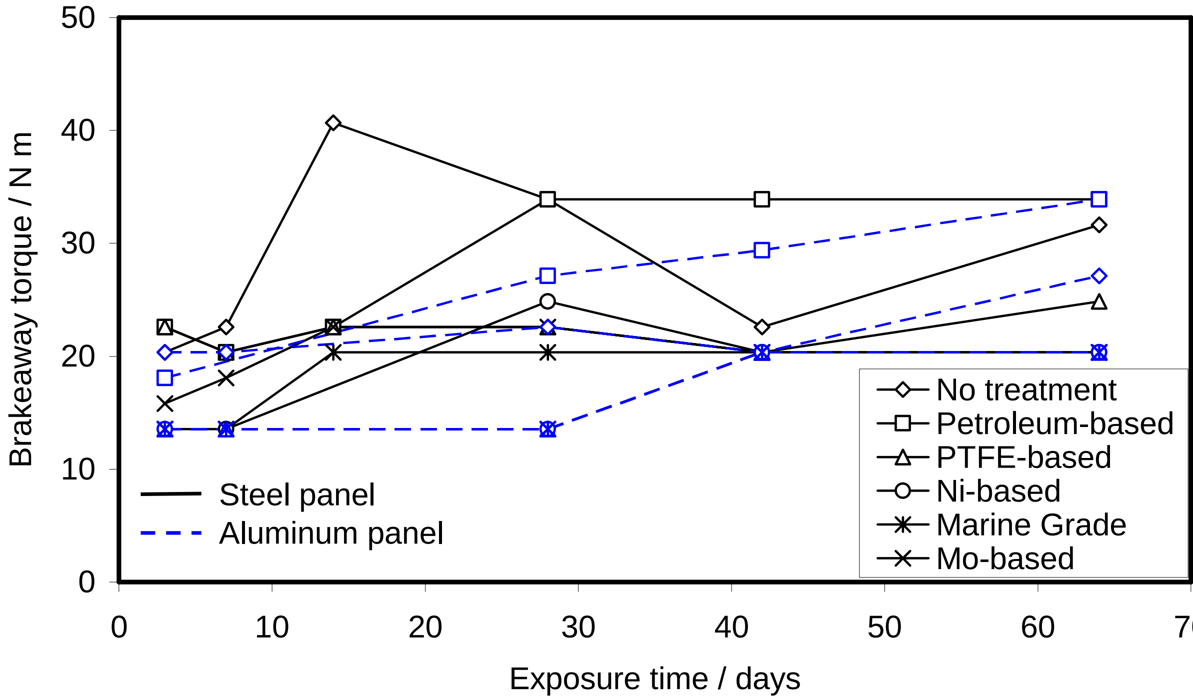

Fig. 11: Torque required for removing zinc-plated bolts in 1018 steel and in 6061 aluminum alloy panels.

Fig. 12: Photograph of a broken untreated black oxide-coated bolt in a 1018 steel panel after 28 days of exposure. Severe galling/seizing was noted after 28 days of exposure.

Fig. 13: Photograph of disassembled test pieces of cadmium-plated steel/steel panel assemblies after exposure in the atmospheric chamber for a period of 7 days. For the untreated fastener (a), thread corrosion is visible. The PTFE-treated bolt (b) still retained much of the white colored fastener treatment and the silver colored petroleum-based anti-seize (c) is also visible after 7 days.