Effects of Liquid Propellants on Mechanical Properties of Nonmetals

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Aerospace fluids such as hydrazine, monomethylhydrazine, and nitrogen tetroxide (oxidizer) are primarily appraised for their performance as propellants. Unfortunately, most propellants come with a list of undesirable side effects, such as toxicity and material incompatibility, which require attention as well. If the chosen propellant has detrimental effects on its storage and delivery systems, the consequences could be a significant loss in performance and inadvertent release of propellant. For example, figure 1 depicts the effect of MON-3 (mixed oxides of nitrogen, 3% nitric oxide) on a nonmetal o-ring constructed of a material considered compatible; i.e., chemically stable, with MON-3, which has been used for decades in this capacity. The results are dramatic; however, the effects of propellant exposure on a material may not always be as obvious as figure 1 illustrates.

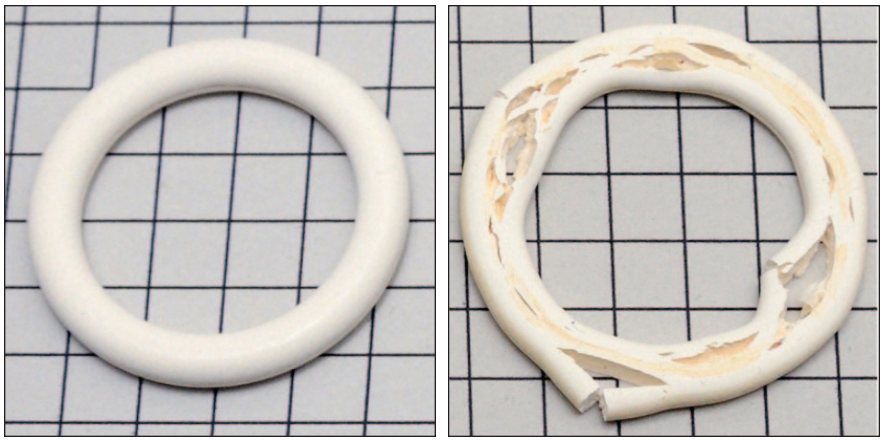

Fig. 1*. Oxidizer-compatible O-ring test sample (unexposed [left], exposed [right]).*

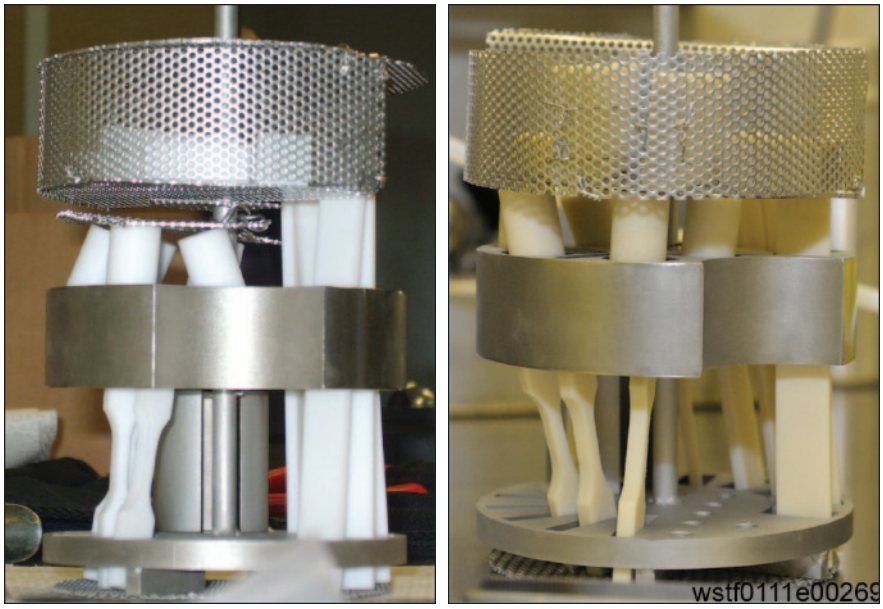

Fig. 2*. Oxidizer-compatible bar-stock fabricated test samples (unexposed [left], exposed [right]).*

The nonmetal test samples shown in figure 2 were fabricated from bar stock in accordance with the appropriate American Society for Testing and Materials standard for their respective mechanical property tests. The samples were exposed to MON-3 in a similar manner as the o-rings in figure 1; however, the samples do not show obvious signs of degradation other than a change in coloration. Material properties testing is needed to determine whether this change in color also correlates to a change in the mechanical properties of the samples. The NASA Johnson Space Center's White Sands Test Facility has the capability of performing material properties tests on samples conditioned in propellants. The mechanical property measurements commonly performed on propellant-conditioned samples are: tensile/elongation, hardness, compression set, compressive strength, flexural strength, swelling, and mass. Additional mechanical property tests may be performed per customer requirements.

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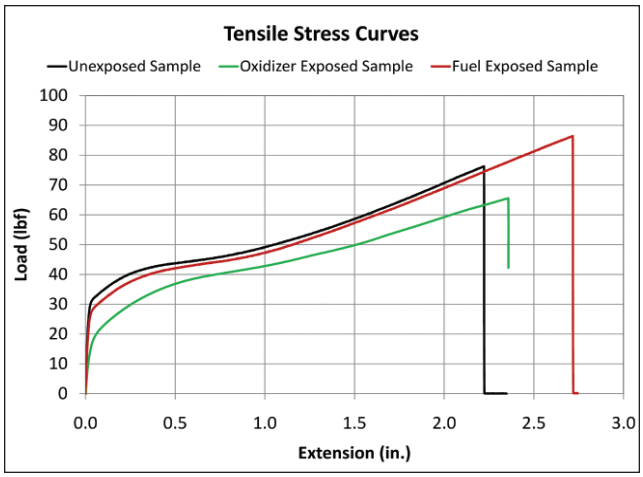

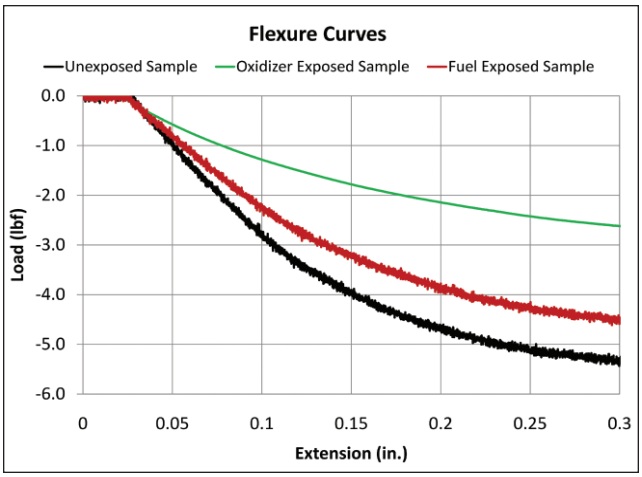

***Fig. 3**. Tensile and flexure curves for unexposed and exposed test samples*

The results of the tensile and flexure data of the samples in figure 2 are shown in figure 3, which also includes data for the same material conditioned in monomethylhydrazine. The data indicate that a change occurred in the mechanical properties of the material as a result of conditioning the sample. Qualitative data, such as visual inspection of the samples (figure 1), are sufficient for deeming a material incompatible with the propellant tested. However, the quantitative data shown in figure 3 can be used to determine whether the material is compatible in its intended use condition.

Conclusion

Previously, propellant system designers focused on materials to avoid in propellant systems because the data available were often qualitative and based on visual observations. The performance of a material after exposure to the intended use condition can be evaluated quantitatively with materials properties data. White Sands Test Facility can perform material properties testing of materials exposed to a variety of propellants. Testing data equips system designers with the information they need to confidently specify the best materials for successful use in propellant systems.