Submarine Propulsion Shaft Life: Probabilistic Prediction and Extension through Prevention of Water Ingress

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Current submarine propulsion shafts provide the necessary reliability when they are inspected and refurbished at least every 72 months. In several decades of service, no shaft failures have been experienced, and inspection results support continued performance. The next class of submarines requires equivalent reliability when inspected and refurbished at least every 144 months. Experience and improved design have eliminated many threats to the life of a submarine shaft, leaving corrosion fatigue as the current concern with the greatest risk. Inspections of existing shafts show a high percentage with signs of wetting, leaving designers with less-than-acceptable confidence to approve this longer service life.

Many paths might achieve the necessary shaft life; this paper focuses on quantifying the necessary level of water ingress prevention. Methods to prevent water ingress include seals, O-rings, and protective coatings. No direct information is available on which systems currently fail, nor when, allowing water to contact the shaft steel; only summary data of inspection results and numbers of defects have been reliably recorded.

This thesis uses probabilistic models from literature for pitting and cracking of wetted shafts, along with Monte Carlo simulations, to predict results of shafts inspections. Each possible water ingress distribution is analyzed by simulating shafts under 72 months of exposure to the water ingress, pitting, and cracking models. A water ingress distribution that predicts inspection results closest to actual inspection results is identified. Some information about water ingress can be inferred from this distribution. Next, using the same literature models, a water ingress distribution that predicts acceptable performance at 144 months is identified. The two water ingress distributions are compared, though it is identified that poor metrics exists for comparing distributions in this way.

Despite this difficulty, it is shown that the time a shaft is in service prior to becoming wetted must increase substantially. As one example, it is estimated that in the current design around one-third of shafts have developed water ingress by the 1000 day point, while for acceptable performance in the next class, only about three percent can be wetted in this time. This thesis recommends that inspection procedures are updated to provide more robust information for future analyses, which would better identify the appropriate distributions and greatly reduce uncertainty.

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