DEVELOPING HYBRID PHM MODELS FOR PIPELINE PITTING CORROSION, CONSIDERING DIFFERENT TYPES OF UNCERTAINTY AND CHANGES IN OPERATIONAL CONDITIONS

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Pipelines are the most efficient and reliable way to transfer oil and gas in large quantities. Pipeline infrastructures represent a high capital investment and, if they fail, a source of environmental hazards and a potential threat to life. Among different pipeline failure mechanisms, pitting corrosion is of most concern because of the high growth rate of pits. In this dissertation two hybrid prognostics and health management (PHM) models are developed to evaluate degradation level of piggable pipelines, due to internal pitting corrosion. These models are able to incorporate multiple sensors data and physics of failure (POF) knowledge of internal pitting corrosion process. This dissertation covers both cases when in some pipeline's segments the pit density is low and in some segments it is high. In addition, it takes into account four types of uncertainty, including epistemic uncertainty, variability in the temporal aspects, spatial heterogeneity, and inspection errors.

For a pipeline segment with a low pit density, a hybrid defect-based algorithm is developed to estimate probability distribution of maximum depth of each individual pit on that segment. This algorithm considers change in operational condition in internal pitting corrosion degradation modeling for the first time. In this way a two-phase similarity-based data fusion algorithm is developed to fuse POF knowledge, in-line inspection (ILI) and online inspection (OLI) data. In the first phase, a hierarchical Bayesian method based on a non-homogeneous gamma process is used to fuse POF knowledge and in-line inspection (ILI) data on multiple pits, and augmented particle filtering is used to fuse POF knowledge and online inspection (OLI) data of an active reference pit. The results are used to define a similarity index between each ILI pit and the OLI pit. In the second phase, this similarity index is used to generate dummy observations of depth for each ILI pit, based on the inspection data of the OLI pit. Those dummy observations are used in augmented particle filtering to estimate the remaining useful life (RUL) of that segment after the change in operational conditions when there is no new ILI data.

For a pipeline segment with a high pit density, a hybrid population-based algorithm is developed to estimate the probability density function of maximum depth of the pit population on that segment. This algorithm eliminates the need of matching procedure that is computationally expensive and prone to error when the pit density is high. In this algorithm three types of measurement uncertainty including sizing error, probability of detection (POD), and probability of false call (POFC) are taken into account. In addition, initiation of new pits between the last ILI and a prediction time is modeled by using a homogeneous Poisson process. The non-linearity of the pitting corrosion process and the POF knowledge of this process is modeled by using a non-homogeneous gamma process.

The estimation of these two algorithms are used in a series system to estimate the reliability of a long pipeline with multiple segments, when in some segments the pit density is low and in some segments it is high. The output of this research can be used to find the optimal maintenance action and time for each segment and the optimal next ILI time for the whole pipeline that eventually decreases the cost of unpredicted failures and unnecessary maintenance activities.

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