Paper presented to . *USAF Inaugural Engine Condition Monitoring (ECM) Workshop*, October 21-23, 1997, San Diego, CA.

Automated Health Monitoring of the M1A1/A2 Battle Tank

Lars J. Kangas
Frank L. Greitzer
Pacific Northwest National Laboratory, Richland, WA

LTC Mark Melius, US Army Logistics Integration Agency, Washington, DC

Abstract

Pacific Northwest National Laboratory is developing an operational prototype of an automated health monitoring system for the Army M1A1 main battle tank. TEDANN (Turbine Engine Diagnosis using Artificial Neural Networks) will collect data in real time from onboard sensors and assess current and near-term engine health. The current annual/semiannual engine health check requires that the engine be removed from the vehicle—an expensive, time consuming, and intermittent procedure. Continuous health checks during normal operations will enable deviations to be detected so that preparations for unscheduled maintenance can be made. TEDANN will also enhance battle readiness: Placing TEDANN's diagnostic/prognostic functionality in each vehicle will enable command and control to assess fitness for battle using average vehicle health ratings or expected service lives of vehicles.

TEDANN's model-based diagnostics approach uses artificial neural networks (ANNs). These ANNs will recognize and classify deviations from normal vehicle behavior.

Summary

Background

The Army's current maintenance practices for the Army's M1A1/A2 main battle tank (MBT) employ largely manual diagnostic procedures. Rather than using automated diagnostic and prognostic paradigms, the current practice verifies only whether the operational states are within or out of tolerance. There is a need to automate the monitoring of the MBT in real-time to assess the current vehicle health and to predict near term vehicle health.

TEDANN Vision

Pacific Northwest National Laboratory is developing the first functional prototype of TEDANN (Turbine Engine Diagnostics using Artificial Neural Networks), a vehicle health check system to assess battle readiness in real-time. Ultimately, an onboard computer system will continuously monitor the health of tank subsystems. This information will be available to command and control, logistics and maintenance support, and direct support.

Vehicle and engine health checks will be assessed through diagnostics/prognostics and onboard sensors. The health condition will be sent periodically through telemetry to the command and control system to enable a battle readiness assessment. Health check information that deviates from normal operation will be conveyed to the tank crew and sent to the maintenance support to prepare for unscheduled maintenance.

Health checks. Currently, engine health checks are recommended for semiannual or annual scheduled maintenance. These health checks are performed with the engine running, but removed from the vehicle and placed in a ground hop support system. This procedure is expensive, time consuming, and does not allow continuous health checks. TEDANN will perform these health checks continuously while the vehicle is in normal operation. TEDANN thus eliminates the need to remove the engine from the vehicle for health checks.

The continuous health check information will be used by TEDANN to predict (prognose) the future availability of the vehicle and to schedule maintenance. Planning for maintenance based on engine and vehicle condition (rather than an arbitrary schedule based on number of hours of operation) increases the battle readiness of the vehicle while reducing unnecessary maintenance.

Crew. TEDANN will be able to inform the onboard crew of all operational deviations of the vehicle subsystems that immediately require their involvement. This could include mechanical conditions that require that the tank be removed immediately from a critical tactical situation.

Organizational and Direct Support. The maintenance support should receive an automatic request for support from the vehicle through telemetry when TEDANN identifies an operational deviation that requires immediate action by the maintenance staff. This request will properly prepare the maintenance operation by identifying necessary labor and parts. The automatic request for support should go to a central maintenance computer that tracks all the vehicles. This computer can automate and prioritize the scheduling of labor and parts for all vehicles.

TEDANN could also interact with a central computer supporting maintenance to assure that parts will be available at a future date for a fault that is prognosed to occur in the near future. The central computer should develop a list of required parts through advanced integrated electronic technical manuals (IETMs) which determines whether the parts are in stock or should be ordered prior to the need.

Command and Control. Placing TEDANN's diagnostic/prognostic functionality in each vehicle will provide sufficient information to the command and control staff for assessing a unit's battle readiness. Such information might include a display of the average vehicle health status (or the average expected service life of the vehicles if they do not undergo extensive maintenance); and health status displays; other detailed information might be accessed for individual vehicles.

Maintenance scheduling. The periodic vehicle and engine health check information sent to maintenance through telemetry makes it possible to provide an automated scheduling program for maintenance. Automation will reduce the cost of maintenance by only servicing vehicles with actual diagnosed maintenance needs. Further, *because TEDANN predicts the urgency of maintenance, the vehicles can be serviced in order of priority.*

Approach

Model based diagnostics. Model based diagnostics is based on two major algorithmic systems. The first system models the real world phenomena, and the second system uses the deviations between the real world and the modeled phenomena to reason about the real world. In a dynamic system, such as the MBT, the vehicle's behavior is modeled during operational conditions when the vehicle and its subsystems are assumed healthy. Subsequently, any vehicle subsystem that deviates from its normal behavior can be recognized as a deviation from the modeled behavior of the subsystem.

TEDANN is being developed using a model based diagnostics approach that uses an adaptive technology, artificial neural network systems. This technology allows the diagnostic/prognostic system to adapt to each individual vehicle for increased diagnostic sensitivity and specificity. Using this approach, some artificial neural network systems will be developed to model normal behavior of the tank systems. Other artificial neural network systems will be developed to recognize deviations from normal behavior and classify these deviations as conditions that require maintenance attention.

Predictive trends. TEDANN will trend vehicle health checks to predict the overall battle readiness of the vehicle. These predictive trends will be developed in real-time at different system levels, i.e., the highest level is the vehicle, an intermediate level includes engine, transmission, turret, etc., the lowest level includes systems that are replaced as units during maintenance, e.g., the electromechanical fuel system, the electronic control unit, etc.

TEDANN will learn to recognize the difference between the slow decrease in health caused by normal wear and tear, and those caused by a accelerated wear associated with an imminent catastrophic event. The trending of the gradually decreasing, normal health trend enables the optimal scheduling of preventive maintenance. The prediction of imminent catastrophic events enables the scheduling of immediate maintenance to reduce potential damage to other components caused by the failing component. For example, timely identification and replacement of a rapidly failing bearing in a transmission will prevent other bearings and gears to fail or wear excessively.