Development of Monitoring and Diagnostic Methods for Robots Used in Remediation of Waste Sites 1999 Technical Progress Report

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The final assembly of the test rig was completed in January 1999 (see Figure 1). The test rig incorporated a wheel motor typical of those used for hydraulic robots, and allowed wheel motor loading at expected operating conditions. The rig included instrumentation, as shown in Figure 2, for acquisition of key parameters for both unfaulted baseline and inserted fault runs.

Checkout of the test rig was accomplished in two phases. In the first phase, only the wheel motor was connected to the hydraulic supply and the driven pump disconnected. With the rig in this configuration, operation of the wheel motor control loop and the monitoring and diagnostic (M&D) data acquisition system was verified. In the second phase, the driven pump was connected to the wheel motor and the operation of the rig under load was confirmed and unfaulted baseline data were acquired.

A list of 13 faults was developed (see Table 1). All faults were inserted and data were acquired. The data files were electronically transmitted to Rice University for analysis using Analytical Redundancy (AR), a model-based static space technique that derives the maximum number of independent tests of the consistency of sensor data with the linearized system model and past sensor and control inputs.

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Figure 1. Test Rig Assembly

Sensor Measurement Ranges			
P1 – P3	0 to 3000 psi to 100 Hz	F1 – F3	0 to 10 gpm turbine flow meter
P4	0 to 100 psi to 100 Hz	I1 – I3	0 to 50 A, 3-phase ac current*
P5	0 to 5000 psi to 100 Hz	L1	0 to 2 in. liquid level*
T1 – T5	K-type thermocouples (60°F to 200°F)*	K1	ac power, 0 to 50 kW (not shown)
G1 – G2	0 to 1 g acceleration (100 Hz)*		

*Sensors T1, G1, I1 - I3, and L1 are not shown on the test rig diagram as these sensors were included on the HPSS.

Figure 2. Test Rig Hydraulic Schematic

Table 1. Implanted Faults

Fault No. and Component	Fault	Method of Detection	Method of Installation
<i>Hydraulic Power Supply System (HPSS)</i>			
1. High-pressure filter	Plugged	Low-load side pressure and flow at high-load conditions and rise in oil temperature	Variable restriction in feed pressure line
2. Accumulator	Loss of charge	Poor transient response	Discharge accumulator
3. Pump drive motor (ac)	Motor fault; open winding	Case vibration and motor current	Remove fuse from one ac phase
4. Cooling fan	Loss of oil cooling; open winding (Rosie fault)	Pump motor and fluid temperature increases	Shut off cooling water flow
5. Hydraulic pump	Scored housing	Low output pressure/flow, vibration	Use existing damaged pump
6. Hydraulic pump	Internal leakage	Increased flow to tank	Remove internal seal or install broken seal
7. Relief valve	Broken spring	Low pressure	Install weak or broken spring
<i>Wheel Motor</i>			
8. Hydraulic motor	Loss of casing oil	Vibration	Bleed casing oil
9. Control valve	Open winding	Change in delta P or flow	Relay-controlled line break
10. Control valve	Sticking valve	Change in delta P or flow	Change control profile in software
11 Hydraulic motor	Ruptured supply line	Tank level change	Tee flow to separate tank
12. Resolver	Broken belt or damaged resolver	Loss of speed control	Relay-controlled line break
13. Hydraulic motor	Internal leak	Changes in flow or pressure	Valve between feed line and return line

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