NPAS Physics Pump Models for Autonomous Monitoring

PREPARED BY PETTE JOSEF RAMOS
ELGIN COMMUNITY COLLEGE
FERNANDO FIGUEROA, MENTOR
AUTONOMOUS SYSTEMS LABORATORY
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Introduction

- **Major:** Biomedical Engineering
- **College:** Elgin Community College in Elgin, Illinois
- **Prior to Internship:**
  - NASA Community College Aerospace Scholar
  - Biomedical Engineering Volunteer
  - Taekwondo Instructor
Background

- NPAS is a platform for autonomous operations developed at SSC’s Autonomous Systems Laboratory (ASL)

- The Intelligent Stennis Gas House Technology (INSIGHT) is a project that uses NASA Platform for Autonomous Systems (NPAS) to implement autonomous operations at the Gas House

- Initially INSIGHT is implementing autonomous operations of the Nitrogen system
Background From Previous Interns

- Andrew Yeo, a former NASA intern, provided the theory of how the centrifugal pump should work and left behind equations and parameters to begin coding in NPAS.

- Former Interns Kyle Bentain and Wilson Barce laid the groundwork for reasoning using the physics pump model.
Project Objectives

- Learn how to program using the G2 Software environment
- Create procedures and methods to detect cavitation in a centrifugal pump and other features such as efficiency
- Verify that the code and theory work by implementing test cases
- Begin implementation of the generic rotational pump model package for the High Pressure Gas Facility
Solutions

- Created a workspace to test the code of the previous interns and modified the code as needed

- Acquired data at the High Pressure Gas Facility to verify calculations

- Create rules to make relevant calculations automatically in 5 second intervals
This workspace was used to simulate a running pump and motor.
Instances/Objects

- Each instance is a representation of an object that is used at the Gas House with the exception of the “RULE” instance (more on that later)
- RP1 represents a centrifugal pump that is connected to MOTOR-1
- The connectivity automatically enables use of the linked motor and pump parameters in the modeled equations
- N2 represents the commodity that is being passed through the pump (RP1), which is Liquid Nitrogen
- RULE is used to disable and enable the use of the model when needed
Attributes

- Each instance contains a set of attributes
- The attributes in this case hold raw data and calculations
- These calculations are made through procedures and methods
- Raw data was collected by reading pressure, temperature, and flow rate sensors at the HPGF
The following procedures have different functionalities:

- Begin-calculations calculates all attributes of a class through the use of a button
- Enable-and-disable-rule turns a rule on/off when in administrator mode

Buttons trigger these procedures to begin

Rules were used to have the procedures run automatically
Procedures, Rules and Buttons (cont.)

BEGIN-CALCULATIONS, a procedure

begin
  (calling all pump calculations)
  start calculate-inlet-head (RP1)
  start calculate-head (RP1)
  start calculate-pump-efficiency (RP1)
  start calculate-flow-density (RP1)
  start calculate-outlet-density (RP1)
  (calling motor calculations)
  start calculate-input-voltage (MOTOR-1)
  start calculate-motor-efficiency (MOTOR-1)
  start calculate-shaft-torque (MOTOR-1)
  (radius and the radius of the motor)
  start calculate-inlet-pressure (MOTOR-1)
  start calculate-net-positive-suction-head (MOTOR-1)
  start check-inlet-head (MOTOR-1)
  start check-suction-head (MOTOR-1)
  start check-outlet-pressure (MOTOR-1)
  start check-motor-efficiency (MOTOR-1)
  start check-pump-duty (RP1)
  start check-pump-pumping-capacity (RP1)
  start check-pump-pumping-capacity (RP1)
  end

Motor 1, a pm-motor

Motor 2, a pm-motor
Programmatically Disabling and Enabling a Rule

**UUID:** 761d99ad9e61e8813ad4256bf7213b

**Notes:** OK

**Item configuration:** none

**Names:** RULE

**X:** 1

**Rules**

- **UNCONDITIONALLY START BEGIN-CALCULATIONS (RP1)**

**Buttons**

- **Enable/Disable Rule**
Logic

Button is pressed

Procedures and methods begin

Rule calculates automatically if enabled

Procedures calculate/update attributes

If a problem (in this case, cavitation) occurs, a message is posted to the operator
Common Problems

- One of the biggest problems when running a procedure lied within the units being used for each equation.

- As a way to distinguish the required units, documentation and comments were made for each procedure to keep all units uniform to the equations.

- Miscellaneous equation errors

**UNITS:**

- Length/Distance: Inches (in)
- Weight: Pounds (lbs)
- Time: Minutes (min)
- Volume: Gallons (G) * (in^3 for calculations) [conversion factor: *231]
- Pressure: Pounds per square-inch (psi)
- Density: Pounds per cubic inch (lbs/in^3)
- Rotational Speed: Revs/Minute (rpm) [revs for calculations] [conversion factor: * 1/60]
- Linear Speed: Inches per second (in/s)
- Volumetric Flow Rate: Gallons per minute (GPM) [in^3/s for calculations] [conversion factor: * 3.85]
- Gravitational Constant: inches per second^2 (in/s^2)
- Power: in-lbs/s

**Note:** When doing calculations, convert all units to pounds, inches, and seconds.
Importance of ISHM

- The Integrated System Health Management (ISHM) is a component of NPAS that utilizes 4 functionalities:
  - Anomaly Detection
  - Diagnostics
  - Prognostics
  - Integrated Awareness
- Each of these functionalities work hand in hand to detect a problem in a system and to predict possible outcomes.
Moving Forward

- Further develop symcure functionalities for root-cause analysis
- Implementation to the Gas House
- Implementing a saturation table that include temperature, pressure, and density
Lessons Learned

- How to program in the G2 Software environment
- Familiarity and coding for NPAS
- Application of physics in real world situations
- The properties of cryogenics and liquid nitrogen and their affects in the operations at Stennis Space Center
- How the Gas House system functions
Skills Acquired

- Programming for the first time
- Coding using object-oriented programming
- Project management using scrum
- Root cause analysis
- Physics models for rotary pumps and motors
Future Plans

Spring 2019
Finish ECC with an Associates in Engineering Science

Fall 2019
Transfer to the University of ????

Future
Graduate with a Bachelors in Biomedical Engineering

Spring 2020
Co-Op?

Graduate School
Masters in Biomedical Engineering
Acknowledgements

- Fernando Figueroa, NASA Mentor
- Andrew Tidwell, D2K Contractor
- Mark Turowski, NASA- High Pressure Gas Facility
- Wilson Barce, Former NASA Intern
- Lauren Underwood, NASA
- D2K Technologies (Mark Walker, Jon Morris, Neal Gross, Joshua Broberg, Brian Rey)
Thank You NASA!