P10227 Variable Intake System for FSAE Race Car

Test Plans & Test Results

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1. MSD I: WKS 8-10 PRELIMINARY TEST PLAN

1.1. Introduction: Overview and Purpose

1.1.1. The RIT Formula SAE Racing Team is a student run, all volunteer organization that produces a competition ready vehicle every year. This vehicle is then judged on engineering validity, marketability and on track performance. To be competitive innovations must be made each year to keep ahead of the competition. The variable intake system is one advancement for this year's vehicle.

1.1.2. As each competition passes, fuel efficiency and technical superiority becomes much more prevalent in competition scoring. This senior design project will develop a variable intake system for the Formula SAE racecar that will allow for increased fuel efficiency, design advancements and a greener methodology to produce more engine power.

1.2. Sub-System Breakdown

1.2.1. Mechanical System

The mechanical system is comprised of the sliding interface that allows the change in runner length and the plenum that the runners interact with. This system must allow for the desired change in length, not leak, maintain desired plenum volume, and comply with the FSAE rulebook.

1.2.2. Actuation System

The actuation system will move the mechanical system based on inputs from the control system. Actuation speed is critical for this application as transient times must be kept under 100ms. This system must also be able to gauge the system's location.

1.2.3. Control System

The controls for this system will be fully integrated into the engine control unit (ECU) for the vehicle. Using inputs such as RPM, throttle position, manifold pressure and current runner length the control system will output a desired runner length to be achieved by the actuation system.

1.2.4. Supporting Systems

The variable intake will interface with the engine on one end and a throttle/ restrictor assembly on the other. Sufficient information on the flow characteristics of the throttle/ restrictor assembly will be needed to design and tune this system.

The electrical requirements of the actuation system will be provided by the vehicle's stator. There is a limited amount of power available from this system, which must be taken into account.

The intake manifold also houses an air temperature and manifold pressure sensor. This information is critical to the ECU to provide the correct outputs for engine operation.

1.3. Approval; Guide, Sponsor

Approved by: RIT Department of Mechanical Engineering
Team Members – Dave Donohue, Dan Swank, Matt Smith, Kursten O'Neill, Tom Giuffre
Guide – Dr. Alan Nye
Consultant – Mr. Chris Deminco
Sponsor – FSAE, RIT Department of Mechanical Engineering

1.4. Test Strategy

1.4.1. Product Specifications

Engr. Spec. #	Import-ance	Source	Specification (description)	Unit of Measure	Marginal Value	Ideal Value	Comments/Status
ES1	2	Weight	The overall weight of the system compared to non-adjustable	lbs	4.0	1.85	Current system 1.478 lbs
ES2	1	Performance	The reduction of lap times due to system performance	sec	1	2	Will vary depending on event
ES3	3	Fuel Economy	The impact this system has on fuel consumption	lbs/hr	0	-2	
ES4	6	Manufacturing Time	Time required to produce a working unit	days	20	10	
ES5	5	Current Draw	Current required by the system to operate	amps	5	1	
ES6	4	Actuation Time	Time required to change position	milliseconds	200	100	

1.4.2. Hardware and Software

Hardware includes the system and interfaces required to operate it effectively on the vehicle. This system should be a standalone system only requiring power and data from the rest of the vehicle.

The software made available to the customer will allow for easy tune ability and ease of trouble shooting.

1.4.3. Test Equipment available

Machine shop equipment

DC Dynamometer

Chassis Dynamometer

Honda CBR 600 test engine

RIT FSAE race car

Electronic test equipment

Computers

1.4.4. Test Equipment needed but not available

Flow bench

Vehicle based data acquisition system (DAQ)

1.4.5. Phases of Testing

1.4.5.1. Test Variable Intake Manifold (wks 2-6)

The team will design and build a prototype intake manifold that will allow for a wide range of intake runner lengths to be tested. Although this will be quasi-static testing the system will be highly adjustable and quickly tuned to different lengths.

This testing will occur on the DC Dynamometer in the ME machine shop.

1.4.5.2. Subsystems (wks 6-13)

The mechanical subsystem will be tested on the dynamometer in its initial phase. During this time the system will be set at a range of lengths to match those from the test intake. The data can then be compared to ensure the system is producing the maximum power at the desired RPM's.

The actuation subsystem will be tested as assembled to the intake system. It will first be tested for actuation speed and current draw. If these variables are within range the system can be fully tested as controlled by the ECU.

The control system will be tested as the engine is tuned. It will be considered fully operational if it performs without issue on the dynamometer.

1.4.5.3. Reliability and Performance (wks 11-15)

This will be on car based testing. After the system has been tuned on the dynamometer it will be installed on the vehicle. The first test will be fitment and interference. If any issues are detected they will need to be corrected immediately.
The system will be in place for the entire track testing of the vehicle before the competition season. Tuning will continue to occur throughout this period. Any issues with the operation or longevity of the intake system will be addressed as they occur. Additional testing and tuning may take place on a chassis dynamometer if it is deemed viable.

1.4.5.4. Customer Acceptance (wks 20-21)

If the variable intake system proves reliable and beneficial during the on car testing period it will be ready for competition use. At this time the system will be checked over and either rebuilt or be decided competition ready.

2. MSD II WKS 2-3: FINAL TEST PLAN

Final testing of the completed system will determine its longevity and effectiveness. The vehicle that this system is designed for must compete in a 22 km endurance event. This specification makes overall reliability and fail safety the most important design consideration. All of the testing will ensure that this requirement is met. Second is performance to justify the added weight and complexity of the system.

2.1. Data Collection Plan; Sampling Plan

2.1.1. Data Collection Structure

Most data for final testing will be in the form of elapsed times for each test. Comparisons will be made between elapsed times with the system operating and inactive. Fuel economy data will be in the form of mg/stroke or lbs/lap. Driver feedback will also be considered for tuning and overall system effectiveness determinations.

2.1.2. Phases of Testing

2.1.2.1. Test #1: Acceleration

The system will be tested on the designated 75 meter track. For all runs environmental and tire conditions will be maintained as similar as possible. Runs will be made with the system fully active compared to a set specified length. The runs with the system active should show a measurable reduction in the elapsed time. The system must also be repeatable and not interfere with the drivability of the car.

2.1.2.2. Test #2: Skid Pad

The skid pad event should not see large gains from additional horsepower provided by a variable intake. Running with the system active versus inactive should not negatively affect the handling of the vehicle for the test to be a success. Times will be measured for this event to see if any gains can be made.

2.1.2.3. Test #3: Autocross

The autocross event is where the largest performance gains from the system should be recognized. Direct comparisons can be made between the active and inactive system on single runs and overall time from 10 continuous laps.

2.1.2.4. Test #4: Fuel Economy

Fuel economy will first be tested on the dynamometer using information from the engine controller. Final testing can use this method or an empirical method. For the second method the vehicle will be fueled to a set level, driven for 10 laps and refueled. The mass of fuel used can then be compared between active and inactive systems.

2.1.2.5. Overall Customer Acceptance

Not all of these tests must be passed to declare the system a success. Drivability and fuel economy must be maintained but overall performance gains only need to be apparent in one area to prove successful.

2.1.3. Sampling Techniques

The data collected will be obtained from a timing system and the engine controller along with a vehicle DAQ. The timing system will provided lap and elapsed times with great precision and repeatability. The engine controller allows engine parameters to be recorded and will be logging during our testing.

2.1.4. Sample Size

For each of the tests at least three runs should be recorded for each test condition. Tests should also be repeated for different track conditions (hot, cold, or wet) to ensure the system performs as desired in all environments.

2.1.5. Reporting Problems; Corrective Action

If problems develop the first action will be to properly identify the problem and what subsystem is responsible. If the problem is not catastrophic the team will try to recreate the problem to better identify the conditions that surround it. The system can then be removed and examined further for additional information.

Using these findings a solution can be devised and implemented. If necessary the system can first be bench tested on the dynamometer before being returned to service on the Formula car.

2.2. Measurement Capability, Equipment

2.2.1. Currently there is not an adequate data acquisition system (DAQ) to log all of the parameters the team must record.

2.2.2. The RIT Formula SAE team has adequate timing equipment for this testing

2.3. Test Conditions, Setup Instructions

2.3.1. Tests will be set-up to match those of SAE events that the vehicle will be competing at.

2.3.2. All environmental test conditions must be representative of what the vehicle will undergo at a competition.

2.4. Sponsor/Customer, Site Related, Requests / Considerations

2.4.1. The customer is integral to aiding in the performance tuning of the final system. The design team has already gained a large amount of knowledge in running the dynamometer and tuning the engine, but customer knowledge is needed.

2.4.2. The team will need to work with Parking and Transportation to ensure adequate testing time is available in G&H lots.

3. MSD II – WKS 3-10 DESIGN TEST VERIFICATION

3.1. Test Results

3.1.1. Subsystem
Each subsystem will have been thoroughly tested in the final system by the conclusion of this project.

3.1.2. Integration
Integration issues should be quickly resolved as they will prevent the use of the system on the vehicle.

3.1.3. Reliability
Reliability is our greatest concern in developing and testing this system. Any issues with reliability must be documented and quickly resolved.

3.1.4. Customer Acceptance
This will depend on the overall benefits seen from the system. It must provide enough gains to make up the weight and complexity it adds to the vehicle.

3.2. Logistics and Documentation

Data will be logged using computer and hand documentation. This data will then be input into Excel spreadsheets for comparison. Final system comparisons will be shown on the EDGE website and project reports.

3.3. Definition of a Successful Test, Pass / Fail Criteria

A successful test will be any test in which no errors arise from the system. For the variable intake to pass a test it must show a result that will improve performance of the vehicle at the competitions it will be attending.

3.4. Contingencies/ Mitigation for Preliminary or Insufficient Results

Insufficient results would most likely be due to a lack of development time. Overall system failures will need to be re-engineered and tested again. Most issues should be solved by different manufacturing methods or added tuning time.

3.5. Conclusion or Design Summary

Inadequate results in any of the tests performed must be reviewed to find the fundamental issues with either the system or the vehicle it is interfacing with. It is quite possible that testing of this system will reveal other issues with the engine package. These interactions must be understood well to determine a route to a better overall design. Any information learned during this project will be valuable to increasing the team's engineering knowledge.

3.6. Function/ Performance Reviews

3.6.1. Debriefing your Guide and Faculty Consultants

The team interacts with our guide on a weekly basis, having him present for a portion of each meeting. This and visits during testing and development from consultants allows a greater number of ideas to be explored and problems solved.

3.6.2. Lab Demo with your Guide and Faculty Consultants

Our guide will be presented with our findings as they are recorded. This information will then be compiled to present in a final review.

3.6.3. Meeting with Sponsor

As our sponsor works with us through this project they will have a firsthand look at how the system is performing. By the completion of MSD II the customer will have learned a majority of the information regarding the system and should be fully self sufficient in using it.