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Design of Sensor Data based Control on Pulse Detonation Engine for Aerospace Applications

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ABSTRACT: Application of various types of sensors to Pulse detonation engine to predict the dynamic performance and its control, which has resulted in quantifying engine functionality during various operations under typical conditions. After evaluating the performance, techniques of improving it, were applied in multiple areas of relevant interest. This produced encouraging results and helped in upscaling efforts in a significant manner. The current paper deals in the details of sensor based control implementation and systematic identification of key areas of improvements. The improvements were carried out after careful selection of plans in the engine, ground rig and instrumentation setup etc. It also yielded better reproducibility of performance and optimization of main subsystems of PDE. Further, this will also contribute to reduce the development cycle and trial complexity also, if researchers continue to extract concern areas to be addressed.

KEYWORDS: Pulse Detonation Engine, Thrust, control, Thrust measurement, Engine ground rig, Deflagration to Detonation (DDT), control, sensors

A. Abbreviations and Acronyms

Abbreviation	Nomenclature	Units
PDE	Pulse Detonation Engine	-
PDRE	Pulse Detonation Rocket Engine	-
P_1	Chamber pressure at station 1	bar
PFR	pressure flow regulator	-
CFD	Computational Fluid Mechanics	-
FCS	fire control system	-
DDT	Deflagration to Detonation	-
AC	Alternating Current	-
NI	National Instruments Inc.	-

I. INTRODUCTION

Pulse detonation engines (PDE) offer a lightweight, low-cost & high thrust alternative for aerospace applications up to hypersonic velocities. PDE is an aerospace engine, which works on detonation principles. It has got few components of simple geometry and have no complex moving parts. Currently, PDE technology is being developed for upper stages that boost satellites to higher orbits. The advanced propulsion technology could also be used for lunar and planetary landers and excursion vehicles that require throttle control for gentle landings. It is also a competitive contender for missile systems application due many other advantages also. It would allow rockets to carry heavier load, reduce costs of launch into orbit too. Even though, PDE is key engine option from last 5 decades for aerospace applications, but a very limited progress has happened in development of fly worthy engine based on these principles.

In a breakthrough move, Russian scientists have become the first ever to successfully test a pulse-detonation rocket engine (PDRE) in July and August, 2016, on clean fuel (**oxygen-kerosene pairing**), claiming this will be the future of space travel. Americans, Japanese, French and Chinese teams are busy in making PDE powered missions a reality.

PEC is also engaged in PDE design and is in mature stage to development and testing. Getting the desired thrust at all intervals is a key concern of designers. Detonation achievement phenomenon by using Schelkin spiral blockage ratio optimization was carried out in CFD and experiments to enhance the thrust [1]. During PDE development, designers have faced frequent thrust fluctuations of significant range and emerged as key area to be addressed in addition to integration challenges [2], [3] and [4]. Researchers have earlier developed gaseous PDE ground demonstrator [5] and presently working on liquid fuel based PDE on detonation principles [6]. The power fluctuations will result due to random variation of chamber pressure P_1 . Calibrated and careful selection of various parameters in PDE cycle will help to handle these issues to a large extent.

To reproduce the consistent thrust in PDE, sensors are applied at various phases of engine. Its data is processed and commands are generated based upon these sensor data. The coming paras is dwelling on our approach to handle this issue too.

II. PDE TRIAL SETUP

Experimental PDE trial setup planned by TBRL (refer fig.1) for getting the measurement of various parameters to assess the performance of the PDE [2]. The fuel and air are injected into PDE tube at certain pressure and interval using a unique injection schemes at typical pressures and equivalence ratio established after series of calculations and perfected in experiments. A test rig consisting of purified compressed air cylinder bank, Dome regulator, pressurized flow regulator (PFR) and its allied instrumentation of dial gauges and pressure gauges instrumented through recorders for data storage. This rig also supports to meter and force fuel to be pumped in PDE tube through injector. The current setup helps the PDE input parameter control and regulation.

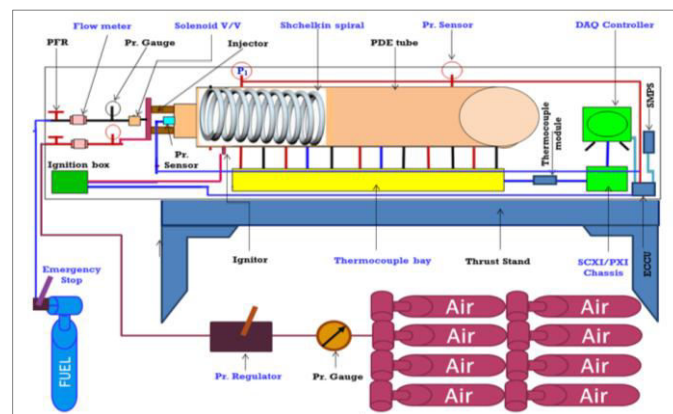


Fig. 1 Trial Setup of PDE experimental plan

The various operations of PDE cycle are carried out in a particular sequence and timing plan, which are altered and fine-tuned to meet our practical requirements. Generally, with a small shift in parameters require retuning of all parameters to get proper output, which is still having performance parameters variations of the order of 20-30% due to various reasons. The paper deals with the handling of this issue using complex statistical pattern study and plan to pin point the cause and strategy to address it.

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A dedicated fire control system (FCS) is designed to create significant ignition flame spark [5] using high voltage setup, which is commanded for deflagration / detonation at specific intervals through complex electronic command and control unit (ECCU), inputted remotely through serial link. In present configuration, all these systems are AC powered.

A powerful NI data acquisition system is used to acquire the data from multiple sources at separate sampling rates and being analyzed online and stored in tdms format for detailed offline analysis also. The current paper uses this stored data for doing statistical data analysis.

NI Diadem, Mathworks Matlab & MS Excel is used to carry out data processing, analysis and graphical visualization. This is covered in para V in details.

III. SENSOR NETWORKING

A sensor network is designed and powered using various rating of SMPS. Sensors used are :

1. Meas Pressure sensors for line pressure measurements
2. Analogue gauges for indications and manual recording
3. Zuma pressure gauge (10/20 bar)
4. Max load load cells for force measurement
5. K/J type thermocouple network for hot mixture and tube surface temperature measurements

Some other devices are also used:

1. Solenoid valves for gas filling to settling chambers/PDE tube
2. Flow controllers for auto filling of gauges to settling chambers

A special network is created to establish the connectivity is shown in fig 2. Organizing the sensors and control components as per fig. 2 has helped team to achieve a structured architecture of the plan. It has created a modular approach to highly reliable electronics and instrumentation setup to ease the rapid recording and processing of data in a organized pattern. This has also helped team to easy detection of problems and resolve the major issues in a simplified diagnostics approaches.

IV. DISCUSSION

From the above analysis, it is proved that reproducibility of pressure variations in PDE tube at pressure ports, is significant, random and repetitive, but within limits. Team has carefully studied the causes of these variations. The main causes are listed below [2]:

- Variation of source line pressures due long pressure lines
- Higher pressure range gauges at rig
- Purity and homogeneity of fuel and air
- Injector issues:
 - design and fabrication issues
 - non homogenous mixing

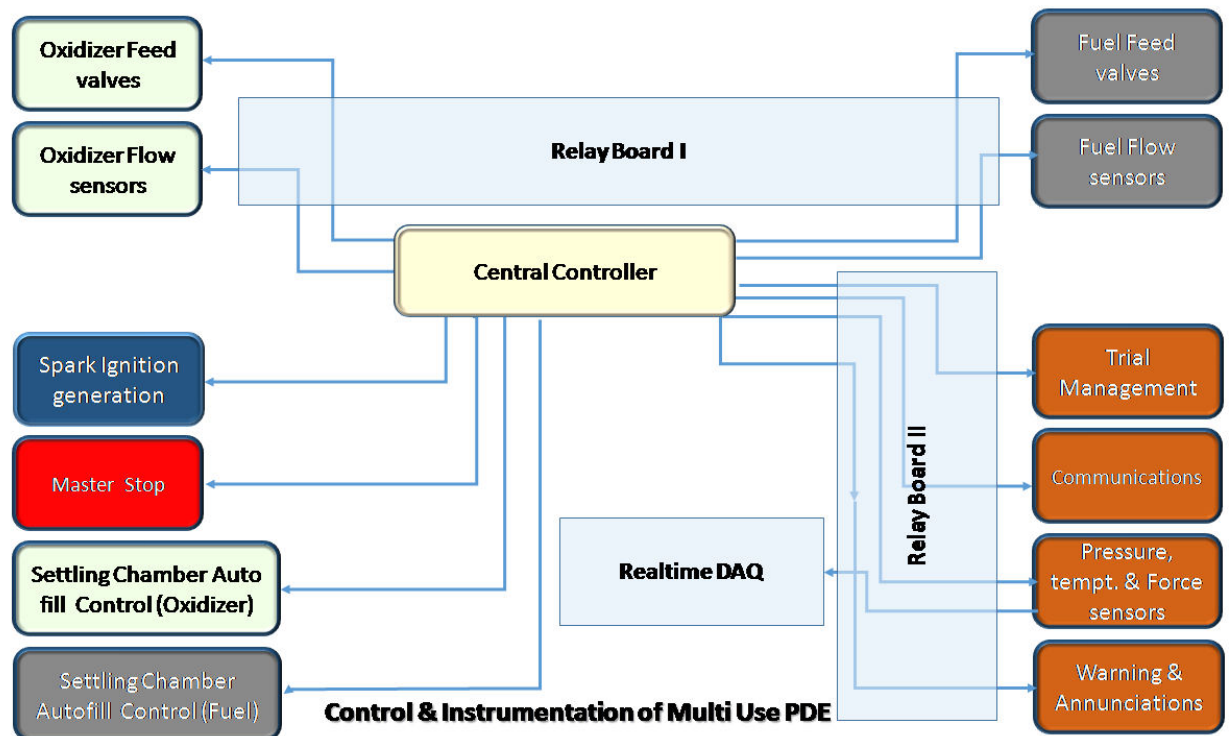


Fig. 2 PDE structured Control plan

- Schelkin spiral issues:
 - Mounting mechanism not restrained from vibrations
 - Long length giving shock reflections
 - Random pressure sensor/transmitter touches
- Ignition Command Issues:
 - relay getting stuck or improper contacts
 - Mechanical lags in command following
- Ignitor Issues:
 - Body cracking due vibration or ceramic damage
 - Carbon formation at tip
- Misc. Issues
 - heating of tube
 - online variation of pressure
 - contamination
 - sediments in lines and filters
 - leakage and age related problems

All these problems are being addressed simultaneously. The variations in pressures have reduced and Fire control system will take one year plus and remaining issues also will get resolved. If these problems are addressed properly, then PDE can be easily to an engine for future aerospace applications [10].



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REFERENCES

- [1] Subhash Chander, TK Jindal, “**Mathematical Simulation of Performance Parameters of Pulse Detonation Engine**”, XII International Conference on Aerospace, Mechanical, Automotive and Material Engineering (ICAMAME-2015), Dubai, UAE by World Academy of Science, Engineering & Technology (WASET) - 2015.
- [2] Subhash Chander, TK Jindal, “**Integration Challenges in Design and Development of Pulse Detonation Test Rig**” International Journal of Advance Research in Electrical, Electronics and Instrumentation Engineering, Volume 1, Issue 4, ISSN: 2278-8875, DOI : 10.15662/ijareeie, pp 291-304, 2012.
- [3] Frank K. Lu, “**Progress and Challenges in the Development of Detonation Engines for Propulsion and Power Production**”, Applied Mechanics and Materials, ISSN: 1662-7482, Vol. 819, pp 3-10, 2016.
- [4] Subhash Chander, Tejinder Kumar Jindal, “**Performance Enhancement of Surface to Air Missile by Application of Pulse Detonation Engine based Secondary Propulsion System**”, International Journal of Mechanical Engg. (IJME), Recent Science Publications, 2014.
- [5] Subhash Chander, Dr. TK Jindal, “**Design of Automated Fire Control System for C₂H₂/O₂ Pulse Detonation Rig**”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 2, ISSN: 2278-8875, DOI : 10.15662/ijareeie, pp 924-932, 2013.
- [6] Ramamurti, K, “**Explosions and Explosion Safety**”, Tata Mcgraw Hills Publishing Co. Ltd., ISBN 9780070704473, 2010
- [7] Kothari, CR, Garg, G., “**Research Methodology: Methods and Techniques**”, ISBN-13: 978-8122436235, New Age Publishers, 2014.
- [8] Montgomery, D.C., Runger, G.C., “**Applied Statistics and Probability for Engineers**”, John Wiley & Sons, 2003.
- [9] Eva Ostertagová, Oskar Ostertag, “**Methodology and Application of Oneway ANOVA**”, American Journal of Mechanical Engineering, Vol. I issue 7, ISSN (Print): 2328-4102, ISSN (Online): 2328-4110, DOI : 10.12691, pp 256—261, 2013.
- [10] Subhash Chander, Tejinder Kumar Jindal, “**A study of possible technical aspects needed to be addressed in respect of system engineering of surface to air missile by application of pulse detonation engine**”, International Journal of Mechanical Engineering (IJME), Volume 1, Spl. Issue 1, ISSN: 1694-2302, pp 40-43(2014).



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