Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 50(2) (2018) 135-138
DOI: 10.22060/mej.2017.11936.5222

The Design of a New Rotary Flow Control Valve with a Pressure Compensator for a Turbojet Engine

S. Mojallal agh, J. Pirkandi*, M. Mahmoodi, M. Jahromi

Malek Ashtar University of Technology, Tehran, Iran

ABSTRACT: This paper presents a new rotary flow control valve with cam-nozzle structure that consists of a pressure compensator valve with an electronic actuator. This configuration installed in a turbojet engine fuel control system. This valve actuation is accomplished directly with a rotary servomotor. The purpose of this new design is to modify and optimize of a single speed turbojet engine performance for new missions. The rotary actuator selection, rotary metering valve design with high travel, direct drive rotary metering valve design and the special metering flow area are the innovations in the presented design. Because of rotary direct drive metering section, versus usual methods, number of parts(15-20%) and cost and hence weight of system are decreased. The fuel metering area is the lateral area of a cylinder with variable height. The mathematical model and simulation of the system is performed to obtain optimized design parameters. After manufacturing the prototypes, they are tested on a special stand for evaluation of system performance and adjusting the fuel system. The test results compared with the simulation results. Maximum (5%) deviation between model and test results shows that the model is accurate for prediction of system function.

Review History:

Received: 23 September 2016
Revised: 13 January 2017
Accepted: 22 January 2017
Available Online: 28 January 2017

Keywords:

Flow control valve
Metering valve
Turbine engine
Rotary valve

1- Introduction

The contemporary trend in the industry towards the performance increase of mechanical systems and with simultaneous cost reduction, as a result of the implementation of electronic controls has its impact also in the area of small gas turbine engines [1,2]. The purpose of this new design is to modify a single speed turbojet engine performance for new missions and modify the hydropneumatic without throttle fuel control system to a new throttleable and electro-hydraulic fuel metering and control system. The rotary actuator selection, rotary metering valve design with high travel, direct drive rotary metering valve design and the special metering flow area are the innovations in the presented new design. The fuel metering area is the lateral area of a cylinder with a variable height. Because of rotary direct drive metering section design, versus usual methods decrease the number of parts and cost and hence decrease the weight of the system. The result of increase in metering valve rotation angle range is the high control resolution. The mathematical model and simulation of the system to obtain design parameters of the system are performed. After manufacturing the prototypes, they are tested on the stand for the evaluation of system performance and adjustment of the fuel system. The experimental and simulation results are compared. In 1990, Krepec & Geogantas [3] presented a linear metering valve coupled to a linear digital actuator as a simple and low-cost fuel control system for a turbojet engine. In 1997, Mohtasebi [4] presented two new designs for a fuel control and metering system. In 2003, Ford Peter [5] presented a new fuel system for gas turbine engine. From 1999 to 2012 Montazeri et al. [6-8] presented some fuel systems. In 2007 to 2010 Microturbo developed two new fuel metering units; first, with a servo valve linked to a pressure regulating valve and the second with an electro pump [9]. In 2011, Robert and Solihull [10] presented a rotary metering valve for a turbine engine fuel control system.

Corresponding author, E-mail: jpirkandi@mut.ac.ir

2- Description, Modeling, and Simulation

The schematic diagram of the new proposed fuel metering system is shown in Fig. 1. This system consists of two main sections; the rotary metering valve and plunger type pressure regulating valve. Depending on the position of the metering valve, the fuel flow rate to the engine is controlled. Since the pressure regulating valve maintains a constant differential pressure across the metering valve, regardless of variations in the fuel injection pressure the fuel flow rate is essentially a function of the metering valve position. The system steady

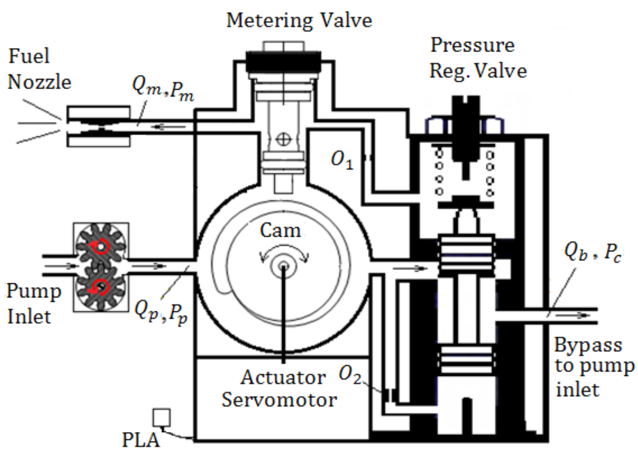

Figure 1. Schematic diagram of a metering section

state and transient function are governed by these equations [13-18]:

$$\begin{cases} Q_p = Q_m + Q_b \\ Q_m = Q_n \\ A_b (P_p - P_m) = Ky + F_0 \end{cases} \quad (1)$$

where Q_p , is input flow rate, Q_m , is metered flow rate Q_b , is bypass flow rate, A_b is bypass flow area, K is spring constant, is F_0 spring preload. P_p , P_m are pump outlet and metering valve outlet pressure, respectively and ρ is fuel density.

$$\frac{dP_p}{dt} = \frac{\beta}{V_p}\left[Q_p - Q_m - Q_b - Q_{bp}\right] \quad (2)$$

$$\frac{dP_m}{dt} = \frac{\beta}{V_m}[Q_m + Q_{mb} - Q_n] \quad (3)$$

Where V_p is enclosed volume between flow restrictions before the metering valve. β is the effective bulk modules of fuel. V_m is enclosed volume between flow restrictions after the metering valve. Q_{mb} is the flow rate in orifice 1, Q_{bp} is the flow rate in orifice 2. Pressure regulating valve plunger dynamic:

$$\frac{d^2 y}{dt^2} = \frac{1}{M}\left[A(P_{lb} - P_{ub}) - Ky - F_o\right] \quad (4)$$

3- Simulation and Test Results

Figs. 2 to 4 show the simulation and test results at steady state and transient modes. Fig. 2 shows the metered, bypass and pump outlet fuel flow versus input command or throttle angle in the steady-state mode. Fig. 3 shows the input command in the transient mode and Fig. 4 shows the metered, pump outlet and bypassed fuel flow rate in the transient mode.

4- Conclusion

This paper presented a new electro hydromechanical fuel metering and control valve with a cam-nozzle structure that consists of a pressure compensator valve for a turbojet engine. A new direct drive rotary proportional metering valve was proposed for the use on fuel metering units in fuel control systems. The new valve directionally was coupled to a rotary actuator (servomotor type).

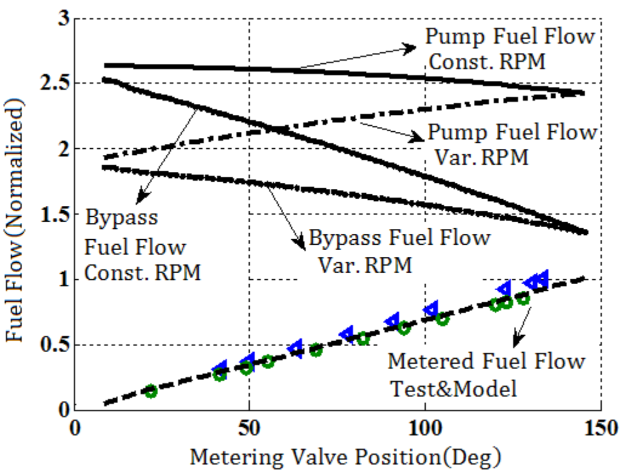

Figure 2. Metered, bypass and pump outlet flow versus input command (throttle angle)

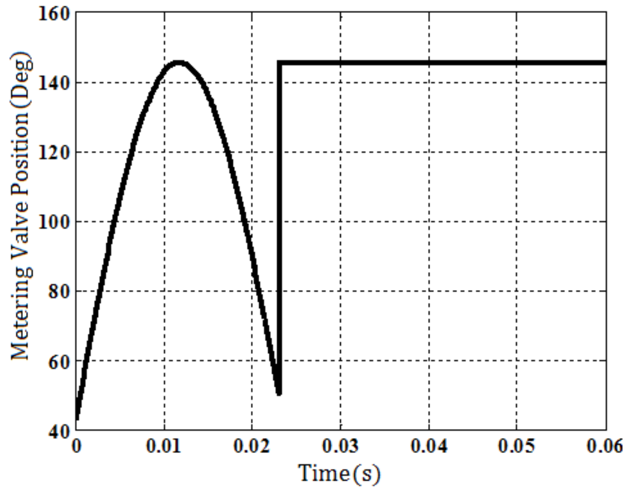

Figure 3. Input command in the transient mode

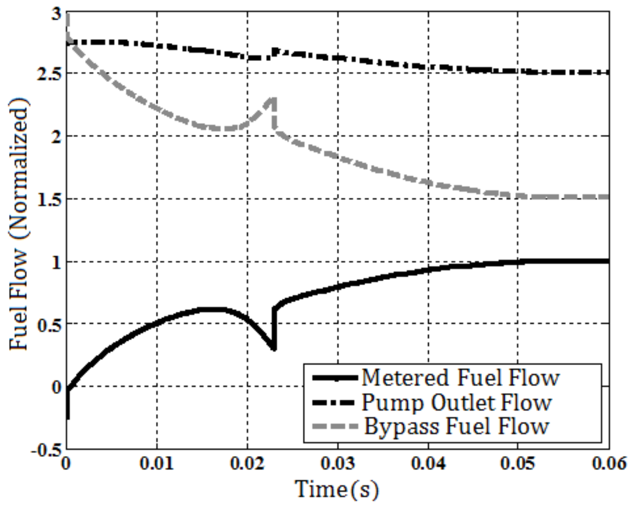

Figure 4. Fuel flow rate versus time

References

[1] S.R. Balakrishnan, Control System Development Experience for Aero Gas Turbine Demonstrator Engines, *Progress in Nonlinear Dynamics and Chaos*, 1 (2013) 15-22.

[2] B. MacIsaac, R. Langton, *Gas turbine propulsion systems*, 1 ed., John Wiley and Sons Ltd, USA, 2011.

[3] T.Krepec, A.I. Georgants, New family of low cost electronic fuel control units for small gas turbine engines, *Journal of Aerospace*, 99 No.1 (1990).

[4] S.S. Mohtasebi, *Investigation on New Low Cost Electronically Controlled Fuel Metering Systems for Small Gas Turbine Engines*, Concordia University Montreal, Quebec Canada, Canada., 1997.

[5] F. Peter, W.L. Spa, *Fuel system for a gas turbine engine*, in: E.P. Office (Ed.) European Patent Office, England, 2013, pp. 8.

[6] M.Montazeri, T.Hamzehpoor, *Modeling and simulation of a new electro hydro mechanical fuel control system for a gas turbine engine*, Iran University of Science and Technology, Iran Tehran, 2003.

[7] M.Montazeri, H.Bagerinezhad, *Manufacturing of an electro hydro mechanical fuel control system for a gas turbine engine*, Iran University of Science and Technology Iran, Tehran, 2004.

[8] M.Montazeri, A.Yousefi, *Designing of an electro hydro mechanical fuel control system for a gas turbine engine*, Iran, Tehran, Iran University of Science and Technology Tehran Iran, 2006.

[9] R.J. Francois, G. Gilles, C. Alain, MICROTURBO Families of Turbojet Engine for Missiles and UAV's From the TR60 to the new bypass turbojet engine generation, in: 44th AIAA/ASME/SAE/ASEE Join Propulsion Conference & Exhibit, *AIAA* 2008-4590, France, 2008.

[10] J.R. Paul, B.D. James, *Rotary metering valve arrangement*, in: E.P. Office (Ed.) European Patent Office, France, 2011.

[11] M. Klimko, *Mathematical model of the jet engine fuel system*, in: D.o.P.S. Engineering (Ed.) EPJ Web of Conferences, published by EDP Sciences, Bohemia, 2015.

[12] Direct Drive Servovalves (D.D.V), in: http://www.moog.com, 2009.

[13] N.S. Nise, *Control System Engineering*, John Wiley & Sons, Inc., Printed in the United States of America., 2011.

[14] J. Lal, *Hydraulic Machines*, USA, 1975.

[15] M.Montazeri, S.Jafari, *Design And Optimization of jet engine fuel controller based on Min-Max approach*, Iran University of Sience and Technology, Iran Tehran, 2011.

[16] O. Katsuhiko, *Modern control engineering*, Prentice Hall, United States Of America, 2010.

[17] W. Wilson, *Rotary-Pump Theory*, ASTM, 68 (1946) 371.

[18] H.E. Merritt, *Hydraulic Control Systems*, John Wiley and Sons Ltd, USA NY, 1967.

[19] Q. Yuan, P.Y. Li, An Experimental Study on the Use of Unstable Electro hydraulic Valves for Control, *Journal of Dynamic Systems, Measurement, and Control*, (2002).

Please cite this article using:

S. mojallal agh, J. pirkandi, M. mahmoodi, M. jahromi, The Design of a New Rotary Flow Control Valve with a Pressure Compensator for a Turbojet Engine, *Amirkabir J. Mech. Eng.*, 50(2) (2018) 413-424.

DOI: 10.22060/mej.2017.11936.5222