Variable Selection and Indices Proposal for the Determination of an Aeronautic Valve Degradation

Ananda S. Ribeiro[1], Takashi Yoneyama[2], Rodrigo F. Souto[3], and Wallace Turcio[4]

[1,3,4]*Embraer S.A., S.J. dos Campos, SP, 12227901, Brazil*

ananda.ribeiro@embraer.com.br
rodrigo.souto@embraer.com.br
wturcio@embraer.com.br

[2]*ITA – Instituto Tecnológico de Aeronáutica, S. J. dos Campos, SP, 12228900, Brazil*

takashi@ita.br

ABSTRACT

This work presents a method to select parameters and use them in an index to identify the degradation level of an aeronautic valve of the type PRSOV (Pressure Regulator and Shutoff Valve), a valve of the bleed air system of aircrafts. This index function is to be used as an input to the valve controller reconfiguration as the valve presents degradation while ages. The monitoring of degradation rates can provide information to modify the controller parameters in order to increase the valve useful life, to allow maintenance services planning or even to prevent the system performance being meaningfully impacted by the valve aging. The sorts of degradation considered were: friction increase, charging orifice obstruction and venting orifice obstruction. The study was made based on the valve mathematical model, in which was possible to vary those degradations levels and verify how each one influences the model response. The hysteresis graphic morphology was analyzed and also the sensibility and robustness after disturbances in the inlet air pressure with the system in closed loop, where the objective was to identify a monitoring that could be realized with the aircraft in air. The results allowed the identification of the most recommended parameters to monitor and the evaluation of the valve degradation through them.

1. INTRODUCTION

The motivation for the development of this research was to monitor an actuator degradation caused by the time of use and operation conditions (actuator aging) in a way that trough the controller reconfiguration it is possible to mitigate the degradation consequences. The impacts caused by the degradation are:

1. System performance deterioration, since the actuator will deviate from its nominal condition.

2. Actuator useful life reduction, causing an impact on the actuator replacement and on the logistics planning for maintenance.

These two consequences were considered. An actuator diagnosis that identifies the valve aging can send this information to reconfigurable controllers that will modify its control law. A convenient performance can be achieved, despite the degradation, or the remaining useful life can be increased. These two goals are usually conflicting.

Even when using controllers that are robust to changes in the actuators parameters, the degradation index monitoring would allow the issue of warnings before critical levels of damage are reached. Therefore, one difficulty is to define the limits for the actuator replacement.

In this context, this work proposes a methodology to measure the aging of an actuator. For this study it was selected the pneumatic valve PRSOV, which is a pressure regulator valve and it is part of the pneumatic system of aircrafts (Moir & Seabridge, 2008; Turcio, 2014). This system extracts air from the motors and provides pressurized air to the air conditioning, pressurization and anti-ice systems among others.

This subject is related to the field of study PHM (Prognostics and Health Management). Health can be defined as the extent of degradation or deviation from an expected normal condition. Prognostics is the prediction of the future state of health based on current and historical health conditions (Pecht, 2008). A system health management may provide several benefits such as the reduction of maintenance costs and safety increase (Gomes,

Ferreira, Cabral, Glavão, & Yoneyama, 2010). A major motivation in the use of more advanced diagnostic and prognostic requirements is that they are necessary to new logistic support concepts. The goals are both to maximize equipment up time and to minimize maintenance and operation costs (Vachtsevanos, Lewis, Roemer, Hess, & Wu, 2006).

Other researches about the application of PHM techniques on a pneumatic valve were already made. Daigle and Goebel (2011) apply a particle filtering algorithm to a pneumatic valve from the Space Shuttle cryogenic refueling system. The binary classification algorithm Support Vector Machine (SVM) was used in a prognostics method applied to aircraft bleed valves by Moreira and Nascimento Júnior (2012). Gomes et al. (2010) applied a health management system to a pneumatic valve employed in pressure regulation systems. The method is based on the statistical analysis of deviations of the controlled pressure signal from a baseline behavior in the presence of valve degradation.

1.1. Object of study
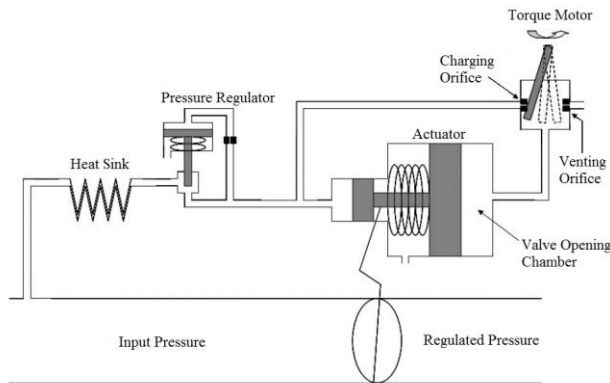
The Figure 1has a diagram of a typical PRSOV.

Figure 1. Diagram of a pressure regulator valve PRSOV Adapted from Turcio (2014).

The results achieved using the presented method depends on the valve architecture. The valve considered in this research is pneumatically actuated and electronically controlled through a torque motor. This valve contains a pressure reducer valve (PRV) and a pneumatic feedback (not included in the valve of the Figure 1) that connects the downstream pressure with its closing chamber.

The valve degradation is related to problems such as leakage, friction, orifices obstruction and torque motor magnetic hysteresis. The degradation can cause consequences as discomfort because of the high cabin pressure fluctuation rates, impact on the air conditioning machines, spurious alarms shown to the pilots and deactivation of the bleed air system.

1.2. Valve Model

A mathematical model of a PRSOV valve, implemented at Simulink®, was used to the development of this research. The model was created by the Environmental Systems Simulation team of Embraer S.A.. The Figure 2 shows the model.
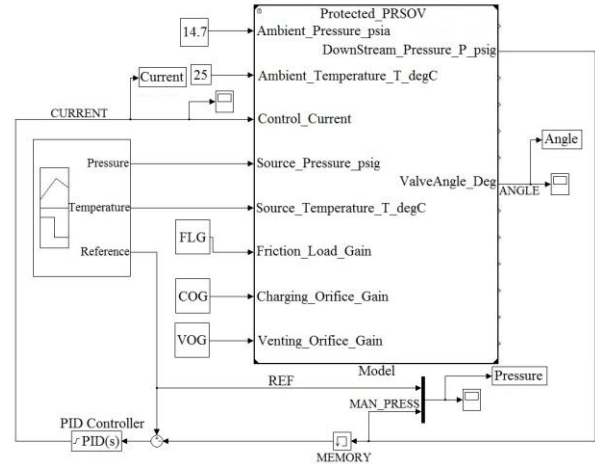

Figure 2. PRSOV valve Simulink® model.

The main block of the Figure 2 has inputs to simulate the degraded behavior of the PRSOV. These inputs receive gains that are proportional to the degradation level and they can be manipulated to evaluate the influence of the degradation on the valve model.

The available inputs represent the friction, charging orifice obstruction and venting orifice obstruction. They are related to the gains FLG (friction load gain), COG (charging orifice gain) and VOG (venting orifice gain), respectively. The nominal value of the gains is unitary, that means without degradation. The degradation increases as the gain FLG increases and as the gains COG or VOG decreases. This study considered the effects of each type of degradation only separately.

2. METHODOLOGY AND OBJECTIVES

This research considered that the software to diagnose the valve aging should be on board of the aircraft. A typical aircraft on board environment presents several implementation challenges, as a limited bandwidth available for on board message traffic, limited data storage capability and limited computing processor availability (Black et al., 2004). For this reason, the monitoring and the logic to identify the degradation must be simple and the data necessary must be as minimal as possible.

Two analyses were performed using the valve model: hysteresis curve analysis (without the system controller) and an analysis of the effect of disturbances while the system is

2

in closed loop. The second analysis verified the sensibility and robustness to changes in the inlet air pressure.

The objective was to find parameters that are simple to be measured, calculated and characterized based on the degradation level. The two analyses represent two different ways to select parameters to be used in a degradation index. The analyses also had the objective of defining the maximum acceptable limits for the degradation that could be tolerated. The selected parameters and the limits were used to propose the degradation index.

The degradation gains were modified from the condition where the valve is new, without degradation, until a condition with high degradation in order to evaluate the effects on the valve model. The impact on the output air pressure and on the current of the torque motor was observed.

2.1. Parameter Selection through the Hysteresis Curve

In this analysis it was evaluated the influence of degradation on the valve hysteresis curve. The curve was created applying a current profile in the torque motor as described in Figure 3. The inlet air pressure was constant and equal to 45 psig. In the following plots, the real current value in mA was not used. Its value was given in percentage, in order to protect this information.
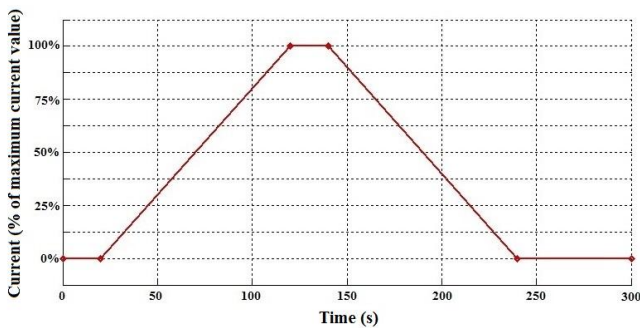

Figure 3. Regulated current (%) for the hysteresis curve.

A curve of the output pressure varying with the current was generated. The parameters evaluated are represented in the Figure 4.
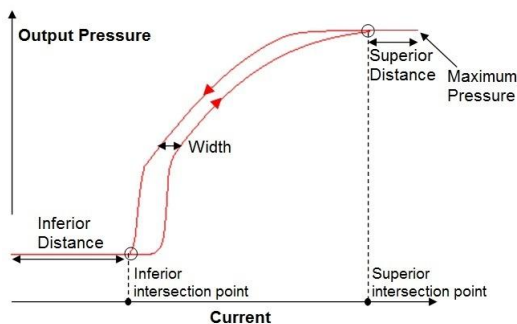

Figure 4. Hysteresis curve parameters.

The maximum output pressure is the maximum value after the hysteresis rising curve, when the current reaches the value 100%. The curve width is the difference between the current in the rising and descent curves, for a specific pressure value. The inferior intersection point is the current value where the descent and rising curves meet for pressure equal to zero. The superior intersection point is the current value where the descent and rising curves meet for maximal pressure. All parameters were calculated in percentage of the maximal current, with exception of the maximal pressure.

The parameters selection depended on their sensibility to the increase of the degradation and the curve characteristic.

The following criteria were used to define limits for the degradation gains, when the valve should be replaced. They are related to the difficulty to control and regulate the valve and its capacity to fully open and close.

- The inferior distance should represent at least 25% of the maximal current.

- The pressure curve width should be lower than 25% of the maximal current.

- The maximum pressure should be at least 40 psig.

The disadvantage of using the hysteresis curve to monitor degradation is that a specific test is necessary and it must occur on ground. This monitoring cannot be executed with the aircraft in air.

2.2. Parameter Selection through the Analysis of Effects of Disturbances when in Closed Loop

This analysis inserted disturbances at the system inputs and verified the effect in the outputs while the system was in closed loop configuration. The analysis was divided in sensibility and robustness analyses.

2.2.1. Procedure for the Sensibility Analysis

The inlet air pressure, inlet air temperature and reference output pressure were configured as shown in the Figure 5.
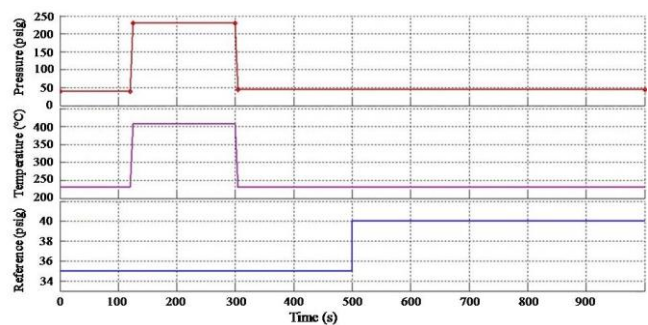

Figure 5. Air input pressure, air input temperature and reference pressure.

In the plots of Figure 5 there are three disturbances that affect the output pressure and the motor current and were observed. They occur in the following instants:

- T=120s: there is a rising ramp in the inlet air temperature and pressure.

- T=300s: there is a descent ramp in the inlet air temperature and pressure.

- T=500s: there is a step in the reference pressure.

In the sensibility analysis it was evaluated how certain parameters behave as the valve degradation increases. They were calculated based on the output pressure and current signals. A typical output signal is represented in Figure 6.
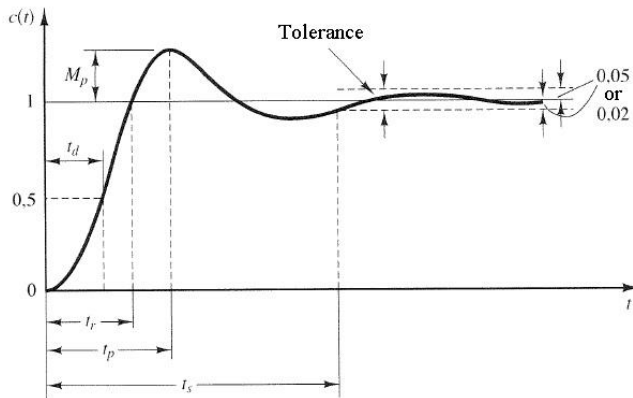

Figure 6. Parameters analyzed. Adapted from Ogata (2000).

The parameters investigated are listed below:

- Overshoot – "MP" at Figure 6.

- Peak time – "Tp" at Figure 6.

- Settling time (2% criterion) – "Ts" at Figure 6.

- Undershoot.

- Number of cycles: times that the signal crosses its stationary value until stabilize.

- Area under cycles: area of the cycles between the output signal and its stationary value.

- Impact in the motor current: stabilized current value and maximum value.

The sensibility of each parameter as the degradation increases was observed as well as the characteristics of the curve.

2.2.2. Procedure for the Robustness Analysis

This analysis verifies how changes in the amplitude and in the slope of the inlet air pressure ramps influence the output pressure and the motor current. The same parameters of the sensibility analysis were analyzed. The parameter selected

with the result of the two analyses must be sensible to the degradation but also robust to changes in the input pressure signal disturbances. This second characteristic will allow the monitoring to be realized with the aircraft in air, since no specific input pressure signal disturbance will be necessary.

The nominal inlet pressure signal, used in the sensibility analysis, has maximum amplitude of 230 psig and its ramps last 5s. To study the influence of changes in the ramps slope, three cases were tested: rising and descent ramps that last 4s, 6s and 8s, while the maximum amplitude was kept in 230 psig. To test amplitude changes, two cases were analyzed: the first had maximum amplitude of the input pressure 20% over the nominal and the second had the maximum amplitude 20% lower than the nominal. The slope was held as the nominal case. The input pressure values for each case are described in the Table 1.

Table 1. Inlet air pressure values for each case.

Case 1: nominal	Pressure (psig)	40	40	230	230	45	45
	Time (s)	0	120	125	300	305	1000
Case 2: Ramps last 4s	Pressure (psig)	40	40	230	230	45	45
	Time (s)	0	120	124	301	305	1000
Case 3: Ramps last 6s	Pressure (psig)	40	40	230	230	45	45
	Time (s)	0	120	126	299	305	1000
Case 4: Ramps last 8s	Pressure (psig)	40	40	230	230	45	45
	Time (s)	0	120	128	297	305	1000
Case 5: Amplitude 20% over the nominal	Pressure (psig)	40	40	276	276	45	45
	Time (s)	0	120	126	299	305	1000
Case 6: Amplitude 20% under the nominal	Pressure (psig)	40	40	184	184	45	45
	Time (s)	0	120	123.6	301.4	305	1000

A criterion was created to define if the parameter was robust. The greatest difference between the curves generated for each case should be less than 10% of the total change of the parameter value with degradation.

One difficulty encountered on the analysis of effects of disturbances with the system in closed loop is that most of the parameters considered depend on the controller configuration. In this work the analyses were made considering a standard controller that does not adapt with the valve aging. In the case of one of the transitory parameters (overshoot for instance) be selected for the degradation monitoring, it will be necessary to map different curves for each possible controller configuration.

3. ANALYSES RESULTS

3.1. Hysteresis Analysis

The Figure 7 represents hysteresis curves for different values of the gain FLG. When the friction increases, the curve width increases and the maximum pressure reduces.
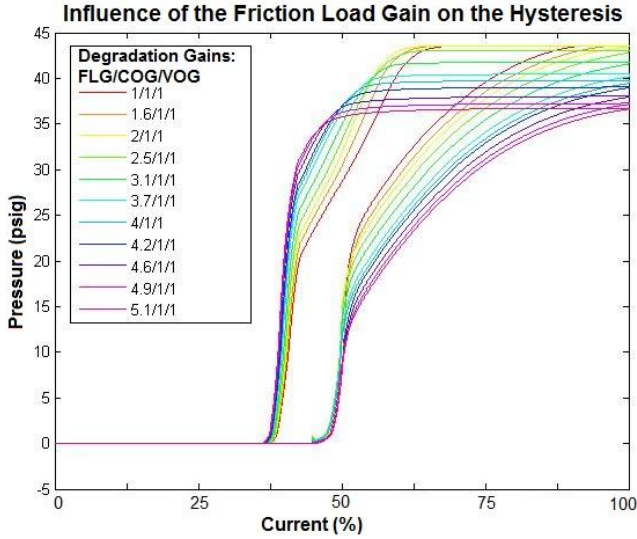
Figure 7. Influence of the friction on the hysteresis curve.

The curve width exceeds the limit of 25% for a friction load gain equal to 3.9, as shown in Figure 8.
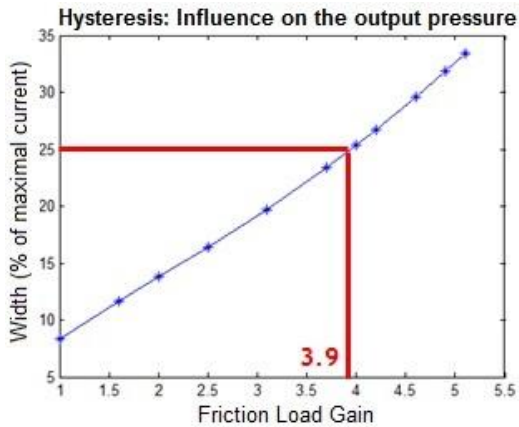

Figure 8. Influence of friction on the hysteresis curve width.

This parameter varies approximately linear with the degradation and has a significant sensibility. It can be used to identify FLG.

The maximum pressure reduces to values below the minimum. The limit of 40 psig is exceeded for FLG equal to 3.78, as shown in Figure 9. This result is tighter than the one found for the curve width and, then, is the gain maximum value. The inferior distance is always over 25%, this limit was not exceeded.

An equivalent analysis was made to the degradation caused by obstruction of the charging and venting orifices. The hysteresis plots are shown in the Figure 10 and Figure 11 and the result of the three analyses is presented in Table 2.
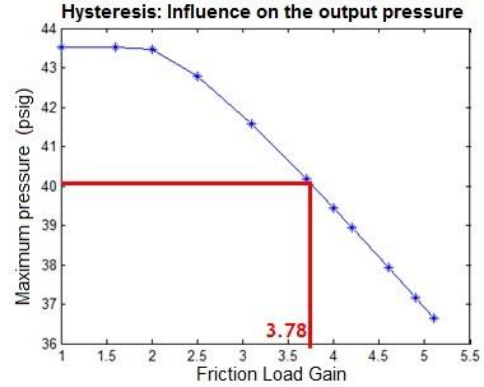

Figure 9. Influence of friction on the hysteresis maximum pressure.
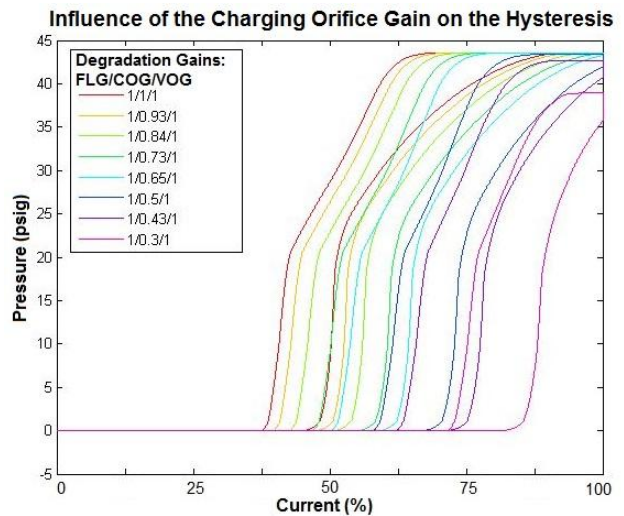

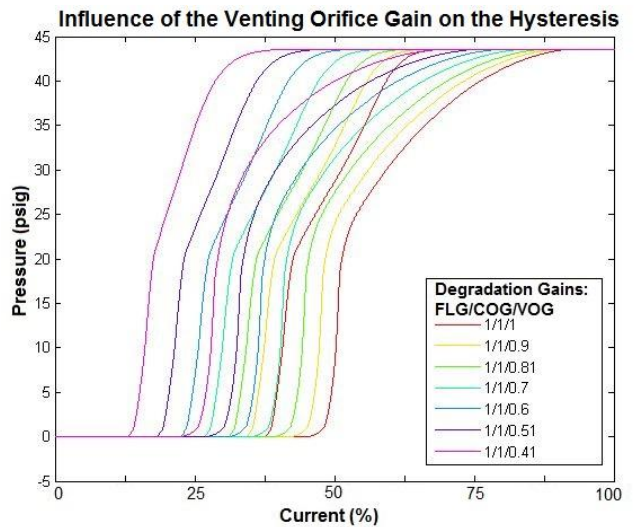Figure 10. Influence of the charging orifice obstruction on the hysteresis curve.

Figure 11. Influence of the venting orifice obstruction on the hysteresis curve.

5

Table 2. Hysteresis analysis results

Gain	Limit	Selected Parameter
Friction (FLG)	Maximum = 3.78	Hysteresis curve width
Charging Orifice (COG)	Minimum = 0.41	Inferior intersection point
Venting Orifice (VOG)	Minimum = 0.66	Inferior intersection point

3.2. Disturbance effects analysis when in closed loop

3.2.1. Sensibility Analysis

The plot of the output pressure in time has the characteristic showed at Figure 12. In this figure it is possible to observe the effects of the disturbances inserted.
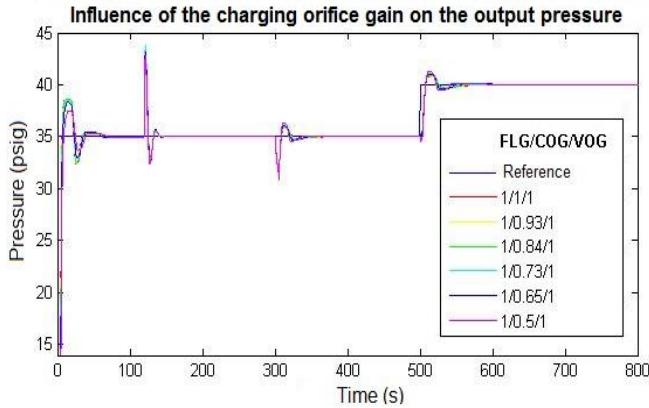

Figure 12. Influence of the charging orifice gain on the output pressure.

Through the plots of the parameters evaluated varying with the degradation, it was possible to notice that the friction influences the output pressure more than the other two kinds of degradation. No parameter calculated based on the output pressure was adequately sensible to be used to monitor valve degradation. The parameters with the best characteristics were the overshoot and the undershoot after a descent ramp. They can be seen at Figure 13 and Figure 14.
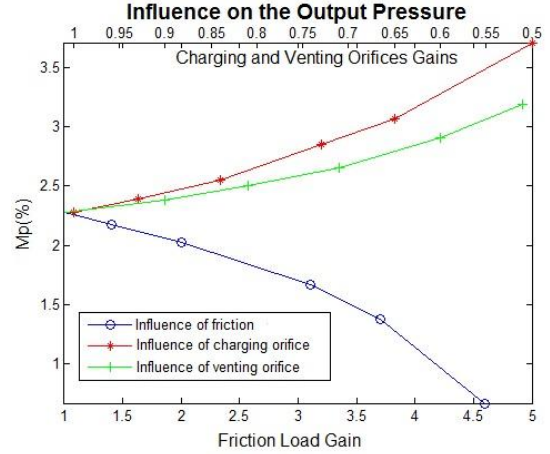

Figure 13. Overshoot on the output pressure at descent ramp.
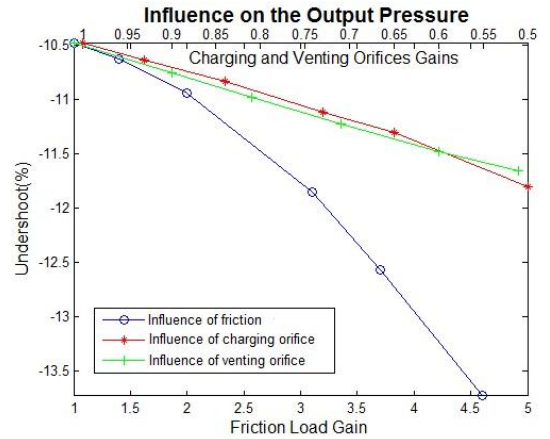

Figure 14. Undershoot on the output pressure at descent ramp.

Despite the adequate characteristics, the parameters have too low sensibility. The undershoot has a greater sensibility and varies only 3.2%, what corresponds to 1.1 psig. These parameters could be used only with a high precision pressure sensor but, in this case, the monitoring could have spurious errors with pressure fluctuations.

The parameter overshoot at the rising ramp has a great sensibility. It is represented at Figure 15.
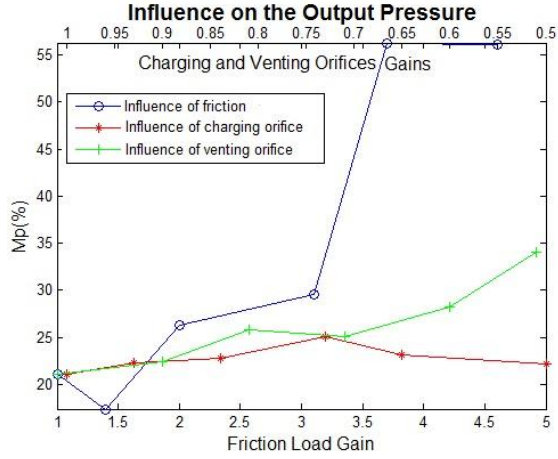
6

Figure 15. Overshoot on the output pressure on rising ramp.

Because of the plot irregular characteristic it could not be considered to monitor valve aging. The Figure 16 shows the characteristic of the current variation in time.
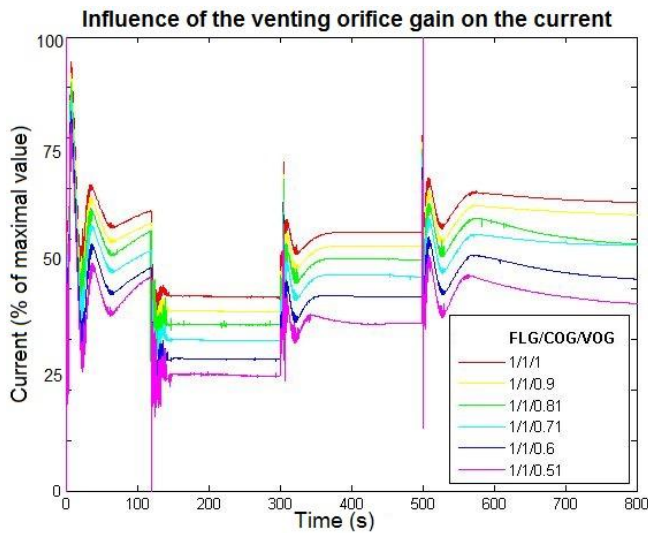

Figure 16. Influence on the venting orifice gain on the motor current.

In this analysis it could be noticed that the motor current is more influenced by the charging and venting orifice obstructions than the friction. The parameters evaluated were maximum current value and stabilized value in steady state. It was given preference to the use of the current stabilized value, since it is not transitory and, in this way, it does not depend on the controller configuration. The best parameters chosen are listed in Table 3. The plots of how these parameters vary with degradation are in Figure 17 and Figure 18.

The current final value had low sensibility with the friction load gain. However, this value is perceptible and this parameter can be used to monitor friction. The low

sensibility can cause spurious messages. In order to avoid that behavior, it is possible to monitor the integrity of the input data as well as filter the raw data.

Table 3. Sensibility analysis results

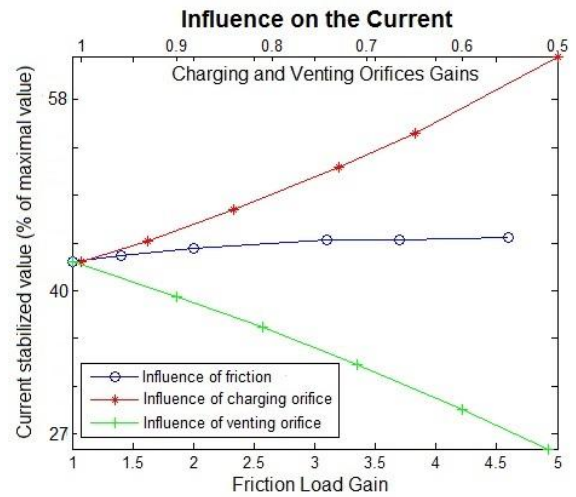| Degradation	Selected Parameter
Friction	Current final value at rising ramp
Charging orifice obstruction	Current final value at rising ramp
	Current final value at descent ramp
Venting orifice obstruction	Current final value at rising ramp
	Current final value at descent ramp

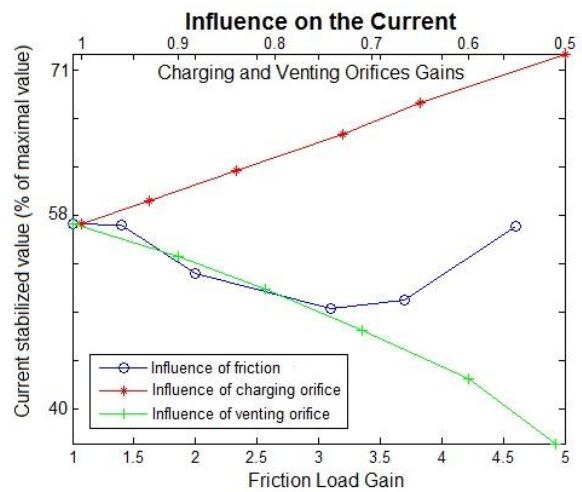Figure 17. Current stabilized value at rising ramp.

Figure 18. Current stabilized value at descent ramp.

3.2.2. Robustness Analysis

This analysis was separated in two: influence of slope changes and influence of maximum amplitude changes. For each case, the parameters that were considered robust are listed in the Table 4.

Table 4. Robustness analysis results

Degradation	Robustness to ramp slope changes	Robustness to ramp maximum amplitude changes
Friction	-	Overshoot on output pressure at descent ramp
Charging orifice obstruction	Maximum current value at rising ramp	Overshoot on output pressure at descent ramp
	Current final value at rising ramp	Current final value at descent ramp
	Current final value at descent ramp	Maximum current value at rising ramp
Venting orifice obstruction	Current final value at rising ramp	Current final value at descent ramp
	Current final value at descent ramp	Maximum current value at rising ramp

The study of ramp slope changes for friction had as result no robust parameter. As an example of the robustness analysis, the plots of the parameter current final value at descent ramp for the venting orifice obstruction are shown in the Figure 19 and Figure 20.
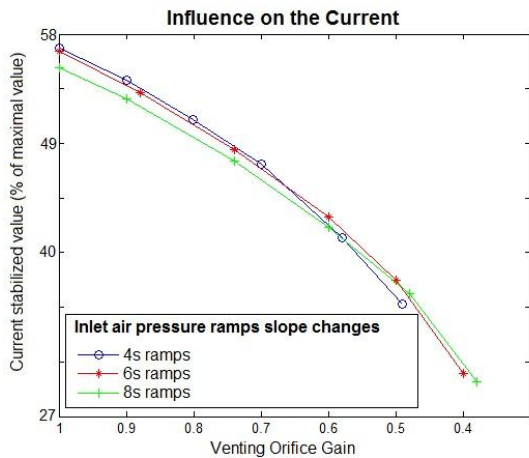

Figure 19. Slope changes analysis. Influence in the motor current at descent ramp for venting orifice obstruction.
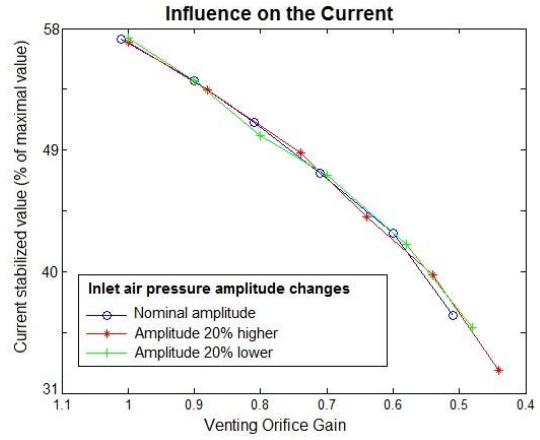

Figure 20. Amplitude changes analysis. Influence in the current at descent ramp for venting orifice obstruction.

When comparing the results of the sensibility analysis with the ones of robustness analysis, it is possible to notice that to determine FLG there is no parameter that satisfies all criteria. That means that to monitor this type of degradation it is necessary a specific signal of the inlet air pressure, with defined ramp slope and amplitude. The parameter selected to monitor the FLG was the current final value at rising ramp.

The obstruction of the charging and venting orifices can be determined by the current final value at descent ramp, since it is sensible to the degradation and robust according to the analyses. In this way, these degradations can be monitored with the aircraft in air after disturbances are inserted in the inlet air pressure, since the disturbance is within the limits considered in the robustness analysis: slope between 4 to 8s and amplitude 230 psig ± 20%.

4. DEGRADATION MONITORING PROPOSAL

With the results of the analysis, two possible solutions for the initial problem were proposed. The first one uses the result of the disturbance effects analysis when in closed loop and the second one is based on the hysteresis analysis result. The degradation is monitored trough the following parameters in each case.

- Solution A:
  - o FLG: current final value after a rising ramp in the inlet air pressure (CRR).
  - o COG and VOG: current final value after a descent ramp in the inlet air pressure (CDR).
- Solution B:
  - o FLG: hysteresis curve width (W).
  - o COG and VOG: inferior distance of the hysteresis curve (IP).

4.1. Calculation of the Degradation Gains

With the data obtained in the simulation for the parameters selected for the solution A, equations that represent the degradation gains in relation to these parameters were determined. A curve adjustment was made for each case, the polynomial regression method (Chapra & Canale, 2008) was applied. The adjusted curves are shown in Figure 21, Figure 22 and Figure 23 with their respective equation.
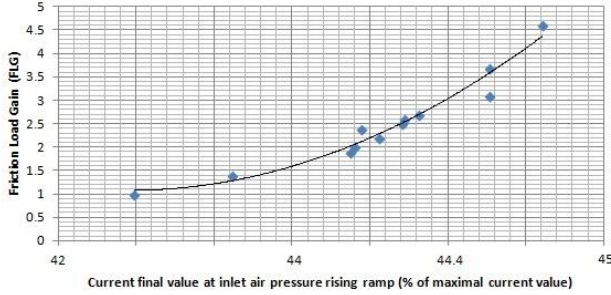

Figure 21. Determination of FLG through the current value after a rising ramp.

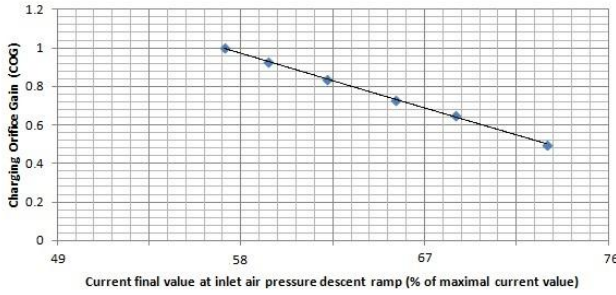$$FLG = 2.915694 \times 10^{-2} \times CRR^2 - 11.18469 \times CRR + 1073.694 \qquad (1)$$

Figure 22. Determination of COG through the current value after a descent ramp.

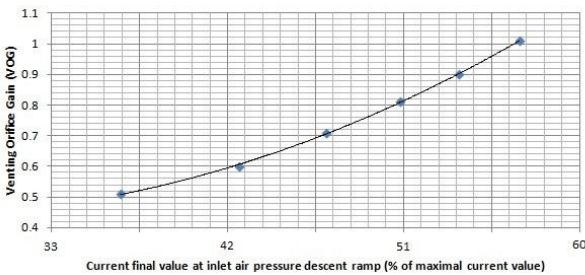$$COG = 1.3 \times 10^{-6} \times CDR^2 - 0.00783 \times CDR + 2.918 \qquad (2)$$

Figure 23. Determination of VOG through the current value after a descent ramp.

$$VOG = 2.97 \times 10^{-5} \times CDR^2 - 0.00701 \times CDR + 0.855 \qquad (3)$$

The same procedure was repeated for the parameters of the solution B. The equations generated are listed below:

$$FLG = -9.858 \times 10^{-5} \times W^2 + 0.057786 \times W - 0.8575 \qquad (4)$$

$$COG = 1.917 \times 10^{-5} \times IP^2 - 0.01343 \times IP + 2.576 \qquad (5)$$

$$VOG = 1.58 \times 10^{-5} \times IP^2 + 0.00277 \times IP + 0.226 \qquad (6)$$

The standard error of the adjusted curves was always under 0.02 for both solutions, except for the friction load gain with respect to the current final value (Solution A) that had a standard error equal to 0.22. A linear adjustment of the data would increase the error, because of that the second order regression was chosen.

4.2. Degradation Indices for the PRSOV

With the values of FLG, COG and VOG calculated through solution A or solution B and with the limit defined for each gain, from the hysteresis analysis, the valve degradation (DV) in percentage can be determined through the following equations.

- In the presence of friction:

$$DV_{FLG} = \frac{FLG - 1}{3.78 - 1} \times 100 \qquad (7)$$

- In the presence of charging orifice obstruction:

$$DV_{COG} = \frac{1 - COG}{1 - 0.41} \times 100 \qquad (8)$$

- In the presence of venting orifice obstruction:

$$DV_{VOG} = \frac{1 - VOG}{1 - 0.66} \times 100 \qquad (9)$$

DV equals to 0% represents a new valve and DV equal to 100% represents a valve on its useful life limit, when it is necessary to be replaced. As each degradation type effects were considered only separately, the indices are independent. The general valve aging is then represented by the highest one of the three indices, the one that is most close to the limit for the valve replacement. The general valve degradation index is represented by equation 10.

$$DV = \max(DV_{FLG}, DV_{COG}, DV_{VOG}) \qquad (10)$$

5. CONCLUSION

This research proposed two possible solutions for the problem of evaluating the aging of a PRSOV valve. The same method could be applied to other types of degradation not addressed in this study and can be adapted to other types of actuators.

One limitation of the solution proposed is that it was not considered the combined effects of the different types of degradation. And it was also not considered possible

disturbances and perturbations different from changes in the inlet air pressure. In order to apply this method, it will be necessary to obtain real valve aging data for comparison and validation.

This work contributed to parameters selection that can be used for degradation indices conception and aging identification proposal. That monitoring can influence the maintenance logistics or the development of controllers that can mitigate the degradation of components.

Some possible future works are: (i) calculate model and sensor uncertainty and the error associated to the degradation index; (ii) evaluation the effects of the valve aging when more than one type of degradation is present; (iii) development of an algorithm to the controller reconfiguration based on the degradation index; (iv) analysis of the valve aging based on historical data and comparison with the solution proposed based on the model.

ACKNOWLEDGEMENT

NOMENCLATURE

FLG   Friction Load Gain
COG   Charging Orifice Gain
VOG   Venting Orifice Gain
PHM   Prognostics and Health Monitoring
PRSOV Pressure Regulator and Shutoff Valve
CRR   Current final value after a rising ramp
CDR   Current final value after a descent ramp
W   Hysteresis curve width
IP   Inferior intersection point

REFERENCES

Black, S., Keller, K., Swearingen, K., Vandernoot, M., Hood, M., & Urnes, J. (2004). Reconfigurable control and fault identification system. In *2004 IEEE Aerospace Conference Proceedings (IEEE Cat. No.04TH8720)* (Vol. 5). doi:10.1109/AERO.2004.1368154

Chapra, S. C., & Canale, R. P. (2008). *Métodos Numéricos para Engenharia* (Quinta Edi.). São Paulo - SP: McGraw-Hill.

Daigle, M. J., & Goebel, K. (2011). A Model-Based Prognostics Approach Applied to Pneumatic Valves. *International Journal of Prognostics and Health Management*, 2, 1–16.

Gomes, J. P. P., Ferreira, B. C., Cabral, D., Galvão, R. K. H., & Yoneyama, T. (2010). Health Monitoring of a Pneumatic Valve Using a PIT Based Technique. *Annual Conference of the Prognostics and Health Management Society*, 1–6.

Moir, I., & Seabridge, A. (2008). *Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration* (Third., Vol. 40). Wiley. doi:10.1002/1521-3773(20010316)40:6<9823::AID-ANIE9823>3.3.CO;2-C

Moreira, R. de P., & Nascimento Júnior, C. L. (2012). Prognostics of aircraft bleed valves using a SVM classification algorithm. In *IEEE Aerospace Conference Proceedings* (Vol. 4400, pp. 1–9). doi:10.1109/AERO.2012.6187377

Ogata, K. (2000). *Engenharia de Controle Moderno* (Terceira e.). LTC - Livros Técnicos e Científicos Editora S.A.

Pecht, M. G. (2008). *Prognostics and Health Management of Electronics*. John Wiley & Sons, Inc.

Turcio, W. H. L. (2014). *Projeto de um controlador quasi-LPV para um sistema pneumático aeronáutico*. Instituto Tecnológico da Aeronáutica.

Vachtsevanos, G., Lewis, F. L., Roemer, M., Hess, A., & Wu, B. (2006). *Intelligent Fault Diagnosis and Prognosis for Engineering Systems*. John Wiley & Sons, Inc.

BIOGRAPHIES

Ananda S. Ribeiro is a Product Development Engineer of flight control systems at Embraer S.A. since 2014. She holds a bachelor's degree on Electrical Engineering from Universidade Federal da Bahia (UFBA, 2011), Brazil and participated in a bachelor sandwich program at Technische Universität Ilmenau, Germany in 2010. She holds a master degree on Aeronautical Engineering from Instituto Tecnológico de Aeronáutica (ITA), São José dos Campos, SP, Brazil.

Takashi Yoneyama is a professor of control theory with the Electronic Engineering Department of ITA. He received his bachelor's degree in electronic engineering from Instituto Tecnologico de Aeronautica (ITA),Brazil,the M.D. degree in Medicine from Universidade de Taubate, Brazil, and the Ph.D.degree in Electrical Engineering from the Imperial College London, U.K. (1983). He has more than 350 published papers, has written four books, and has supervised more than 90 MSc and PhD Theses. His research is concerned mainly with stochastic optimal control theory. He served as the president of the Brazilian Automatics Society in the period 2004–2006.

Rodrigo F. Souto is a Product Development Engineer at Embraer since 2009. Rodrigo has worked with some projects dealing with modeling and simulation of flight controls systems, bleed systems and cargo handling systems. He is an inventor on a US patent for Embraer and won the 4th edition of the SAE BRAZIL Young Engineer Award. Rodrigo has BS and MS degrees in Controls Engineering from University of Brasilia.

Wallace Turcio is a Product Development Engineer at Embraer S.A. since 1998. Wallace has worked developing Air Management Systems (Bleed, Air Conditioning, Cabin Pressurization and Oxygen Systems) for several programs acting as a Product Engineer until 2005, since then he has supported the product development acting as a Simulation and Control Engineer being a member of Embraer System Simulation and CFD Team. Wallace receives the D.Eng. degree in Electronic Engineering (Systems and Control) from the Technological Institute of Aeronautics (ITA) in 2014. He has received the M.Eng and B.Eng degrees in Mechanical Engineering from Polytechnic School of the University of São Paulo respectively in 2003 and 1997.