Intelligent Control for Aerodynamics Research Test

JIA Janming CHENG Yaohui LIU Huiming

Department of Aerial Instrument and Electric Engineering

The First Aeronautical Institute of Air Force

Xinyang, China

qiankun_0306@163.com

***Abstract*—This paper proposed an intelligent control system for the aerodynamics research test in wind tunnel experiment, which can fulfill the air pressure data collecting and data processing automatically, it completes the normal control and the abnormal processing through the monitoring of the working state. In the process control, some deterministic index and fuzzy evaluation are applied so as to direct the inference engine to reason and select proper control strategy through multi-mode controller .the rules in rule base and the data in data base can be added or erased on-line. This system has been successfully used in aerodynamics research test and teaching in our college.**

***Keywords*—Intelligent Control, Expert system, Aerodynamics, Wind tunnel**

I. INTRODUCTION

Aerodynamics research test takes key function to develop fluid mechanics and aircraft. the Wind tunnel (WT) is one of the important facilities for aerodynamics research and teaching. It is required starting fast, fluid-field steady, safety and reliability. But, it is difficult to establish a lumped parameter model for WT at present. The controller design is not easy due to the short operation and the changeable working state. In past, a lot of man - power and energy was wasted in the tunning. Meanwhile, the system performance will be unsatisfactory as the working condition change. This paper presents an intelligent control system for WT. It can solve the problem as stated above. Fig.1 shows the structure of the aerodynamics research test system.

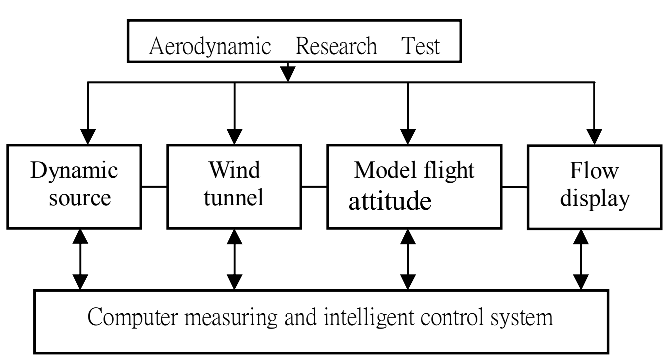

Figure.1 The structure of the aerodynamics research test system

The system is divided into two parts: normal control and abnormal processing. In abnormal processing, either warning information or emergency action is given through reasoning; in normal control, the deterministic evaluation and the fuzzy estimation are made in terms of the properties of the system dynamic action. So, they can provide some directing information to inference engine on-line or off-line so as to take some action. The rule in knowledge base and the data in data base can be added or erased on-line. This system has been applied to some WT successfully in our institute .

II. INTELLIGENT CONTROL SYSTEM FOR WT

The intelligent control system for WT is shown as Fig 2. It is made up of working state monitoring, normal control, and abnormal processing and control mode decision.

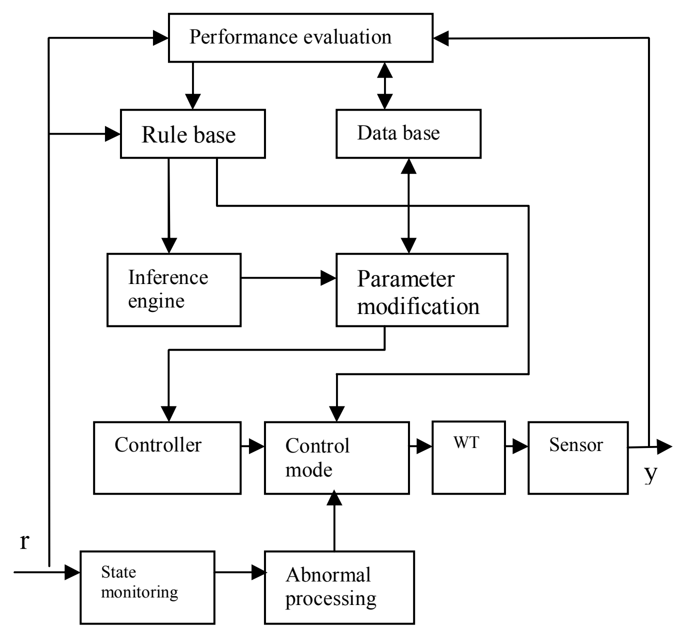

Figure.2 The intelligent control system

A. Working State Monitoring

The working state, according to the setpoint and the measured value, will be classified through the monitoring mechanism. Hence, the efficiency of the knowledge matching and the effectiveness of evaluation can be improved because the reasoning and the data searching are implemented in their sub-bases.

B. Normal Control

Normal control consists of performance evaluation, data base, rule base, inference engine, parameter modification and controller.

1) Performance Evaluation: In WT, the evolved performance index is as follow:

a) steady error: $\varepsilon|_{t>tg}<\varepsilon_g$ (1)

b)overshoot: $\sigma<\sigma_g$ (2)

c) rising time: $t_r \rightarrow \min$ (3)

d) transient time. $t_s \rightarrow \min$ (4)

As above, index (a) and (b) show the accuracy and the safety. (c) and (d) show the economy. However, performance (a) is the most important. If it is not met, the test is meant unsuccessful. Connecting with other performance, we can determine the test is {"unsuccessful" "unsatisfactory", "satisfactory", "successful"} based on the expert experience after index (a) is reached. Controller parameters can be adjusted automatically by computer if the result is "unsuccessful" But, if the result is "unsatisfactory" or " satisfactory", the expert need determine whether the result is useful and parameters should be reset or not.

2)Data Base: Data base (DB) contains the following sub-bases:

a) the controller parameter base,
b) the transducer coefficience base and initial value,
c) the normal valve value and the emergency action value in every state,
d) operating parameter base.

In these sub-bases, the controller parameter and the operating parameter can be change on-line.

3)Rule Base and Inference engine: According to the results of knowledge acquisition from the control expert, we catalog all of rules in to three classes: parameter matching (PM), parameter tunning (PT) and control mode decision (CMD).

By rule of parameter matching, the different control parameter can be gotten on the authority of every working condition. Typical rule of this type is

PM: IF the pressure in the tank of air storage is less then P_{gi}
AND IF the absolute error is less then e_i
THEN $\{K_{pi}\quad K_{ii}\quad K_{di}\}$
Where: P_{gi}, e_i —the given pressure and error.

The rule of parameter tunning determines the controller parameter modification based on the test result.
We can illustrate this idea by the following rule:

PT: IF the system overshoot is more than σ_g
THEN the proportional coefficience would be increased $□_{pi}$

The control mode decision rules select the proper mode controller on the basis of the test condition. These rules can be illustrated as follow:

CMD: IF the model attack angle changes rapidly
THEN the feedforward control would be introduced.

Inference engine, first, decide the current working state. Then, it scans through the rule base, finds one to apply and applies it.

4)Parameter Adjusting and Controllers: We use the Bang-Bang controller when the system error is large. While the disturbance is strong, the feedforward control would be introduced. The PID controller is applied when the measured value is adjacent to the setpoint. The coefficience of PID controller can be set on-line or off-line through the relay signal applied . In tunning , the coefficience is set off - line . These coefficience and knowledge are stored in DB and RB individually. They can be used as the basis of parameter modification. In operation, the parameter is set on - line and stored in DB if the result of evaluation is "unsatisfactory", Meanwhile, these new rules which set the parameters are added in RB. IF the new rule is in contradiction with the old one, it can be reconstructed as follow:

$$\left.\begin{aligned} K_p &= \rho_p K_{pn} + (1-\rho_p) K_{po} \\ K_i &= \rho_i K_{in} + (1-\rho_i) K_{io} \\ K_d &= \rho_d K_{dn} + (1-\rho_d) K_{do} \end{aligned}\right\} \quad (5)$$

where: $\{K_{po}, K_{in}, K_{dn}\}$—new coefficience,
$\{K_{pn}, K_{io}, K_{do}\}$—old coefficience,
$\{\rho_p, \rho_i, \rho_d\}$—the degree of confidence in correspondence with the $\{K_{pn}, K_{io}, K_{do}\}$

C. Control Mode Decision

The multi-mode controller includes:
a) Changeable amplitude Bang-Bang controller,
b) Proportional controller,
c) Integral controller,
d) Differential controller,
e) feedforward controller.

In the process of control, one or several mode controller are taken through reasoning according to the environment and the error.

D. Abnormal Processing

In this part, inference engine must supply warning information and emergency action as the test occurs abnormal. It's rule can be expressed as follow:

AP1: IF the voltage of sensor 1 is more than it's valve value THEN warning "sensor 1 failure".
AP2: IF the pressure is higher than αP, AND the increasement of pressure is more than □Pg, THEN stop test.
Where: α-constant which is decided by expert.
Pg, □Pg -pressure and it' s increasement given.

III. CONCLUSION

This paper introduces an intelligent control system for WT. It can complete the normal control and the abnormal processing through the monitoring of the working state. In normal control, the parameter can be adjusted automatically and the data in DB, the rules in RB can be added, erased and changed through reasoning and evolving. This system has been applied successfully in our institute .

REFERENCE

[1] Ching F. Lo and Frank W. Steile, "Application of Intelligent System for Wind Tunnel Test Facilities", AIAA 88-0193, AIAA 26th Aerospace Science Conference, 1988.

[2] Jing-sun Fu, Zi-xing Cai and Guang-you, Xu, Artificial Intelligence and it's Application, Beijing: Qinghua University Publishing House, 1987.

[3] Qian Kun, Xie Shousheng, Zhang Wei, He Xiuran. "Neural network identifier with fuzzy logic compensation for aero-engine rotating speed control system". Journal of Aerospace Power, 2006, 21(1): 213~218.

[4] Qian Kun, Xie Shousheng, Dong Xinming. "Design of limiter in extreme state for certain aircraft based on fuzzy control". Aerospace Control, 2004, 22(6): 84~88.

[5] Zhang Sheng-liang, Xie Shou-sheng. "Test System for FADEC of an aeroengine". Journal of Propulsion Technology, vol. 24(2), pp. 190~192, April 2003.

[6] Yan Pingfan, Zhang Changshui, Artificial Neutral Networks and Analog Evolution Algorithm. Beijing: Qinghua University Publishing House, 1999.