ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Engineering 15 (2011) 1282 – 1287
Procedia Engineering
www.elsevier.com/locate/procedia

Advanced in Control Engineering and Information Science

Application of Neural-Fuzzy System in Twin-Turbo Hydraulic Torque Converter's Performance Testing

Guofu Tian[a], Shuhui Sun[b],Zhongwei Ren[a],a*

[a]*School of Mechanical Engineering, Shenyang University of Technology,Shenyang 110870,China*
[b]*School of Software, Shenyang University of Technology,Shenyang 110870,China*

Abstract

Twin-turbo hydraulic torque converter's performance testing is very important in the product's development and production. According to the needs of data processing and analysis in performance testing, A neural-fuzzy algorithm was used to analyze the test data in this paper. It can improve computing speed and programming capability, decrease artificial involved times, realize the data analysis processing's automation. The application shows that the digital information's relationship can be expressed very well by this method. At the same time, this method has high degree of accuracy and quick speed on data recognition and can satisfy the requirement of designing.

Selection and/or peer-review under responsibility of [CEIS 2011]

Keywords: twin-turbo hydraulic torque converter; performance analysis; Neural-fuzzy System; fitting

* Corresponding author. Tel.: +86 0 13624039633; fax: +86 24 25691399.
E-mail address: tianguofu@126.com.

1877-7058 © 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeng.2011.08.237

1. Introduction

The twin-turbo hydraulic torque converter is the key component used widely in engineering fields such as military industry, automobiles, tractors and construction machines. Its performances have a direct impact on machine's performances and service life[1,2]. The hydraulic torque converter's performances are generally determined by the relationship between torque and rotational speed of the pump pulley and turbo shafts[3]. Among the twin-turbo hydraulic torque converter's performances, the more important and representative performances are convert torque, economic performance and penetrability. They are usually called the three basic performances of the twin-turbo hydraulic torque converter[4,5]. In the performance evaluation of twin-turbo hydraulic torque converter, the above performances in several typical conditions can be applied as foundation.

The performance of twin-turbo torque converter was evaluated on specialized testing equipment[6]. The main processes include:

1) Collect testing data. Acquire rotational speed, torque, oil pressure, oil temperature, flow and other parameters following certain rules. Calculating the parameters according to the corresponding formula.

2) Find out the laws of testing data and derive fitting equation.

3) Draw characteristic curves.

4) Calculate the data of typical operating condition and print the evaluating report.

In the actual test, due to the external environment, instruments' precision, and many other factors, the data sometimes involve some irregular deviated points, which will greatly affect the post-data processing, result in inaccurate curve, impact on the results of the torque converter's performance evaluation. In order to solve these problems, the apparent singularities were removed manually in traditional method and several times tests were being done to improve detection accuracy[7]. These methods reduce the efficiency and the level of automation , the testing is not accurate too.

The twin-turbo hydraulic torque converter is the more complex product among the hydraulic torque converters. There is a turning point in the performance evaluation curves. The traditional fitting method is fitting by section. The determination of turning point demands human's judgments. It also made the testing process can not be done automatically[8].To solve the two issues, a neural fuzzy system is applied to dispose and analyze the test data, the result is more exact.

2. The Operation Principle of Neural - Fuzzy System

An ANFIS system proposed by J.-S R Jang uses a hybrid learning algorithm to determine the parameters, it combines the least squares method with the BP gradient descent method to train data on a given data collection. This system has the characteristics of fast convergence and accurate fitting[9,10,11]. Fig.1 shows the corresponding inference principle.

Assuming that the system has two input *x* and *y*, a single output *z*. For the first-order Sugeno fuzzy model, there are two fuzzy rules:

a) If x is A_1 and y is B_1, then $f_1 = p_1x + q_1y + r_1$

b) If x is A_2 and y is B_2, then $f_2 = p_2x + q_2y + r_2$

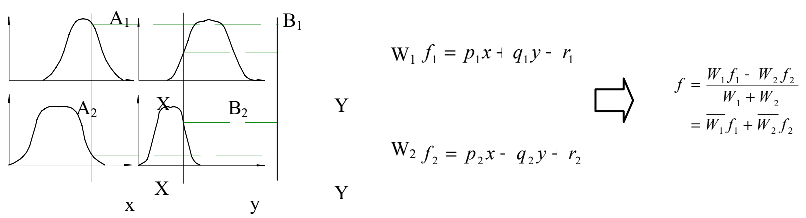

Fig. 1. Sugeno model's inference principle

The corresponding Neural-fuzzy system inference system shown in Fig.2.

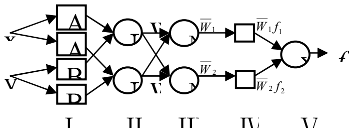

Fig. 2. Neural-fuzzy inference principle

It can be seen from the Fig.2 that if Ⅰ layer's parameters are fixed, the system's total output can be expressed in linear combination , that f can be written as:

$$\begin{aligned} f &= \frac{w_1}{w_1+w_2} f_1 + \frac{w_2}{w_1+w_2} f_2 \\ &= \overline{w_1}(p_1 x + q_1 y + r_1) + \overline{w_2}(p_2 x + q_2 y + r_2) \\ &= (\overline{w_1} x)p_1 + (\overline{w_1} y)q_1 + (\overline{w_1})r_1 + (\overline{w_2} x)p_2 + (\overline{w_2} y)q_2 + (\overline{w_2})r_2 \end{aligned} \quad (1)$$

It is a linear function of p_1, q_1, r_1, p_2, q_2 and r_2 . So parameter's identify speed will accelerate by applying the hybrid learning rules of steepest descent and least square estimator. In the forward channel of hybrid learning algorithm, the output of each node can put forward to the fourth level , and identify the parameters with least squares procedures. In the reverse channel, the error signal send back, and update the premise parameters using gradient method. Accordingly, owing to hybrid learning method reduce the pure back-propagation algorithm's searching space dimension, algorithm has more faster convergence speed[12,13]. Application of this system can achieve a faster convergence rate and a good fitting purpose[14].

3. Specific Application

Here a twin-turbo hydraulic torque converter type YJSW315-6 was analyzed. It was used in construction machinery widely and its Application environment is complicated too. The experiment was test on a experimental equipment of 160KW hydraulic torque converter's performance. The measured data were shown in Table 1 partly. The torque convert ratio, efficiency, energy content curve under different speed ratio can be received then.

For comparison, the collected data were analyzed by the traditional least squares method first. The torque converter's fitting function is an arbitrary algebraic polynomial. The singularities should be determined and removed before fitting the data points. The original characteristic curves were drawn by the empirical formula. The evaluation parameters in the started operating condition, the maximum efficiency's working condition, the efficient operating condition and other several typical operating condition can be calculated too. Specific fitting curves were shown in Fig.3(a).The calculated parameters in the typical conditions are shown in Table 2. Table 3 is the summary table of the torque converter's parameters.

Table 1 Twin-turbo hydraulic torque converter test data (Part)

No.	Input speed $n1$ (r/min)	Output speed $n2$ (r/min)	Input torque $M1$ (N • m)	Output torque $M2$ (N • m)	Ratio i	Coefficient K	Transmission efficiency η	Capacity Mbg (N • m)
1	2001.8	2164.7	177.1	126.0	1.081	0.71	0.769	44.20
2	2001.8	2062.8	292.9	231.9	1.030	0.79	0.816	73.09
3	2001.8	1962.1	330.3	280.3	0.980	0.85	0.832	82.43
4	2001.8	1876.5	348.3	309.5	0.937	0.89	0.833	86.92
5	2001.7	1768.0	370.9	345.1	0.883	0.93	0.822	92.57
6	2001.7	1673.7	389.2	376.9	0.836	0.97	0.810	97.13
7	2001.7	1571.3	405.7	410.9	0.785	1.01	0.795	101.25
8	2001.8	1465.2	424.4	448.0	0.732	1.06	0.773	105.91

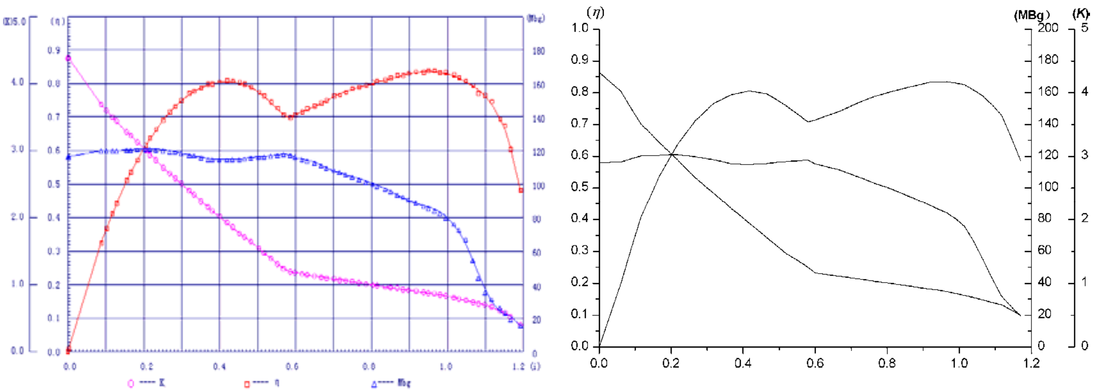

Fig. 3. (a)Characteristic curve 1; (b) Characteristic curve 2

Table 2 Typical working parameters(a)

No	Ratio i	torque coefficient K	Coefficient η	Capacity M_{Bg}(Nm)	Remarks
1	0.000	4.375	0.000	116.46	Braking condition
2	0.301	2.496	0.750	118.47	High -efficiency Point
3	0.418	1.928	0.806	114.70	First part Peak -efficiency Point
4	0.529	1.419	0.750	117.02	High -efficiency Point
5	0.682	1.100	0.750	110.04	High -efficiency Point
6	0.714	-0.010	-0.007	117.43	Transition point
7	0.801	1.000	0.801	100.68	Coupling Condition
8	0.950	0.880	0.836	86.34	Second part Peak-efficiency Point
9	1.109	0.677	0.750	33.35	High -efficiency Point

Table 3. Twin-turbo torque converter characteristic parameters (a)

torque coefficientK_0	First part Highest efficiency η_{1max}	Second part Highest efficiency η_{2max}	First Capacity M_{Bg0}(N·m)	Second Capacity $M_{Bg\eta}$(N·m)
4.375	0.806	0.836	116.46	86.34

Table 4 Typical working parameters (b)

No	Ratio I	torque coefficient K	Coefficient η	Capacity M_{Bg}(Nm)	Remarks
1	0.000	4.373	0.000	116.48	Braking condition
2	0.300	2.498	0.750	118.48	High -efficiency Point
3	0.418	1.927	0.808	114.71	First part Peak -efficiency Point
4	0.530	1.417	0.750	117.04	High -efficiency Point
5	0.680	1.101	0.750	110.06	High -efficiency Point
6	0.713	-0.010	-0.007	117.43	Transition point
7	0.801	1.000	0.801	100.66	Coupling Condition
8	0.947	0.880	0.837	86.35	Second part Peak-efficiency Point
9	1.110	0.676	0.750	33.35	High -efficiency Point

Similarly, applying the neural-fuzzy system for processing the test data. Select several fitting process' parameters based on the actual fitting cases and the data number. Finally, confirm 22 groups data and 1000 times training. The resulting curves shown in Fig.3.(b).

This system has a function of the automatic noise filter and improves the fitting realism by selecting the appropriate iterative approximate error and iterative times. The fold point needn't to be differentiated manually too and the purpose of real-time testing by directly calculating and programming can be achieved. The degree of automation increased significantly. Table 4 is the typical operation parameters which are calculated by this method, Table 5 is the summary table of the torque converter's parameters.

Comparing the obtained data and curves obtained by two different methods, it can be seen that the latter having gotten smoother curves, the inflection points also reflect more realistic. There are few differences between them on the typical operating condition point for the calculation of data values. New approach reduces the drawbacks of human intervention and facilitates to realize the automation of data processing.

Table 5. Twin-turbo torque converter characteristic parameters (b)

torque coefficient K_0	First part Highest -efficiency η_{1max}	Second part Highest efficiency η_{2max}	-First Capacity M_{Bg0}(N·m)	Second Capacity $M_{Bg\eta}$(N·m)
4.373	0.808	0.837	116.48	86.35

4. Conclusion

The application of neural fuzzy system for twin-turbo hydraulic torque converter's performance evaluation is feasible. It can effectively remove the abnormal test data points, automatically determine the break point, reduce the data processing's times of human involvement. The number of times can meet the test accuracy. Of course, the key to the right fitting is to determine the appropriate iterative times according to the practical condition.

Intelligent algorithm for solving practical engineering application has unique advantages, applying it with the traditional method can greatly improve the precision and speed of the application's handling. At the same time, the effective integration of multiple intelligent algorithms is a further explored problem in the practical application .

Acknowledgements

This project has gained the support of educational funds of Liaoning province education department(20091468)

References

[1] Lu Zhao Da. The principle and engineering of hydrodynamic transmission. Harbin:Harbin University of Technology Press ;2004.

[2] Jilin University of Technology. Construction Machinery hydraulic transmission. Beijing: Mechanical Industry Press;1999.

[3] Zhu Jing Chang . Vehicule hydraulic transmission . Beijing : National Defence Industry Press;1998.

[4] Song Zhi Gang. Design of computer system in hydraulic torque converter performance test instrument. Mining machinery,1997;7:29–31.

[5] Li You Yi, YAN Guo Jun, Wan Yong. The experimental study of axial-flow type hydraulic torque converter.Construction machinery,2001;5:9–10.

[6] Li Jie Min. Automobile and tractor test study. Beijing : Mechanical Industry Press;2003.

[7] Chen zheng xing. Data fitting. Xi'an: Xi'an Jiaotong University Press;1999.

[8] M. Abadi. On Access Control, Data Integration, and Their Languages. In Computer Systems: Theory, Technology and Applications, A Tribute to Roger Needham. 9-14.Springer-Verlag,2004.

[9] Jiao Li Cheng. Neural Network's Application and Implementation. Xi'an :Xi'an Electronics Technology University Press;1993.

[10] Jiao Li Cheng: Neural network theory. Xi'an :Xi'an Electronics Technology University Press;1990.

[11] Zhang Zhi Xing ,Sun Chun Zai. Neural - Fuzzy and Soft Computing. Xi'an :Xi'an Jiaotong University Press; 2000

[12] Yang Tei Nv.Artificial neural network for selecting tolerances. Beijing : Machinery Manufacturing,2001;39(5):13–15.

[13] Zhang Cheng Bao,Ding Yu Lan,Lei Yu Cheng: Artificial Neural Networks in Automotive Gear Fault Diagnosis, Automotive Engineering,1999;21(6),374–378.

[14] R. Geambasu, S. Gribble, and H. M. Levy. CloudViews:Communal Data Sharing in Public Clouds. In Workshop on Hot Topics in Cloud Computing (HotCloud);2009.