Study on Fuzzy Automatic Transmission Strategy of vehicles

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***Abstract*—In this study we discussed automatic transmission method of vehicles utilizing fuzzy technology and composed a control unit using PLC(PLC: programmable logical controller), and verified the correctness of this method on the automotive transmission testing table. The result of the experiment showed that, using the fuzzy automatic transmission strategy, different shifting strategies would be used in different working conditions, with effectively avoided the problems occurred in circulated shifting and delay shifting. This control rule has enriched the operational theory of the vehicles and has produced a kind of practical control method.**

***Keywords*—vehicles, automatic transmission, fuzzy control, PLC**

I. INTRODUCTION

Most of the vehicles have bad operation and working environment. The driver should operate the working devices and at the same time manually and frequently change the gears in order that the power performance of the vehicles can satisfy the working performance[1]. The operators work with great working strength while the economy performance of the vehicles can not be secured. The realization of the automatic transmission of the vehicles will be able to increase the transmission efficiency, the working efficiency, and at the same time, decrease the laboring force. So it is practical to realize automatic transmission system of the vehicles.

When the driver wants to shift, he can decide according to the surrounding conditions checked and the running conditions of the vehicles and the experience in driving. This system utilizes the fuzzy controller to imitate human being. Through the analysis on the samples of signals of engine rotation speed, turbo output rotation speed and the throttle degree and the analysis on the operation status of the vehicles, the analysis results are delivered to the fuzzy reasoning unit to conduct inference. The result will drive gear-shift(Type is 4D180, XuGong Co.,Ltd, China) in automatic shifting, this can ensure efficiency of the torque converter is high .

II. NOMENCLATURE

η : Efficiency of hydrodynamic torque converter (ideal value,$\eta \geq 0.75$) [-]
$\lambda_B\gamma$:Moment modulus of hydrodynamic torque converter [-]
K :Change torque modulus of hydrodynamic torque converter [-]
i :Transmission ratio of hydrodynamic torque converter [-]
i_1 : Setting Min-transmission ratio [-]
i_2 : Setting Max-transmission ratio [-]
n_1 : Engine Rev [r/min]
n_2 :Turbine Rev of hydrodynamic torque converter [r/min]
i_g : Shift position [-]
T : Load torque [Nm]
α : Throttle position [°]

III. RULES OF FUZZY CONTROL

A. *Rules of fuzzification*

In constructing the rules of shifting, all the operational parameters, such as engine rotation speed, turbo output rotation speed and throttle opening degree and other information alike, shall be collected into the controller in order to get the corresponding shifting rules with fuzzy calculation.

The following is the fuzzy shifting rules got from summarizing the operational experiences of the drivers and according to the utilization characters of the vehicles.

1) In case of operation in higher shift, the economy performance shall be regarded as the rule of shifting.

2) In case of operation in lower shift, the power

performance shall be regarded as the rule of shifting.

3) In case that the hydrodynamic torque-converter does not work in the high efficiency area, the shift shall be decreased or increased to make it work in the high efficiency area

4) In case that the throttle opening degree is very large, the shift shall be increased in normal travel, or shall be decreased in working condition.

5) In case that it is in traveling condition for a long period, the economy shift shall be adopted and at the same time, considering the efficiency of hydrodynamic torque-converter.

6) In case of short period traveling or to-and-fro traveling, the usage range of lower shift shall be increased.

7) In case that the engine will be over the speed, the shift can not be increased.

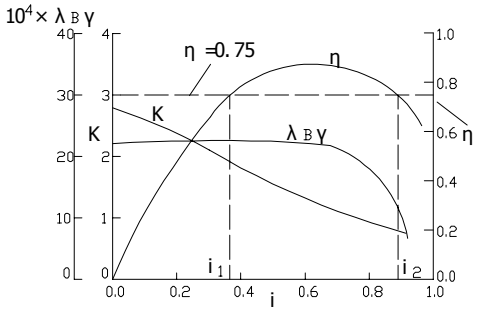


Figure 1 original characteristic for hydraulic torque converter

B. *Basic technology of fuzzy Automation transmission*

In this system, the increasing and decreasing of the shift is accomplished according to the efficiency of the hydrodynamic torque-converter , see Figure 1. Wherein, i refers to the transmission ratio of the hydrodynamic torque-converter.[2](general $\eta < 0.7$[1], in this paper $\eta_{min}=0.75$)

1） When $\eta>\eta_{min}$, the working point of the hydrodynamic torque-converter is in the high efficiency area, it is not necessary to change the speed of the gear-shifting, and at this time, we choose the original shift of the gear-shifting.

2） When $\eta<\eta_{min}$, the working point of the hydrodynamic torque-converter is in the low efficiency area, the gear-shifting shall be adjusted or the additional loading moment shall be adjusted in order to ensure the torque-converter working in the high efficiency area. As there are two low efficiency areas in the hydrodynamic torque-converter, we call the area with torque-convert ratio of K>1 as K1, and the area where K<1 is called K2[3] .

If K>K1, the gear-shifting shall be decrease by one shift;

If K<K2, the gear-shifting shall be increased by one shift.

3） If the gear-shifting is different(form 1 to 4) in the Figure 1, the η curve will change ,so i_1 and i_2 will change too($i_{1,2}$=f (η)). We set four group data of i_1 and i_2 in the fuzzy controller. The shift will be changed by the fuzzy controller according different i_1 and i_2.

IV. STRATEGY OF FUZZY AUTOMATIC TRANSMISSION

A. *Structure of the controller of fuzzy Automatic transmission*

Automatic transmission controller is the core of the whole control system. Figure 2 shows the structure of the controller for fuzzification reasoning transmission. It is decided by the controller through collecting the throttle degree, engine rotation speed, hydrodynamic torque-converter output rotation speed and analyzing the parameters, the working condition of the system and according to the gear-shifting rules, thus guaranteeing the highest transmission efficiency of the system and the best performance.

Herein, the input is engine rotation speed n_1, turbo output rotation speed n_2, the output is shift ig. the throttle degree is α, it is the parameter for selecting the rules in database.

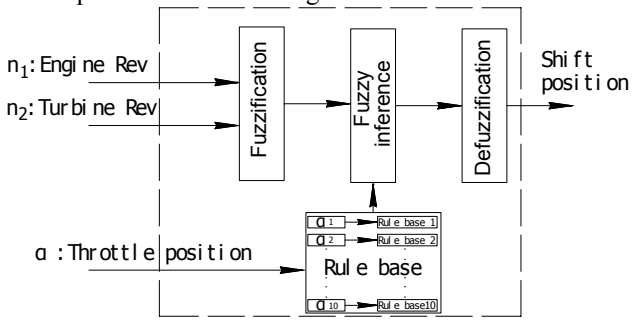


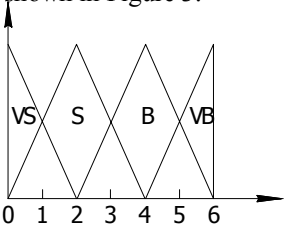
Figure 2 Fuzzy transmission controller structure

B. *Rules of fuzzy gear-shifting*

1） 4 fuzzy sets are used to describe the engine rotation speed n1: min, small, large, max, marked as {VS, S, B, VB}; 5 fuzzy sets are used to describe the turbo output rotation speed n2: min., small, middle, large, max., marked as {VS, S,M, B, VB}; 4 fuzzy sets are used to describe shift 1, 2, 3, 4, marked as {I, II, III, IV}. The true areas needed for sampling are respectively converted into internal areas of the fuzzy controller: {0,1,2,3,4,5,6}, {0,1,2,3,4,5,6,7,8}, {0,1,2,3,4,5,6,7}, and its

$$y = \frac{12}{b-a}[x - \frac{a+b}{2}] \qquad (1)$$

mapping relation is (x`s actual change range is [a,b],it will change accurate variable of [a,b] into y variable of {0,6}or {0,8}or {0,7}.If y is not a integer, it will be come down to a integer that it is the nearest y[4]) , then triangle-trapezia method are utilized to establish membership functions for n1, n2, and ig, the results are shown in Figure 3.



(a) n1: Membership functions of engine rev

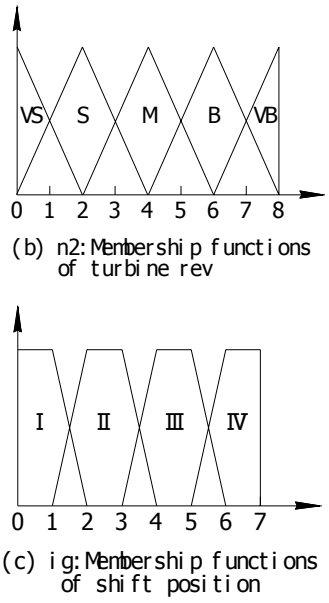


Figure 3 Membership functions

2）To determine 20 reasoning principles by summarizing the experiences of the people.

IF n1 IS VS AND n2 IS VS THEN i_g IS Ⅰ
IF n1 IS VS AND n2 IS S THEN i_g IS Ⅱ
……

The results from the fuzzy reasoning using Mamdani algorithm constitute the fuzzy control inquiring list for a certain degree of throttle[5]. Table 1 is the fuzzy control form of traveling with accelerated speed.

Table.1 Inquiring list of fuzzy control in some throttle

n_1 \ n_2	1	2	3	4	5
1	1	1	1	1	2
2	2	2	2	3	3
3	3	3	3	4	4
4	4	4	4	4	4

The target of the control system is to maintain the best efficiency of the system. So fuzzy control makes also the best transmission efficiency as the gear-shifting principle.

Through large amount of experiments, collecting the transmission status with throttle of different degrees (engine rotation speed, turbo output rotation speed, shift position), and make them as the specimen for making the fuzzy lists and generating the fuzzy control form on off-line. The fuzzy control basing on this form can achieve the control target in steady status. Save the fuzzy inquiring forms under various conditions into the controller, then the controller will control on the gear-shifting according to the real operational conditions inquiring data in the list.

C. Constitute of fuzzy controller

As Figure 4 shows, hardware of the fuzzy controller is combined by PLC, HMI, input signal sensor, output drive, communications, computer program and configure.

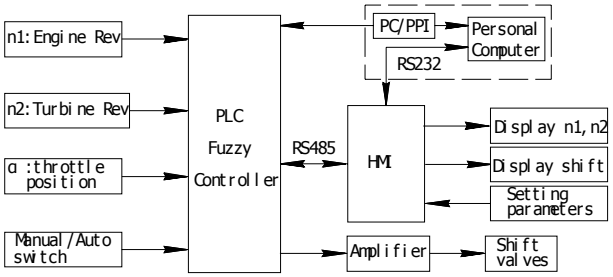


Figure 4 constitutes of fuzzy controller

In following, we will introduce each part purpose.

PLC(Programmable Logical Controller, S7-200 CPU214 transistor output, SIEMENS Co.,Ltd.): hardware of fuzzy controller; software include sample subprogram, main program, fuzzy reasoning program etc. When PLC fuzzy controller samples input signals(engine Rev, turbine Rev, throttle position), these signals will be changed and fuzzified and delivered to the fuzzy reasoning unit in PLC, the result will drive shift valves.

HMI(Human Machine Interface, PWS1700-TSN, Delta Co.,Ltd.): setting and display parameters.

RS485: communication interface connect PLC with HMI.

Amplifier: amplify PLC output signal to drive shift valves.

Personal computer: program and configure to PLC and HMI, connect PLC with PC/PPI cable, connect HMI with RS232 interface.

Control procedure: if instruction for forwarding is given, it shall be given to the first forward shift, and then the controller will give the proper operational shift according to the samples input signals and through fuzzy calculation and reasoning.

The following regulations are given for the gear-shifting delay: the interval of two shifts is allowed to be 2s (which can be adjusted according to the practical situation), that is, after one shift, the next is allowed after 2s.

The following regulations are for intervals of shifts:

When shift is allowed, the time taken for changing from one shift to another is 0.1-0.5s (which can be adjusted according to the real situation).

V. EXPERIMENT

A. Automatic transmission system test bed

Figure 5 shows the structure of the automatic transmission system test bed. It is composed by diesel engine, hydrodynamic torque-converter, gearing box, accelerator and electric-eddy power measuring instrument. Wherein, the engine is the origin of the power. The gearing box is composed by 4 forward shifts and 4 backforward shifts, which are controlled by 6 electro-magnetic valves. The electric-eddy power measuring instrument is a device for adding load to the transmission testing bed. The braking load will be adjusted by

adjusting the winding current, thus imitating the operational conditions of the vehicles. The accelerator is mainly used to match the central distance between the two transmission shafts. The fuzzy controller is made of PLC, which set up and display the parameters using HMI, and change the shift by controlling the electric-magnetic valves according to the fuzzy gear shifting rules through sampling of the engine rotation speed, turbo output rotation speed and throttle opening degree.

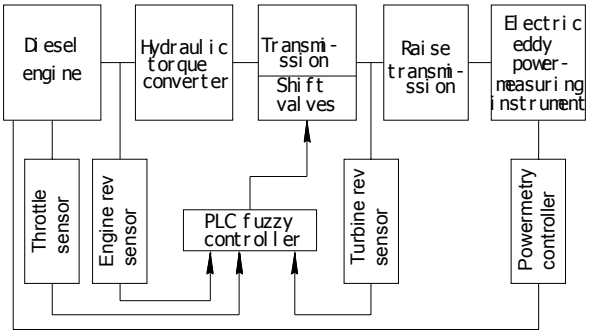


Figure 5 constitutes of automatic transmission system test bed

B. Analysis on the testing results

Firstly we shall calculate the loading torque needed in various working conditions, then load it through adjusting the electric-eddy power measuring instrument so to imitate the gear-shifting process of the vehicles under various working conditions. Figure 6 shows the curves of the gear-shifts that is changing with the time in the situation of accelerate running and of load conditions.

The running process of the vehicle without load is: start, accelerate, steady running process. The change of the shift, see left of Figure 6a, the vehicle start from the first shift and change it continuously to the fourth shift and keep it at this shift during running, no circulation shifting process. When it is in load condition(Figure 6c), the change of the shift ,see right of Figure 6a. with the working shift strategy, though increase load of the power measuring instrument, Fig 6b shows efficiency curve changed form four shift high efficiency area into one high efficiency area. It satisfy the condition of $\eta_{min}>0.75$.

According to the performance curve (Figure 1) of hydrodynamic torque-converter, the efficiency of hydrodynamic torque-converter is changing with its transmission ratio, that is, $\eta=f(i)$. The transmission ratio i will come through the engine rotation speed n1 and hydrodynamic torque-converter n2 and the efficiency curve η will come into being through the efficiency curve. If $\eta>0.75$, the hydrodynamic torque-converter will work in the high efficiency area and it need not to change the shift; if $\eta<0.75$, the hydrodynamic torque-converter will work in the low efficiency area and it need to change the shift (increase or decrease shift).

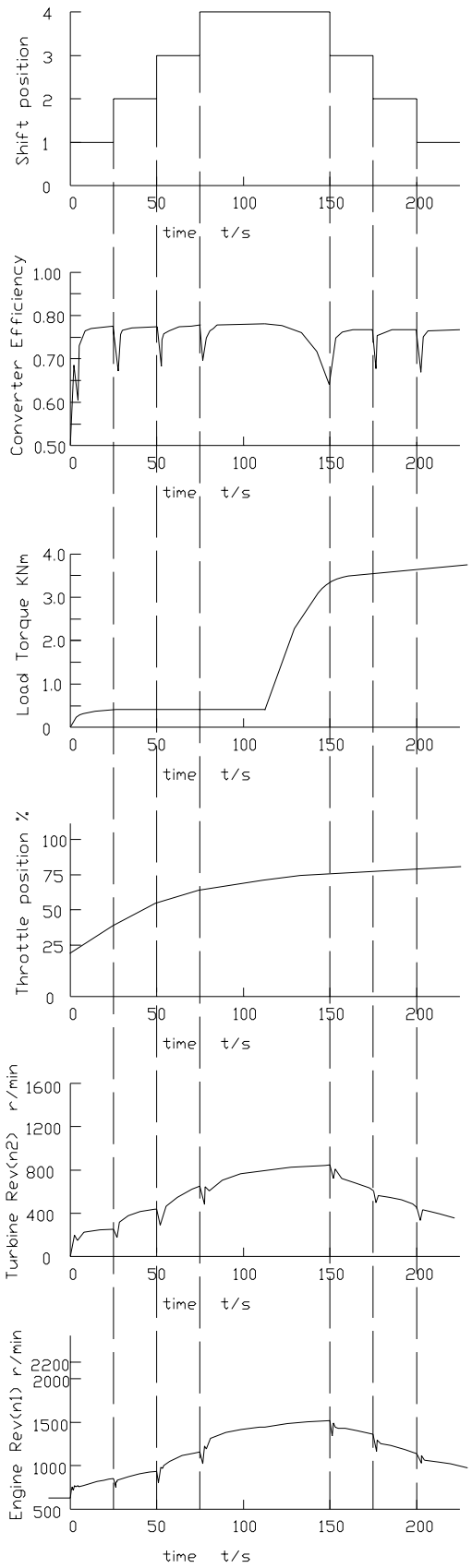


Figure 6 change rule of automatic transmission test bed

VI. CONCLUSION

The results show correctness of the automatic transmission and the efficiency of hydrodynamic torque-converter is high(η>0.75). Shift is steady and smooth and very little impact.

The control system is working reliably from testing, the fuzzy control strategy can determine the running status of the vehicle, thus realizing the change of shifts correctly. Due to the high reliability of PLC, the period of development is very short, PLC can constitute the controller used for test, and it is also can be used in real vehicles. From the above, the fuzzy control strategy is suitable for automatic transmission in vehicles, and it has a high steadiness and excellent performance.

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