A new approach of shift schedule optimization for AMT vehicle based on optimal theory

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ABSTRACT
This paper is aimed to solve the problem when the car shift is not smooth with the feeling of being stamped, in view of the two parameters of the automatic transmission (AMT) shift schedule, using AVL Cruise software modeling and Cruise with the working condition of the new European road spectrum (NEDC) simulation, it concludes that transmission of the original shift schedule curve, in view of the AMT shift schedule, the optimized data import controller and generate new shift schedule, shift schedule is more smooth than before, making shift more smoothly and reducing fuel consumption. The result shows that this method could generate the shift schedule accurately and quickly and optimize the transmission states on the specific cycle conveniently. These works could be used in the effective calibration of automatic transmission and shorten the vehicle development cycle.

CCS Concepts
• Computing methodologies→ Modeling and simulation→ Results analysis → summarizing

Keywords
AMT; Shift schedule; Two parameters; Optimization analysis

1. INTRODUCTION
Shift schedule is mainly aimed at shifting physical variable, how to select parameters, and how to optimize the reasonable transmission ratio, make the engine output torque how maximum limit by clutch and gearbox transmission ratio allocated to the rear axle and the wheel. Its quality directly affects the vehicle's fuel economy, performance and emissions of quality and comfort, so the shift schedule is one of the cores of the automatic control system. The development of the shift schedule roughly experienced the traditional, based on experience and intelligence. [1].

The number of control parameters is guiding for vehicle shift gears. Such as, single parameter shift schedule can usually choose throttle percentage [2], engine speed, and the speed as control variable, the speed can be obtained according to the formula (3) type of integral, the control system structure is relatively simple, but bad road conditions require frequent shift gears[3]. With speed and throttle opening commonly as two parameter shift schedule control parameter，according to the two parameters to control the timing shift, it can improve the adaptability of vehicle on road and the driver can also process operated by particular intervening shift .Compared with the two parameter shift schedule, three parameters shift schedule introduction the vehicle acceleration, further reflects the actual control rule of the vehicle, but it is based on the engine dynamic experimental data, the present theoretical research is more, less in engineering application. In recent years, with the new shift schedule is put forward based on experience and intelligent, its essence is also speed, throttle opening, vehicle acceleration as the main parameters, such as, supplemented by other important parameters. Due to some limitations of chip resources and technical maturity, which is based on the experience and intelligent shift schedule is currently mainly limited in theoretical research, has not been widely used. [4]. The two parameter shift schedule between the above two, not only can meet the requirements but also control the cost, so this article take on the basis of two parameters, using the Cruise GSP module analysis of automotive AMT shift schedule, And considering the road slope, driving environment, economy and emission of vehicle optimization, with period can rapidly and accurately generate shift gear shift schedule and its optimization rule, for the present technology situation, to accelerate the development of the vehicle, and fast transmission calibration has certain reference significance.

ICAIR and CACRE '16, July 13-15, 2016, Kitakyushu, Japan

DOI: http://dx.doi.org/10.1145/2952744.2952767

2. ESTABLISHING VEHICLE SYSTEM MODEL

2.1 The vehicle modeling parameters
Table 1. Simulation of vehicle parameters

Vehicle size/mm	4425×1815 ×1485
The mass/kg	1779
Rolling resistance coefficient	0.015
Windward area/m^2	1.93
Moment of inertia of the wheel kg/m^2	0.2793
Engine displacement/cm^3	1995
Engine power/kW	92

Variable speed ratio	3.91/2.11/1.39/ 1.02/0.82/0.67
The main reduction ratio	3.37

2.2 Cruise vehicle model is established

Cruise software was by the Austrian Liszt company research and development, its good parts parameter Settings interface can provide convenient modeling and simulation for the traditional automobile, new energy automobile, also provide guidance for the development of new models. For the study of the two parameters shift schedule of the AMT, choosing Cruise the built-in shift schedule module-GSP Generation/Optimization. The article according to the boundary of the user-defined to control and Optimization shift .Fig.1 is a model of AMT in the cruise.

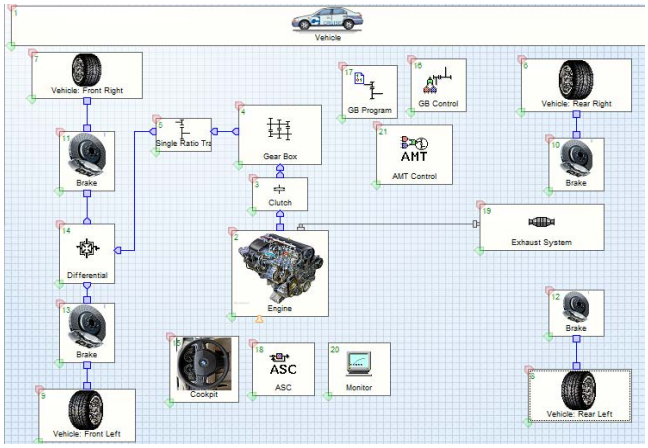

Figure 1. Cruise vehicle simulation model

As the Figure 1 shown, the design of HCC control algorithm can be divided into three layers. The first layer is composed of optimal DCI (Driver Command Interpreter) controller, which will not only calculate the desired C.G forces and moment intelligently but also make the optimal outputs adapt the actual road conditions. The second layer is HCC optimization which In the following sections the function of each layer are detailed described.

2.3 Generated shift schedule

Shift principle: Transmission system of the reasonable matching and selection of related parameters directly determine the stand or fall of performance and fuel economy of vehicles. Make shift schedule is in order to get the best fuel consumption under the speed between two gear shift points, according to the speed to go get the engine under the characteristics of the throttle opening, dynamic total success rate is calculated from (a, v) and the engine torque, but due to the delayed shift, calculated data can only be infinitely close to the ideal characteristic curve. Therefore, according to the acceleration characteristics to formulate economy shift schedule, then input parameters of vehicle components, under the GSP module subdirectory shift parameter is set, and the cycle set under the run cycle working condition. Below for the relationship between the speed and the throttle opening between adjacent gears, used to guide shift parameter Settings.

According to the throttle opening, the double parameter shifting rule area is divided into low load, medium load area and high load. Low load and middle load area according to the experience of the calibration engineer, a kind of 20% ~ 25%, high area generally refers to more than 80% load. Full throttle at 100% load, refers to the accelerator for short periods of time in the one state. In practical engineering, transmission calibration due to generally full throttle opening and urgent to accelerate case full throttle opening of the vehicle response is different, and the shift schedule is different, so using 100% said vehicle general conditions of the full throttle opening, using 110% show urgent to accelerate the vehicle under full throttle opening. As shown in figure 2 for car shift schedule

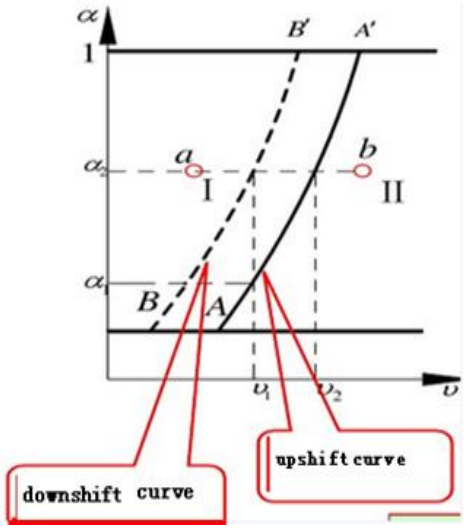

Figure 2. GSP shift principle

The following high area shift points as an example to show shift principle: High load area vehicle performance in order to obtain the best performance as the prerequisite, namely shifting Vehicle always maintain the maximum acceleration intensity. According to the relevant information: under the same load, if two adjacent acceleration characteristic curves intersect, if the point of intersection is not negative, shift points for each block intersection; If two adjacent block acceleration curve of disjoint, shift points for each block of the highest speed. The actual shift response should also be considered in the process, the influence of the shift time. At the same time, guarantee upshift and downshift delay the speed difference between block within a reasonable range. Similar to the low load area, shift schedule also use such delay.

In order to generate the shift schedule, need to first obtain the vehicle acceleration curve [5]. Speed resistance is the vehicle accelerated must overcome inertia force, according to the Newton's second law, acceleration resistance make the vehicle generate line acceleration.

$$F_{acc} = M_{v,a} = M_v \frac{dv}{dt} \tag{1}$$

The total driving force: $F_{te} = F_{rr} + F_{ad} + F_{rg} + F_{acc}$ (2)

So, the vehicle acceleration is:

$$a = dv/dt = (F_{te} - F_{rr} - F_{ad} - F_{rg})/M_v \tag{3}$$

Among them, a is the vehicle acceleration, F_{te} is the traction, F_{rr} is the roll damping, F_{rg} is the ramp resistance, F_{ad} is the air drag, M_v is the quality of the vehicle. According to the formula to get the vehicle acceleration curve and shift time sequence curve [6], as shown in fig 3, 4, under different throttle opening, vehicle acceleration curve:

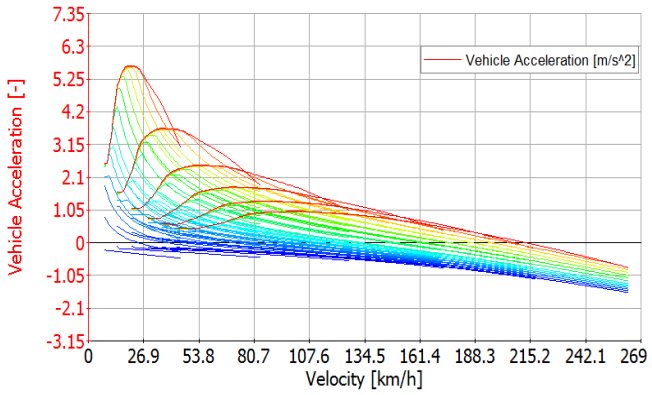

Figure3: The vehicle acceleration curve

By the AVL Cruise software simulation with shift schedule:

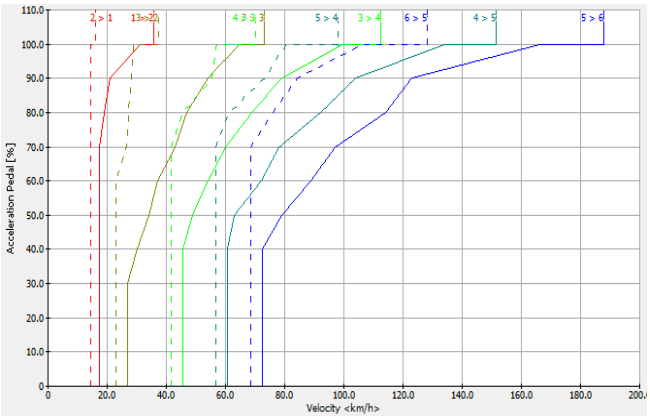

Figure4: Upshift and downshift schedule in the economic mode

Analysis Figure 4 shows, the shift schedule is a mandatory shift of divergent shift schedule, on the one hand, keeping the divergent engine working speed higher, fewer shift, the advantage of high comfort; on the other hand, increasing the function driver intervention force to reduce block, in order to obtain the throttle fully open good power utilization, which has been widely applied in the calibration of the automatic transmission. The same method can get dynamic pattern and other patterns shift schedule. 110% shows vehicles urgent acceleration cases full throttle opening. In addition, we can export the point data of the picture and process these date, import the transmission control unit as transmission calibration data, to accelerate the development of the vehicle, convenient transmission calibration has certain reference significance.

2.4 The transmission optimization process

Because of vehicle is moving usually based on a drive cycle, so it is necessary to research shift schedule how to have any influence on automobile transmission system state in the working condition of a loop [7]. Cruise GSP module is based on the Cruise environment to build the vehicle model, primarily set up two parameters, a task is fixed in the different gear the engine speed when 1000 revolutions, pedal sample point, etc. Another is the optimize parameter Settings and fuel emissions caps, driving cycles and other Settings. According to these Settings, considering the gears, the throttle opening, pedal parameters, running under the given operating conditions, it is concluded that optimal data, such as operating mode optimization, K curve optimization, the optimization of the throttle opening and so on, thus it is concluded that the balance of the fuel economy and emission performance curve.

According to Cruise optimization process, a brief description of auto shift schedule optimization process: GSP module reads the Settings of the engine speed data and the speed of the car, and then fitting the engine map diagram, and then according to set limits on emission sand circulation condition data to run , to calculate the vehicle fuel and emission, the software according to the time speed condition to calculate the power of corresponding conditions , calculate the different K-factor, get the corresponding transmission system state[7] , the balance of the fuel economy and emission performance curve. After the task, according to GSP generated report, you can view the different range of performance, fuel consumption and exhaust emission, driving cycle's sensitivity analysis data, etc. simplify the process figure as shown：

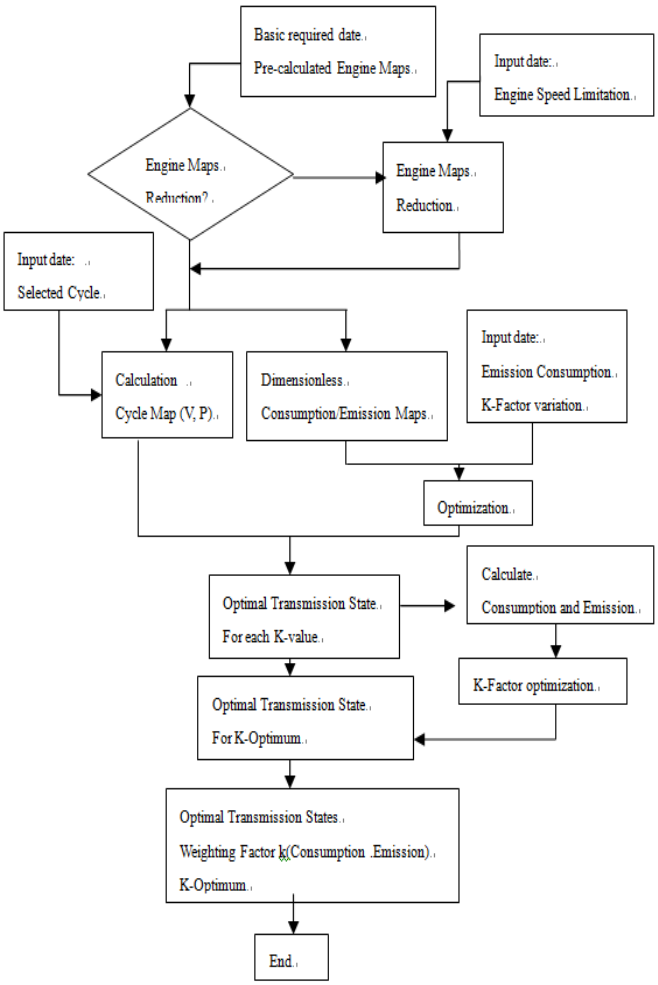

Figure5: Optimization flow chart

In the GSP Optimization, Cruise through the K - Factor to achieve a given driving cycles to balance calculation of fuel consumption and emissions. The definition of the optimal K-factor as shown in the following type:

Optimum = (l-K) ×Consumption + K × Emission [7] (4)

Type, Optimum: the optimal result, Consumption: fuel Consumption, Emission: NO_x emissions

2.5 Drive train optimization results

(1) the figure 7 is overlay chart for K factor curve and emissions, according to the design of engine emissions standards[8], incorporating the NEDC condition and calculation accuracy, calculated NEDC cycle under the condition of the car as a result, K value optimum option is 0.7 （K value associated with the emissions of Settings), 5.35 L / 100 km fuel consumption; NO_x emission is 0.299 g/km. Table 3 for the NEDC driving cycles shift schedule optimization operation fuel consumption before and after contrast, compared by fig.4 and figure8, the optimized shift schedule curve fairing than before much, shifting more smooth and stable, can effectively reduce the shift's stamped and reduce fuel consumption and emissions[9].

(2) Table 3, K = 0.7, the notch sensitivity analysis under the condition of NEDC cycle. In the 85s, when the gear is 3, respectively in the scheme 1, 2, gear shift down to shift up, change into gears 2 and 4, can observe downshifts with shift up the corresponding percentage change of fuel consumption and emissions. Thus, according to need in the cycle of a given condition, choosing the right gear, to balance the vehicle efficiency and emissions. Table 3 for the NEDC driving cycles shift schedule optimization operation fuel consumption before and after contrast, change the shift schedule can improve fuel consumption.

(3) To develop a new car, we can through the GSP Optimization predefined fuel consumption and exhaust emission of the Optimization goal, in the appropriate K curve generated points, and then the given cycle is obtained by simulation calculation under different speed under the condition of optimized throttle opening (Figure 8), finally the data graph overlay chart (Figure 9 and Figure10), integrated shifting curve, improve the shift schedule of a given condition. The final will be revised shift curve data import transmission control unit. Through this method can fast optimization under the working condition of a given shift schedule, is conducive to the development of engineering vehicles

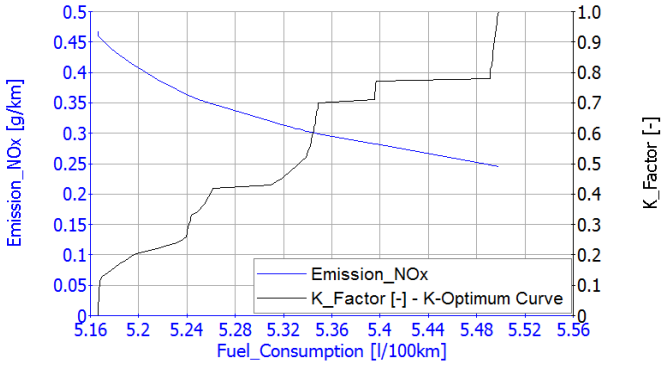

Figure 6. Fuel economy and emission performance of equilibrium curve

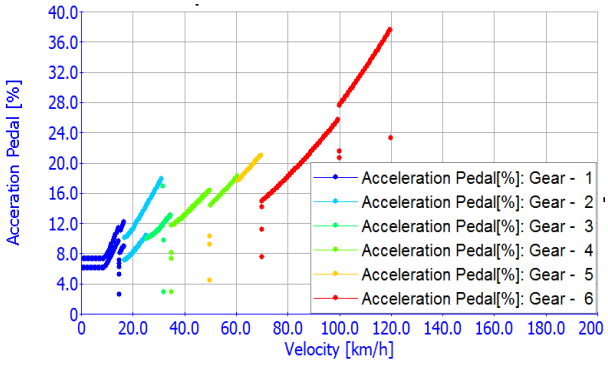

Figure 7. Under the optimal speed of throttle percentage

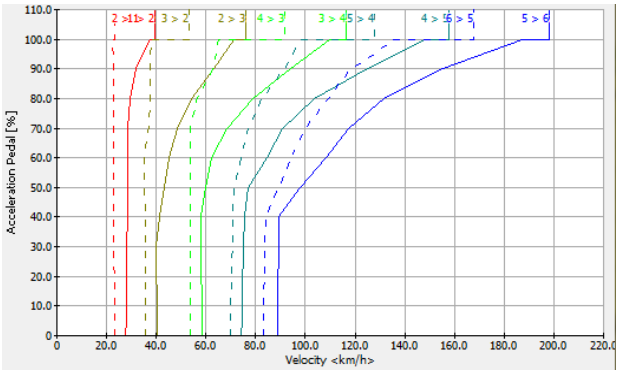

Figure 8. Shift time series optimization

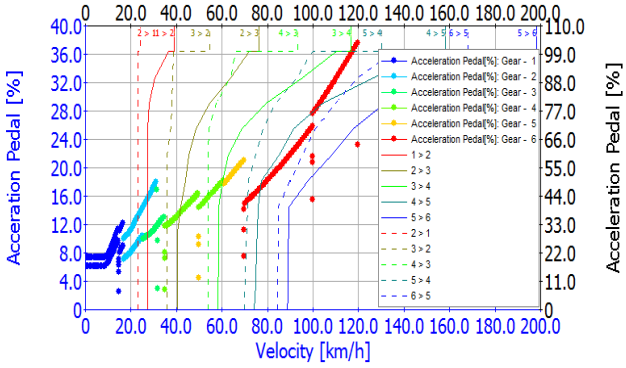

Figure 9. Throttle percentage, the transmission ratio and speed of optimization

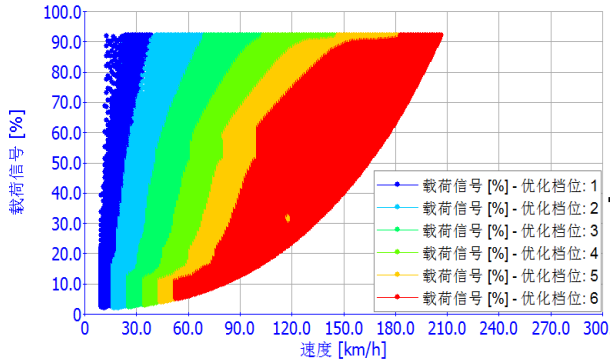

Figure 10. Comparison and optimization in NEDC

Table 3. Optimum of NEDC states

time/s	Initial speed/ (km/h)	end speed/ (km/h)	gears	distance/m	Fuel consumption/ $(_{L/100km})$	NO_x Emission $/(g/km)$	scheme1			scheme2		
							gears	$FC/\%$	$X_{NOx}/\%$	gears	$FC/\%$	$X_{NOx}/\%$
15	0	15	1	8.33	17.59	2.523	2	-24.67	-305.79	3	-10.13	-333.38
23	15	15	1	32.92	6.08	0.162	2	-73.08	-735.04	3	-36.73	-1139.86
61	0.3	32	1	51.39	16.65	2.101	2	-34.00	-97.94	3	-37.40	-105.11
85	32	32	3	212.4	2.88	0.519	2	39.48	-85.18	4	-16.64	-68.57
143	0.3	50	3	195.14	7.60	0.190	2	23.44	96.43	4	-11.64	73.24
155	50	50	5	165.28	2.49	0.301	4	10.53	-61.83	6	-5.98	3.85

Table 2. NEDC driving cycles shift schedule optimization operation fuel consumption before and after contrast

Type / Computing project	Original results	optimization results
Hundred kilometers fuel consumption （L/100km）	7.69	5.35
NO_x emissions （g/km）	0.669	0.299
CO_2 emissions （g/km）	202.38	140.29

3. CONCLUSIONS

(1) Using Cruise optimize module, select shift parameters, and generate the best fuel economy shift schedule. Integrating optimizes the shift schedule data, with a consolidated data to generate new shift curve and the vehicle simulation again. As it turns out that the generated again shift curve shifting guidance can improve the vehicle performance

(2) Taking the Cruise GSP module, set the shift parameter, to generate the best economic performance shift schedule. And according to the working condition of NEDC, curve to shift schedule is optimized and the performance simulation of the vehicle. Compared with the original vehicle performance, GSP optimized shift schedule curve to improve the performance of the vehicle. Thus verified the correctness and reliability of GSP module generates shift schedule.

(3) In this paper, the more in-depth study of some passenger car AMT shift schedule, obtaining some achievements, but mainly to study of shift schedule also based on the theoretical research and develop, so also in be used actually need to continue to modify and adjust the calibration data transmission. In addition to our country's road conditions and NEDC condition difference, it is necessary to collect the corresponding road spectrum data to import the Cruise to detect the optimal shift schedule.

4. ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of Collaborative Innovation and Platform Environment Construction Project of Guangdong Province (2015A050502053)

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