

Development of a Control Method to Reduce Acceleration Shock in Motorcycles

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ABSTRACT

The purpose of this paper is to propose a control method to reduce acceleration shock in motorcycles. Reducing the acceleration shock is very important in improving drivability of motorcycles. Motorcycles equipped with manual transmission have some backlashes in the transmission, with large backlash especially in dog clutch portions. We have figured out that one of the main causes of the acceleration shock is the collision of the dogs at high relative angular velocity during acceleration. Also, our data analysis has revealed that there is a correlation between a peak value of the longitudinal body acceleration and the relative angular velocity at the moment of the dog collision. A simulation was undertaken to verify this phenomenon, and its results have made it clear that we need to decrease the relative angular velocity at the moment of the dog collision so as to reduce the acceleration shock. Therefore, we have developed a control method that estimates a relative angle of the dogs and implements ignition timing retard control just before the dog collision to decrease relative angular velocity at the moment of the dog collision. This control method is characterized as being effective even when a throttle is opened slowly, in which case the conventional method is not so. As a result of a riding test, we have proved this control method can reduce the peak value of the longitudinal body acceleration using this control method, and received good evaluation from riders regarding acceleration shock.

1. INTRODUCTION

In order to enhance marketability of motorcycles, it is important to improve riding feelings as well as maximum speed and maximum power. Being able to accelerate motorcycles smoothly at the corner enables safer riding at higher speed, therefore it is especially important to reduce

acceleration shock while making a transition from deceleration to acceleration. In order to reduce the acceleration shock, we have tuned a fuel injection map and characteristics of transmission such as stiffness and damping. But we have not reduced the acceleration shock enough by these countermeasures. We have to apply some countermeasures such as temporarily decreasing engine torque at just the appropriate moment implementing ignition timing retard control on ignition devices, which are especially superior in response among electronic control devices of engines. In this paper, we discuss development of the system that estimates the relative angular velocity of rotational driving elements that is caused by backlashes existing in power train, and implements an ignition timing retard control based on the estimated value in order to reduce the acceleration shock.

2. OBJECTIVES OF THE DEVELOPMENT

Conventionally, as one of the methods to reduce the acceleration shock, ignition timing retard control based on the differential of throttle opening angle has been often used as shown in [Fig.1](#). However, since riders need to adjust angles of the throttle opening according to running speed, curvature of corners, friction coefficients of road surfaces and such conditions, there has been problems in the conventional control system that the ignition timing retard control is not activated because the differential is too small when the throttle is opened slowly. Especially for large-size motorcycles whose engine displacement is more than 1000cc, the acceleration shock can be significant enough to be problems even when a throttle is opened slowly or slightly as well as opened quickly, for which countermeasures have been needed. Our development aims to realize a control method

that is able to implement ignition timing retard control stably for any types of throttle operations.

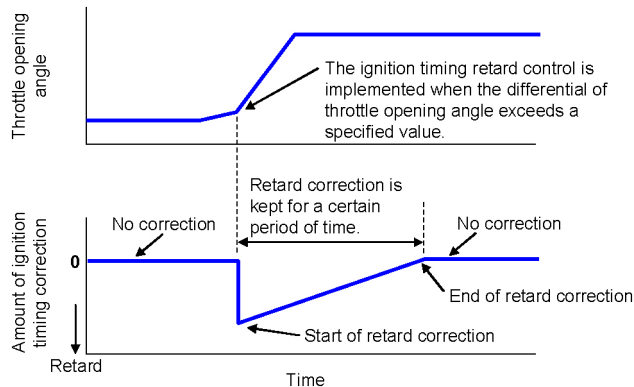


Fig.1. Conventional ignition timing retard control system

3. CAUSE OF THE ACCELERATION SHOCK

3.1. CAUSE ANALYSIS BASED ON A TEST

An actual motorcycle test was conducted to analyze the cause of the acceleration shock. On the assumption that the probable cause exists in dog clutch portions where the amount of backlash is largest in power trains (around 20 to 30 degrees), the speed of the engine and the output shaft, both linked to the dog clutch portions, were measured. Combustion pressure sensors were set at 4 cylinders to evaluate an effect of ignition retard control. Also, a longitudinal body acceleration sensor and a torque sensor were set on a fuel tank and the output shaft respectively to evaluate the acceleration shock quantitatively as shown in Fig.2.

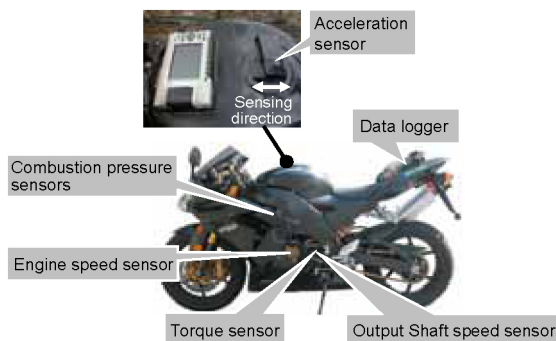


Fig.2. Measurement system

Fig.3 shows measurement data obtained when an acceleration shock occurred. During deceleration, the engine speed is equal to the output shaft speed (corrected according to reduction gear ratios). Once a throttle is opened, however, the

engine speed increases first, and then the output shaft speed increases rapidly and finally becomes equal to the engine speed. The difference between engine speed and output shaft speed represents that dogs were rotating without contact, and we can assume that the dogs might have collided each other while the output shaft speed was increasing rapidly. In addition, as soon as the output shaft speed became equal to the engine speed, large peaks were observed in longitudinal body acceleration and output shaft torque, and acceleration shock was found to have occurred.

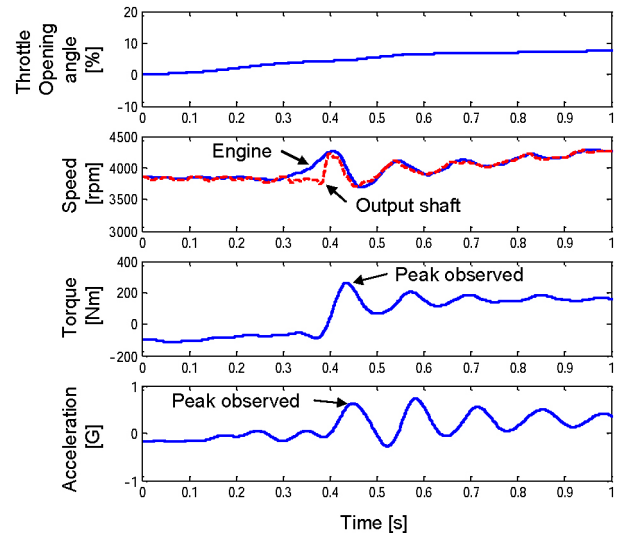


Fig.3. Test results obtained when the acceleration shock occurred

We have analyzed the cause of the acceleration shock based on these measurement data, and Fig.4 shows the results of the analysis. We have assumed that the acceleration shock is caused because the dogs rotate without contact at the moment of acceleration and collide each other at high relative angular velocity due to large backlashes (necessary for gear changes) in the dog clutch portions.

3.2. CAUSE VERIFICATION BASED ON A SIMULATION

A simulation was undertaken to verify the results of the cause analysis based on the test. The simulation model was developed using Simulink®. The simulation model includes crankshaft, clutch, transmission, wheel and chassis of the motorcycle. The input of this simulation model is engine torque calculated from combustion pressure. In order to clarify a relationship between relative angular velocity and output shaft torque at the moment of the dog collision, we have compared results of the simulation and the test, opening a throttle quickly and slowly. As Fig.5 shows, the simulation results coincide well with the test results, especially the increase in the engine speed due to rotating without contact of the dogs. In addition, both in the simulation and the test, we

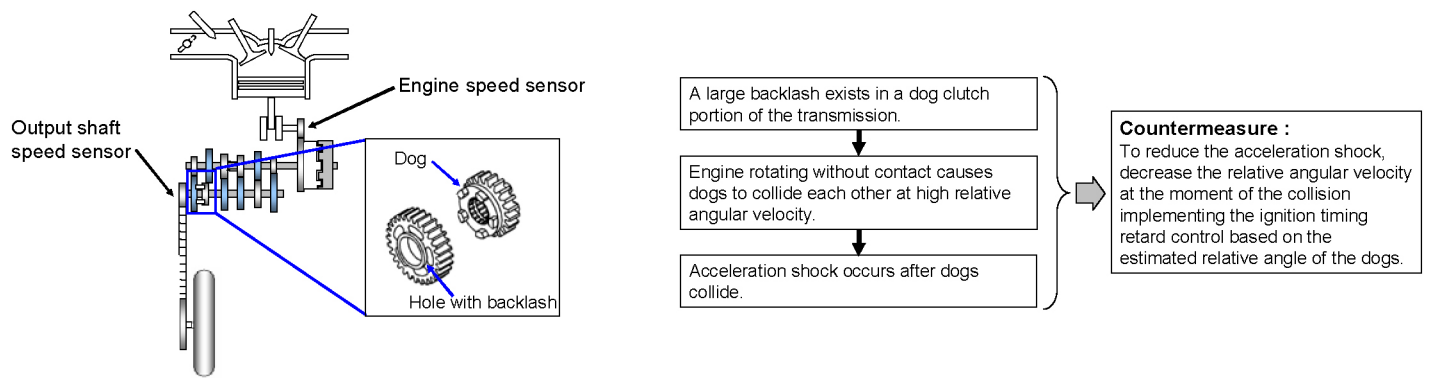


Fig.4. Cause analysis of the acceleration shock

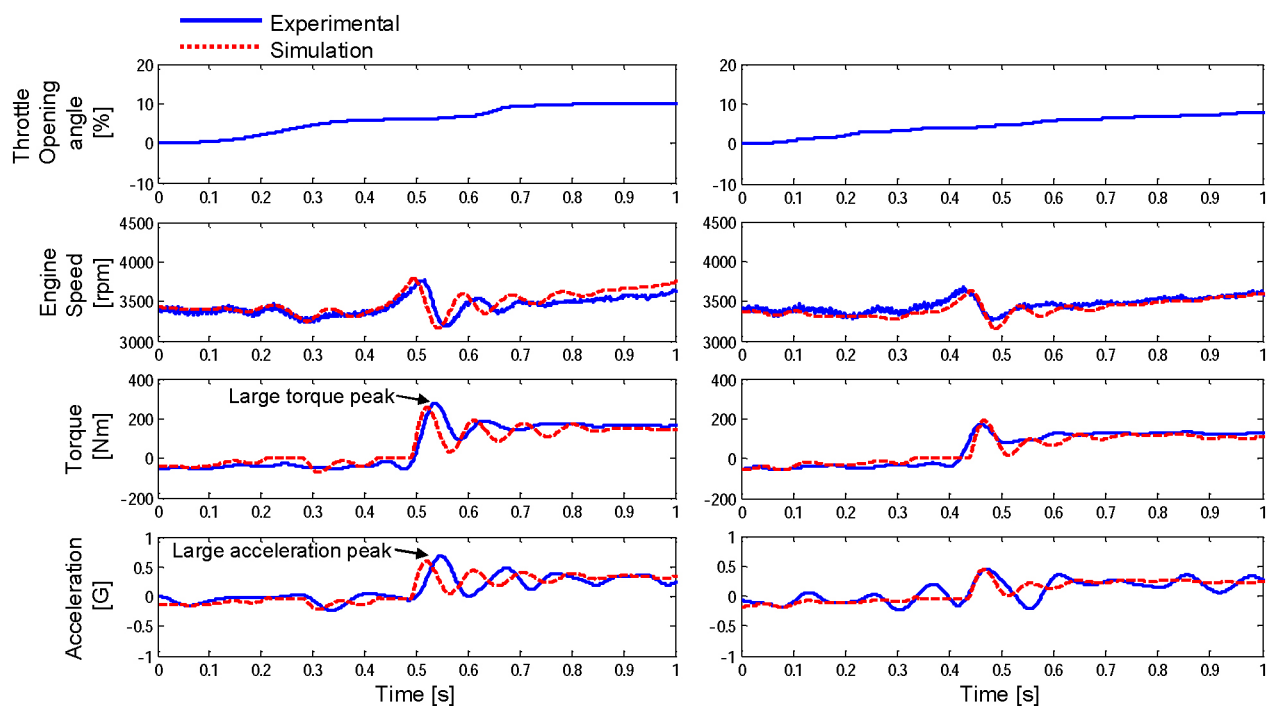


Fig.5. Simulation results

have confirmed the same tendency that the higher the relative angular velocity of the output shaft becomes at the moment of the dog collision, the larger torque peak of the output shaft becomes. We were able to simulate the occurrence of the acceleration shock, and it allowed us to conclude that the dog collision is the cause of the acceleration shock, and there is a great correlation between relative angular velocity at the moment of the dog collision and scale of the acceleration shock.

4. ACCELERATION SHOCK REDUCTION CONTROL

4.1. BASIC LOGIC

According to the above verification results, we find out that the acceleration shock can be reduced by decreasing the relative angular velocity at the moment of the dog collision, therefore we have developed a control method that detects the timing just before dogs collide each other, and implements the ignition timing retard control. The control method is illustrated by Fig.6. To detect the timing of the dog collision, the relative angular velocity of the dogs is calculated from the engine speed and the output shaft speed, and the calculated data is integrated to estimate the relative angle. The basic amount of ignition retard is calculated based on the estimated