

Improvement of the Startability with Reverse Stroke Intake Devices for a Motorcycle Engine

Takahiro Masuda, Kouji Sakai, Yuki Yamaguchi, Jun-ichi Kaku,
and Hirobumi Nagasaka
Yamaha Motor Co., Ltd.

ABSTRACT

This paper proposes a novel engine starter system composed of a small-power electric motor and a simple mechanical valve train. The system makes it possible to design more efficient starters than conventional systems, and it is especially effective to restart engines equipped with idling stop systems.

Recently, several idling stop systems, having intelligent start-up functions and highly-efficient generate capabilities have been proposed for motorcycles. One of challenges of the idling stop systems is the downsizing of electric motors for starting-up. However, there are many limitations to downsize the electric motors in the conventional idling stop systems, since the systems utilize the forward-rotational torque of the electric motors to compress the air-fuel mixture gas in the cylinders.

Our studies exceeded the limitations of downsizing the electric motors by mainly using the engine combustion energy instead of the electric energy to go over the first compression top dead center. The starter system described in this paper consists of (A) an electric motor which can rotate an engine crank shaft in normal or reverse directions, (B) a valve train to initiate the intake valve during the exhaust stroke in the reverse rotation, and (C) a control unit to inject and ignite at arbitrary timing.

Then, this engine starts-up with the following: (1) the electric motor rotates the crank shaft in the reverse direction, (2) a fuel is injected to the intake port, (3) a generated air-fuel mixture gas is led to the cylinder from the intake port during the exhaust stroke, and (4) the air-fuel mixture gas is ignited in the expansion stroke. Since the ignition generates the combustion energy to push back the piston, the piston is forced to be fallen down and the crank shaft is driven in the normal direction. At last the piston goes over the first compression top dead center by the normal-direction without the torque of the starter motor. After that it begins the normal operation.

The mechanism above can decrease the required time and the required torque to start-up the engine, and it leads to the downsizing of the starter motor, as well as a reduction in the battery consumption. When the mechanism is applied to starter-generator systems for motorcycles, the excess capability of the electric generation can be suppressed because it is not necessary to install the large-power starter-generators.

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INTRODUCTION

Background

This paper proposes a novel engine start system. This system is composed of a small-power electric motor and a simple mechanical valve train. The system makes it possible to design more efficient starters than conventional systems. It is especially effective to restart engines equipped with idling stop systems. When the system is applied to the engines with starter-generators (starter functions are integrated to a

generator) for motorcycles, the excess capability of the electric generation can be suppressed because it is not necessary to install the large-power starter-generators.

Recently, reflecting growing worldwide concerns for the environment, it is requested to improve further fuel economy of not only cars but also motorcycles. One technology to answer such requests is an idling stop system. This technology can achieve the fuel economy to cut off the fuel consumption during

idling. However conventional idling stop vehicles have concerns about the restart response after idling stop, so that it is difficult for the vehicles to secure comfort and safety.

Furthermore some systems install larger-power starter motors to keep the startability and durability. To solve the issues, a system controls the piston stop position of the cylinder on stopping the engine [1] [2]. Another system utilizes the crank inertia and a decompression device to reduce the cranking torque with the starter motor [3].

Problem

However, there are many limitations of the downsizing the starter motors on such systems. One of them is caused that almost all engines have to go over the first compression top dead center with the electric motor power to obtain the first combustion. On the other hand another engine installs direct injection devices or variable valve trains to reduce the cranking torque. These systems can be expensive and complex with such devices.

Novelty

This study notices this point. Therefore a proposal engine starter system obtains the first combustion without the piston going over the first compression top dead center. In other words the piston goes over the first combustion top dead center with the combustion torque mainly. Specifically the engine system consists of a single-cylinder engine, a reversible rotary electric motor, a mechanical valve train with a slide cam, a normal port injector and an igniter. The devices are integrally controlled by this system.

Additionally, this system yields two benefits of the startability for motorcycle engines compared with conventional system in cool and warm-up condition.

1. The required time for obtained the first combustion is about 200msec. It means that the proposal system can start-up the engine in shorter time than the conventional system in cool condition, and the time in warm-up is almost same.
2. The battery consumption for the engine cranking can reduce to about 70J. It means that the proposal system start-up the engine with half energy of the conventional system.

Organization

In this paper, first, the start-up mechanism is illustrated, next, the required mechanics and controls are revealed, and lastly, the results of numerous simulations and experiments are shown.

OVERVIEW

First of all, two different engine start systems are compared in order to explain this proposal engine start mechanism.

Preceding Study, Swing-Back Start

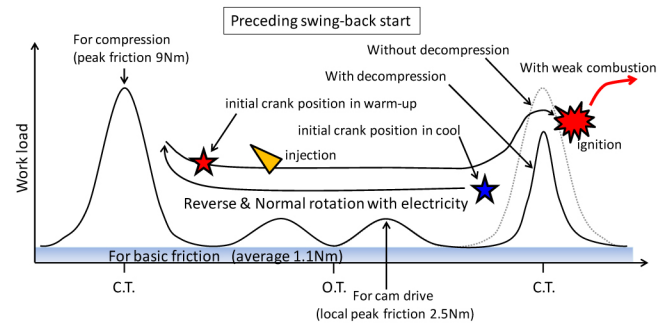


Fig 1. Preceding Study, as know as Swing-back Start Method.

A system of the preceding study includes a single-cylinder engine. The engine installs a starter-generator on the crank shaft so that it drives the crank shaft directly.

The starter-generator is an outer-rotor type, three-phase DC brushless motor. The motor has a sensor unit which can detect the position of crank angle and the timing of magnet pole changes. Thus the motor can rotate in normal or reverse directions.

The motor is downsized by a starting method using inertial force. Therefore it is important to raise the engine cranking speed higher at the beginning of the compression stroke. The mechanism is shown in Fig 1.

When the engine starts in cool, the starter-generator drives the crank shaft in the reverse direction from the current position to the end of the expansion stroke in the previous cycle temporally, and then begins the crank shaft to rotate in the normal direction (swing back movement). This can provide an adequate cranking angle up to the beginning of the compression stroke, and can utilize the inertial force maximally.

Furthermore the system installs a decompression device to reduce the cranking torque. Depended on the cranking speed with the starter-generator, the rocker arm is temporarily pushed up by the decompression cam during the engine compression stroke. The rocker arm lifts the exhaust valve and reduces the pressure in the cylinder, and makes a reduction of the cranking torque when the engine starts.

When the engine starts in warm-up, for example it's time to start-up again after automatically engine stopped by an idling stop system, the swing back movement is performed right after the engine stops, so that the engine can start cranking promptly in the normal direction the next time. [1]

This proposal study system installs the same devices around the crank shaft as the preceding study system. However the engine has an original mechanical valve train with a slide cam, the starter-generator is driven only in the reverse direction for cranking, the processes for engine start-up is the same both in cool and warm-up.

In most case, a piston of single-cylinder engines stops before reaching the compression top dead center where the cylinder pressure is at peak. The system always starts cranking from before the compression top dead center so that the system doesn't consume much electric energy to initiate the crank position for start-up.

The mechanism is shown in Fig 2, and the process is illustrated in Fig 3.

Proposal Study, Reverse Stroke Intake Start

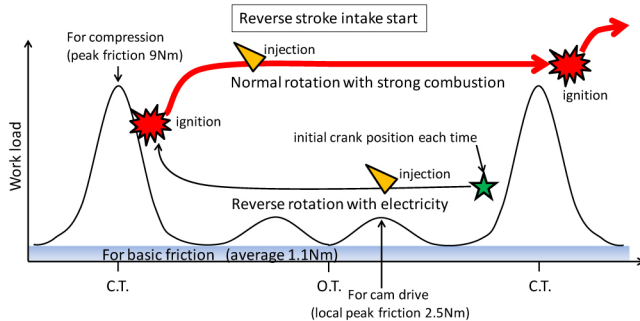


Fig 2. Proposal Study, Reverse Stroke Intake Start Method

First, when the system gets engine start signal, the crank shaft begins to be driven in the reverse direction by the electric motor from the initial crank position. Around the same time the predetermined fuel is injected, and an air-fuel mixture gas is generated in the intake pipe.

While the crank shaft passes through the intake stroke in reverse rotation. Then the piston doesn't fall down but rises up. Therefore the air-fuel mixture gas can't be led to the cylinder if the intake valve is driven.

By the way, the engine installs an original valve train with a slide cam which drives the intake valve during the exhaust stroke only in the reverse rotation. While the crank shaft passes through the exhaust stroke, the piston falls down, and the intake valve and the exhaust valve are driven around the same time. Therefore the air-fuel mixture gas can be led to the cylinder.

After that the air-fuel mixture in the cylinder is compressed with the rising piston which is pushed up by the crank shaft in the reverse rotation during the expansion stroke, and the piston doesn't reach the compression top dead center.

At last the air-fuel mixture is ignited by the ignition device, and the piston is kicked back by the combustion energy in the cylinder such that the crank shaft is rotated in the normal direction. Thus the combustion torque is so large that the piston can go over the first compression top dead center easily. Finally the engine can begin the normal operation.

Further it means that the system can start-up such engines that has larger displacement or the piston is more difficult to go over the first compression top dead center because the system has the larger torque for cranking the engine.

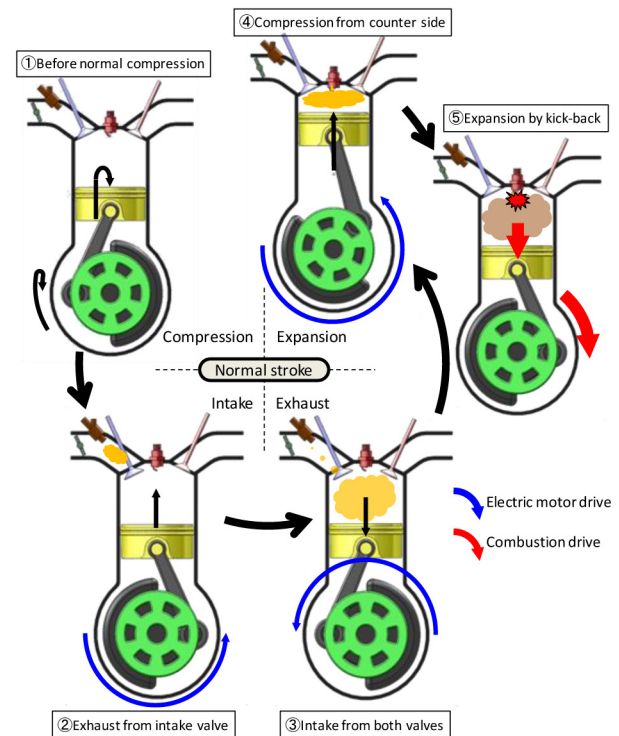


Fig 3. Operation Principle

System Structure

Engine

Table 1. Major Specifications of Engine

Engine type		SOHC 2-valves single cylinder
Displacement	[cc]	124
Bore	[mm]	52.4
Stroke	[mm]	57.9
Conrod length	[mm]	93.5
Compression ratio		9.1
Valve diameter	Intake	26
	Exhaust	22
Intake system		YMJET-FI

The proposal study is verified with an engine which specification is indicated in table 1. The engine is 4-stroke, single-cylinder, SOHC 2-valves, and liquid-cooled type with 124cc displacement. And lift curves of the engine in the normal operation are shown in Fig 4.