Approximately 500,000 new vehicles sold in the United States in 2013 had Start/Stop technology. It is estimated that by 2022, 55 million vehicles will have this technology.

In simple terms, Start/Stop technology automatically shuts down the engine every time the vehicle stops and restarts it instantly when needed. Restart is accomplished by the driver releasing the brake pedal, depressing the accelerator pedal, or by depressing the clutch pedal. Start/Stop is a fuel savings technology that is most efficient in urban traffic where the vehicle spends a significant amount of time waiting at traffic lights or standing still in traffic jams. In addition, since the engine is not idling, emission output is reduced. Some systems even provide for engine Start/Stop during vehicle driving, such as when coasting. With its ease of adoption and considerable benefits for a small cost, the Start/Stop technology is poised to become a key technology in the automobile market worldwide. There are many different Start/Stop technologies that have been adopted by various vehicle manufacturers.

**Start/Stop System Battery Requirements**

The addition of the Start/Stop system to today’s vehicles will have a large impact on the aftermarket. One area that will be impacted is battery requirements. For the system to function properly, any replacement battery must have exactly the same specifications as the original. Start/Stop places a huge demand on batteries since it requires starting an engine many times on a daily basis. In comparison to a conventional battery, batteries used for Start/Stop applications must be able to withstand starting the engine a high number of times with limited engine off periods between starts.

**Belt-Drive Starter/Generator**

Manufacturers use differing methods to start the engine. Some have replaced the conventional starter with a reversible generator. The belt-driven starter/generator (BSG) not only starts the engine but also supplies electrical energy to charge the battery and to power electrical accessories. The BSG is integrated into the belt drive system of...
The BSG system uses a generator that also functions as a starter. A conventional internal combustion engine (ICE). It can be integrated in the same way as a normal alternator, using the same fixing points. A major modification on the belt drive system is the reinforcement of the belt tensioning system. This is necessary since the BSG rotation is bidirectional on the belt to speed up the combustion engine during start-up.

Due to the increased forces on the belt, the belt has to be tensioned more than a normal belt drive system. The BSG can use either a mechanical or an electrically controlled belt tensioner that allows the BSG to drive or be driven by the belt. Some systems may also use an electromagnetic clutch attached to the front crankshaft pulley that engages when the engine is running to allow for the BSG to operate as a generator. The clutch is disengaged when the engine is shutdown so the BSG can act as a starter.

The larger forces required a redesign of the belt drive system, such as a wider belt, the use of a deflection pulley with a higher bearing force, and reinforced bearings. The changes to the belt drive system leads to different loads on the crankshaft and to modifications to the flywheel.

To start the engine, current is directed to the stator windings. This generates magnetic fields in the rotor and causes the rotor to turn. The BSG pulley rotates and pulls the belt that in turn rotates the crankshaft to start the engine.

Enhanced Starter

The Start/Stop system may use an enhanced starter (also called an advanced engagement starter). The enhanced starter is basically a conventional starter motor that has been modified to meet the requirement of multiple restarts. Modifications include dual layer brushes and a unique pinion spring mechanism. This is the least expensive method for adding the Start/Stop feature, but it does have a more noticeable engine restart than the other systems.

Tandem Solenoid Starter

The tandem solenoid starter was developed by Denso for use in Start/Stop applications. A co-axial dual solenoid provides independent control of the starter’s pinion gear engagement fork and starter motor rotation. Solenoid SL1 is used to engage the pinion gear with the flywheel ring gear. Solenoid SL2 is used to energize the starter motor.

This starting motor provides for quick and smooth engine restarts. The engine can even be restarted if it has not yet come to a complete stop. This scenario can come into play if the driver has a “change of mind” after the engine has been shut down. When the engine is shutdown at 600 rpms, it takes between .5 and 1.5 seconds for the crankshaft to stop rotating. The use of a starter motor that does not allow for engagement to a spinning flywheel requires the engine to come to a complete stop before the starter can be engaged.

Conventional starters will first engage the pinion gear into the ring gear, and then rotate the motor. The tandem solenoid system is capable of first spinning the motor, and then engaging the pinion gear. Software controls the timing and synchronization aspects for pinion gear shifting into the spinning flywheel. At higher flywheel speeds the motor is energized first to increase the speed of the pinion gear, and then the pinion gear is shifted forward when the rotation speed of the ring gear and pinion gear match. If the flywheel rpm is slow enough to allow the pinion gear to engage the flywheel, the pinion gear is first moved forward and then the motor is energized.

Since this system allows for starter motor engagement into a spinning flywheel, the engine can be shut down during coast conditions and immediately restarted when the accelerator pedal is depressed.
Permanent Engaged Starters

The permanent engaged (PE) starter has “change of mind” capabilities. In addition, this system provides the quickest and quietest restart times of all systems that use a starter motor. The conventional starter’s pinion gear engagement fork is eliminated in the PE starter since the starter motor is mounted to be permanently engaged to the flywheel. This eliminates the issue of engaging the pinion gear into a rotating flywheel.

When the engine is restarted, the motor is simply energized and immediately begins to rotate the crankshaft. The permanent engagement of the starter eliminates any delays associated with pinion gear movement. The flywheel is fitted with a special clumping mechanism to disconnect it from the engine after the engine starts to prevent continued rotation of the starter motor.

Direct Starter System

The Mazda i-Stop system is an example of a direct start system. This system uses direct injection and combustion of the air/fuel mixture to instantly restart the engine. The operating principle of this system is the placement of the pistons into an optimal position during engine shutdown so it can be instantly restarted by injecting fuel into the cylinder.

The engine is restarted by directly injecting the fuel into the cylinder and then igniting it to create downward piston force. The control module is responsible for identifying and providing precise control over the piston position during engine shutdown. Stopping the pistons when all of them are level with each other provides the correct balance of air volumes in the cylinders and is key to quick restarts.

As the vehicle is coming to a stop, the control module will allow the engine to “pulse” until the cylinder air volumes are balanced. When the engine is stopped, one of the cylinders will be in the combustion stroke. The control module identifies this cylinder and injects fuel directly into it. The atomized fuel is then ignited to allow combustion to take place and forcing the piston to move downward, rotating the crankshaft. At the same time, the starter motor applies a small amount of additional momentum to the crankshaft. As engine speed increases, the cylinders are continuously selected for ignition until the engine reaches its idle speed.

The Mazda i-Stop system uses two batteries. The main battery delivers energy supply to the vehicle accessories, while the sub battery is used exclusively for starting the engine.

Start/Stop Inhibits

The Start/Stop system will typically have an indicator to inform the driver that the system is operational. Many diagnostic trouble codes (DTCs) that are set in the engine management system can inhibit the Start/Stop function. These can include DTCs associated with variable valve timing (VVT), manifold absolute pressure (MAP), barometric (BARO), mass air flow (MAF) and many other inputs.

Start/Stop is typically inhibited during cold engine operation. Many systems will not operate until the engine temperature is greater than 140°F. In addition, the system may be inhibited if engine temperature is greater than 230°F. The system may also be inhibited due to unsafe conditions, such as the driver seatbelt unbuckled. The driver can also disable the system by use of cancel switch.
Start/Stop Effect On Other Systems

No technology is ever seamless and Start/Stop is no different. The addition of this technology to the vehicle effects the operation of many different systems. For example, the engine lubrication system may have redesigned oil filtration that prevents oil from draining from the filter while the engine is shutdown. This provides immediate lubrication upon engine restart.

Vehicle accessories that require the use of vacuum to operate will be adversely affected during periods of engine shutdown. To assure the functionality of these systems, the vehicle may be fitted with an electric vacuum pump.

Another system that is affected by the Start/Stop function is the air conditioning (A/C) system. With the engine shutdown, the A/C compressor will not be operating and the cabin compartment may begin to heat up. This can be overcome by use of an electric compressor or by using an ejector cycle evaporator. The ejector pipe is a specially shaped pipe that produces a pumping action from the pressure of the A/C system using no moving parts.

Tech Tips

- Always replace the battery with the exact same type as the original battery.
- Belt tension is critical for proper BSG operation.
- Some ISG systems require high voltage. Be sure to reference any safety information before servicing the system.
- The enhanced starter operates in the same way as a conventional starter; it is modified for the increased demands of the Start/Stop system.
- The tandem solenoid start is capable of engaging the starter while the flywheel is still rotating.
- If the tandem starter requires to be utilized during high flywheel speed, the motor is energized first and then the pinion gear is engaged.
- Permanent engaged starters require the use of a flywheel clutch to prevent the engine from rotating the starter motor.
- The direct starter system used the combustion of fuel to restart the engine.
- The Start/Stop function can be disabled by DTCs set by other engine management systems.
- Most Start/Stop systems will have a cancel switch so the driver can disable the function.
- Other vehicles systems have been modified to accommodate the Start/Stop system.

Review Questions

1. The BSG and ISG systems combine the starter and generator functions into a single unit.
   a. True
   b. False

2. Which of the following is NOT a true statement?
   a. Other vehicle systems are affected by the use of Start/Stop.
   b. The Mazda i-Stop system does not require the use of a starter motor.
   c. The permanent engaged start does not require a pinion gear shift mechanism.
   d. DTCs in other engine management systems can prevent operation of the Start/Stop system.

3. Technician A says the tandem starter is not capable of restarting the engine until the flywheel stops. Technician B says the tandem solenoid starter always engages the pinion gear prior to energizing the starter motor. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B