Fault Versus Responsibility: Starter Run On

COLUMN BY NATHAN UNGER

"But the key switch is fine." I'm sure we've all heard some version of that after a starter has been returned, completely destroyed from running on with the engine after it started. The matter is more complicated if the unit was sold through a distributor or through another mechanic's shop. Whose fault is it? Who takes responsibility for it?

The best example of no-fault responsibility I can think of was portrayed so vividly on the blockbuster film, "The Passion of the Christ." There was no fault on Jesus' part, yet he took responsibility for the faults of everyone.

We see that fault and responsibility do not necessarily rest with the same party. Starter run on may be the mechanic's fault for not knowing to replace the key switch, or maybe the customer's fault for not telling the mechanic that it felt kind of 'wiggly' or had caused intermittent problems before.

In spite of the unmistakable racket that a starter makes when it's running on, the untrained ear may not become aware of it. We the rebuilders have to make sure there is no fault on our part, even though we may sometimes have to 'warranty' the claim just to keep our customers happy.

The last time this happened to one of my rebuilds, I split the cost with the mechanic just to show some goodwill, even though I could have let the responsibility stay with him. It is important to understand how to tell if run on is caused by the starter/solenoid, or if something in the vehicle is causing it. That way, even if you end up with the responsibility of the comeback, at least you will not be at fault, and you can work toward educating your customers to prevent these occurrences.

There are at least three main problems inside the starter that cause run on.

Solenoid coil problems; coils imbalanced, or the hold coil not strong enough. If the hold and pull coils do not cancel each other's magnetism in that instant when the key switch is released but before the plunger has moved, then the remaining magnetism might be enough to keep the plunger in. This will keep the starter engaged even with the key switch off.

You can easily test if the coils cancel each other by connecting B+ to the motor stud, B- to the case or ground terminal, and manually inserting the plunger to see if it sticks at all. If it does, then your coils are not canceling each other out, and might cause run on.

If the hold coil is not strong enough against the various springs involved, then the solenoid will chatter, leading to possible welding of the contacts. This could cause run on after the key switch is released, even if the drive itself disengages the ring gear—run on can occur whether the drive is engaged or not.

Also, any type of chattering could, over time, burn out or even weld the key switch contacts because the pull coil is activated repeatedly during the chattering action, and the pull coil draws considerably more current than the hold coil. Many key switches are not designed to handle this much current for too long.

Linkage too tight. Parts interchanged or replaced during the rebuilding process could cause the shift lever linkage to be too tight, causing run on. When the starter is free run tested on the bench, this problem will not show up because no torque load is applied to the drive.

In the vehicle, the spiral splines of the armature shaft cause the starter drive to stay engaged as long as the pinion is cranking the engine. Then even though the 'S' terminal voltage is removed, the solenoid contacts will be forced closed by the drive which pulls on the shift lever which in turn pushes the plunger onto the contacts (a form of positive mechanical feedback). This will result in the starter continuing cranking without the key switch being on. If the customer cannot get his battery disconnected in time, the starter could overheat.

Tapping the starter during this kind of malfunction will not release it, as it might in the case of the contacts being welded. If the engine starts up, the tight linkage fault will not be detected because the drive is then released.

You can check this condition with a battery and a test light. Connect your ohmmeter or continuity checker between the B+ terminal and motor stud of the solenoid, with the battery disconnected. Then hold the drive fully extended with a pry bar or vise grip. If your meter shows continuity, then the linkage is too tight. In this type of a malfunction, the starter drive and solenoid coils may survive OK, but the solenoid contacts, field coils, armature, and brushes may show signs of heat.

By the way, one thing I have seen done when starters were being tested is to connect the 'S' terminal to the B+, and then pulse them together to free run the starter. This is incorrect. The B+ should have continuous power during the test, and the 'S' terminal only should be pulsed.

What happens when pulsing the B+ and 'S' together is that if there are unbalanced solenoid coils, they will not hold the starter engaged on the test bench like they will in the car, and so escape your notice. In the car, the B+ is hot all the time, and therefore serves to supply current to the unbalanced coils through the motor stud as long as the contacts are closed—and the contacts will stay closed if the coils are unbalanced and holding the plunger in.

And yes, there is at least one exception to this rule; the old Ford starter with the Delco style solenoid; Lester no. 3142 and similar. This means you have to disconnect the OE-supplied strap during testing.

Also, on some PMGR starters, the 'generator effect' will cause the solenoid to stay energized longer than normal. You see, the armature is winding down in the presence of the magnets for a little while after the battery voltage is removed. This creates its own voltage.

Since the B+ and 'S' are connected together when they shouldn't be, this generated voltage supplies power to the solenoid coils, making it seem as if the solenoid is hanging up excessively long on your bench test. This 'generator effect' has been known to cause problems in certain vehicles, making it necessary to install an anti-feedback diode.

Bad grounds inside the starter. What happens with a really bad connection is that the solenoid sees enough voltage to engage, but when the contacts close, the starter also becomes connected, and that draws a lot more current. This might be causing the voltage to drop across the bad connection to a point where the solenoid now does not have enough voltage to stay engaged, and so it lets go. At this point, the contacts release the starter, and the heavy draw is gone, allowing the voltage to bounce back up again.

Then the cycle repeats. This chattering causes the contacts to arc heavily, and in some cases, they may even weld together. This would cause run on just like an unbalanced solenoid, with one exception—the gear is not thrust forward, and so the starter would be free spinning. Since the contacts are welded together, it will not shut off with the key switch. Starters are intermittent duty motors, and will self-destruct if they run for more than 30 seconds without a cool down period of at least five to 10 minutes in between.

Bad grounds inside the starter should be cleaned right from where the solenoid ground connects to where the starter ground connects to the engine block.

For example, a 35MT starter uses a solenoid which grounds to the field case. The field case ground connects through the center support housing, which grounds to the drive end housing, which grounds to the engine block. All those ground connections must be clean and tight.

Sometimes the through bolts get loose. The resultant bad ground may cause the solenoid to chatter.

You can measure the resistance of a starter by measuring the voltage drop across it while conducting a fixed current through it. To do this test, block the drive gear (this is the locked rotor test), and then power the starter with a battery and a carbon pile all in series.

You don't have to run the solenoid current through your ammeter, just do it the same way each time. Crank the carbon pile until the current reading on your ammeter reaches your baseline for all starters of that part number, say 100A. Use Ohm's Law; Volts/Amps = Ohms. Compare this to a known good starter. This resistance reading will represent how good your solenoid contacts and internal starter connections are.

In the car, there are at least four main problems that cause run on.

Faulty ignition or key switch. If the contacts stick intermittently, this might be hard to detect, but one sign of trouble is excessive contact voltage on the switch. To measure key switch contact voltage, connect your voltmeter across the key switch terminals that serve the starter, and watch the reading while cranking the starter. Compare your reading to a known good one, or 'golden sample.' If contact voltage is too high, it indicates that these contacts are suspect. The contacts will also generate more heat than normal, contributing to them spot welding together.

Bad connections, especially grounds, and insufficient wire size. These problems cause low voltage and therefore could cause the solenoid to chatter, possibly resulting in the contacts welding together. The voltage drop from positive battery terminal (not the connector) to the 'S' and terminal of the solenoid should be checked while cranking. It should not be more than 0.5V. Do the same for the B+ and ground circuits.

Sticking relays. Contacts or plungers that stick can cause the starter to stay engaged when the key switch is released.

Bad battery. Low voltage when under load can cause chattering, possibly resulting in welding of contacts.

Here is a list of the damage you should check for and correct when rebuilding a starter core that has run on.

- Replace/rebuild the solenoid in every case, visually inspecting the coils if you reuse them. If you smell something burned inside the solenoid, that's a helpful clue too. Heat damage cannot always be perceived from your current readings.
- Check to see if the commutator bars have become loose or splayed out due to the excess centrifugal force. In that case the field coils, field coil leads, brushes, and brush holders may be physically damaged as well.
- Thoroughly check the armature for galled bushing material on the shaft, heat damage, shorts/grounds, including shorts that only show up when the armature is spinning. (Do a free run test to reveal it.) Also make sure the splines are not damaged, and that the drive moves smoothly in and out.
- Shift lever pins may be damaged.
- Brushes should be replaced, due to overheating.
- Be sure to check your brush spring tension.
- Bushings overheated, galled.
- Damaged center support housing. Armatures that are not perfectly straight may cause excessive hammering on the center support at high rpm.
- Damage/excess wear on the gear assembly inside the starter, especially if it has a plastic crown gear.
- Look for signs of solder on the inside circumference of the field housing. When the armature gets hot enough to melt the solder, centrifugal force will spray the solder out radially.
- Solenoid contacts may show signs of excessive arcing, especially with bluish peaks on the arc marks. This is a probable indication of contact chattering.
- Take a good look at the starter drive. Has the clutch lost its internal spring tension? Are any parts of it blue from heat? Has the drive bushing been excessively worn or otherwise damaged? Are the teeth milled as if they were trying to engage while the flywheel was turning? If the solenoid was balanced, then the contacts may have been welded, or the key switch may have been stuck on.

Here's the sequence to explain why the leading edges of the drive get milled and mushroomed so badly during run on.

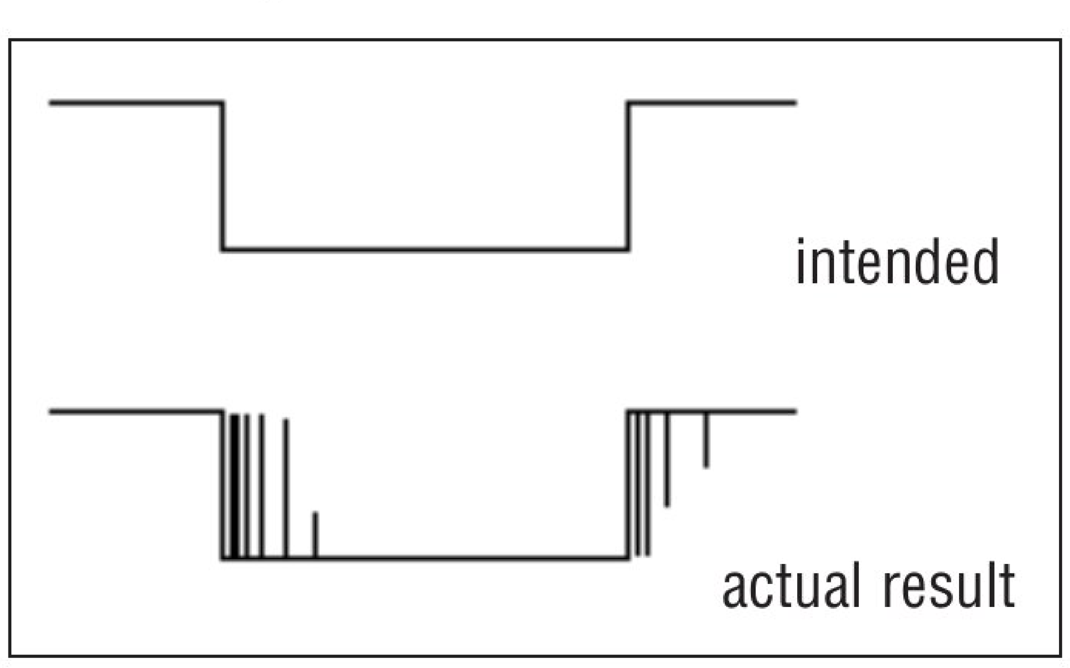
1. Engine starts, solenoid stays engaged keeping pressure on the drive.
2. Ring gear and drive pinion speed up, but because of the clutch/ratchet action, the armature speeds up more slowly.
3. The effect of this is that the drive pinion backs out of mesh because of the spiral splines of the armature—against the pressure of the shift lever pressing on the drive spool spring.
4. This is just enough to clear the ring gear teeth, but then since the solenoid is still energized, the shift lever and drive spool spring hold the drive forward against the now accelerated ring gear.
5. This difference in rpm prevents engagement, and so the drive pinion starts to get milled down. The ring gear is made from harder steel than the drive pinion so the drive takes most of the abuse.

Exception: If your drive is the older roller clutch style with straight splines, then it might not show this exact milling pattern because it might stay fully engaged. However the gear will still be overheated. The 40 MT style will still get milled even though it has a straight spline because the pinion is on an internal spiral spline.

Let's now take a closer look at the run on scenario caused by welding of contacts. All kinds of things have been done to deal with this: solid and semi-solid link solenoid designs, silver inlays on the contact bolts, coating the disc/contact bolts with cadmium and other substances, making the contact bolts out of various alloys (for example chromium copper), using a stronger contact plunger return spring, adjusting the contact disc pressure spring for more or less contact pressure, cross-hatching or dimpling the contact disc or bolts so any welding that occurs would be too weak to hold against the return spring, making the contact plate with a high side and a low side (Valeo style) so that the connections will not make or break simultaneously, and even increasing the number of turns on a solenoid to give it greater magnetic strength in case of a low voltage problem.

All mechanical contacts will bounce on closing and opening, and this bounce could last up to 50 milliseconds, depending on the size of the contacts. Since a solenoid is disconnecting coils at high current, there is a lot of inductive kickback, causing arcing. Inductive kickback occurs because the magnetic field in the coil collapses when the current stops flowing. However the collapsing magnetic field generates a voltage in the coil, hence the term kickback.

Here are two scope patterns of a contact opening and closing again. Notice in the second trace how the contact takes awhile to settle on opening and closing. This in itself causes a lot of arcing, but the problem is much worse if the contacts are also chattering due to low voltage, as described earlier.



Think preventively: Educate the customer in advance. For example, if the starter comes in for rebuild at the first but is damaged as described above, then you should definitely warn him verbally and in writing. Warn him that his ignition switch and any starter relays (such as Ford uses) have to be replaced before the starter is installed. Even one attempted start with a bad ignition switch can destroy the starter. If it has the symptoms of run on without being engaged, then warn him that he needs to address low voltage problems, such as a bad battery, bad connections, and grounding problems. Ask him questions relating to the symptoms so that he can understand the problem through his own answers.

For example: Did the starter ever make a chattering noise? If you had the headlights or dome light on while cranking, did they get really dim? Is there corrosion at the battery? Has the ignition switch ever given trouble of any kind, i.e. sticking, feels loose, not always connecting, etc.? Did you ever hear an unusual grinding or howling after the engine was started?

To conclude, the object here is to eliminate through proper understanding and correct practices, any possibility of *fault* on our part, even though for public relations purposes, we may still sometimes have to take *responsibility* for the error.

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