Starting motor components may fail prematurely for a variety of reasons, including prolonged cranking, high engine vibration, loose connections and even low voltage. Problems can be minimized or eliminated by using common sense, checking the control and cranking circuits more often, and improving the parts maintenance program. Additionally, it is a good idea to check driver habits to make sure that improper starting procedures have not caused the failure.

In the following actual examples, components with over 100,000 miles (160,000 km) of average service were returned and taken apart. On each, the reported complaint, the failed part, the most probable cause of failure and how a recurrence of the problem can be minimized have all been noted.

Solenoid failures

Figure 1 shows a burned solenoid winding due to prolonged engagement. The particular complaint is a stuck solenoid, and the first corrective action would be to check the control circuit to make sure a magnetic switch, key switch or push switch is not hanging up, even intermittently. The solenoid contactor and studs look good and show no signs of high heat. The brush rigging also appears to have suffered no ill effects, and there is no visible indication of vibration on the brushes. The sprag drive is fine, except for some milling in the overrun direction.

The example in Figure 2 shows a unit that will not crank. Because the drive is slipping, it is probably caused by prolonged engagement and high speed overrun. Overall, the solenoid contactor and studs are in good shape, and while there are slight signs of heat, it did not cause the failure. The brush rigging shows average wear and the brush ends do not indicate the presence of excessive heat. Also, there are no vibration problems, but the one-way clutch drive shows slippage in both directions.

Figure 3 shows that a high-speed overrun occurred because the armature shaft itself has a transference of copper in the drive-end area. This tells us that the pinion was forced to rotate at high speed for an extended period of time, and was actually grinding into the armature shaft.

In the next example (Fig. 4), the burned connector was caused by either a loose connector nut or by extended cranking. The engine would not crank and the problem must be corrected by using a heavier connector or perhaps more frequent checks for loose connections during PMs.

Also, as shown in Figure 5, the solenoid contactor and studs were coated from elements heated and drawn out of the insulator plate.

The contactor, however, shows no ill effects of excessive current draw. We know that the connector stud (Fig. 6) was exposed to excessive heat due to the fact that melted material was present on the outside of the connector. If the connector nut had been properly torqued, a high-resistance connection might have been avoided.

Combine the complaint that the engine will not crank with evidence that the solenoid contactor is badly burned in just two places (Fig. 7), and you can be quite confident that low voltage to the solenoid caused the problem. It is imperative that you check the battery condition, state of charge and measure for excessive voltage loss in the control circuit, as this is one of the most frequently
ERS:

Failure Analysis

Studying failed components can prove valuable in minimizing future starter problems . . .

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occurring types of failures.

The worn contactor bushing in Figure 8 would not allow the system to engage, and its condition is probably due to engine vibration. Adding a commutator end-frame support (Fig. 9) sometimes helps prevent vibration failures. Of course, they should never be taken off the original engines.

There are no high-heat indications on the brush or brush shunts, but there are signs of moderate vibration on the brushes (Fig. 10). The problem resulted because the flange usually present at the end of the nylon bushing was worn away by the vibration of the contactor rod.

Pinion failure

The next failure (Fig. 11) is a milled pinion. The complaint was
that sometimes the starter would not engage. In this instance, the solenoid contactor and studs show normal wear, and there are no high-heat indications on the brushes or brush shunts (Fig. 12). The one-way clutch drive has a good pinion wear pattern, although some teeth have been slashed (a few more than others). Although not the suspected cause in this failure, improper pinion clearance adjustment is frequently observed as a cause of milled pinions.

However, metal has been displaced on the gear teeth in the overrun direction, and notice also the cracked pinion sleeve, indicating a high-impact side shock loading (Fig. 13). Most likely, the operator did sense that the engine had already started or tried to engage the pinion into a ring gear that was already moving. Obviously, teeth will be milled off the starter pinion. Review driver procedure or check the control circuit for possible momentary interruption during starting.

Non-engagement

In Figure 14, the complaint is again non-engagement, and blame was placed on a bad solenoid. Actually, the problem was due to an armature spline that had been twisted and not the solenoid at all. The cause was engine rockback, or intermittent cranking, which frequently can be corrected by checking the control circuit for possible high voltage loss and/or looking for the cause of the engine false start.

On this starter, the solenoid contactor and studs appear to be in satisfactory condition and show a good wear pattern. There is no high-heat discoloration on the brush shunts and no vibration signs on the brushes. The sprag drive pinion is good and indicates no abnormal bronze bearing transfer to the shaft, friction discoloration or milling.

Generally, there is nothing wrong with any of the major components on this cranking motor, except a closer examination shows that the very slightly twisted armature splines would allow the drive to hang up in the disengaged position (Fig. 15). Remember that the complaint was that the solenoid was bad, which tells us that the solenoid would not shift the drive and pinion.

A thrown armature conductor, which is frequently caused by engine overrun, resulted in the motor in Figure 16 not starting. A thorough inspection of the control circuit for hang-up of start or magnetic switches will usually correct this problem. In this particular case, the splines were in good condition, but there was also bearing transfer to the shaft on the commutator end. In addition, the friction heat discoloration of the shaft in the nose housing bearing area (Fig. 17) is further evidence of high-speed extended overrun.

In the event that you have an unstartable engine, such as in cold weather with wax-clogged fuel filters, a starting motor can be burned up (Fig. 18). It takes a long, extended cranking cycle to do this, however. Usually, almost two full minutes of continuous cranking at a near lock stall current draw of about 1,800 amps is necessary to do this kind of damage. As a matter of fact, the solenoid contactor looks excellent, attesting to its current-carrying ability, and one can almost count the number of starts the contactor has seen.

Overcrank protection

Remember that the cranking motor is an intermittent-duty machine, and most manufacturers suggest no more than 30 seconds of continuous cranking with two minutes of rest between cranking attempts. In order to utilize the longer, continuous cranking time
### Starter Troubleshooting Guide

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potentially available in electric starters and avoid overheating damage, overcrank protection models have been developed, and are available upon specification with integral thermostat interrupters (Fig. 19).

Figure 20 shows a motor that will not crank due to worn mounting bolts caused by engine vibration. One of the bolt heads has started to work itself into the flange. It is also possible to see where its threads have worn into the interval diameter of the mounting hole. Torquing the bolts to specs and/or adding a commutator end support could help reduce vibration effects.

The examination of failed parts is a good tool that can help determine areas of needed improvement, both from the manufacturer’s and user’s standpoint. It also aids the study of design sufficiency and reliability, and of compatibility with total vehicle systems. Also, product examinations have historically indicated that many perceived product failures that occur at moderately high miles but prior to expected wearout are the result of conditions occurring in normal service, over which the fleet maintenance department has some control.

A large percentage of starting system problems are invariably associated with low voltage, due either to the battery condition or loss of voltage through wiring and control circuits. If you do not have one, institute a starter PM program that includes battery performance checks (load tests) with state-of-charge checks to help minimize starter problems. Also check for manufacturer’s guidelines on cranking and control-circuit voltage losses, which can extend starter service. Although the findings of failed component examinations are often very subtle and failure causes are not always obvious, help with analysis is usually available from the component or vehicle manufacturer.

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