Basic Maintenance and Testing of DC Electric Motors
Part 1

Howard W Penrose, Ph.D., CMRP
President, SUCCESS by DESIGN Reliability Services

Introduction

So far in this series on motor testing we have covered AC induction motors only. We will now expand this evaluation of machine testing, maintenance and diagnostics to Direct Current (DC) electrical motors. In Part 1, we will discuss basic DC motor operation, application and general maintenance.

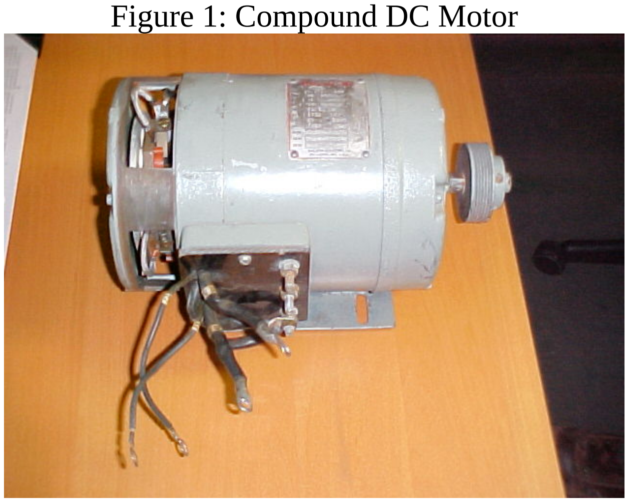
DC electric motors remain a part of our industry, both heavy and light manufacturing. In fact, according to the 2003 "Motor Diagnostics and Motor Health Study" [Penrose and O'Hanlon], approximately 60% of reporting companies were still using DC machines. Within industry, a majority of DC motors will be found in the heavy steel, mining and other, similar industries as well as for conveyors in the automotive and related industries. Winding/Unwinding machines, pulp and paper, cranes and other applications where high torque and variable speed is required.

Because of the contact surfaces in the DC electric motor, they require far more maintenance and adjustment than a three phase AC induction motor.

Construction of a DC Machine

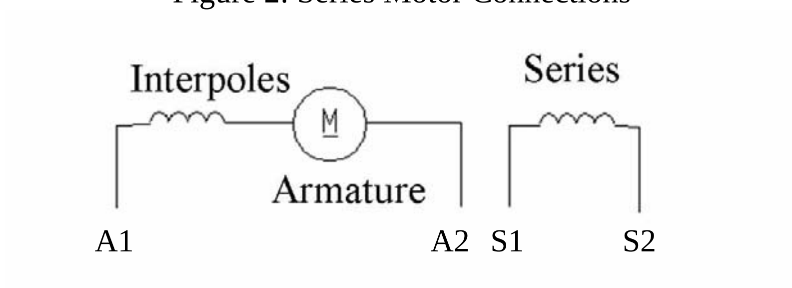
There are three common types of DC machines which include the series, shunt and compound. The types refer to the connection and windings in the machines. An additional type, which will not be discussed in this article, is the permanent magnet DC machine. A typical, small, DC machine can be identified in Figure 1.

Figure 1: Compound DC Motor



The Series Motor, as shown in Figure 2, is described because the power enters through the series coil, then through the interpoles, then the armature through the brushes and back out to the armature leads. The armature and interpole leads are labeled A1 and A2, the series fields are labeled S1 and S2.

Figure 2: Series Motor Connections

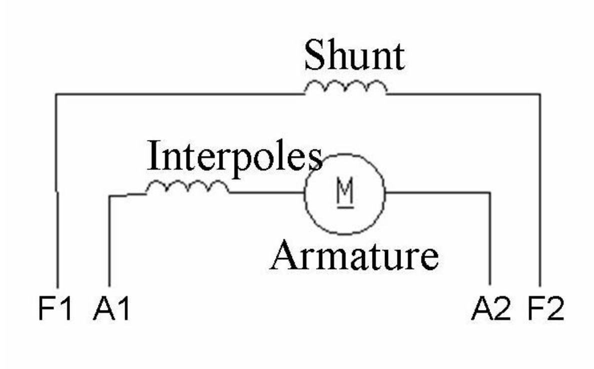


The interpoles are common to all of the DC machines we will be discussing and consist of a few turns of very large wire. The purpose of the interpoles is to compensate for a shifting magnetic field due to the amount of current and rotation of the armature. The armature is constructed of a core, which contains the armature winding, and a commutator which consists of a series of brass or copper-alloy sections separated by mica insulation.

The series field consists of a few turns of a heavy wire located on a 'pole piece,' which is made up of laminated steel. Very old machines would have cast pole pieces and cannot be used with modern DC drives. The result of the connection of the armature circuit to the series circuit is a machine that can provide a very high starting torque of up to 500%. The speed is regulated by the load and a load must be applied to an energized series machine, otherwise it will continue to accelerate until it mechanically fails. The speed is normally controlled through a rheostat. These machines are normally used in cases where very heavy starting torques are required such as: Traction motors; Locomotives; Hoists; Bridges; and, Car Dumpers. The lightest load that can be applied must not be below 15 – 25% of the full torque.

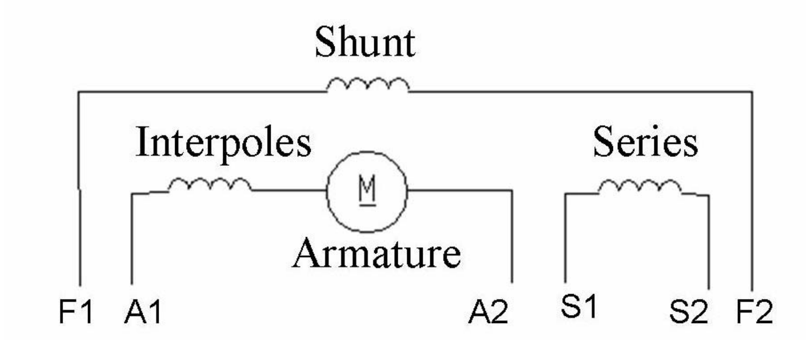
The Shunt Machine, as shown in Figure 3, is a more common machine meant for speed control and tends to be applied in pumps, fans, blowers, conveyors, machine tools, printing and similar applications. In this case, a winding consisting of many turns of a small wire is placed in parallel with the armature winding. This design provides approximately 250% starting torque, 5-10% speed regulation and the windings are separately powered and provide speed control by up to 200% with field weakening control and decrease speed by reducing armature voltage. The field wires tend to be very small as the circuit carries only a little current as opposed to the armature leads which can carry a very large current.

Figure 3: Shunt Motor Connections



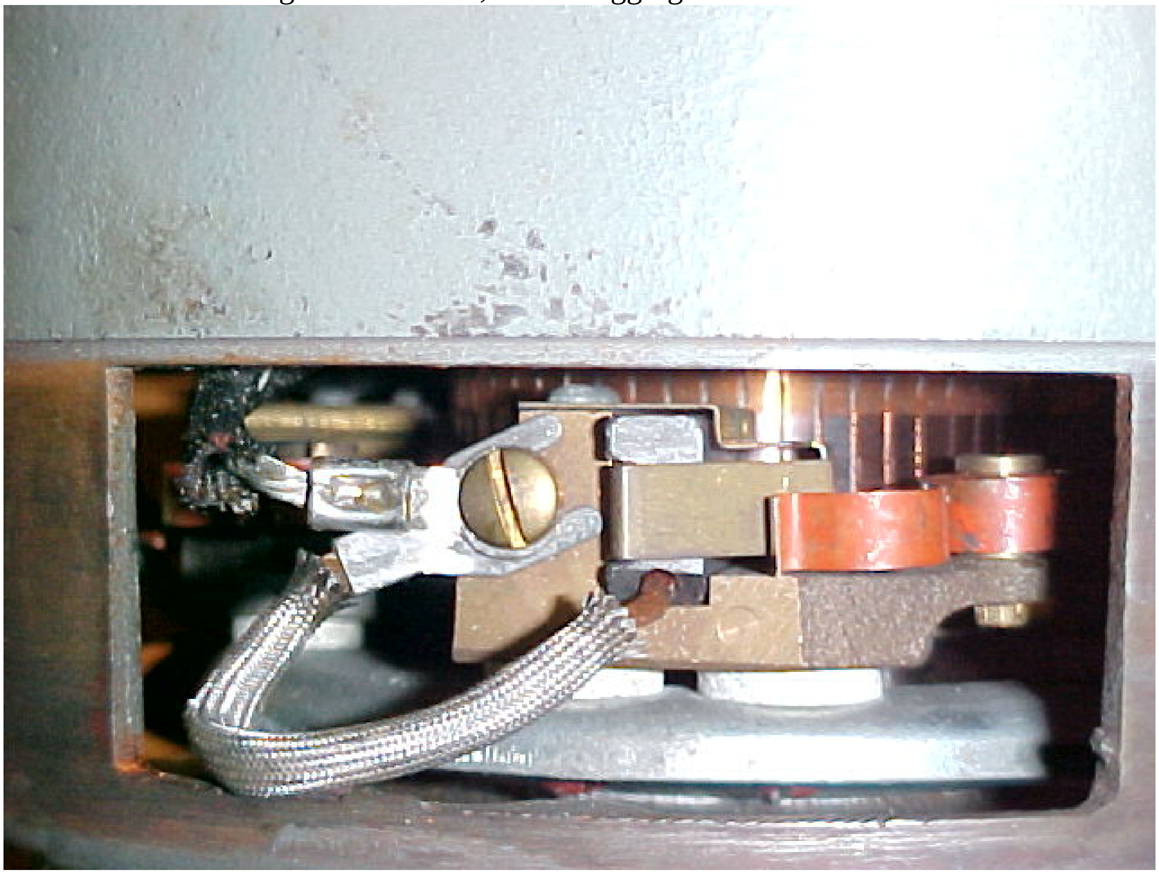
The final general type of machine to be discussed is the Compound Motor. This motor connection includes a combination of both the shunt and series windings, as shown in Figure 4. The compound motor provides a machine that can provide a good torque across a broad speed range, with the ability to provide excellent speed control to both high and low speeds. Compound motors tend to be used for applications requiring adjustable speed control, either constant or variable torque, such as rolling mills, paper mills, pumps, fans, conveyors and machine tools.

Figure 4: Compound Motor Connections



The conversion of electrical power occurs as a result of the interaction between the static DC fields and the armature magnetic fields which must be 90 electrical degrees from the static fields in order to produce the most efficient torque. This is done through the brushes and armature commutator with the operation of the motor causing the fields to shift off-center as the machine operates at different speeds. This effect causes the need to 'tune' the motor by finding electrical neutral, which requires movement of the brush rigging.

Figure 5: Brushes, Brush Rigging and Commutator



Basic Considerations in Maintenance

Unlike the AC induction motor, the DC electric motor has a number of moving and wear parts that are in contact with each other. One of the more serious is the contact area between the brushes and the commutator that generates heat and wear on the commutator and brushes, which generate contaminants within the components of the motor. In particular, one of the most common areas for carbon brush dust to collect is between the commutator and motor shaft with the next most common area being in the armature winding itself.

The result is that additional maintenance must be performed on a DC machine. The very basic steps include: Insulation resistance; Circuit resistance; and, Blowing out the motor. According to the latest IEEE Std 43-2000 (Reaffirmed in 2006), the insulation resistance value must be 100 MegOhms, adjusted for temperature. If the readings are low, it will normally indicate a buildup of carbon dust inside the motor that must be corrected. Resistance readings must also be corrected for temperature to the value that is often indicated on the motor nameplate. A few newer technologies provide earlier detection of armature winding contamination.

The correction for contamination is the use of low pressure dry air, where company and safety rules apply [NOTE: There are very specific OSHA safety rules where the use of compressed air applies, use this method of cleaning at your own risk]. Caution should be taken because if air pressures over 25 psi are used; particles can become embedded in the insulation system and cause failure. The other, and safer, method involves the removal of the electric motor, disassembly and cleaning of the armature and components in a motor repair shop.

Conclusion

Direct Current electric motors require additional maintenance efforts over those of AC induction motors. While there are several basic designs of DC machines, the general components wear over time causing contamination and degradation of the condition of the machine. In this series of articles, we will be discussing the maintenance and testing of these devices. In Part 2, we will focus on brush and commutator maintenance.

Bibliography

Penrose and O'Hanlon, Motor Diagnostics and Motor Health Study, SUCCESS by DESIGN, Old Saybrook, CT, 2003. Download from: http://www.motordoc.org.

Author's Bio

Howard W Penrose, Ph.D., CMRP, is the President of SUCCESS by DESIGN Reliability Services. SUCCESS by DESIGN specializes in corporate maintenance program development, motor management programs and maintenance and motor diagnostics training. For more information, or questions, see http://www.motordoc.net, contact info@motordoc.net or call 800 392-9025 (USA) or 860 577-8537 (World-Wide).