

DC MOTOR ANALYSIS & TROUBLESHOOTING

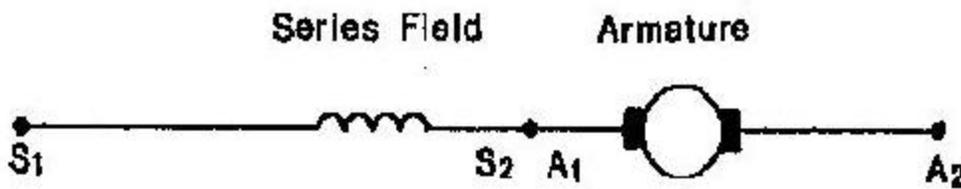
By Don Shaw

Condition assessment of DC motors requires a basic understanding of the design and operating characteristics of the various types available: the series motor, the shunt motor, and the compound motor. Each type has unique operating characteristics and applications. These characteristics enable the operator to perform a wide variety of tasks.

DC motor fault zone analysis is a vital part of any DC motor maintenance program. Visual inspection and electrical testing of the armature and fields give the maintenance personnel an understanding of the condition of the motor. Implementing a predictive maintenance program takes a PM program to the next level. We will review some case studies that will illustrate the utilization of an effective predictive program.

Series DC Motor

Components of a series motor include the armature, labeled A1 and A2, and the field, S1 and S2. The same current is impressed upon the armature and the series field. The coils in the series field are made of a few turns of large gauge wire, to facilitate large current flow. This provides high starting torque, approximately $2\frac{1}{4}$ times the rated load torque. Series motor armatures are usually lap wound. Lap windings are good for high current, low voltage applications because they have additional parallel paths for current flow. Series motors have very poor speed control, running slowly with heavy loads and quickly with light loads. A series motor should never drive machines with a belt. If the belt breaks, the load would be removed and cause the motor to overspeed and destroy itself in a matter of seconds.

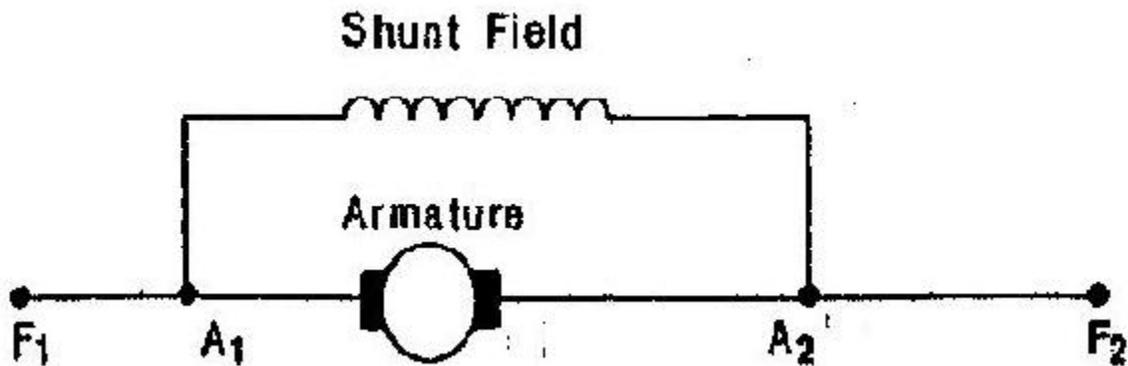


Common uses of the series motor include crane hoists, where large heavy loads will be raised and lowered and bridge and trolley drives on large overhead cranes. The series motor provides the starting torque required for moving large loads. Traction motors used to drive trains are series motors that provide the required torque and horsepower to get massive amounts of weight moving. On the coldest days of winter the series motor that starts your car overcomes the extreme cold temperatures and thick lubricant to get your car going.

Shunt DC Motor

The shunt motor is probably the most common dc motor used in industry today. Components of the shunt motor are the armature, labeled A1 and A2, and the field, labeled F1 and F2. The coils in the shunt field are composed of many turns of small wire, resulting in low shunt field current and moderate armature current. This motor provides starting torque that varies with the load applied

and good speed regulation by controlling the shunt field voltage. If the shunt motor loses its field it will accelerate slightly until CEMF rises to a value sufficient to shut off the torque producing current. In other words, the shunt motor will not destroy itself if it loses its field, but it won't have the torque required to do the job it was designed for.



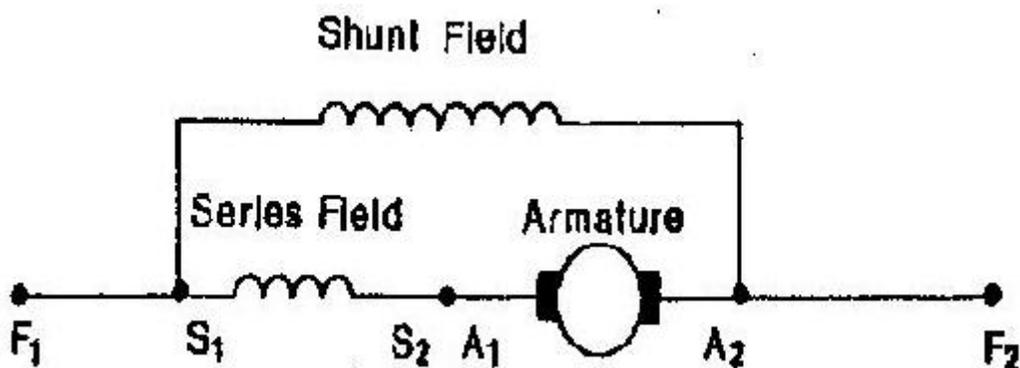
Some of the common uses of the shunt motor are machine shop lathes, and industry process lines where speed and tension control are critical.

Compound DC Motor

When comparing the advantages of the series and shunt motors, the series motor has greater torque capabilities while the shunt motor has more constant and controllable speed over various loads. These two desirable characteristics can be found in the same motor by placing both a series field and shunt field winding on the same pole. Thus, we have the compound motor.

The compound motor responds better to heavy load changes than a shunt motor because of the increased current through the series field coils. This boosts the field strength, providing added torque and speed.

If a shunt coil is added to a series motor at light loads (when a series motor tends to overspeed) the added shunt field flux limits the top speed, eliminating self-destruction.



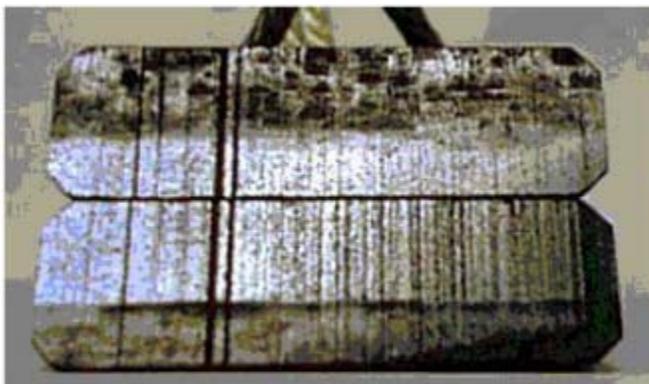
Common uses of the compound motor include elevators, air compressors, conveyors, presses and shears. Compound motors can be operated as shunt motors by disconnecting the series field. Many manufacturing process lines are designed this way. The reason being that, most off the shelf motors are compound motors, and the series field can always be connected later to provide additional torque, if needed.

Compound motors can be connected two ways, cumulatively and differentially. When connected cumulatively, the series field is connected to aid the shunt field, providing faster response than a straight shunt motor. When connected differentially, the series field opposes the shunt field. Differentially connected compound motors are sometimes referred to as “suicide motors,” because of their penchant for self-destruction. If perhaps, the shunt field circuit were to suddenly open during loading, the series field would then assume control and the polarity of all fields would reverse. This results in the motor stopping, and then restarting in the opposite direction. It then operates as an unloaded series motor and will destroy itself. Differentially connected motors can also start in the opposite direction if the load is too heavy. Therefore, it is seldom used in industry.

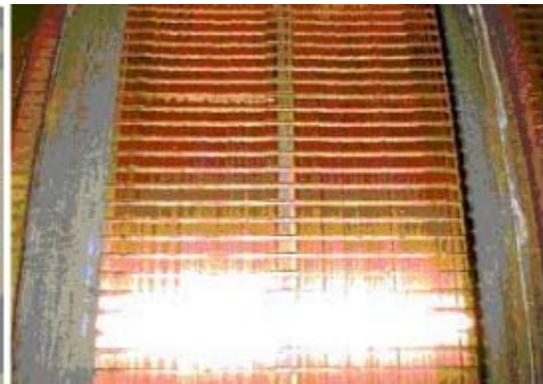
Fault Zone Preventative Maintenance

Fault zone preventative maintenance on dc motors includes electrical testing and visual inspection of the armature, commutator, brushes and fields. Over the years, people have been performing insulation to ground tests on DC equipment to evaluate the condition of insulation, particularly with regard to moisture and dirt. These parameters are valuable readings when taken under similar conditions at various times. High insulation resistance values do not necessarily indicate high dielectric strength. Insulation that is mechanically damaged may show high resistance values but fail at relatively low dielectric test voltages. Insulation resistance varies inversely to the temperature of the motor. As the temperature increases, resistance will decrease. Approximately 8 to 15°C temperature rise will half the resistance.

Checking brushes and commutator condition are very important parts of an effective PM program. The brush face condition can provide valuable insight into the motor operation. The commutator surface condition can also indicate how the motor is reacting to various load and atmosphere conditions.



Brush face from burned commutator

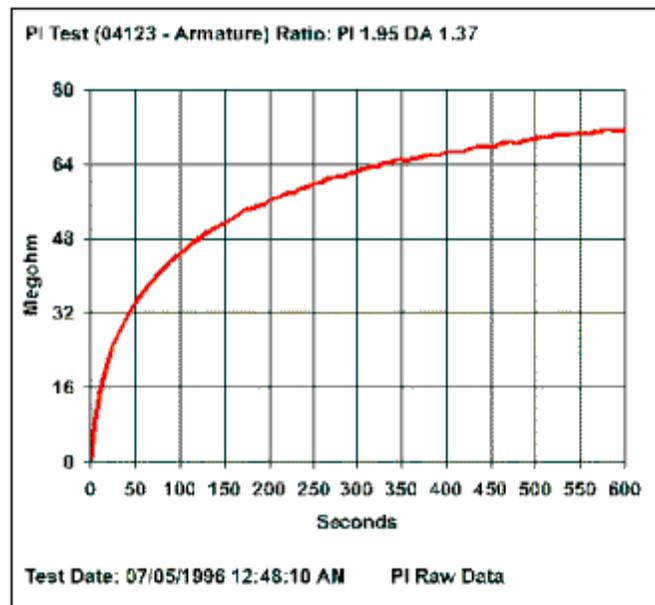


Grooved commutator

Armature

Visual inspection of the armature should include the search for cracked or brittle insulation, loose or broken banding, and any dirt or oil contamination. Leakage to ground testing of the armature indicates the relative condition of the insulation. Performing a bar-to-bar resistance check will indicate any shorted windings or defective solder joints at the risers. Infrared inspection of the armature can reveal overheating of the brushes, commutator, as well as loose or hot connections on the risers. The ideal temperature for proper commutation is between 120-140 °F.

Figure below shows a typical leakage to ground profile graph



Fields

Visual inspection of the field coils will reveal cracked or brittle insulation. Leakage to ground testing provides a general assessment of the insulation condition.

The most common method used to check for shorted windings is to perform a drop test. In this test an ac voltage, normally 110 volts, is applied to the field leads. The voltage drop across each field pole is measured with a voltmeter. In a healthy motor, all voltage drops should be equal.

Commutator

Commutator film is developed by the chemical reaction that takes place between the copper surface of the commutator, the graphite surface of the brush and the air surrounding both. This film is very delicate and any variation in load or atmosphere can destroy it. Where poor commutation is present excessive physical wear will result on both the commutator and the brushes. The following pages indicate common conditions that contribute to poor commutation.

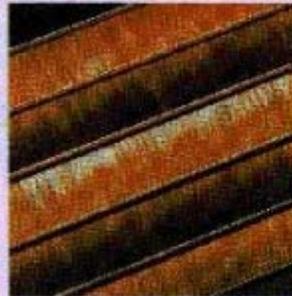
SATISFACTORY COMMUTATOR SURFACES



LIGHT TAN FILM over entire commutator surface is one of many normal conditions often seen on a well-functioning machine.



MOTTLED SURFACE with random film pattern is probably most frequently observed condition of commutators in industry.



SLOT BAR-MARKING, a slightly darker film, appears on bars in a definite pattern related to number of conductors per slot.

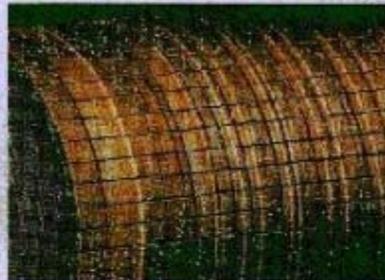


HEAVY FILM can appear over entire area of efficient and normal commutator and, if uniform, is quite acceptable.

WATCH FOR THESE DANGER SIGNS



STREAKING on the commutator surface signals the beginning of serious metal transfer to the carbon brush. Check the chart below for possible causes.



SPREADING of commutator with fine lines results when excessive metal transfer occurs. It usually leads to resurfacing of commutator and rapid brush wear.



GROOVING is a mechanical condition caused by abrasive material in the brush or atmosphere. If grooves form, start corrective action.



COPPER DRAG, an abnormal built-up of commutator material, forms most often at trailing edge of bar. Condition is rare but can cause flashover if not checked.



PITCH BAR-MARKING produces low or burned spots on the commutator surface. The number of these markings equals half or all the number of poles on the motor.



HEAVY SLOT BAR-MARKING can involve etching of trailing edge of commutator bar. Pattern is related to number of conductors per slot.

CAUSES OF POOR COMMUTATOR CONDITION

Frequent visual inspection of commutator surfaces can warn you when any of the above conditions are developing so that you can take

early corrective action. The chart below may indicate some possible causes of these conditions, suggesting the proper productive maintenance.

	Electrical Adjustment	Excessive Overload	Light Electrical Load	Armature Commutation	Unbalanced Shunt Field	Brush Pressure (light)	Vibration	Type of Brush in Use		Contamination	
								Abusive Brush	Perma Brush	Grease	Abusive Dust
Smoking			X			X		X	X	X	X
Threading			X			X			X	X	
Greasing								X			X
Copper Drag						X	X	X		X	
Pitch bur-marking				X	X	X	X	X			
Oil bur-marking	X	X								X	

High Mica: Mica is the insulation material used between each segment in a commutator. The mica is approximately 1/16" lower than the adjacent commutator bars. If the commutator bars are worn or if the mica becomes loose and extends higher than the commutator bars the result will be brush chatter. Putting the dumb end of a lead pencil, or other insulated device, on a brush while the motor is rotating and feeling for vibration can identify this.

High Commutator Bars: This condition is usually caused by the wedge or wedge ring that hold the bars in place coming loose. Normally you can hear the brush chatter caused by this condition or you can use the pencil method described above.

DC motors have definite applications in today's industry. Each type offers specific characteristics and strengths, depending on the task at hand.

Because they are expensive to replace and repair, proper maintenance is a necessity. Utilizing fault zone analysis should be an integral part of any DC predictive maintenance program. Utilizing both electrical testing and visual inspection of the armature, commutator, brushes and fields will ensure a thorough understanding of overall motor condition, giving you the knowledge necessary to keep these motors operating.