How to Design an Electric Motor Regreasing Program

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Rolling element bearings used in electric motors have many failure causes such as incorrect bearing selection, improper bearing fits, poor handling during installation, improper installation techniques, excessive thrust loads, loss of lubricant, contamination and overgreasing.

Grease volume control has been a long-standing problem for industry, and simply following OEM recommendations may not be enough to solve this problem.

A motor relubrication practice was developed by the Electric Power Research Institute (EPRI) in 1992 and is widely used by the nuclear power industry today. The program was designed to minimize overgreasing motor bearings in-between required bearing replacements. The relubrication program, associated retrofits and details are discussed in this article.

Background

The problem of overgreasing electric motors was first identified in the nuclear power industry in 1988. Several motor and/or bearing failures occurred at various nuclear power plants due to excessive grease addition. In 1992, EPRI's Nuclear Maintenance Application Center developed an electric motor predictive and preventive maintenance guide. This guide, outlined a complete maintenance program for various electric motors based on size and bearing type. Part of this maintenance program offered guidance on regreasing motor bearings. This program has helped utilities save money by reducing labor cost for regreasing and reducing bearing failures due to overgreasing.

Bearing Housing Designs

There are two basic bearing housing designs used in most motors with regreasable rolling element bearings.
More motors are manufactured with a same-side design (Figure 2) than a flow-through design (Figure 1). Figure 2 shows the drain plug is the only external path for the grease to exit the grease cavity.

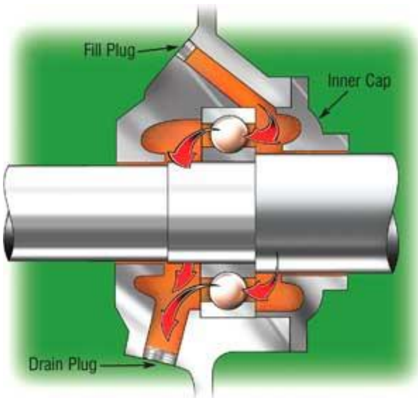

Figure 1. Flow-through design - used only with open face bearings.

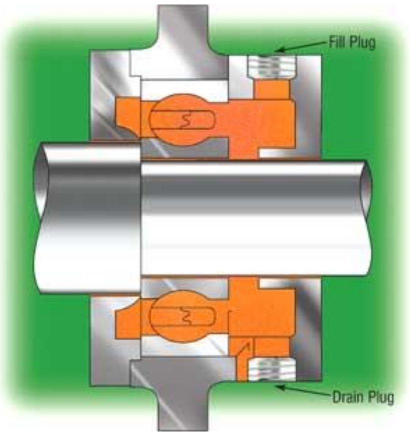

Figure 2. Same-side fill and drain – used with open, single-shielded, and double-shielded bearings.

Four Basic Bearing Types

Open Face Bearing – This bearing consists of the inner and outer race, the balls and the ball cage. It does not retain grease within shields and requires a grease cavity around it for lubrication.

Single-shielded Bearing – This bearing has a metallic shield on one side only, and is usually installed with the shield facing the motor winding. It can be regreased and typically has the same regreasing intervals as an open face bearing.

Double-shielded Bearing – This type has a metallic shield on both sides of the bearing and is designed to retain grease between the shields. There is a small air gap between the shields and the inner race which allows a certain amount of oil transfer over a long period of time between the grease in the grease cavity and the grease between the shields. There is some debate whether this type of bearing can be regreased. Regreasing double-shielded bearings has been successful and this article provides guidance for those who choose to place double-shielded bearings in a regreasing program.

Sealed Bearings – These bearings are designed similar to a double-shielded bearing with one exception. The inner race slides against the seals resulting in the absence of an air gap between the seals and the inner race. This type of bearing cannot be regreased.

Grease-related Bearing Failures

There are several types of grease-related bearing failures:

Lubricant starvation – Occurs when the grease cavity is not packed with the proper amount of grease during bearing installation, when the bearing is not regreased at the appropriate interval with the proper amount or when the oil is removed from the base of the grease by bearing overheating.

Grease incompatibility – Greases are made with different base compounds such as lithium or polyurea. Not all greases are compatible with each other; therefore it is important to use the same grease or compatible substitute throughout the life of the bearing.

Wrong grease – It is important to use the correct grease for the correct application. Some bearing designs and applications need only general purpose (GP) grease while others need extreme pressure grease (EP). Selecting or regreasing with the wrong grease can lead to premature bearing failure.

Overpressurization of the bearing shields – When grease is added to a grease cavity, grease volume and cavity pressure increase. Damage can occur to the shield on a single- or double-shielded bearing during regreasing if the grease is added too fast. When the motor is placed into service, the grease will thermally expand. If the grease cavity is full, thermal expansion can create damaging pressure on the bearing shields. In either case, the shields can be dislodged from the bearing or the outside shield can be pushed against the bearing cage by grease pressure, which can lead to a bearing failure (Figures 6 and 7).

Figure 6. Overgreasing Failure

Figure 7. Shield was pressurized by

Figure 7. Shield was pressurized by excessive grease which caused a cage failure.

Inside of motor full of grease – If the grease cavity is full and regreasing continues, the excess grease can find its way between the inner bearing cap and the shaft and flow to the inside of the motor. This allows the grease to cover the end windings of the insulation system and can cause both winding insulation and bearing failures (Figure 8).

Figure 8. Overgreasing caused inside of motor to fill with grease.

Overheating due to excess grease – The balls of a bearing act as tiny viscosity pumps which roll on a small amount of oil film between the balls and the race. Too much volume will cause the elements to churn the grease, resulting in parasitic energy losses and high operating temperatures, which in turn increase risk of bearing failure.

Hardware to Limit Overgreasing and Overpressurization of Bearing Cavities

One thing that happens with adding grease to motors is that there is a limited path for excess grease to exit a bearing cavity. Two examples of hardware that can assist in limiting overgreasing and overpressurization of a bearing cavity are shown in Figures 9 and 10. The use of these fittings can eliminate the need to remove the drain plug for excess grease and pressure release during the regreasing activity.

The fittings shown in Figures 9 and 10 are commercially available from Alemite and have been used successfully in the nuclear power industry.

Figure 9. The pressure cut-off-fill-plug does not allow additional grease to be added to a grease cavity when the pressure exceeds 20 psi. (Left)
Figure 10. The plunger drain plug opens the center plunger on 1 to 5 psi to purge excess grease and pressure. (Right)

Grease Degradation

Grease degradation is a gradual process. Most grease degrading influences are more present only while the motor is running; however degradation can occur while a motor is idle. Grease degradation can be caused by any of the following conditions:

- Grease hardening – This usually results from absorption of dirt, moisture or oxidation over a long period of time.
- Chemical breakdown – Typically caused by excessive heat. Overgreasing can cause overheating.
- High bearing loads – Side-loaded motors can load a bearing system more than a direct coupled motor.
- Oil separation from grease base material – This occurs on motors that remain idle for long periods of time, when the grease is churned excessively, and over time due to the designed normal bleed rate.
- Rotational speed of the bearing – The higher the speed, the more grease will degrade.
- Bearing size – The larger the bearing, the more grease degradation can occur. The size of the bearing can usually be equated to the horsepower of the motor.
- Environment – Bearings operating in ambient temperature above 140°F can cause more rapid degradation of the grease.

Regreasing Program

Clearly, several factors must be considered to develop a sound regreasing program for all of the motors in a plant.

1. Verify the type of bearings installed in both the inboard and outboard ends. This will determine if the bearings are regreasable.
2. Verify the initial grease fill of the grease cavity to ensure available space for future regreasing.
3. Identify the grease type (GP, EP, synthetic, etc.) and the manufacturer if possible.
4. Make grease fittings accessible, both fill and drain fittings.
5. Establish cleanliness around the fill and drain fittings.
6. Identify an owner of the program. If there is no owner, then a successful program is unlikely.

Regreasing Techniques

How Should the Grease Be Added?

Because the bearing balls act as tiny viscosity pumps, and the grease is less viscous when hot, a bearing should be regreased while the motor is running. If this is not practical, then perform regreasing immediately after the motor is removed from service while the grease is still hot. Although no program eliminates overgreasing an already filled grease cavity, the steps listed below will help minimize overgreasing-related failures.

The following steps should be performed in the sequence listed:

1. Ensure the grease gun contains the appropriate lubricant for the bearings to be regreased.
2. Clean the areas around the fill and drain fittings.
3. Remove the drain fitting and if possible, run a spiral bottle brush into the grease cavity and remove a small amount of grease to form an exit path. If the plunger-type drain plugs are used, this step can be eliminated.
4. Grease the bearing with the proper amount of grease. Add grease slowly to minimize excessive pressure buildup in the grease cavity.
5. If regreasing is performed with the motor out of service, operate the motor until bearing temperature stabilizes to allow thermal expansion of the grease. Ensure the drain plug is left out during this run unless the plunger-type is used.
6. After excessive grease has been purged, reinstall the drain plug and clean excessive grease from the drain area.

How Often Should Bearings be Regreased? The program presented in this article and listed in EPRI NP-7502 Report is based on the following information about the motor design and operation:

1. Continuous operation
2. Intermittent operation
3. Standby or lay-up
4. Open face, single-shielded or double-shielded bearing (inboard and outboard). Different types can be used for the inboard and outboard bearings. Note: Sealed bearings cannot be regreased.
5. RPM of the motor
6. Horsepower of the motor
7. Load configuration – side-loaded verses direct-loaded
8. Ambient temperature - less than 140°F and greater than 140°F

Table 1 was designed for a relatively clean nuclear plant environment. A dirty or contaminated environment may require adjustments to the recommended intervals.

RPM			HP		Load Configuration		Ambient Temperature (°F)		Operation		Regreasing Interval Months
1200	1800	3600[a]	>100[a]	<100	Belt[a]	Direct	>140[a]	<140	Cont.[a]	Stby/Lay-up	
X			X			X	X		X		12-18[e]
X			X		X			X	X		12-18[e]
X			X		X		X		X		6-9[f]
	X			X		X		X	X	(b)	36-54[c]
	X			X		X	X		X	For all	24-36[d]
	X			X	X			X	X	standby	24-36[d]
	X			X	X		X		X	or lay-up	12-18[e]
	X		X			X		X	X	motors	24-36[d]
	X		X			X	X		X		12-18[e]
	X		X		X			X	X		12-18[e]
	X		X		X		X		X		6-9[f]
		X		X		X		X	X	(b)	24-36[d]
		X		X		X	X		X	For all	12-18[e]
		X		X	X			X	X	standby	12-18[e]
		X		X	X		X		X	or lay-up	6-9[f]
		X	X			X		X	X	motors	12-18[e]
		X	X			X	X		X		6-9[f]
		X	X		X			X	X		6-9[f]
		X	X		X		X		X		6-9[f]

(a) Motors with these design characteristics have less time between greasing intervals. The number of characteristics designated by (a) for which each motor is marked with an X (1, 2, 3, 4, or 5), was used for determining the greasing interval.
(b) The greasing intervals for motors in the standby or lay-up mode should be 1.5 times that of motors operating continuously.
(c) Once per 3 operating cycles, not to exceed 58 months.
(d) Once per 2 operating cycles, not to exceed 40 months.
(e) Once per operating cycle, not to exceed 22 months.
(f) Twice per operating cycle, not to exceed 11 months.

Note: Nuclear plant operating cycles are based on an 18-month cycle.

Table 1. Regreasing Intervals for Open Face and Single-shielded Bearings

For intermittent duty cycle motors, the greasing intervals should be the same time frame as continuous duty cycle motors measured by their operation time, not calendar days.

For example, if an intermittent duty cycle motor runs 50 percent of the time and meets the same characteristics in the table as a continuous duty cycle motor that has a 24 - to 36-month regreasing interval, then the intermittent duty cycle motor's regreasing interval will be 48 to 72 months.

Because there is still some debate whether or not a double-shielded bearing can be regreased, the double-shielded bearing column was not included on the table in the EPRI report. However, for double-shielded bearings, it is recommended to double the frequency in the table and halve the amount added shown on the grease fill chart.

It is worth noting that this regreasing program was designed to minimize overgreasing of bearings in between bearing replacement. When a bearing is replaced, not only should the bearing be packed (open and single-shielded bearings), but the grease cavity is filled with grease to around 50 percent fill, leaving additional space for regreasing. The grease should be added to the grease cavity in such a way as to provide grease around 360 degrees of the cavity. It should also be added in such a way as to allow the grease to come in contact with the bearing. If the grease is packed only in the bottom of the grease cavity, no contact will occur between the grease and the bearing.

For bearing configurations that have their open side toward the bearing cavity, no grease contact would allow the bearing to sling out the grease packed around the balls and cause a lubricant starvation issue and possible bearing failure. Once the grease cavity fills, any excess grease must vent through the designated vent port, or will be pushed into the motor. Unfortunately, due to frequent inaccessibility to the vent port after motor installation, this often does not happen. Overgreasing can lead to bearing shield deformation, cage failure, overheated bearing or filling the inside of the motor with excess grease
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How Much Grease Should be Added?

This is another area in which different manufacturers give differing recommendations. However, to provide guidance on the amount of grease to be added for different size motors, a grease weight versus shaft diameter curve was determined to provide the most useful information (Figure 11).

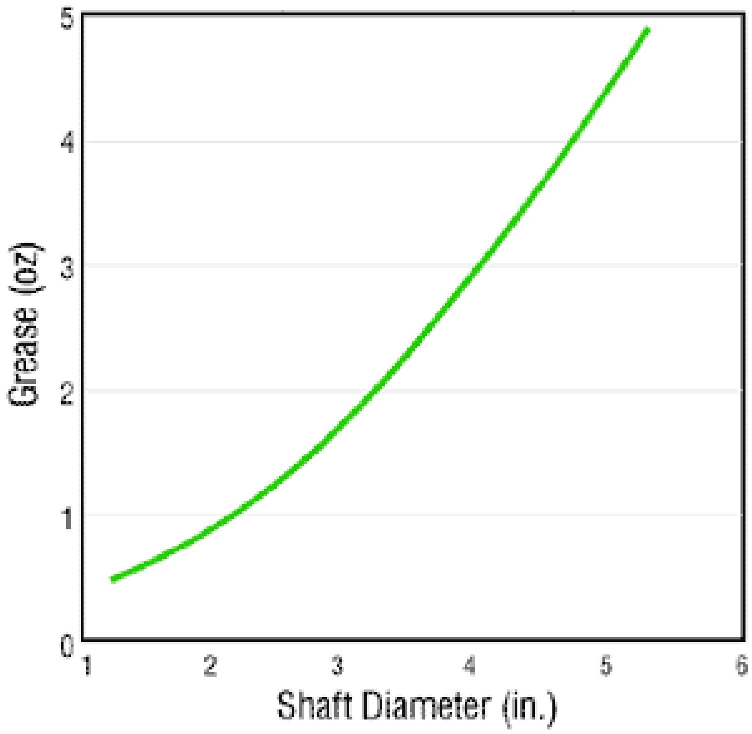

Figure 11. Grease Fill Curve

For ease of plant implementation, the number of ounces of grease should be converted into strokes for each different type grease gun used, or a calibrated grease meter can be attached to the output of a grease gun.

For motors in standby or lay-up mode and double-shielded bearings, the ounces of grease identified by the above curve for any given motor should be divided by two and that value should be used for the amount added.

The development of a regreasing program that will work for all motors requires ownership by someone familiar with motor designs, operating conditions, history of bearing replacements and type of grease used. Once the program is developed, it can be implemented by simply following procedures. This program has proven to be effective in providing adequate lubrication during the bearing life. It has also minimized bearing failures from overgreasing. Many of the nuclear power plants in the U.S. have implemented this program for motor relubrication since the EPRI report was published in 1992.

Editor's Note:
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