

APPLICATION GUIDELINE #18

(Efficiency – Part 2)

Brought to you by your Motor & Drive Specialists.....

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(cont. from AG#17)

-D- BREAKDOWN OF LOSSES

Losses are grouped into five categories and typically have associated loss contributions as follows:

- 1) Stator I^2R(35%)
- 2) Rotor I^2R(25%)
- 3) Core Loss.....(25%)
- 4) Stray Load Loss.....(10%)
- 5) Mechanical Loss.....(5%)

-E- LOSSES AND METHODS OF REDUCTIONS

1) Stator I^2R : Stator losses are due to the I^2R heating effect of current flowing through the resistance of the stator windings.

The EQP III motor utilizes:

- A new stator geometry which allows for increased slot fill.
- Optimized magnetizing current.
- Turns optimized for the lowest resistance.

2) Rotor I^2R : Rotor losses are due to the I^2R heating effect from the induced current that flows through the resistance of the rotor bars.

The EQP III motor incorporates:

- A new rotor geometry which increases the volume of aluminum in the rotor bars.
- Increased end ring area to reduce resistance.
- Rotor bar resistance optimized to maintain design C starting torque and close to normal slip values.

3) Core Loss: Core losses consist of hysteresis losses (the energy required to magnetize the core) and eddy current losses in the stator core (magnetically induced circulating currents).

The EQP III motor employs:

- Extremely high grades of annealed magnetic Silicon Steel to reduce hysteresis losses. Type M36 steel is used for motors up to 320 frame and type M22 steel is used for motors above 320 frame.
- Thinner laminations to reduce eddy current losses. 26 gauge steel as opposed to 24 gauge is used on the EQP III series motor.
- C5 coreplating which allows burnout at up to 1000°F without damage to the core.
- Low flux densities through longer rotors.
- Enlarged air gap to reduce the rotor surface harmonic heating.
- Reduced rotor surface losses are accomplished through a two pass machining process which reduces the possibility of shorted rotor laminations due to reduction of smearing caused by normal single pass machining.

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4) Stray Load Loss: Stray load losses are defined as losses other than Stator I^2R , Rotor I^2R , Core and Mechanical. They are primarily attributed to leakage reactance fluxes induced by load current. The EQP III motor minimizes stray losses by:

- Optimizing the skew of the rotor bars.
- Increasing the air gap to reduce harmonics.
- Maintaining tighter air gap tolerances.
- Increasing the rotor and stator length which increases cross sectional area which reduces magnetic flux density.

5) Mechanical Loss: Mechanical losses are caused by friction in the bearings and windage of the external fan and internal rotor fins. The EQP III motor utilizes:

- Smaller rotor fins in conjunction with the larger end rings (mentioned earlier) to reduce windage within the motor.
- An optimized external fan.
- Larger than industry standard bearings, even though smaller bearings are lower in losses, they are not used on the EQP III.

-F- IMPORTANT FACTORS RELATING TO EFFICIENCY

Maintaining Normal SLIP Values

The most cost-effective method of increasing efficiency is to reduce rotor resistance and thus I^2R losses. Reducing resistance can reduce SLIP to the point where total system power consumption increases to a higher value than with the existing standard efficiency motor that was replaced. This is because on a centrifugal load, HP increases proportionally to the speed increase cubed. In addition to potentially increasing power consumption on centrifugal loads, reducing rotor resistance will also reduce locked rotor torque. This means that decreasing rotor resistance too much can make a motor less suitable for both variable torque and constant torque applications.

Temperature Rise - Cooling Fan

One of the easiest ways to increase the efficiency of a motor is to simply downsize the cooling fan, thus resulting in reduced windage losses. The motor will then run more efficiently for the entire duration of its shortened life. The reduced volume of cooling air results in higher temperature rise on the motor frame and bearings. A motor's insulation life is reduced in half for every 10°C increase in rated insulation temperature, therefore, it is very important to consider a motor's temperature rise when comparing efficiency values.

Torque

Increased stator and rotor lengths utilizing better quality magnetic steel results in a lower flux density and a more linear magnetic circuit. At low frequencies, the improved cores require less current to produce the same amount of torque. This means less heating at low speed and more breakaway torque for a given sized inverter. In overspeed conditions, the improved magnetic qualities have less core losses. This translates into a motor with an improved useable speed range. Redesigned Rotor and Stator geometry combined with longer cores and optimized rotor skew has increased the breakdown torque values which provides more linearity between current and torque further up the torque speed curve. This means that in overload conditions, the motor produces more torque per amp. Increased breakdown torque also makes the motors more capable of being effectively utilized in overspeed conditions. Furthermore, increasing the rotor length, provides more rotor inertia which increases the WK^2 capabilities of the motors and increases thermal mass of the rotor which also helps the motor handle longer periods of transient overloads or longer acceleration times. Redesigned stator and rotor geometry combined with increased rotor length allowed design C locked rotor torque nameplate capability for almost every motor size and RPM except for 2 pole motors. (Note that 2 pole motors do not have a NEMA design C torque classification category) while still improving breakdown torque and maintaining design B inrush).

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Bearing Size

Larger bearings provide for higher load rating capabilities, but also have higher losses due to their larger running surface area. Larger bearings are often selected, though, because these advantages are felt to outweigh the increase losses they create. As in the case of the "Cooling Fan" there is little benefit achieved by permitting the motor to run more efficiently during its significantly shortened life due to early bearing failure. Motor life is influenced to a large degree by the performance of the bearings, and the advantages of good mechanical balance cannot be overstated.

Rotor/Stator Air Gap

It is common for manufacturers of high efficiency motors to reduce the size of the air gap between the rotor and stator, in an effort to reduce the reluctance in the magnetic path, and subsequent magnetizing losses. However, the closer proximity of the rotor and stator ~~also~~ increases the amount of harmonics induced into the rotor, resulting in higher rotor losses. When a motor is to be supplied to a non-sinusoidal power source (i.e. a variable frequency drive), this closer proximity of the rotor and stator can result in significantly higher overall losses, as the increased harmonic heating of the rotor far outweighs the reduced magnetizing losses. It may therefore make more sense to increase the air gap in light of this fact. Maintaining strict air gap tolerances refers to the punching of the lamination, the following creation of the stack for both the rotor and stator and maintaining a steady space between the stator and rotor. This provides a more even pull on the rotor by the stator as the rotor turns. This also extends bearing life. Smaller air gaps also lend to more catastrophic motor damage when bearings fail, due to the rotor rubbing on the stator more quickly.

-G- IMPORTANCE OF QUALITY CONTROL TO EFFICIENCY

Quality of assembly becomes more and more significant as efficiency expectations are pushed further and further upwards. Some significant efficiency gains, which do not negatively impact on performance characteristics are achieved through extra care in manufacturing.

Machining

In order to maintain exact positioning of the rotor in the magnetic center of the motor, extreme care is taken during the machining process. For example, Toshiba's numerically controlled vertical chucking machine achieves a rigid tolerance of 0.0004" on bearing bores with an out-of-round tolerance of 0.0002". Rotor shafts are machined in one operation on computer controlled high-speed lathes at 1000 surface feet per minute. Tolerances are held to below 0.0012" for diameter and 0.002" for runout. Maintaining exact shaft magnetic centering assures a consistent air gap-which reduces stray losses.

Rotor Casting

Extreme care is taken to monitor the temperature and purity of the aluminum alloy used for the injection casting of the rotor bars in Toshiba's state of the art injecting machine. Proper temperatures and purity are vital in production of virtually void free castings. High quality castings are lower in resistance because of better slot fill, which reduces rotor I²R losses.

Balance

Toshiba balances to typically 1/3 the imbalance required by NEMA. Better balance provides for: lower bearing wear, lower bearing temperature rise (which in turn extends grease life), increased mechanical life of all parts, and smoother and quieter operation. Secondary benefits of better balance are: lower transmitted losses to driven equipment, better electrical balance, higher efficiency, higher and smoother torque output, higher power factor (from a more uniform air gap), longer regreasing intervals, longer bearing life, and higher over-speed capabilities.

Zero Defect Manufacturing Philosophy

Toshiba's commitment to ZERO-DEFECT MANUFACTURING PHILOSOPHY assures consistency from motor to motor. Because of the tolerance control and consistency of manufacturing, Toshiba motors have a loss tolerance of 10% between nominal and guaranteed minimum as opposed to the NEMA and CSA allowable loss tolerance of 20%. Therefore, Toshiba motors allow our customers to get the most for their money.

Motor & Drive Specialists

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