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# Role of Energy Efficient Bearings on Performance of Electric Motors

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**Abstract**: Efficient use of energy enables commercial and industrial facilities to minimize production costs, increase profits, and stay competitive. The majority of electrical energy consumed in most industrial units is used to run electric motors. Energy-efficient motors now available are typically from 2 to 6 percent more efficient than their standard motor counterparts. To continue this endeavor further energy efficient bearings are developed which further improves the efficiency of energy efficient motors. This efficiency improvement translates into substantial energy savings as well as become a cost effective tool. There has been a consistent effort with motor manufacturers to evaluate various means to reduce the component losses in the motor to improve the Efficiency value. One of the neglected or less utilised ways is to reduce the friction losses and thereby increase the Efficiency, primarily due to the fact that this method required precise machining practices and use of low friction loss bearings. This paper aims to address this method and try to achieve the partially improved figures of Efficiency in addition to increased Bearing Life, in turn reducing the running cost of the motor. The paper presents comparison of practical values of efficiency during testing of energy efficient motors with normal bearings and with energy efficient bearings. The tests were carried out on field by one of the leading companies. The results obtained are very much encouraging. This is the latest practice and very few industries have adopted this technique. If this innovation is followed by most of the motor industries then it is the new revolution in the field of motor design.

**Keywords**: Energy Efficient (EE) motors, Energy Efficient (E2) bearing, Premium Efficiency.

## I. INTRODUCTION

The efficiency factor defines the efficiency of motors when transforming electrical energy into mechanical energy.
For many years low-voltage three-phase motors have been sold in three efficiency classes **EFF3, EFF2 and EFF1** with EFF1 being the highest class.
EFF3=Motors with a low efficiency level
EFF2=Motors with improved efficiency level
EFF1=Motors with a high efficiency level
Energy efficiency classification systems unfortunately differ from each other in terms of scope, wording and values. That was the reason for the International Electrotechnical Commission (IEC) to develop and publish an energy efficiency standard which replaces all the different national views. In parallel IEC developed and issued a new standard for determining the motor efficiencies. The new standard IEC 60034-30 defines and harmonizes worldwide the efficiency classes **IE1, IE2 and IE3** for low-voltage three-phase motors.

The new IEC 60034-30:2008 defines worldwide the following efficiency classes of LV three-phase motors, in the range from 0.75 to 375 kW.

IE1 = Standard Efficiency (comparable to EEF2)
IE2 = High Efficiency (comparable to EFF1)
IE3 = Premium Efficiency

e.g. For 37 KW[2 pole,50 HP] motor

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| Class | Efficiency |
|---|---|
| IE1 | 91.20% |
| IE2 | 92.50% |
| IE3 | 93.70% |

The difference between IE2 and IE3 efficiencies, ***Delta*** is what we are aiming to achieve by way of reduction of friction loss due to Bearings.

## II. LOSSES IN MOTOR

In general, the motor component losses can be summarized into Table [1] (some tolerance in the percentage specified is possible).

**Motor Component Losses**

| Sr. No. | Component | Total Loss |
|---|---|---|
| 1 | Stator Cu Loss | 39% |
| 2 | Rotor Cu Loss | 29% |
| 3 | Iron Loss | 24% |
| 4 | Friction & Windage Loss | 7% |
| 5 | Stray Loss | 1% |

**Table 1:** Motor Component Losses

Stator and rotor Cu losses have been overcome by the following ways:

- Optimized slots shapes
- Higher copper fill
- Thinner lamination
- Lower resistance bars
- Low loss steel etc

The losses due to bearings are usually less; typically 0.6% of the total mechanical losses and the mechanical losses are around 6 – 7% of the total losses. With better machining practices and with utilization of Energy Efficient (E2) Bearings (which reduce friction loss by 30%) it is possible to achieve the required marginal efficiency improvement of 0.3 to 0.7% (percentage varying as per HP and RPM of motor).

## III. About Energy Efficient Motors

Taking the data available from US Statistical Association, with an average increase of 1% Efficiency of Motors there will be an enormous saving of 20 billion KWh per year equivalent to 3.5 million Oil Barrels which lead to following benefit to the Industry and Society as a whole:

**Benefit to Industry:**

1) 10 billion € per year: Energy cost saving

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2) 5 - 10 billion € per year: Non-energy cost saving
3) 45GW reduction in the need for new power plant capacity over the next 20 years

**Benefit to Society**
1) 6 billion € per year environmental cost saving
2) 79 million tons reduction of $CO_2$ emission (25 % of the EU's Kyoto target)

The following figures 1 and 2 [pie-charts] are self-explanatory:
The algorithm automatically generates mask image without user interaction that contains only text regions to be inpainted.

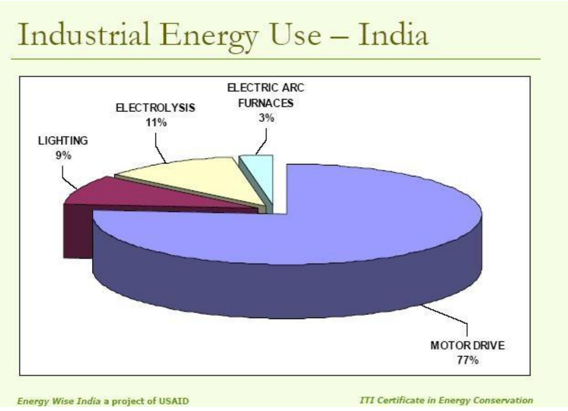


**Fig.1.** Pie Chart for Energy use.

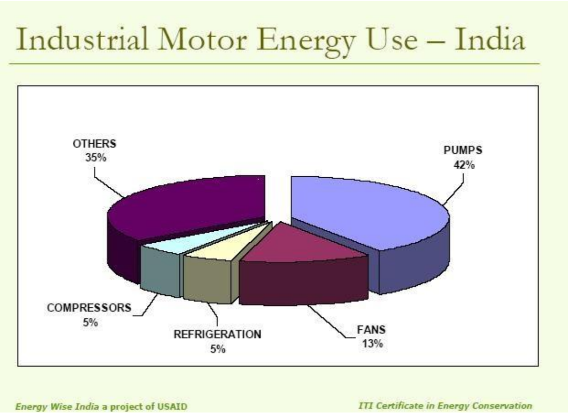


**Fig.2.** Pie Chart for Energy use.

**Courtesy: Energy wise India – a USAID Project**

Keeping the above in mind, we boil down the concept of Energy Efficient Solutions for the applications desired. A careful study of the above charts shows that the majority of the applications in the Industry are of Continuous Duty (S1) type and non – fluctuating load type, wherein there is a huge scope for usage of Energy Efficient systems, thereby reducing the overall burden on Power Authorities.

With this background, one can understand the utility of Energy Efficient Induction Motors in industry and justifies the advent of EFF2 and EFF1 Efficiency Motors for the use. However, even though there have been several efforts put continuously by the motor manufacturers to devise new methods of improving efficiency, still there exist certain

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untapped areas of improvement which are what exactly the paper reveals about. To understand more, one has to carefully examine our old traditional bifurcation data of motor losses which is visualized with following chart:
e.g. Motor efficiency: 80 %, losses 20%

Out of the total losses of 20%, the bifurcation as shown in the chart depicts a value of 4% of total mechanical loss which is comparatively untapped for the purpose of improvement.

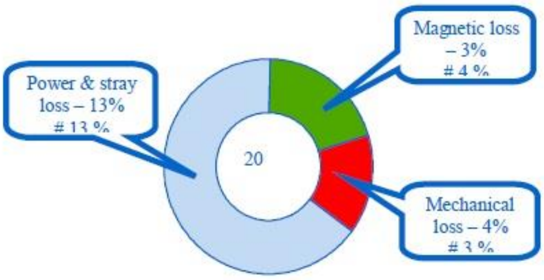


**Fig.3.** Example of losses distribution.

Courtesy: Hindustan Motor Manufacturing Company

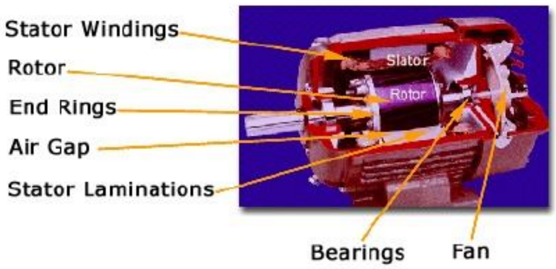


**Fig.4.** Cut Section of Induction Motor.

**Courtesy: Hindustan Motor Manufacturing Company**

With the traditional methods, manufacturers have been able to generate significant improvement in efficiency values of a squirrel cage induction motor and a typical study of performance values as published by leading motor manufacturers in their technical catalogues will reveal an example figure for a sample rating as follows:

**37KW – 2P – 3 Phase Induction Motor:**
EFF2 Level Efficiency – 92%
EFF1 Level Efficiency – 93.3%

With this a typical Payback calculation is also attached herewith contemplating an average extra cost of an EFF1 motor to be around 10 - 12.5% higher than a conventional EFF2 motor.

## IV. Sample Payback Calculations

Taking an example of a 37KW motor with standard pricing available as published by motor manufacturer one can evaluate the saving on account of the use of EFF1 motor (Here Eff1 Efficiency has been achieved by traditional ways as explained above) as follows:

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**Vol. 5, Issue 11, November 2016**

a) Extra Investment on EE Motors

Let X = Cost of EFF2 Motor = Rs 61580/-
Let X1 = Cost of EFF1 Motor = Rs 67775/-
I = Interest Rate on Investment in % p.a. say 15%
Interest on Extra Investment p.a. = (X1 – X) / 100
Extra Investment for First Year (A) = (X1 – X) + (X1 – X)/100 = (67775 – 61580) + (67775 – 61580)/100 = 6257/-

b) Saving on Account of using EE Motor

Let E = Efficiency of EFF2 Motor = 92%
Let E1 = Efficiency of EFF1 Motor = 93.3% Let P = Power Output in KW = 37Kw
H = No of hours of operation of motor per year = 5000 hrs
Energy saved p.a. = P {(1/E) – (1/E1)} x 100 x H in KWh = 37 {1/92 – 1/93.3) x 100 x 5000 = 2775 KWh
Let T be the power tariff = say, Rs 4 per KWh
Hence Savings p.a. in Rs = Energy saved X T
= Rs 2775 x 4 = 11100/-
Therefore Payback Period in months
= Extra Investment (A) / Savings per annum x 12
= 6257 / 11100 x 12
**= 6.7 month**

With the above in mind the fundamental purpose of increasing efficiency does serve in considerable reduction of power input and hence is beneficial to the system and the user.

## V. ABOUT ENERGY EFFICIENT BEARINGS AND CONTRIBUTION OF BEARING FRICTION LOSS

We are aware from fig.[3] that out of total percentage losses in induction motor, mechanical losses contribute to around 4% and further the loss contribution due to bearings in these mechanical losses is around 0.6% which seems very minimal to a motor designer. However when the requirement is of increasing efficiency with the use of all methods why not to attempt in this area as well?

The above percentage may indeed vary with motor size, RPM, design and application conditions.

The advent of Energy Efficient Deep Groove Ball Bearing offers following merits:

1) Friction torque reduction from 30 to 50%
2) Double Service Life when compared with the standard greased bearings

As per the published data of a reputed Bearing manufacturer the Bearing friction losses can be minimized by:


**Fig.5.** Controlled Parameters for a motor.

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Vol. 5, Issue 11, November 2016

**Courtesy: SKF Ltd.**

From fig.[5], implementing the controlled parameters ,the friction torque of the Energy Efficient Bearings can be made 40 to 60% lower than conventional bearings, in the test conditions.

Using the published figures of the Energy Efficient Bearings fig.[6] shows the graph that depicts the reduction in power loss with the use of Energy Efficient Bearings.

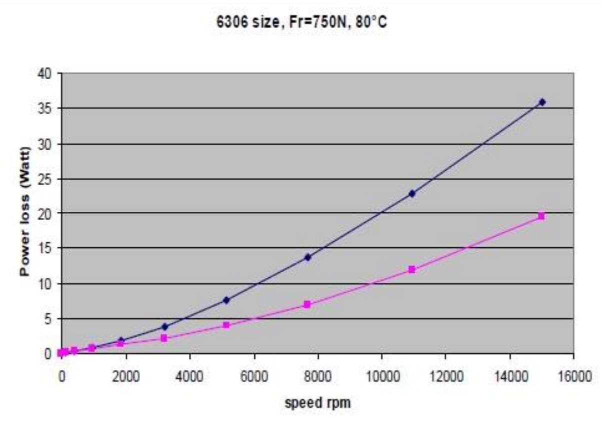


**Fig.6.** Comparison of Power loss with standard v/s energy efficient bearings.

**Courtesy: SKF Ltd.**

The bearing used in the above testing was 6306 size with a Radial load of 750N and Operating Temperature of 80 Deg Centigrade.

Comparison and analysis of various test results on these Energy Efficient Bearings gives following optimum usage scope of these Energy Efficient bearings:

The Energy Efficient Deep Groove Ball Bearing would find a usage particularly in optimized solutions for light and medium loaded applications. Energy Efficient DGBB will give their maximum friction torque reduction and longer service life for the following application conditions:

1) $C/P \geq 10$
2) speed $\geq$ 1000 rpm
3) Temperature range -40 + 150°C

However not only the use of Energy Efficient Ball Bearings would serve the purpose of "Avoiding Energy Wastage", but in addition to the same following steps need to be carefully followed:

- Go for low friction sealing solution when possible
- Ensure proper mounting process for avoiding excessive preload and misalignment

Energy Efficient deep groove ball bearings are fitted on both sides with a shield made of sheet steel, as standard. The bearings are filled with a special low - noise, low - friction grease. The bearings are lubricated properly and are maintenance-free.

The boundary dimensions of Energy Efficient deep groove ball bearings are in accordance with ISO 15:1998. This makes the bearings dimensionally interchangeable with deep groove ball bearings of the same size in the same dimension series.

Features of EEDGBB are as follows:

**Extended grease life means longer bearing service life:**

In light to normal load applications, metal fatigue is rarely an issue, but grease life is a limiting factor when

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Vol. 5, Issue 11, November 2016

determining the life of a sealed bearing.
Compared to standard shielded deep groove ball bearings, Energy Efficient deep groove ball bearings can more than double the mean time between failure due to reduced heat generated by the bearings and the specially formulated low-friction grease.

**Improvement in Operating Temperature**

The operating temperatures of Energy Efficient bearings and standard bearings when measured at certain speeds and compared gave exciting observations:

The test showed that when compared to a standard bearing; the Energy Efficient bearing ran 5 to 15 °C cooler, depending on speed, with the following Test Conditions:

- Bearing: 6205-2Z/C3
- Running time: 24 h at each speed interval
- Ambient temperature: room temperature
- Load: 0.5 kN radial

**Improvement in Cage Behaviour:** The cage design is one of the key features of Energy Efficient deep groove ball bearings. The fundamental redesign produced a lighter cage that is less susceptible to deformation during operation.

**Longer service life lowers cost of ownership:** Optimized to reduce frictional losses in the bearing and provide longer service life, shielded Energy Efficient deep groove ball bearings can last twice as long as comparably sized shielded standard bearings in light-to-normal load applications.

This means that the number of bearings needed to run an application over its lifetime can be halved. In instances where an application is run-to-failure, these Energy Efficient bearings can conceivably outlast other components in the application.
Thus in addition to the partially increased efficiency, a motor manufacturer gets various other features.

## VI. TESTING AND COMPARISON OF RESULTS

Performance Testing of Energy Efficient vis-a-vis Standard Bearing (Deep Groove Ball Bearing)

To assess the difference in efficiency increase due to usage of Energy Efficient Ball Bearing, a sample motor of following specifications was used for Testing:

Rating of the Motor: 37KW (50 HP)
Frame Size – 200L (IEC Frame Size)
Synchronous Speed – 3000 RPM
Rated Voltage – 415V
Rated Frequency – 50 Hz
Duty – Continuous (S1)
Degree of Protection – IP55

The evaluation was based on methodology as outlined below:

1) Load Test of the example Rating with Standard DGBB – 6312 / C3
2) Dismantling of the same motor – Rotor and retrofitting with an Energy Efficient DGBB – 6312 / C3.

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The above procedure of retrofitting was adopted to eliminate the variation in performance parameters of the motor due to:

1. Difference in Magnetic Material properties of Stamping
2. Change in Aluminium quality and therefore Rotor resistance of the motor
3. Machining tolerances on Shaft, Endshield housing, Bearing Cover and Stator housing
4. Fan characteristics and other stray variations

The measurement was done on Water – Brake Dynamometer with Load test set up and calculation of efficiency by Summation of Loss Method as per IS.

In this following test procedure was adopted and readings noted:

1. Measurement of No – Load Performance
2. Loading the motor to the desired Torque with dynamometer and noting the readings of Full Load Current (FLC), Full Load Speed (RPM), Input Watts (By 2 Wattmeter Method), Frequency (Hz).
3. Measurement of Resistance and further correction to $R_{95}$ as per Standard.

The above test was repeated after changing the Bearings (Driving End (DE) and Non Driving End(NDE)) with Energy Efficient DGBB and similar readings noted.

The summary of the readings are outlined in the following Table [2]:

Table 2. Outline of Resistance.

Resistance @34 Deg C – 0.143ohms $R_{95}$ _0.175ohms

Motor performance was calculated after the load test and results are as follows:

Calculated Efficiency with Standard Bearing – 93.3% Calculated Efficiency with Energy Efficient Bearing – 94.1%

The analysis of the above table presents following facts:

1) Difference in No – Load Watts between Std DGBB and EE DGBB = 300 W i.e. Approx Reduction of 20% in No Load Power
2) Difference in Current for same Full Load Input Watts of 40.217 KW between Std DGBB and EE DGBB 0.5A with corresponding increase in Efficiency of 0.8%
3) As per IS 12615 – 2004, EFF2 Efficiency Value is 92% whereas for EFF1 Motor it is 93.3%. As per IEC 60034 – 30, IE2 Efficiency is 92.5%, IE3 Efficiency is 93.7%.

## VII. Payback Results with DGBB Bearings

Using the sample payback calculation as depicted above and replacing the values of Efficiency with 94.1% and 93.3%, with E2 DGBB and Standard DGBB respectively and taking the extra investment for E2 DGBB to be Rs.1580/- for 2 bearings (as per available pricing with Bearing manufacturer), the payback period can be accordingly worked out as given herewith

In the sample payback calculation now,

X = 67775/- and X1 = (67775 + 1580) = 69355/-

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Substituting the above values and assuming same working hours of 5000 per year and tariff of Rs.4/- per KWh, the payback period comes out to hardly 3 months. Thus the extra cost of Energy Efficient DGBB becomes justified anyways.

In addition the marginal increase of 0.8% Efficiency definitely serves a fundamental technique to the motor manufacturer to utilize it to the extent of matching the increased efficiency requirement of IE3 efficiency as per IEC norms as compared to standard EFF1 motors.

Further one can also think of using Energy Efficient DGBB bearings and using normal techniques of increasing efficiency from EFF2 to EFF1. Thus one can directly aim to match the IE3 norms of efficiency. In this case the payback period of EFF1 motors with E2 DGBB would definitely be much less than 6.7 months which can be verified as illustrated herewith.

## VIII. Illustrative Example

To be specific consider an EFF2 motor of same rating of 37KW and EFF1 motor with E2 DGBB of 37KW.
Here let us again use the sample payback calculation technique explained above, but now for a 37KW motor.
Let us take cost of EFF2 motor (37KW) as above – 61580/-Cost of EFF1 motor with E2 DGBB (37KW) – 69355/-

Efficiency of EFF2 motor (37KW) – 92% Efficiency of EFF1 motor with E2 DGBB – 94.1%
Here extra investment is 7853/- and energy saved p.a. is 17760/- with same working hours and tariff.
Then payback period comes out to be 5.3 months instead of 6.7 months! This is amazing!

## IX. Conclusion

The paper presents a unique method of achieving the required marginal rise in Efficiency which can be achieved by changeover from a standard DGBB to a EE DGBB, which can be utilised by motor manufacturer's to cope up with the new NEMA norms of Premium Efficiency i.e. IE3 without major changes in Design parameters, Raw Material Properties, Machining tolerances, Stamping Geometry etc.

In many applications one ignores the Power consumed by the motor in No Load condition, but this is particularly of importance in Industries such as Plastic Injection Moulding Machines, wherein the Machine operates for almost 30% of total cycle time under No – Load condition.

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