Misconceptions about the motor rewinding/repair Industry

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It has been argued that the motor rewind industry cannot effectively rewind motors and maintain efficiency – and that it is more economical to replace failed motors with new motors. This article critically evaluates these claims and shows that the motor rewinding/repair industry plays an important role.

South Africa’s motor repair industry goes back over 100 years and was developed to support mining and industry in the country. Machines were imported from Europe and returning the machine to the manufacturers in Europe for repair or replacement was a long, drawn-out process. The repair industry developed in South Africa over the years and is as good as any in the world as the facilities and equipment are modern and up to date. South Africa has a number of ‘large’ major repairers with qualified staff who can handle the repair of the majority of all machines in the country. The major repairers, including those with a focus in specific fields such as low voltage, dc machines and transformers, travel to exhibitions and conferences abroad to keep abreast with technology and developments. Many of the repairers also have technical agreements with manufacturers of machines and materials.

Misconceptions that are circulating in the industry are many - and include:

- Motors cannot be repaired, nor can they maintain performance and efficiency.
- Motors should only be repaired once or twice.
- Premium or high efficiency motors cannot be rewound.

I do not dispute that efficiency is a critical factor and this should be evaluated at all times - but I question on-site measurements which are extremely difficult to perform with the accuracy required for comparison with factory test figures.

While I question the accuracy of on-site measurement, I admit I have not used this equipment at any stage... but for the losses to double - and in effect this is what would happen if the efficiency dropped from 95% to 90% - the motor would be operating at close to 200°C.

The motor would be designed for a temperature rise of just below 80°C which is the norm and assuming 30°C ambient the operating condition would be around 110°C that is with the designed losses of 5% if the losses increased to 10% the temperature rise would more than double resulting in an operating temperature of approximately 200°C.

An operating temperature of this magnitude would trip the RTDs generally fitted in the winding of any medium voltage motor. The excessive temperature would be sensed by any operator or maintenance stall in the vicinity of the motor. The life of the motor would be extremely short as it is generally accepted that the insulation life is halved for every 10°C increase in temperature.

Maintaining performance and efficiency

Motor efficiency: Determining efficiency

Efficiency is denoted by the Greek letter $\eta$

$$\eta = \frac{\text{Mechanical Output (electric motors)}}{\text{Electrical Input}}$$

Efficiency is the ratio of output power to total input power. Output power is equal to input power minus the losses. Therefore, if two of the three variables (output, input, or losses) are known, the efficiency can be determined by using Equation (1), Equation (2) or Equation (3).

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}}$$

(1)
A form commonly used for motors is:
Efficiency = \frac{\text{Input Power} - \text{Losses}}{\text{Input Power}} \quad (2)

A form commonly used for generators is:
Efficiency = \frac{\text{Output Power}}{\text{Output Power + Losses}} \quad (3)

Unless otherwise specified, the efficiency shall be determined at an operating temperature for rated voltage and frequency. When a load point is available at other than rated voltage, it may be combined with the equivalent circuit to calculate the performance at rated voltage.

Motor losses
Generally, the proportion of losses is as indicated in Figure 1.

![Motor losses](image)

If the total loss is 5%, the motor is 95% efficient, the losses would be as follows:
- Core losses: approximately 1,25%
- IR losses rotor and stator: approximately 2,5%
- Windage and friction: approximately 0,75%
- Stray losses: approximately 0,5%

Note: These are typical figures and the proportions will differ from these, depending on the specific design.

A motor can be successfully repaired whilst maintaining efficiency if the following is complied with:

• The Original Equipment Manufacturer (OEM) conductor size and winding specification must be used.
• Core is tested before stripping and again before winding.
• Ensure the correct bearings are used and fitted to the bearing manufacturer’s specification.
• Use an identical fan as that used by the OEM.
• The OEM’s specified rotor must be used to ensure that the air gap is to OEM specifications.

Any reputable repairer would ensure that these conditions are complied with so that a motor is repaired whilst maintaining its original efficiency.

Rewinding procedure

Medium voltage motors
• Core test
• Check winding details, copper size, connections, number of turns etc
• Check rotor
• Manufacture coil to same specification as those removed, if the machine was originally wound with older type of insulation a new insulation system may be used which could be thinner than the old insulation allowing for a large copper conductor which would reduce the stator copper losses assisting in maintaining or even improving the efficiency, all other factors being equal.
• Medium voltage motor coils are generally wound with rectangular copper cross section conductors which are design to fit and fill the slot without voids this makes it obvious if the incorrect copper area or number of turns is used.
• The repairer would not reduce the copper cross sectional area or make the coils longer; both changes would create additional problems for extra insulation so coils fit tightly in slot and longer coil could foul baffles or internal circulating fans.
• Generally the rotor is balanced fitted with the original fans, new bearings and brought back to the original new mechanical condition.

The South African motor repair industry goes back over 100 years.
• Motors can be repaired to original spec, and in some cases, may even be more efficient.
• The motor repair industry remains critical to the South African economy.
The procedure is the same as for medium voltage motors except for the coil manufacture and winding procedure. Round conductors are generally used and there may be a number of conductors in parallel.

All reputable repair companies will rewinding the same copper area or larger copper cross sectional area. Low voltage motors are generally machine wound and as such the coils are slightly longer and slot fill not as full due to the fact that the machines fitting the coils require a tolerance. This means that hand wound motor can take advantage of this fact by increasing the copper area and a smaller coil reducing the mean turn length, this has no effect on the performance of the motor other than to reduce the stator copper losses.

Quote from Andrew Robins of Anglo-Gold Ashanti: “We know that efficiency deteriorates due to copper losses and there is an increase in air gap during refurbishment of motors but there is no practical way to measure efficiency in situ.”

I agree that there is no simple practical way to measure efficiency in situ but disagree with the implication that the reputable motor repairers are using a small copper cross section and machining the rotor or stators increasing the air gap. I also cannot believe that a motor with double the OEM design losses will operate satisfactorily without all sorts of alarm bells ringing; the operating life would be very short. Increasing the air gap and reducing the copper size is a no-no with any reputable repairer except in special circumstances of a design change where the user would be informed.

The stator winding losses are approximately 25 to 30% of the total losses and even if the repairer cut the copper size to double the stator copper loss the total losses would increase by 30% taking the efficiency down by 1,25% not 5%.

### Energy efficiency programme

The Eskom energy efficiency programme is based on a rebate system where they subsidise the supplier when a user replaces an old standard efficiency motor with a high or premium efficiency motor on proof that the ‘old’ motor is destroyed. This only applies to a limited range of low voltage motors.

Electric motors are reasonably efficient devices, medium voltage machines running well into the mid-ninety efficiency range. A systems approach should be adopted... yes, ensure the motor is operating efficiently, but larger gains could be achieved by looking at driven equipment where efficiency is as low as 30 or 40%, throttling pump deliveries, waste energy in churning the liquid and heating it.

'The results are in motor repair’s impact on efficiency.' (Quote from an article reporting on tests carried out by Austen Bonnett, EASA education and technical consultant[2].)

<table>
<thead>
<tr>
<th>Frame</th>
<th>HP</th>
<th>Space * Factor</th>
<th>Full Load Efficiency</th>
<th>Nominal Nameplate Efficiency</th>
<th>EPAct** Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Rewound</td>
<td>365</td>
<td>75</td>
<td>48%</td>
<td>59%</td>
<td>92,7%</td>
</tr>
<tr>
<td>Original Rewound</td>
<td>404</td>
<td>100</td>
<td>39%</td>
<td>60%</td>
<td>92,7%</td>
</tr>
<tr>
<td>Original Rewound</td>
<td>405</td>
<td>125</td>
<td>43%</td>
<td>59%</td>
<td>93,4%</td>
</tr>
<tr>
<td>Original Rewound</td>
<td>444</td>
<td>150</td>
<td>58%</td>
<td>63%</td>
<td>93,9%</td>
</tr>
<tr>
<td>Original Rewound</td>
<td>445</td>
<td>200</td>
<td>55%</td>
<td>63%</td>
<td>94,1%</td>
</tr>
</tbody>
</table>

Table 3: Random Wound, 4 Pole, Lap Windings, Open Dripproof, Pre-EPAct ** efficiencies.

* Percent space factor =

** EPAct is the US Energy Policy Act of 1992 (federal law) mandating minimum energy efficiency levels for manufactured electric motors.

<table>
<thead>
<tr>
<th>HP</th>
<th>Poles</th>
<th>Frame</th>
<th>End-turn length</th>
<th>Efficiency</th>
<th>Total losses</th>
<th>% Change losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>2</td>
<td>447</td>
<td>10% short</td>
<td>95,1</td>
<td>7697</td>
<td>-2,3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nominal</td>
<td>95,0</td>
<td>7875</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10% long</td>
<td>94,9</td>
<td>8075</td>
<td>2,5</td>
</tr>
<tr>
<td>200</td>
<td>4</td>
<td>447</td>
<td>10% short</td>
<td>95,6</td>
<td>6921</td>
<td>-2,5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nominal</td>
<td>95,5</td>
<td>7099</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10% long</td>
<td>95,3</td>
<td>7278</td>
<td>2,5</td>
</tr>
</tbody>
</table>

Table 4: Effect of coil mean turn length on losses.
Motors should only be repaired once or twice

The only loss that could be effected when rewinding a motor a number of times is mechanical damage and core losses. During a rewind a reputable repairer would ensure that the stator winding is the same as the original, or better, by using additional copper cross sectional areas and keeping the coils tight. The rotor would be tested and, unless mechanically damaged, would not change; no broken rotor bars, same air-gap etc. mechanically bearings, fans etc would be the same. The core losses could increase due to mechanical damage during stripping or excessive heat in burn-out procedure but if core tested before stripping and before rewind and damage would be found. If the burn-out procedure has been controlled it has been found that the core losses after the first and even the second could drop due to the annealing process that occurs in the lamination steel.

Burn-out is usually carried out and controlled at around 380°C which ensures the inter-lamination insulation is not damaged. At this temperature the magnetic properties (hysteresis losses and characteristics) are unaffected.

Premium or high efficiency motors cannot be rewound.

Question: How does the designer or manufacturer achieve the loss reduction by any one, or more methods - additional cross sectional area in the stator winding, increase rotor bar cross sectional area, better grade steel (reduce iron losses), lower flux density (larger core), improved cooling (lower fiction and windage losses) etc?

Answer: None of the changes means the repairer cannot repair these motors as he replaces the winding with the same copper, uses the same core and rotor, fits the same bearings and fan. The repairer follows the same controlled procedure as he does when rewinding a standard motor the only difference is the premium efficient motor has used more or better material in its construction and the repair does not change the motor designed material in any way.

Conclusion

Motors can be repaired maintaining efficiency to a value very close to the original and can, at times, even improve on efficiency. On-site measurement of efficiency is extremely difficult to achieve accurate results and measurements showing a decrease in efficiency from 95% to 90% should be questioned as the motor would operate so hot it would fail practically immediately on obtaining steady state temperature conditions. It must be noted that the winding resistance of both the stator and rotor increase with temperature increasing losses. If the user requested the information for the manufacture of any new motor and compared it with tests carried out by the repairer, after repair they would have a very good idea of any loss in efficiency without expensive load testing. If the stator resistance is compared to the manufacturer’s tested resistance value and this is the same or lower, you can assume the stator copper losses would be the same or better, comparing the no-load current and power (kW) this will indicate the iron, no-load portion of stray losses, windage and friction losses have not changed. These comparisons will give a very good indication of the repaired efficiency of the motor.

References

[2] Bonnett, A. EASA. Results are in motor repair’s impact on efficiency.

Table 4: Multiple renews under controlled conditions.
Test done by Austin Bonnett, in which he carried out controlled multiple burn-out and found no increase in the iron losses[2].

Question: What differences make a motor fall into the category of premium efficient?

Answer: A reduction of losses, not a radical change in basic principles of operation, a premium efficient motor and standard efficiency motor both look the same and operate on exactly the same principles.