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The Effects of an Increased Air Gap of an Electric Motor

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The effects of an increased air gap of an electric motor.

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Introductions

A common result of a failure on an electric motor is that the rotor mechanically damages the stator laminations. This is what is referred to as a "rub".

Frequently it is then necessary to either line bore the stator laminations' ID and/or machine the rotor laminations" OD. This is done to ensure the concentricity of the OD and ID's.

Customers are unfortunately forced to accept such drastic measures, since replacement of the laminations is very costly both on money as well as time. Ordering a new replacement motor frequently takes in excessive of four months to be delivered.

There have been several discussions on the negative effect of the motor's performance due to the increase in the air gap between the rotor and the stator due to the machining process.

This paper attempts to quantify the changes in the motor's performance thought modelling the increased air gap.

The model was run on one of the motors the author designed, and complete design details are available.

Motor Details

This CACA, 820 kW, 4 pole, 6600 V motor was specifically designed to replace an old HSE motor in a prominent South Africa Gold mine near Orkney.

The motor had to be designed to meet the original motors performance characteristics, as well as the mechanical mounting arrangements.

The motor's theoretical performance data was proved by comprehensive full load testing.

[1] *Vector* is the Journal of the Institution of Certified Mechanical and Electrical Engineers and the Journal of South African Institute of Electrical Technician Engineer.

Modelled Values

Unfortunately the data had to be obtained through extensive modelling, resulting in huge amounts of data. This full scope of data is available from the author.

The models were compiled by first increasing the air gap into the stator, i.e. keeping the rotor OD constant and gradually de-creasing the stator ID by reducing the stator slot bridge. Secondly by increasing the air gap into the rotor, i.e. keeping the stator ID constant and gradually decreasing the rotor OD by reducing the rotor slot bridge.

The main areas of importance are listed below, as well as the corresponding explanations.

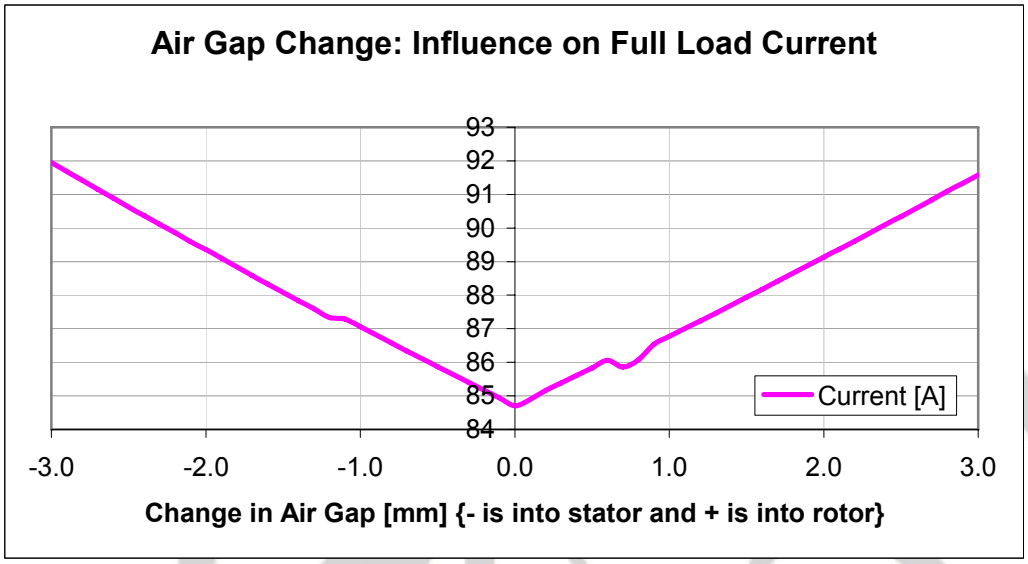
Line No	Physical Dimentions							Performance Values								
	Stator			Rotor		Air gap		Full load values					No-Load		Locked Rotor	
	ID [mm]	Wedge [mm]	Bridge [mm]	OD [mm]	Bridge [mm]	Value [mm]	Δ	Current [A]	Eff [%]	PF	Speed [rpm]	Temp Rise [°C]	NL Power [kW]	NL Current [A]	Sarting Current [A]	Starting Torque [Nm]
1	420.00	2.50	-0.50	415.50	4.00	6.0	-3.0	92.0	96.1	0.811	1488.5	74.0	13.2	40.5	568	4208
10	420.45	2.95	-0.05	415.50	4.00	5.1	-2.1	89.6	96.2	0.831	1488.6	71.5	12.8	36.1	560	3998
11	420.50	3.00	0.00	415.50	4.00	5.0	-2.0	89.4	96.2	0.833	1488.6	71.3	12.7	35.6	559	3998
15	420.70	3.00	0.20	415.50	4.00	4.6	-1.6	88.3	96.2	0.843	1488.6	70.2	12.6	33.6	555	3893
16	420.75	3.00	0.25	415.50	4.00	4.5	-1.5	88.1	96.2	0.845	1488.6	70.0	12.6	33.1	554	3893
17	420.80	3.00	0.30	415.50	4.00	4.4	-1.4	87.8	96.3	0.847	1488.6	69.8	12.6	32.6	553	3840
30	421.45	3.00	0.95	415.50	4.00	3.1	-0.1	84.9	96.3	0.877	1488.8	68.1	12.4	25.8	539	3576
31	**421.50**	**3.00**	**1.00**	**415.50**	**4.00**	**3.0**	**0.0**	**84.7**	**96.3**	**0.880**	**1488.8**	**68.1**	**12.4**	**25.3**	**541**	**3524**
32	421.50	3.00	1.00	415.45	3.95	3.1	0.1	84.9	96.3	0.878	1488.8	68.1	12.4	25.8	539	3576
47	421.50	3.00	1.00	414.70	3.20	4.6	1.6	88.2	96.2	0.845	1488.6	69.9	12.6	33.4	558	4050
48	421.50	3.00	1.00	414.65	3.15	4.7	1.7	88.4	96.2	0.843	1488.6	70.1	12.7	33.8	559	4050
49	421.50	3.00	1.00	414.60	3.10	4.8	1.8	88.7	96.2	0.841	1488.6	70.3	12.7	34.3	561	4103
61	421.50	3.00	1.00	414.00	2.50	6.0	3.0	91.6	96.1	0.815	1488.4	73.4	13.2	39.8	574	4419

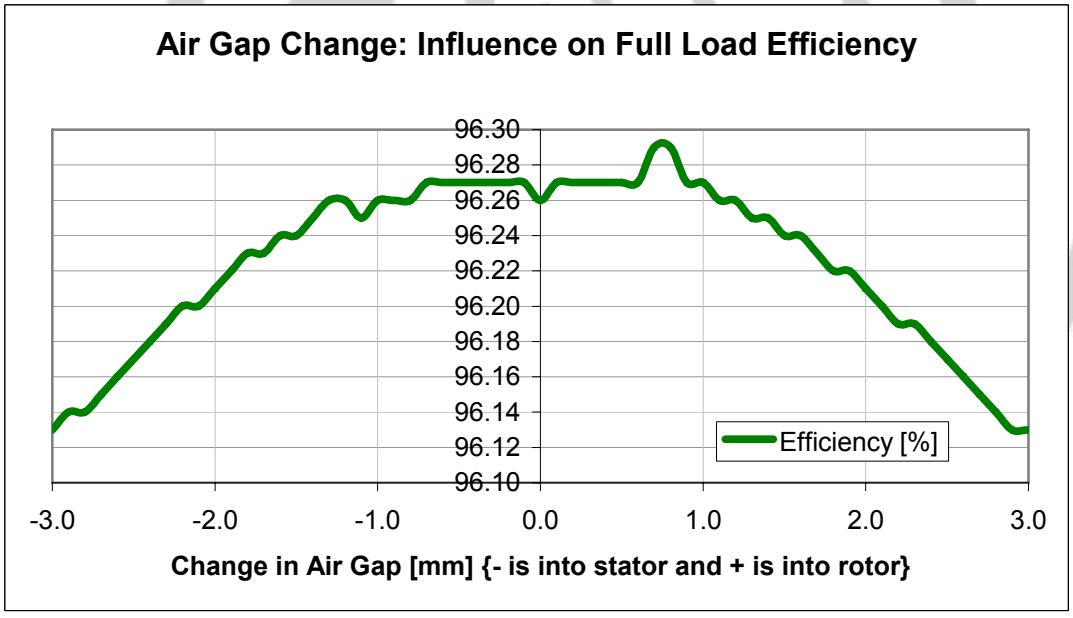
Line #	Explanation
1	The maximum change examined of the air gap into the stator lamination is 100%, i.e. the air gap was increased from 3 mm to 6 mm per side.
11	At this critical point the bridge of the stator slot has been machined away completely, and the machining operation is starting to protrude into the stator slot wedge. This may lead to pre-mature failure of the winding due to the wedges coming loose.
15	The stator temperature rise starts to exceed the specification's permitted temperature rise of 70 °C (AAC 538/11).
16	An increase of 50% of the air gap into the stator lamination appears to be the limit of acceptable change in the motor's performance.
31	This is the nominal value of the air gap without any machining.
48	The stator temperature rise starts to exceed the specification's permitted temperature rise of 70 °C (AAC 538/11).
61	The maximum change examined of the air gap into the rotor lamination is 100%, i.e. the air gap was increased from 3 mm to 6 mm per side.

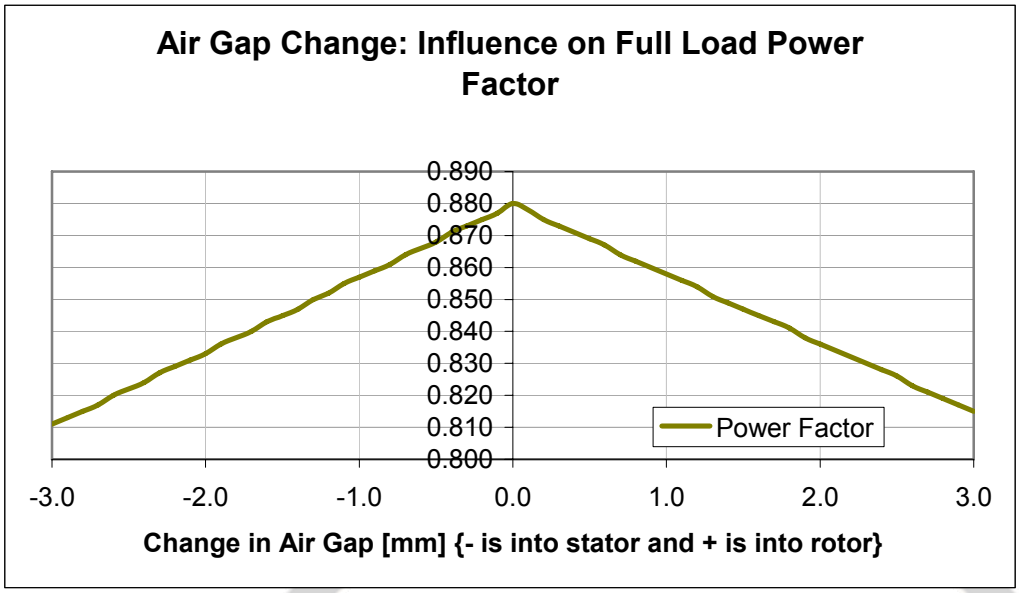
This is a theoretical examination, and does not take into account additional factors, like the change in the actual cooling circuit of the motor due to the increase in air gap, which might affect the windage losses as well as the cooling factors.

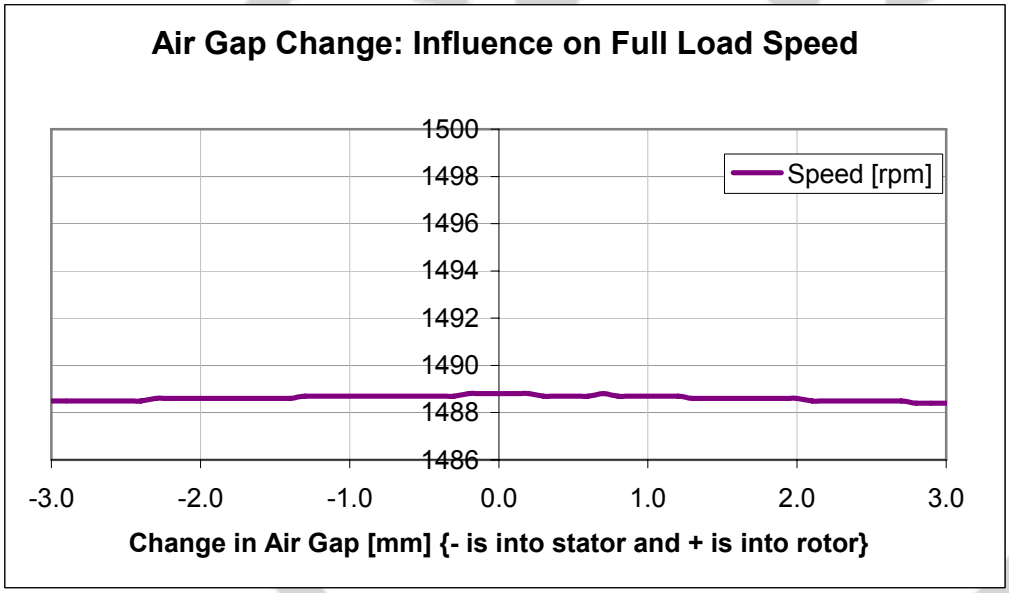
In order to better visualize the changes in the motor's performance, the critical performance values are graphed.

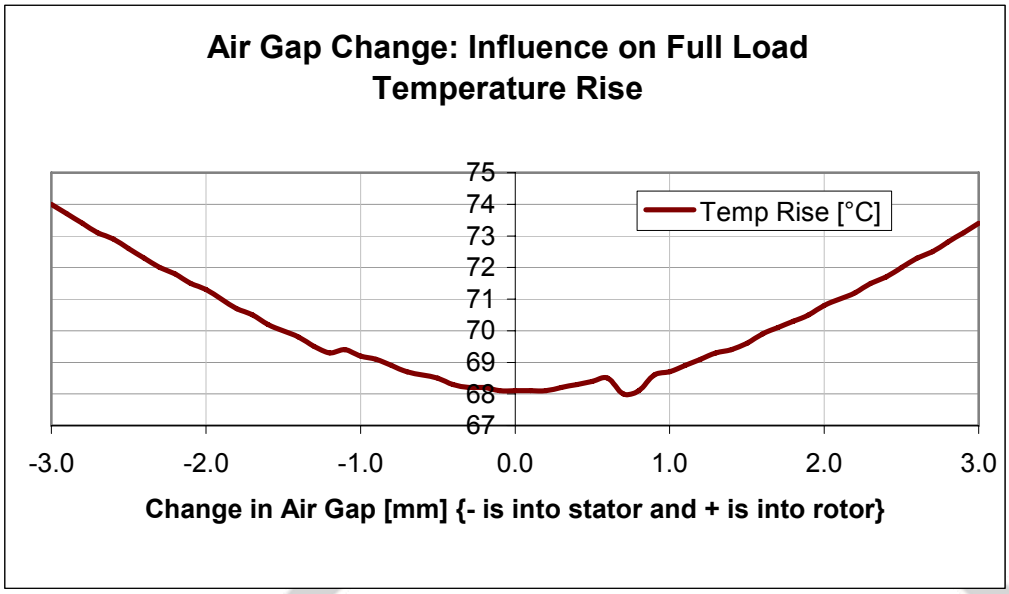
Performance Graphs

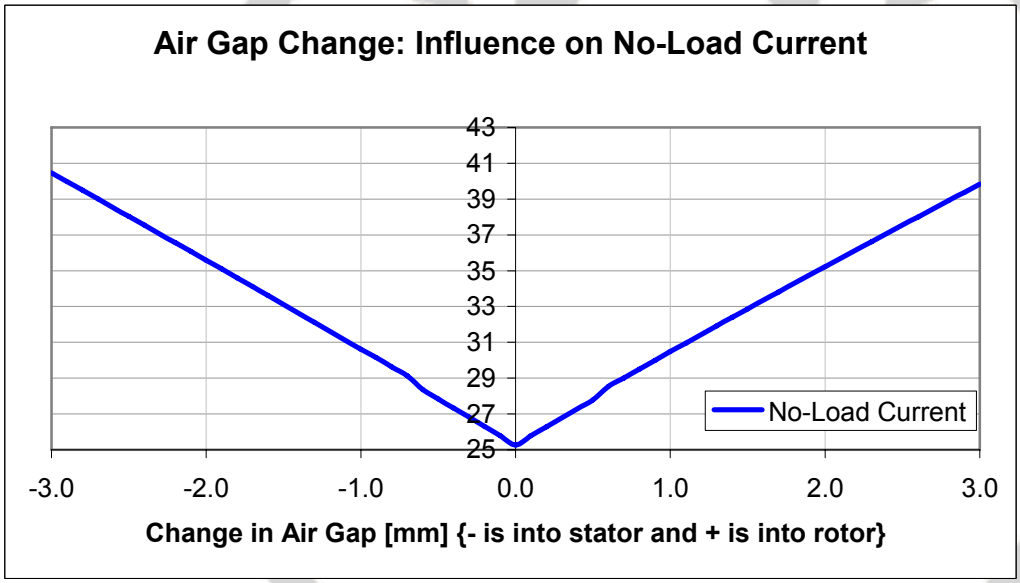


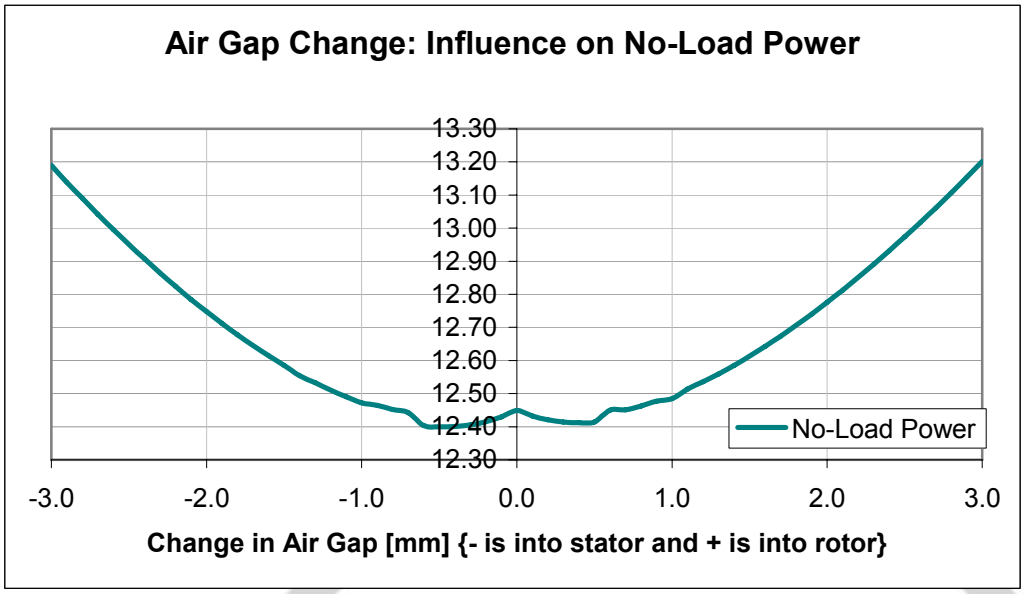


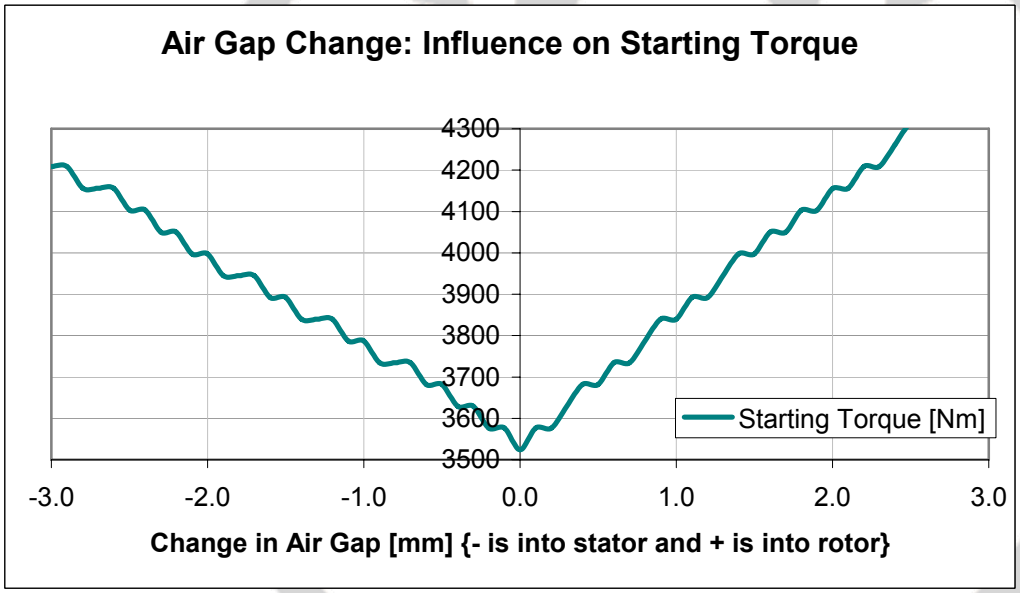

Air Gap Change: Influence on Full Load Power Factor
0.890
0.880
0.870
0.860
0.850
0.840
0.830
0.820
0.810
0.800
Power Factor
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Change in Air Gap [mm] {- is into stator and + is into rotor}

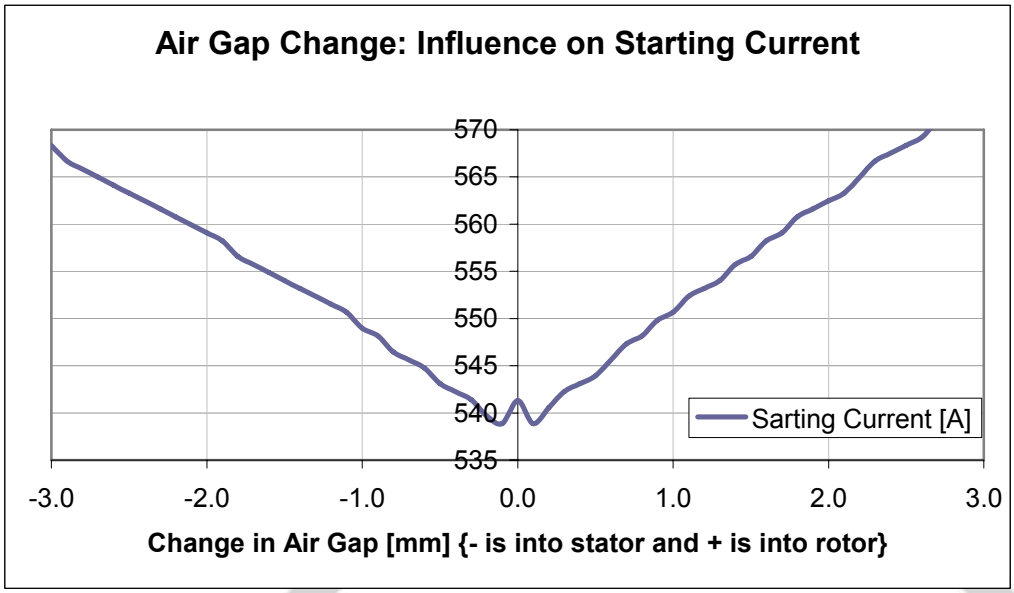

Air Gap Change: Influence on Full Load Speed
1500
1498
1496
1494
1492
1490
1488
1486
Speed [rpm]
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Change in Air Gap [mm] {- is into stator and + is into rotor}


Air Gap Change: Influence on Full Load Temperature Rise
75
74
73
72
71
70
69
68
67
Temp Rise [°C]
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Change in Air Gap [mm] {- is into stator and + is into rotor}


Air Gap Change: Influence on No-Load Current
43
41
39
37
35
33
31
29
27
25
No-Load Current
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Change in Air Gap [mm] {- is into stator and + is into rotor}


Air Gap Change: Influence on No-Load Power
13.30
13.20
13.10
13.00
12.90
12.80
12.70
12.60
12.50
12.40
12.30
No-Load Power
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Change in Air Gap [mm] {- is into stator and + is into rotor}


Air Gap Change: Influence on Starting Torque
4300
4200
4100
4000
3900
3800
3700
3600
3500
Starting Torque [Nm]
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Change in Air Gap [mm] {- is into stator and + is into rotor}


Air Gap Change: Influence on Starting Current
570
565
560
555
550
545
540
535
Sarting Current [A]
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Change in Air Gap [mm] {- is into stator and + is into rotor}

Conclusion

The actual effect on the performance of the motor is relatively limited with fairly drastic increases in the air gap (as much as 50%). Without proper considerations they could however cause major long term problems in the motor, resulting in reduced power factor, efficiency, increase in no-load losses, overheating, etc.

Even though this is a specific example of the possible effects of changes in the air gap to the performance of the motor, a reputable repair company should be able to model other specific cases for their customer in order to rather make an informed decision on whether to machine the rotor and or stator, in stead of just guessing what the influence of an air gap change will be.

Ensure that your electric motor supplier is reputable and able to fully assist you in selecting the correct motor for the correct application, using the correct connections and starting conditions!

We are proud to engineer quality solutions for our valued customers.

Henk de Swardt
Engineering Director
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About the Author:

Henk de Swardt has a B. Sc. in Electrical and Electronic Engineering. He has more than eleven years of electric motors experience, both in the electric motor repair industry, as well as the electric motor manufacturing industry. He was employed for several years by the Largest OEM in South Africa. He also received specialized training in France on the designing of Electrical Motors. He is currently serving the Electric Motor industry at the Largest repairer of MV and HV motors in Africa. For a full C.V. visit http://www.qtime.co.za/CV_Main.html

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