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Design Analysis of Spoke Type BLDC Motor for Spinning Mill Application

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***Abstract*— To design a motor that would overcome the drawbacks of the conventional spinning motor and to evaluate the characteristics of the chosen motor with the help of software packages from Infolytica. The motor which is currently used is three phase Totally Enclosed Fan Cooled Squirrel Cage Induction Motor (TEFCSCIM).The motor employed in the spinning machine undergoes partial loads during most of its operating hours.It is noted that the motor efficiency and power factor are poor in the case of partial load. Heat, Sound and Slip of the motor are few factors to be considered for the change in design. The objective of this project is to design a Permanent Magnet Brushless Direct Current (PMBLDC) Motor which would eliminate the above complications. Initially the design has to be analytically arrived and the same has to be scrutinized through the software packages from Infolytica.Critical key parameters such as speed, average and cogging torque has to be accounted in the analysis. Generally, the cogging torque increases with increase in average torque and hence there is a need to modify the rotor parameters such that the former remains low for significant increase in the latter. The software analysis and comparison will be followed by the final design of the spinning motor. We concentrate mainly on the effects of temperature. Temperature is of main concern because more cool the motor is, more efficient it is.**

***Keywords:-*. Brushless DC motor (BLDC) ,Squirrel Cage Induction Motor(SCIM), Average torque, Temperature.**

I. INTRODUCTION

India is a leading producer of cotton and Indian spinning mills are one of the largest industries in the world, thereby it plays a major role in Indian economy.It contributes to the Indian economy in terms of production, employment and foreign exchange. Therefore many studies have been carried out to reduce the production cost without affecting the quantity and quality of output. In this paper we suggest to do the above with change of conventional spinning motor.The existing motor is three phase AC totally enclosed fan cooled squirrel cage induction motor which lags behind due to temperature and slip. Maintenance cost of these motors is also high. There is a need for an alternate motor which is devoid of above problems. Spinning mills today does not mind about small increase in initial cost of the motor as the same would be retrieved from two to three weeks of electricity consumption rate. Many paper on optimization of existing motor with slight increase in motor cost are successful due to this reason. This analysis aims to pick out the suitable motor to replace existing based on their performance characteristics such as speed, power average and cogging torque. The motor thus opted should be efficient and economical. Another major problem with conventional motor is reduction of average torque along with reduction of cogging torque by skewing. The motor we have chosen through this analysis is IPM spoke type BLDC motor in which we have found that there is a significant reduction in cogging torque with a decent average torque. Moreover it is understood from this study that the effect of temperature is comparatively low in this type of motor.

II. SELECTION CRITERIA FOR SPINNING MOTOR

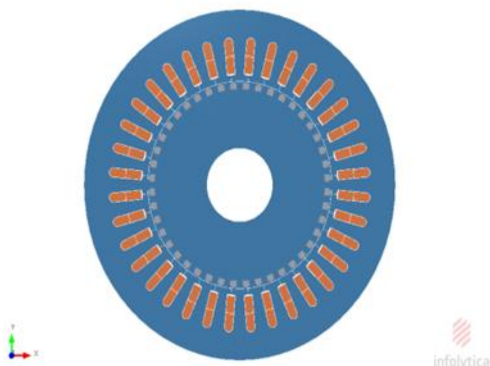
1) There is an increasing need for a motor which would provide the below characteristics to be used as a spinning motor.
2) Heat (temperature) of the motor should be less.
3) Vibration and cogging torque should be low.
4) Slip effects should be minimum or nil.
5) Variation in power factor and efficiency is low in case of partial loads.
6) Average torque should be high.

From the above criteria it is clear that BLDC would provide a better substitute for conventional spinning motor. The other reasons to select BLDC motor is given below

a. Higher efficiency and reliability.
b. Lower acoustic noise due to absence of brushes.

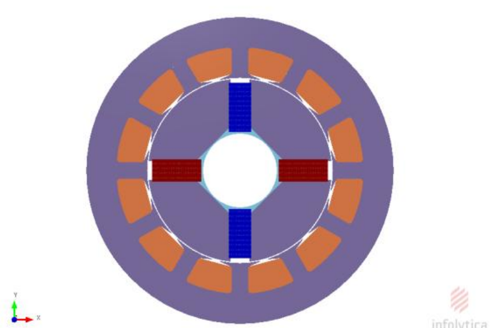
c. Smaller and lighter.
d. Greater dynamic response.
e. Better speed versus torque characteristics
f. Rotor inertia is low.

III. EXISTING MOTORS INDUCTION MOTOR



In Induction motor the rotor inertia is high and it has poor dynamic characteristics. The output power per frame size is also found to be low. The speed torque characteristics of Induction motor are non-linear. Additional disadvantages like slip effects are present inInduction motor.

IV. PROPOSED MOTOR BLDC MOTOR



In BLDC motor the rotor inertia is low and it has better dynamic characteristics. The output power per frame size is high compared to Induction motor. The speed torque characteristics of BLDC are linear. We have gone for IPM BLDC motor instead of SPM BLDC motor due to the following reason.

PARAMETER	SPM BLDC MOTOR	IPM BLDC MOTOR
Air gap	Non-uniform	Uniform
Centrifugal force	Present	Absent

In Surface mounted BLDC motor the magnets are present on the surface of the rotor core, so While using this motor for high speed industrial applications there is a chance of magnets getting detached from the rotor due to centrifugal force. Hence we opt for IPM BLDC motor since the permanent magnets are interiorly placed. The IPM BLDC motor are of two types a) conventional motor b) spoke type. In Conventional IPM motor the magnets are horizontally placed whereas in Spoke type motor the magnets are vertically placed. Due the vertical arrangement provides better flux distribution and flux density through an area and hence it results in better torque value.

V. INPUT PARAMETERS OF SQUIRREL CAGE INDUCTION MOTOR AND SPOKE TYPE BLDC MOTOR

PARAMETERS	SQIUIRREL CAGE INDUCTION MOTOR	BLDC MOTOR
Supply voltage	400 V	166.667 V
Rated current	15.3 A	45 A
Rated speed	1425 rpm	1425 rpm
Rated slip	5%	-
Rated torque	50.26 Nm	50.26 Nm
Stator flux density	1.2 Tesla	1.2 Tesla
Rotor stator ratio	0.55	0.55
No of phases	3	3
No of poles	4	4
No of stator slots	36	24
No of rotor slots	44	-
Stator outer diameter	356 mm	180 mm
Stator inner diameter	211 mm	120 mm
Rotor outer diameter	210 mm	119 mm
Rotor inner diameter	75 mm	33.7 mm
Air gap thickness	0.5 mm	0.5 mm

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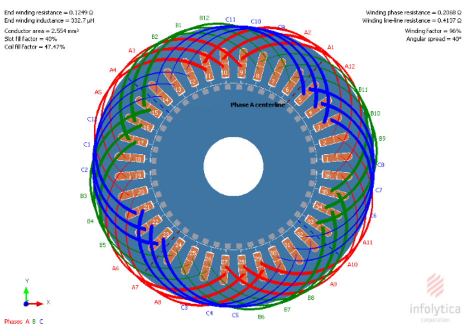
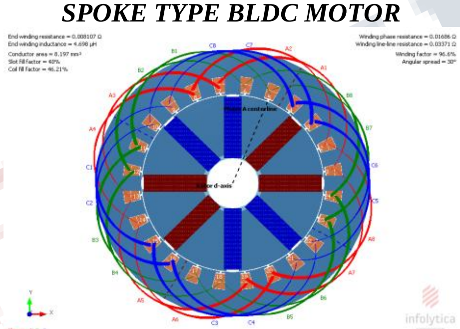
VI. STATOR WINDING

The stator winding of BLDC motor has laminated steel stacked up to carry the windings. The stator windings are arranged in wither of the two types, star or delta. The star winding gives high torque at low RPM and delta type gives low torque at low RPM.

INDUCTION MOTOR



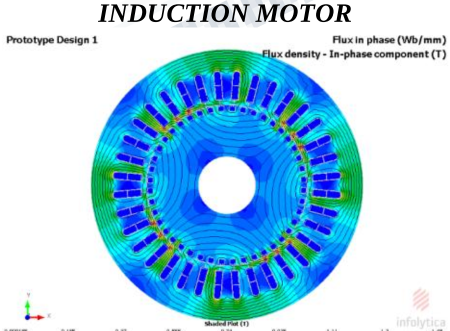
SPOKE TYPE BLDC MOTOR



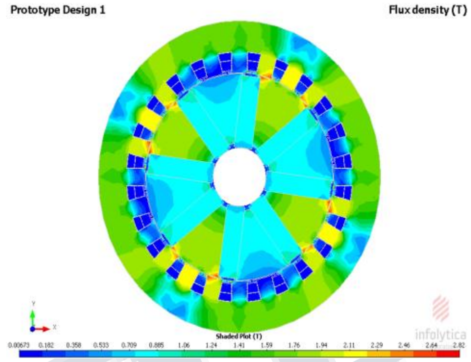
Winding phase resistance = 0.2068 Ω
Winding line-line resistance = 0.4137 Ω

VI. FLUX DENSITY

INDUCTION MOTOR



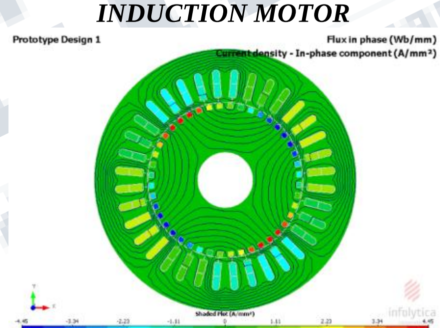
SPOKE TYPE BLDC MOTOR



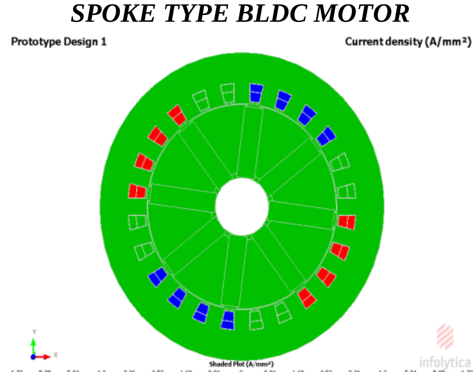
Minimum flux density of existing motor is 0.000185 T and Maximum flux density is 1.48 T. The above given values correspond to the flux density value of BLDC spoke type motor.

VII. CURRENT DENSITY

INDUCTION MOTOR



SPOKE TYPE BLDC MOTOR



Maximum current density = 4.45
Minimum current density = -4.45

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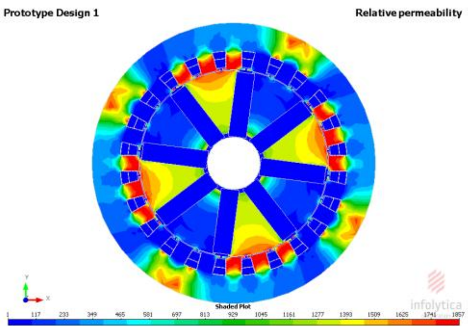
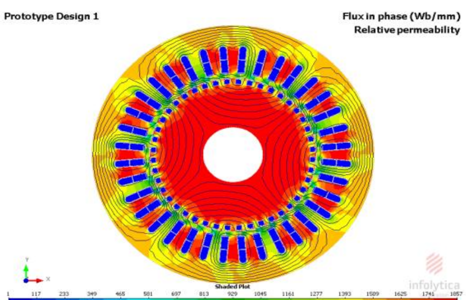
VIII. RELATIVE PERMEABILITY

SPOKE TYPE BLDC



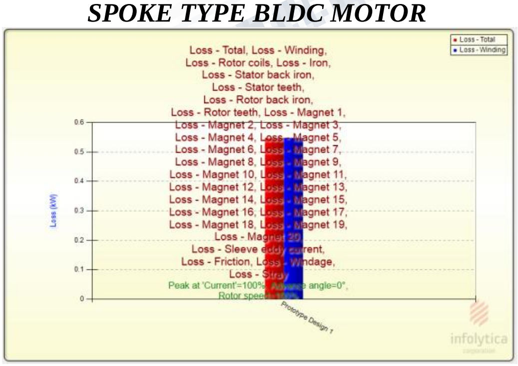
INDUCTION MOTOR



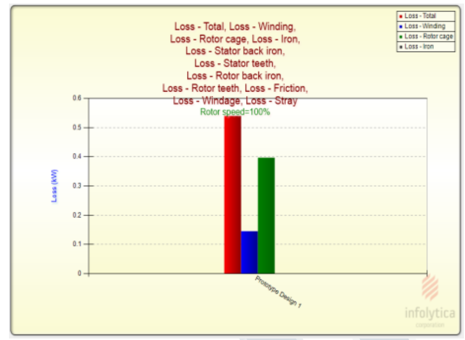
The relative permeability design of BLDC spoke type motor is given. The performance characteristics are better for this motor as compared to induction motor.

LOSS:
The losses are very less in this type of motor compared to the induction motor which is of high advantage. The value of losses is taken from the motor solve software by designing the motor of above given specifications. The following graph shows the losses in the BLDC IPM spoke

SPOKE TYPE BLDC MOTOR



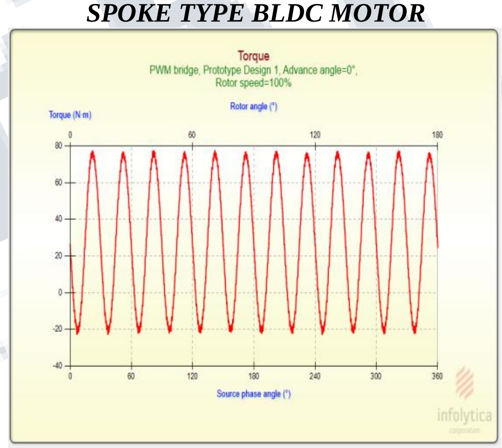
INDUCTION MOTOR



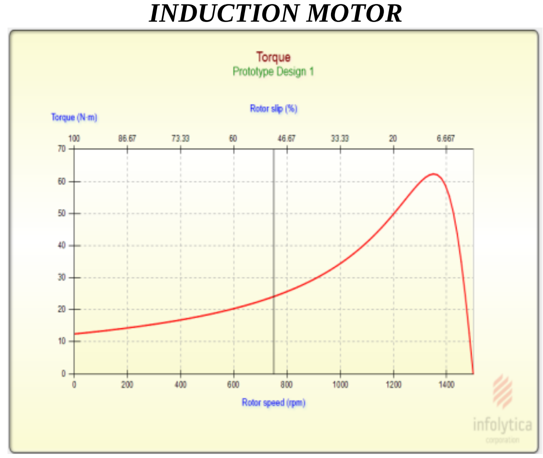
TORQUE:

The average torque value is high for this type of motor and at the same time low cogging torque is achieved. The graph for torque is show below which is obtained from the software.

SPOKE TYPE BLDC MOTOR



INDUCTION MOTOR



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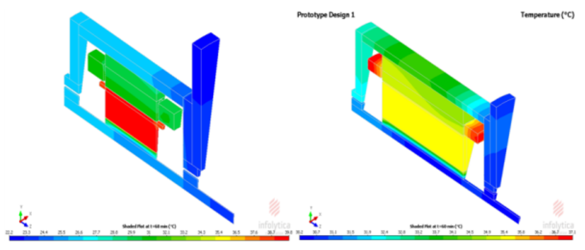
THERMAL ANALYSIS OF IMTHERMAL ANALYSIS OF NdFeB

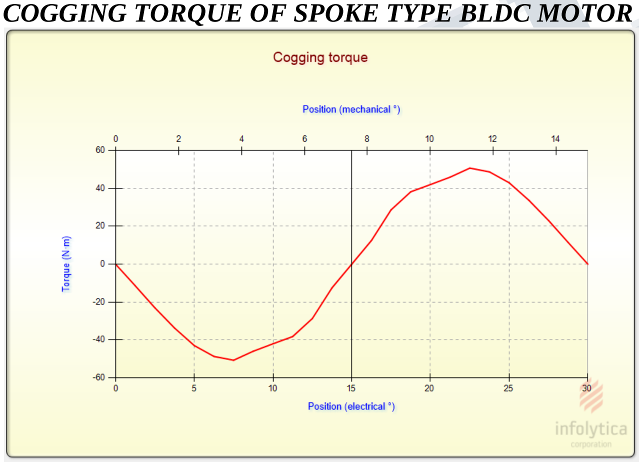


Fi .1.(a) *fig.1.(b)*

Fig .1.Thermal analysis of a) IM b) Spoke type BLDC motor

PARAMETER	SQUIRREL CAGE INDUCTION MOTOR	SPOKE TYPE BLDC MOTOR
Maximum temperature(°C)	39.8	37.1
Maximum flux density(T)	1.48	2.82
Overall Flux density	low	high
Average torque(Nm)	28.68	29.1349
Current density	4.45	4.72
Efficiency (%)	93.3	95

COGGING TORQUE OF SPOKE TYPE BLDC MOTOR



FUTURE SCOPE

The average torque obtained by analyzing spoke type BLDC motor using ceramic ferrite with the same parameters as that of NdFeB is 13.023 Nm. This could be improved by altering the values of magnetic width, magnetic thickness, semi-slot opening width and so on.

IX. CONCLUSION

Even though the performance characteristics of Spoke Type BLDC motor using NdFeB Permanent Magnet is better than that of the Induction motor and spoke type BLDC motor using ceramic ferrite, the cost of NdFeB is more comparatively. Therefore the ceramic ferrite is preferable compared to NdFeB. It has more flux distribution, less loss, high average torque and less maintenance cost compared to Induction motor and less initial cost compared to spoke type BLDC motor using NdFeB.

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7) C.ThangaRaj1, Radha ThangaRaj1, Millie Pant1, Pascal Bouvry2, Ajith Abraham3,"Design optimization of Induction motors with differential evolution algorithms with an application in textile spinning" Indian Institute of Technology Roorkee, India 2 Faculty of Science, Technology and Communications, University of Luxembourg, Luxembourg 3 Machine Intelligent Research Labs (MIR Labs), Scientific Network for Innovation and Research Excellence, USA. 4 VSB Technical University Of Ostrava, Poruba, Czech Republic.