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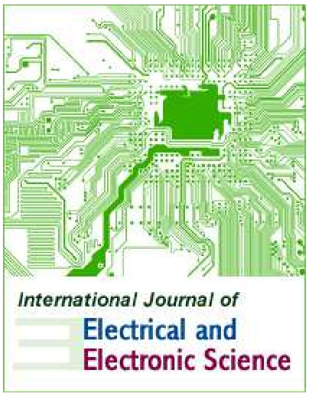

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Energy efficient DC shunt motor fed drives

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Abstract
In the recent days, there was a magnificent improvement in the performance of the electrical machines by coating the windings of the machines by the enamel filled with various nano fillers. Those types of electrical machines were simply called as energy efficient electrical machines or nano electrical machines. This technique was now applicable in DC shunt motors to improve the performance and thermal withstanding capacity of the motor. The maximum efficiency of the DC shunt motor was improved by 4.8% by coating the windings of the motor with the enamel filled with nano SiO_2. The maximum temperature of the DC shunt motor was reduced by 10.81% by coating the windings of the motor with the enamel filled with nano SiO_2. Hence these shunt motor fed drives were called as Energy efficient DC Shunt motor fed drives. The life time of the motors was also improved by reducing the losses and the maximum temperature rise of the motors. This kind of work can be extended for different types of motors by coating with several nano fillers such as TiO2, ZnO, and ZrO2 and also with the mixture of nano composites for both AC and DC motors.

1. Introduction

Electrical energy was the most common and widely used type of energy in the world. The concept of energy conservation is the prime concern, for most energy users, particularly industries. The need for energy conservation is accelerating the requirement for increased levels of electric motor efficiency. Drive systems today determine the productivity and quality of industrial processes. DC motors have been available for nearly 100 years. In fact the first electric motors were designed and built for operation from direct current power. Basic DC motors as used on nearly all packaged drives have a very simple performance characteristic the shaft turns at a speed almost directly proportional to the voltage applied to the armature. The advantages of D.C. drives are: Adjustable speed, Good speed regulation, Frequent starting, braking and reversing. The variable speed applications are dominated by D.C. drives because of lower cost, reliability and simple control. The applications of D.C. drives are: Rolling mills, Paper mills, Mine winders, Hoists, Machine tools, Traction, Printing presses, Excavators, Textile mills and Cranes. With the ever increasing energy cost, the life time operating cost of an induction motor can be traded against a high efficiency and a high capital cost. With rising demand for high efficiency or energy efficient DC motors, designers and manufacturers are stepping up their production of such motors. Improving the efficiency of DC motors, which are the most widely used electric machines in the world, saves much energy. Based on the previous project works, actions were taken to use the enamel filled with SiO_2 nano filler as the coating for the DC motor to improve its efficiency. Definitely, there will be a tremendous improvement in the efficiency of the DC drives and hence the motor can be called as “Energy Efficient DC drives”. DC motors have been used in industrial applications for years. Coupled with a DC drive, DC motors provide very precise control. DC motors can be used with conveyors, elevators, extruders, marine applications, material handling, paper, plastics, rubber, steel, and textile applications.

Nano technology deals with one dimension size from 1 to 100 nm. 1 nm was equal to 10^{-9} m. Nano technology was used to develop high performance products. The spacing between the atoms was 0.12 to 0.15 nm. The diameter of the atom was 2 nm. The size of the nano particles was set up by the size of the atoms. Nano particles were classified into four types:

1. Clusters or powders
2. Multi layers
3. Ultra fine
4. Nano particles equiaxed nm sized grains

The portion of matter whose excitons were confined in all three spatial dimensions was called as Quantum dots. The nano particles of particle size of 10 nm were called as nano wires. The aspect ratio of nano wires was 1000 or more. They were quantum confined. There were three types of nano wires: Metallic (Ni, Pt and Au), Semi conducting (Si, InP, GaN) and Insulating (SiO_2, TiO_2, Al_2O_3, ZnO). The most important properties of nano particles were as follows:

1. The nano particles were having large fraction of surface atoms.
2. The nano particles were having large surface energy.
3. They were spatial confined.
4. They were having reduced imperfections.
5. They have lower melting point.
6. They have lower phase transition temperature.
7. They have reduced lattice constants.
8. They were having higher mechanical properties.
9. The colour change of nano particles was due to surface Plasmon resonance.
10. The electrical conductivity of the nano particles were decreasing in nature.
11. The most important property of the nano particles was self purification.
12. Ferro magnetism was disappeared in the nano particles.

Nano fillers added to the enamel have the following advantages:

1. High resistance to partial discharge
2. Improved thermal properties
3. Lacking of erosion resistance
4. Matching of coefficient of thermal expansion
5. Thermal conductivity enhancement
6. Mechanical reinforcement
7. Abrasion resistance
8. Improved life

Al_2O_3 nano fillers have excellent electrical, thermal, mechanical and physical properties. SiO_2 nano fillers have high level of resistance to partial discharge, high purity, large surface area, good thermal, electrical and mechanical properties. TiO_2 nano fillers have higher thermal conductivity, chemical stability and improved electrical properties. Increase in loading weight of the nano filler would result in the increase of the partial resistance. Some of the drawbacks of nano technology were as follows:

1. Fabrication of nano particles was costly.
2. It produces environmental effects.
3. The nano particles have to overcome the huge surface energy.
4. The nano particles should ensure the desire size, uniform size distribution, morphology, crystalline and chemical composition.
5. The nano particles would be subjected to Ostwald ripening or agglomeration.

2. Proposed Work

Ball mill method was used to convert the micro particles of SiO_2 fillers into nano particles. SEM was used to augment the particle size of the fillers. The prepared SiO_2 nano fillers were mixed with the enamel by using ultrasonic vibrator. Then this enamel was used for coating of the winding and for impregnation with the paper insulation. Various tests were conducted on the normal motor and nano coated motor. Thermal withstanding capacity of the motor was estimated by heat run test. Load test were used to find the efficiency of the motor. Then the results were analyzed and compared. The proposed work setup was shown in the figure 1. The various types of motors used for several applications were DC motors and AC motors. DC motors were of three types: DC shunt motor, DC series motor and

DC compound motor. DC motors were used for constant speed applications like centrifugal pumps, light machine tools, wood working machines, lathes and so on. DC series motors were used in heavy load applications like electric train, cranes, lifts, hoists, conveyors where the starting torque requirement was high. DC Compound motors were used for intermittent loads, ice machine, refrigerators, printing press, punching machines and so on. This method of improvement of efficiency can also be implemented for all the static and rotating machines. Hence the machines operating on the nano coated windings were collectively called as Nano Electrical Machines. This method can be applied to the DC and AC generators also. Hence these generators were called as nano generators. This innovative idea of improving the performance can also be used for all the types of transformers were called as nano transformers. Generally, fillers were added to the enamel to avoid tracking. But these research reports show that the performance of all the static and rotating machines can be improved by adding nano fillers to the enamel used in these machines. Hence, these types of application of nano technology in the field of nano dielectrics were used in all types of the electrical machines. So, these types of electrical machines were called as Nano Electrical Machines or High Efficiency Electrical Machines or Energy Efficient Machines.

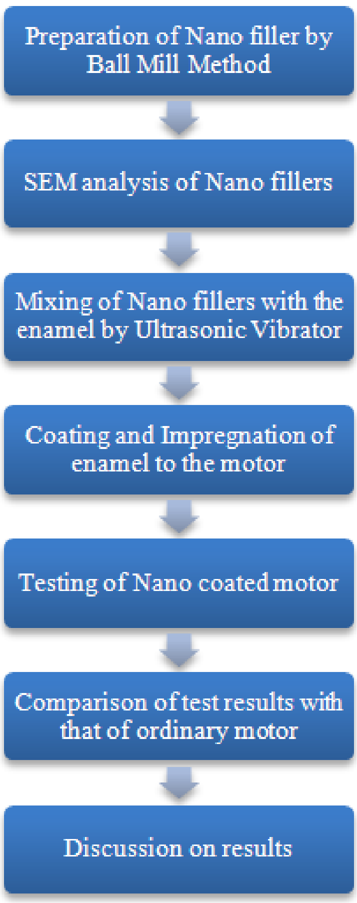

Figure 1. *Proposed work.*

3. Experimental

3.1. Load Test on DC Shunt Motor

Load test was conducted on the DC shunt motor to find the performance of the motor. There were some precautions to be followed before conducting the load test. They were as follows.

- Starter should be in off position before switching on the supply.
- The DPST switch must be kept open.
- The motor field rheostat must be kept at minimum resistance position
- There should be no load on the motor at the time of starting.
- Before connecting the meters check the polarity and zero error.

Load test was conducted as per the procedure explained as follows.

- Connections were given as per the circuit diagram shown in the figure 2.
- The motor was started by using three-point starter
- The rated speed was obtained by adjusting the field rheostat.
- The meter readings were noted at no load condition.
- The motor was loaded by using brake drum with spring balance arrangement and the corresponding readings were noted up to the rated current.
- After observation of all the readings the load was released gradually
- The motor was switched off by using DPST switch.

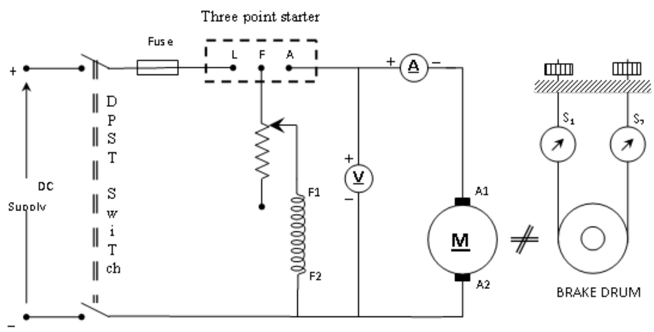

Figure 2. *load test on DC shunt motor. (Specifications of the motor: Voltage: 230 V Current: 2.5 A Speed: 1500 rpm Rating: 0.5 Hp)*

The readings of the load test were shown in the table 1 and 2. The various losses that occur in dc machines were grouped as copper losses, iron losses and mechanical losses. The characteristics of DC motor were classified into three types:

1. Electrical characteristic - Torque Vs armature current (T Vs I_a)
2. Mechanical characteristic – Speed Vs armature torque (N Vs T_a)
3. Speed Vs armature current (N Vs I_a)

The characteristic of the DC shunt motor before and after nano coating were shown in the figure 3 to 8.

Table 1. *Load test on DC shunt motor before nano coating.*

S. No	Voltage (V)	Current (A) Armature Current (A)	Field Current (A)	Spring Balance Reading S_1	S_2	Input Power in Watts	Output Power in Watts	Torque in N-m	Efficiency in %
1	220	0.3	0.38	0	0	149.6	0	0	0
2	219	0.8	0.38	2	3	258.42	113.75	0.765	44.0
3	218	1	0.38	2	4	300.84	208.28	1.530	69.2
4	217	1.2	0.38	3	5	342.86	195.46	1.530	57.0
5	217	1.8	0.38	3	6	473.06	273.97	2.295	57.91
6	216	2	0.38	4	8	514.08	301.21	3.060	58.59

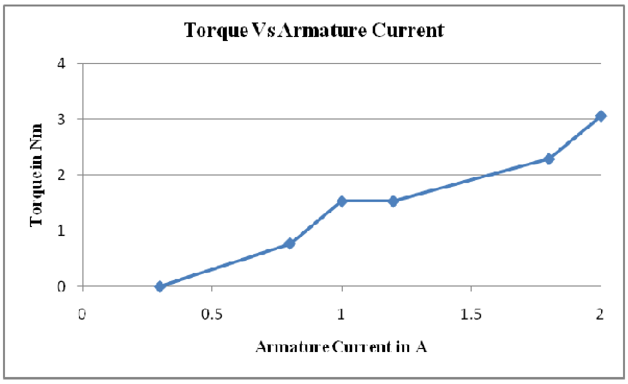

Figure 3. *Torque Vs Armature Current for DC Shunt motor before nano coating.*

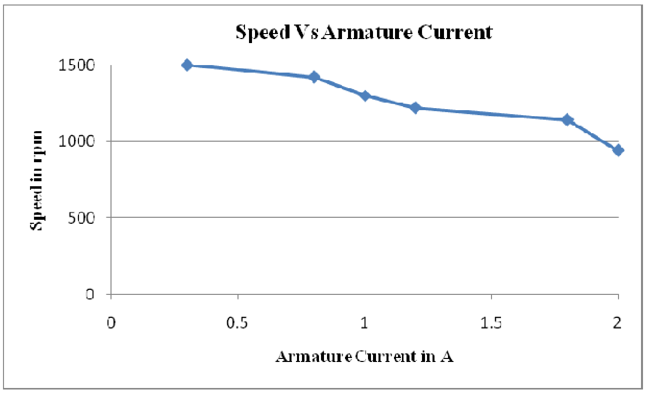

Figure 4. *Speed Vs Armature Current for DC Shunt motor before nano coating.*

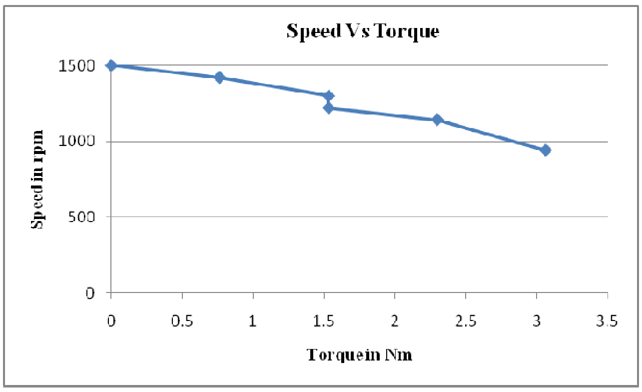

Figure 5. *Speed Vs Torque for DC Shunt motor before nano coating.*

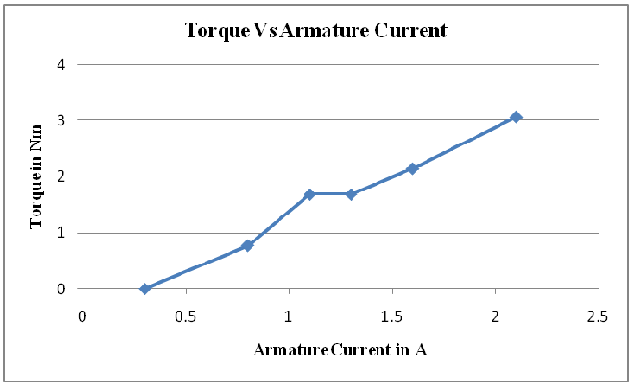

Figure 6. *Torque Vs Armature Current for DC Shunt motor after nano coating.*

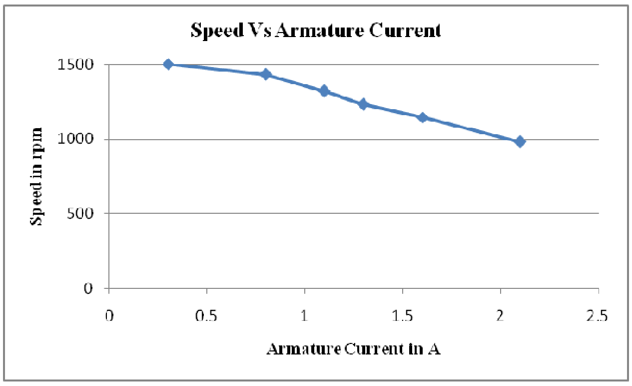

Figure 7. *Speed Vs Armature Current for DC Shunt motor after nano coating.*

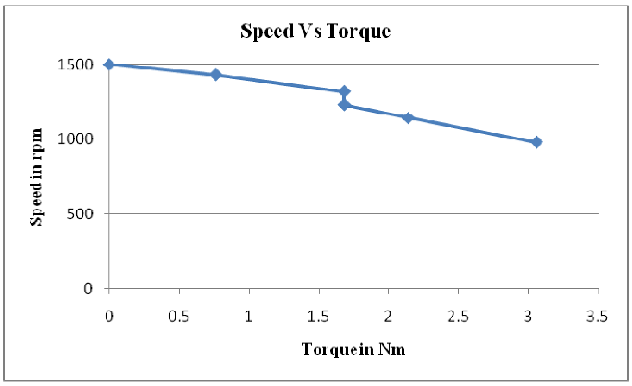

Figure 8. *Speed Vs Torque for DC Shunt motor after nano coating.*

Table 2. *Load test on DC shunt motor after nano coating.*

S. No	Voltage (V)	Current (A) Armature Current (A)	Field Current (A)	Spring Balance Reading S_1	Spring Balance Reading S_2	Input Power in Watts	Output Power in Watts	Torque in N-m	Efficiency in %
1	220	0.3	0.34	0	0	140.8	0	00	0
2	219	0.8	0.34	2	3	249.7	114.6	0.77	45.9
3	218	1.1	0.34	2	4.2	313.9	232.4	1.7	74.0
4	218	1.3	0.34	3	5.2	357.5	216.5	1.7	60.6
5	217	1.6	0.34	3	5.8	421.0	256.8	2.14	61.0
6	217	2.1	0.34	3	7	529.2	314.0	3.06	61.6

The maximum efficiency of the DC shunt motor before nano coating was 69.2%. The maximum efficiency obtained from the DC shunt motor after the nano coating was 74%. The maximum efficiency of the DC shunt motor was improved by 4.8% by coating the windings of the motor with the enamel filled with nano SiO_2.

3.2. Heat Run Test on DC Shunt Motor

Heat run test was conducted on the DC Shunt motor to find the thermal withstanding capacity of the motor. The readings were shown in the table 3. The thermal withstanding capacity of the DC shunt motor was improved by coating the windings of the motor with the enamel filled with nano SiO_2. The maximum temperature of the DC shunt motor before nano coating was 55.5□ C. The maximum temperature of the DC shunt motor after nano coating was 49.5□ C. The maximum temperature of the DC shunt motor was reduced by 10.81% by coating the windings of the motor with the enamel filled with nano SiO_2. Figure 9 shows the comparison of temperature of DC shunt motor before and after nano coating.

Table 3. *Comparison of temperature of DC shunt motor before and after nano coating.*

Time in min	Normal Motor Temperature in ℃	Nano coated Motor Temperature in ℃
2	44	42.5
4	46	43
6	48	43.5
8	48	44
10	48	44.5
12	49	45
14	50	45.5
16	50	45.5
18	51	46
20	51	46.5
22	52	47
24	52	47.5
26	53	48
28	54	48.5
30	55.5	49.5

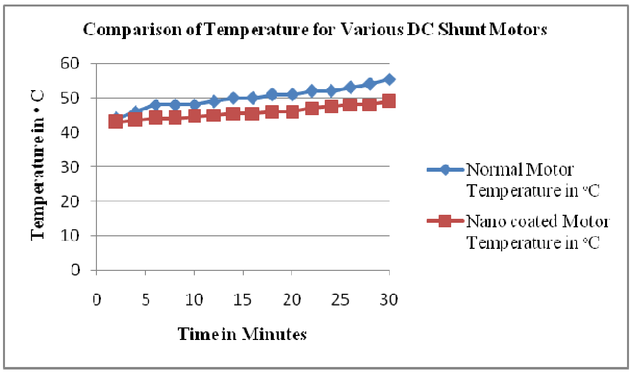

Figure 9. *Comparison of temperature of DC shunt motor before and after nano coating.*

4. Conclusion

It was observed that the performance was improved by adding the nano fillers to the enamel used for the coatings of the winding used in DC shunt motor. The life time was also improved due to the reduced maximum temperature rise of the motors after the nano coatings. The efficiency was improved due to the reduction of losses of the motor. The thermal withstanding capacity was improved due to the fall in the maximum temperature rise of the windings after the nano coating. The maximum efficiency of the DC shunt motor was improved by 4.8% by coating the windings of the motor with the enamel filled with nano SiO_2. The maximum temperature of the DC shunt motor was reduced by 10.81% by coating the windings of the motor with the enamel filled with nano SiO_2. Hence these shunt motor fed drives were called as Energy efficient DC Shunt motor fed drives. In future different nano fillers can be used with the enamel to improve the performance and life time of the various motors.

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