Electrical and Mechanical Modeling of Current Carrying Metallic Filaments in Rotational Magnetic Field

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Abstract
In recent years, applications of conductive fibers in textile products are widely developed especially in E-textile and smart clothing .considering the properties of conductive fibers ,the conductive yarn production systems is going to evaluated. In this paper the novel method to interlacing and false twisting the conductive filament on the base of rotational magnetic field is studied and examined. At first the rotational torque of single phase induction motor is analyzed. Then by using conductive filaments instead of induction rotor the force on filaments is studied and modeled by using finite element method. At last, in accordance with the modeling and theoretical analysis, a prototype of the proposed system is designed and tested. The experimental results prove the capability of the method to false twisting conductive filaments. The proposed method can be employed as a kernel to reach a texturing system for conductive filaments.

Keywords: Conductive Filaments, False Twisting, Rotational Magnetic Field, Single phase induction motor, Modeling

1. Introduction
In recent years, applications of conductive yarns in textile products are widely developed especially in electronic and smart clothing. Combinations of textile structures that are lightweight, flexible, strong, and conformable with electronics have aroused keen interest from many disciplines. With technological innovations appearing in both textile and electronics, integration of these has started giving benefits. Innovations like electrical blankets and heating jackets, wearable electronics, textile based antennas, life-shirts, wearable music players, and smart shirts, just to name a few.
For this purpose at least a part of the clothing fabric should to able to transfer electronic current. To achieve this property blew methods are used to produce the conductive fabric.
1) Coating of fibers with conductive polymers or metals, and make yarn from this kind of fiber and use the conductive produced yarn in the fabric.
2) Use of continuous fibers that are completely made of conductive materials (conductive filament). And make yarn from this kind of fiber lonely or blend with non-conductive fibers and use the conductive produced yarn in the fabric.
3) Spinning the conductive polymers and texturized it and use it in the fabric.
4) Use conductive print on the fabric.
The Last method is the simplest and cheapest and also has least durability against washing and flexibility .in other methods at first the conductive fibers spin then weave in the fabric structure. In this research present and modeled a novel method to false twisting and interlacing the conductive fibers which seems the principle of this research can be used in false twister in conductive polymer filaments texturizing process or as interlacing system to interlace conductive filaments together(lonely or blend with non-conductive fibers) to make conductive yarn.
In the first study[1,2]Regarding the conductivity of filaments and the effect of magnetic field on a wire with electrical current, the principle of an induction squirrel cage electro-machine is used for this propose. Therefore a texturizing box was designed and the magnetic force on conductive filament and the behavior of filament were modeled by using finite element method. In the next research [3] the possibility of interlacing current-carrying conductive filaments in a rotational permanent magnetic field was described. The work contains two parts. Firstly, the effect of magnetic forces on current-carrying conductive filaments in a rotational permanent magnetic field was theoretically studied. And the behavior of a filament under magnetic forces was mechanically analyzed. Secondly, in accordance with the theoretical analysis, a

prototype of the proposed system was designed and tested. The experimental results prove the capability of the method to interlace conductive filaments. In continues [4] regarding the achieved result, the single phase run capacitor induction motor stator was used instead of a rotational permanent magnetic field (which should be rotated mechanically) and the effect of product magnetic field was studied and examined .in this paper the current carrying metallic filaments behavior in rotational magnetic field cause of single phase run capacitor induction motor stator is modeled mechanically and electrically.

2. Methodology

Most small power (generally below 2 kW) induction machines have to operate with single-phase a.c. power supplies that are readily available in homes, and remote rural areas. for constant speed applications (the most frequent situation), the induction motors are fed directly from the available single-phase a.c. power grids. In this sense, it's called single phase induction motors. To be self-starting, the induction machine needs a traveling field at zero speed. This in turn implies the presence of two windings in the stator, while the rotor has a standard squirrel cage. The first winding is called the main winding while the second winding is called auxiliary winding as shown in Fig.1.

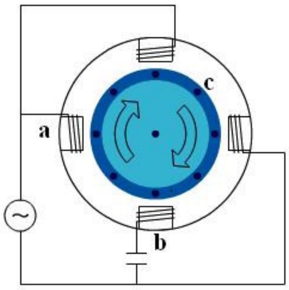

Figure 1: The schematic of Run Capacitor single phase induction motor[4]
a) Main winding b) auxiliary winding c) rotational rotor

As it's observed rotational rotor is the cause of phase differences in stator poles which can be make the rotational magnetic field. By replacing the rotor with conductive filaments it seems that filaments should be twisted each other [5]which illustrated in Fig.2 the diameter of filaments are too smaller than rotor and it makes wide air space between Filaments and stator poles which extremely decrease the induct current in filament. To overcome this matter the dc current is used in filaments.

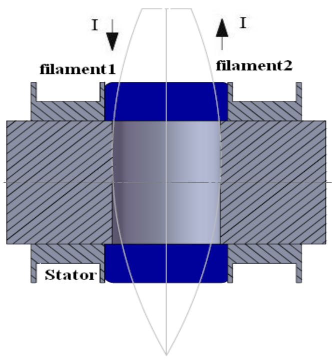

Figure 2: The schematic of false twisting zone

As it's clear in Fig. 2 the conductive filaments, which are carrying opposite currents, are fed between the rotational field which produce by Run Capacitor single phase induction stator. The forces induced in the filaments are:

- Magnetic force between two current-carrying conductive filaments.
- Magnetic force between current-carrying conductive filaments and rotational magnetic field.
- Magnetic force produced by the interaction of induced current from the back electro-motive force in a conductive filament by a rotating magnetic.

3. Laboratory Set-Up and Experimental Results

A Suitable single phase run-capacitor induction motor is used to make rotational magnetic field .the motor properties are illustrated in Table 1.

Table 1: Single phase run-capacitor induction motor properties

Voltage	220v
Power	240w
Frequency(ω)	50Hz
Main winding resistant (Rm)	62 ohm
Auxiliary winding resistant(*Ra)*	62 ohm
Main winding turns(Nm)	900
auxiliary winding turns(Na)	900
Capacitor	270VAC- 6MFD
Inner stator diameter	20mm
Rotor diameter	19mm

The laboratory set-up is shown in Fig.4.as it's observed the filaments are statically fed to the rotational magnetic field zone, and the ends of filaments are connected together and fixed. the filament length's are equal to the stator thickness. the current of filaments can be adjusted up to 3A.for simplification and comparing the experimental to the theory just two filaments used to fed in rotational field. the motor voltage decrease to 110v cause of stator heating .therefore to dynamical feeding it is necessary to design a cooling system for stator frame to avoid burning the stator winding. To get the result the filaments current and the motor started at the same time and the effects on the filaments appear less than one second, increasing the testing time doesn't influence on result anymore. The conductive filaments properties which is used for experiments is illustrated in Table 2.

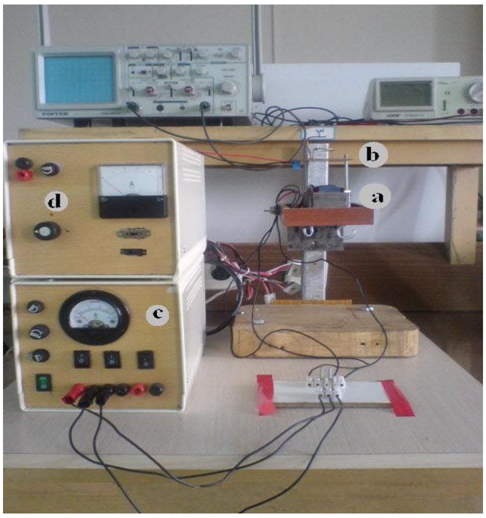

Figure 3: The laboratory set-up[4]: a) single phase run-capacitor induction stator b) feeding part c) Single phase run-capacitor induction driver d) filament current controller

the filaments contact point is fixed during false twisting and the filament is under tension of their weight . The results are demonstrated in Fig.4.in first look it seems that the completely filaments get real twisted .but by pushing the contact point two filament will be separated .however if the number of filaments increase separating by this way is not possible cause of filaments interlacing.

Table 2: Properties of conductive filaments

Material	copper
Conductivity	56,000,000 S/m
Relative Permeability	1
Diameter	70 μm
Density	8.96gr/cm^3
Shearing load	95cN
Tensile strength	0.24 GP
Modules	5.32 N/tex
Cross section	circular

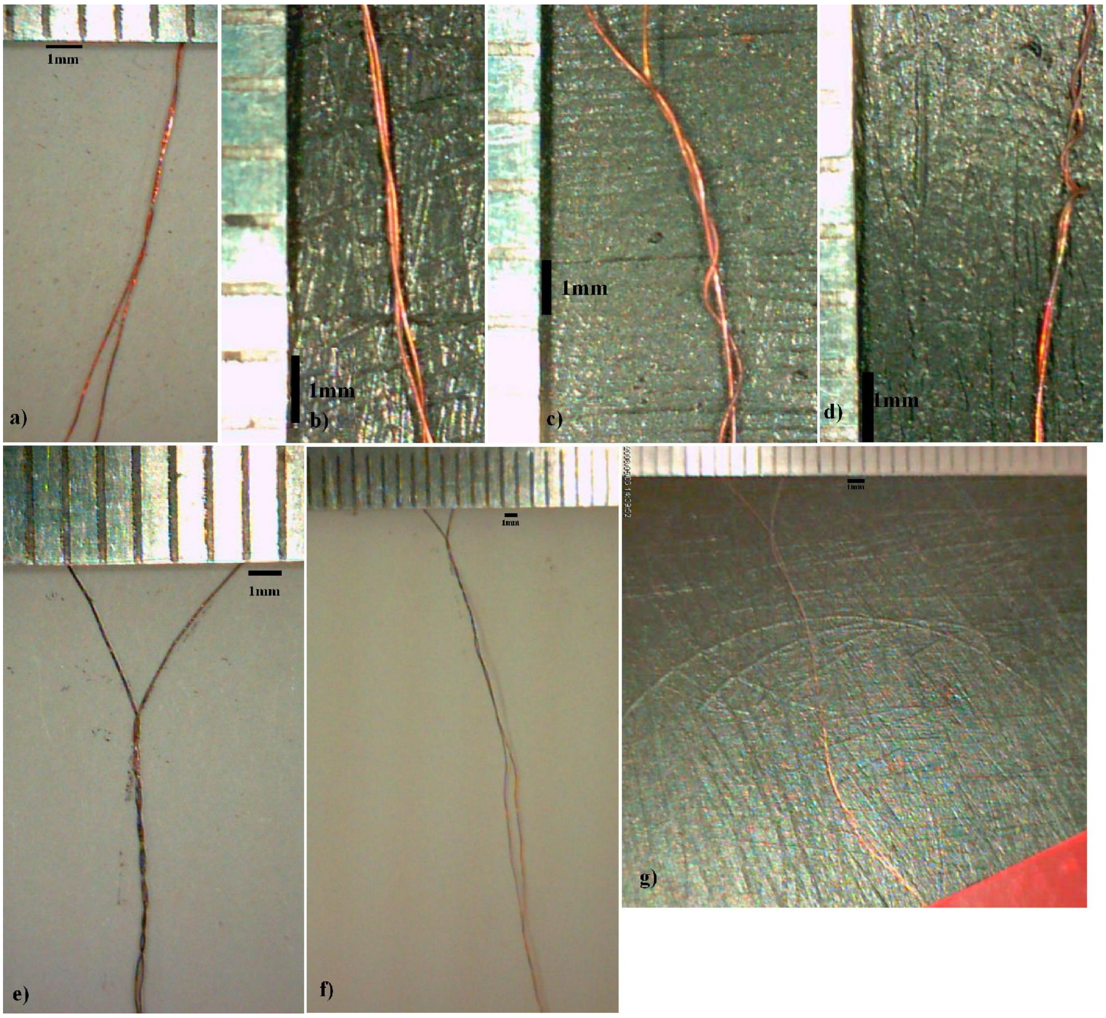

Figure 4: The result of false twisting of two current-carrying conductive filaments by using rotational magnetic field

4. Modeling

To study the force on conductive filaments in rotational magnetic field the magnetic field density of laboratory set-up single phase stator is modeled by using MaxwellVer2.8 software which is work base on finite element method. As it's illustrated in Fig.5 the result shows that the magnetic field density distribution in inner stator space is not uniform.

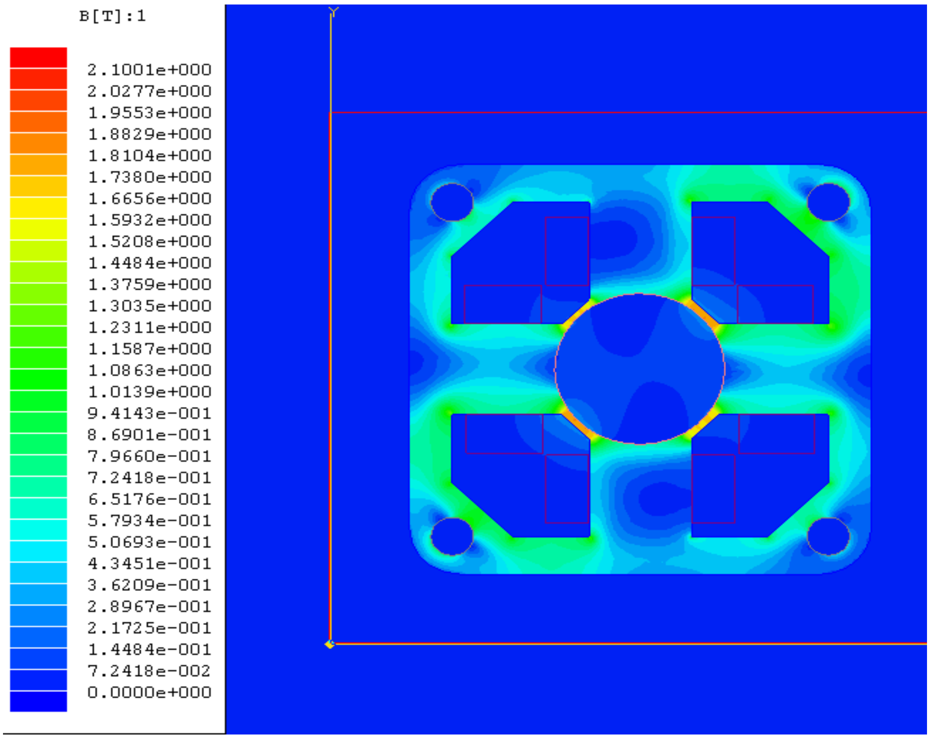

Figure 5: Magnetic field density distribution in inner stator space

In Fig.6 the elector-magnetic force cause of rotational field in middle and inside of the stator poles is shown.

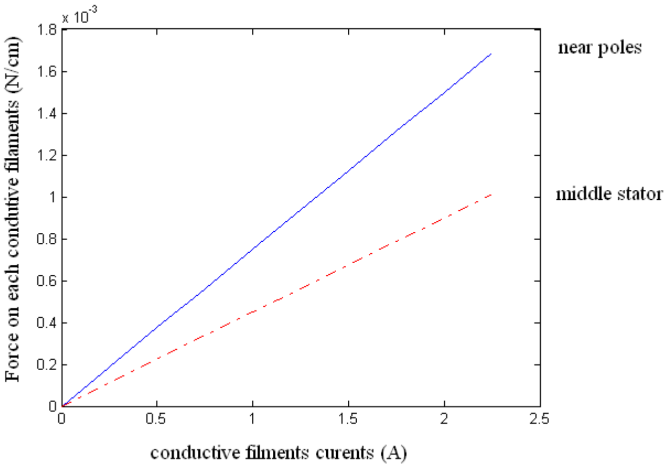

Figure 6: Electro-magnetic force cause of rotational field

Then to determination the conductive filaments behavior under electro-magnetic force a simple mechanical modeling which illustrated in Fig.7 is designed.

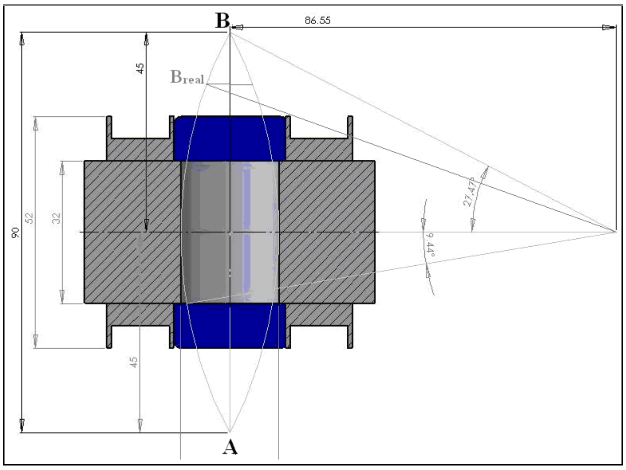

Figure 7: Mechanical modeling of conductive filaments behavior in rotational magnetic field

For simplicity:
-the weight of conductive filaments is ignored
-conductive filaments are placed in two dimensional plane
- conductive filaments are shaped in arc of circle in stator.
-assume model has symmetry around the horizontal axis.
-electro-magnetic force enter on conductive filaments plane normally
- electro-magnetic force assumed to be uniform in stator
-both ends of filaments assume as a fix bearing
The result of torsion and bending of conductive filaments are shown in Fig.8 andFig.9

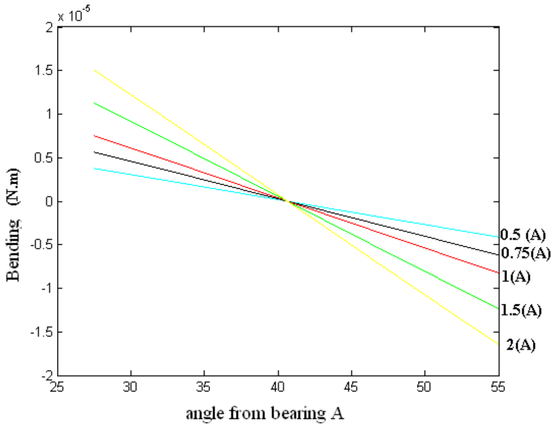

Figure 8: Conductive filaments bending cause of electro-magnetic force in different filaments current

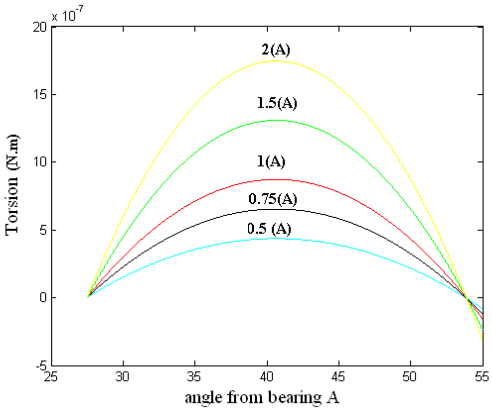

Figure 9: Conductive filaments torsion cause of electro-magnetic force in different filaments current

bending and torsion of conductive filaments under electro-magnetic field are compare torsion and bending needed to plastic deformation. result shows that the interlacing in rotational magnetic field is cause of filaments bending behavior and the magnetic force is not enough strong to make torsion in filaments.

5. Conclusions

The electrical analysis of the developed method demonstrated its feasibility to interlace metallic filaments in the form of false twisted by rotational electro-magnetic fields. The interlaced filaments produced by the invented twisting box, prove the capability of the applied technique. In this work the rotational magnetic force of single phase induction stator is electrically modeled. In next base of magnetic force modeling, the filaments interlacing in stator space are simulated**.** The result shows that the interlacing in rotational magnetic field is cause of filaments bending behavior and the magnetic force is not enough strong to make torsion in filaments.

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