Abstract— Inverters are commonly used in various motor applications. This greatly increases the pulse endurance stress of the wire due to switching transience. A new type of wire with three layers of insulation material has been developed by BCwire® to overcome the aforementioned problem. This paper will give a brief introduction of the wire, details test procedure, preliminary results with compared with traditional insulation wires which are commonly used nowadays. The aim of this paper is to use better understanding of this new type of wire and give enough information for wire selection.

I. NOMENCLATURE

Wire of different insulation materials will be introduced here:

The wire with name PE(I)/PAI is with two insulation layers that Polyamideimide in the outer layer and with a Polyester in the inner layer coat on the conductor. NEMA MW35.

While the new wire developed by BCwire® with name MPE/CR/PAI is with three insulation layers. The outer layer is Polyamideimide. The middle is a Corona Resistant Enamel. The inner layer is Modify Polyester coated on the conductor.

Another new wire also developed by BCwire® with name MPE/PAI-CR is with two insulation layers that Polyamideimide in the outer layer and with a Corona Resistant Enamel in the inner layer of Modify Polyester coat on the conductor. With new nanotechnology the MPE/PAI-CR, the outerlayer with corona resistant enamel with particle size distribution D[v,0.10] (microns)=0.09, the wire flex properties (20% snap) 3x compare the old design 20% 5X has been much improved.

The aforementioned two wires by BCwire® is feathered by the Nanotechnology in the Basecoat or Topcoat can substitutable for MW35 or MW37 & most MEMA standard.

II. INTRODUCTION

Insulation of copper wire is an important process in transformer, inductor and motor design [1-2]. In the past, there are a number of studies in the work including using enamel, corona-resistance enamels, mica tapes, and fuses glass and PET fibers over enamels has been used [3]. The insulation tapes for layer insulation includes corona-resistant enamel, corona resistance enamel, polyester and epoxy-bonded mica, silicone tapes and film-backed mica tapes are used. Corona is an ionization of gas that occurs in between spaces of the insulation material (or namely ‘voids’) when the stress of high voltage gradient exists, that also cause electron discharge. The insulation material will eventually breakdown by the bombardment of ions and case electrical failure.
Fig 3: Void in Magnet wires

Usually using layers of tapes or even gas [4] is very inconvenient and increase the overall size, and cost. Using internal insulation of the wire will reduce the external insulation and cost.

Several types of wire in size AWG18 with the same thickness of insulation have been tested. They are namely:

A.  PE(I)/PAI (MW35) Magnet wire in Single coat
B.  PE(I)/PAI (MW35) Magnet wire in Heavy coat
C.  MPE/CR/PAI   CORONA-R™ Magnet Wire
D.  MPE/PAI-CR—CORONA-R™ Magnet Wire

Voltage and Pulse Endurance tests were performed on above wires. Details description will be explained in the coming sections.

III. WIRE TEST

The Voltage and Pulse Endurance tests are aimed to simulate the situation in realistic application in order to study the wire performance. In this case the voltage test is used to simulate the wire used in traditional line frequency application, while the pulse endurance test is to give better simulation of inverter feeding motor application. The test temperature was also set to a defined possible rise region to make the test closer to the actual environment.

A.  Comparison of Electrical Stress Region

Fig 4: The test condition with respect to the 3-D coordination of voltage, dv/dt and frequency

The above diagram demonstrate the electrical stress region on varies application. The test we conducted is by the suggestion of the existing standards with selection of the extreme point of this diagram.

B.  Pulse Endurance Tester Schematic

Fig 5: H-bridge circuit generating the pulse endurance test waveform

In order to generate a 2000Vpk-pk waveform required for the pulse endurance test, the circuit as shown in Fig 3 has been built to make high speed switching waveform. Fast gate driver was used and the full bridge transformer has been specially built with alternative layer of winding in order to decrease the leakage induction thus enhance the switching dV/dt rate.

Fig 6: Prototype circuit for the endurance test
C. Pulse Endurance Test Conditions

The pulse endurance test specifications as follow:
- The test temperature is 150±5°C, test voltage will be applied when oven reaching target temperature
- test voltage: 2000Vpk-pk
- fall time and rise time: 635ns and 425ns respectively
- trip current: 50mA by fuse
- The wire samples are prepared according to standard IEC-851-5

D. Pulse Endurance Test Results

This test voltage is used to put in twisted pair of wire with a 50mA fuse in series. The breakdown of fuse indicate the insulation breakdown of wire and spark occurred.

The results of the pulse endurance test. The MPE/PAI-CR wire are still going on testing and better performance were expected.
E. Voltage Endurance Results

2000V r.m.s at 50Hz is applied to twisted wire specified by IEC-851-5. This voltage is generated by step up transformer.

![Voltage Endurance test results](image)

Fig 12: Results of the voltage endurance test, two CORONA-R™ wires are still on test on 2006-10-31

F. Electrical Properties Comparison

Table 1: Result of the voltage endurance test

<table>
<thead>
<tr>
<th>Wire Type</th>
<th>MPE/CR</th>
<th>MPE/PAI</th>
<th>18 H</th>
<th>18 S</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 V rms, @ 150 C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse Endurance Index</td>
<td>34.4</td>
<td>#13.3</td>
<td>2.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

* The voltage endurance test are still undergoing at 2006-10-31, the figure above only give a estimated value
# The MPE/PAI-CR wire are still going on testing and better performance were expected

G. MPE/CR/PAI wire applications:

The pulse and voltage endurance test results enable us the measures on now to replace the existing design with the new generation wire. Below are some working examples:

**VDT - Open Ventilated Dry Type Transformers**

![Fig 13: A typical high voltage transformer using open ventilation](image)

VDT – Open Ventilated Dry Type transformer wound with CORONA-R™ wire. The use of CORONA-R™ magnet wire gives higher resistant to these Electrical Stresses and permits design changes that result in improved winding efficiencies. For example, the strand insulation will be designed for the system, including the resin/varnish used for the coil consolidation. Ionization damage can occur in voids, surface, corners, and areas where the field is divergent.

**HVT – High Voltage Transformer**

![Fig 14: HV transformer using Silicone rubber wire](image)

This type of transformer design need to have a filament wire in between the Primary and Secondary coil. This wire need to have high dielectric breakdown (over 12KV) and with good corona resistance. Right now, HVT manufacturer uses Silicone Rubber Wire and with Mica Sheet to protect for the Corona with very high material cost. With new developed CORONA-R™ wire, they can use our CORONA-R™ wire to replace the silicone rubber wire and reduce the Mica sheet thickness.

![Fig 15: Use as secondary wire](image)

**IV. CONCLUSION**

The endurance test for the copper wire has been examined. The new copper wire is insulated by 3 layers of MPE/CR/PAI that is namely BCwire®. Experimental test has confirmed that the endurance is superior as compared to the conventional single and double insulation wire. The new wire can be sued for high voltage transformer and the insulation material or tape can be reduced. IT will also improved the overall coupling of the transformer and improve the efficiency.
V. REFERENCES


VI. ACKNOWLEDGEMENT

The author gratefully acknowledge the financial support of the Hong Kong Polytechnic University and P Leo & Co. Ltd.

VII. BIOGRAPHIES

BCwire® is the registered trade mark of P. Leo & Co., (B.C.) Ltd.

CORONA-R™ is the trade name of P. Leo & Co., (B.C.) Ltd.