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Comparison of different types of coil in Electromagnetic terminal - wire crimping process: Numerical and experimental analysis

Ashish Kumar Rajak*, Sachin D. Kore

Department of Mechanical Engineering, Indian Institute of Technology, Guwahati, 781 039, India

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ABSTRACT

Electromagnetic (EM) terminal - wire crimping process, is a non-conventional high-speed crimping process using the energy density of a pulsed EM field. A subsequent coupled field analysis of EM terminal - wire crimping was performed using finite element method in LS-Dyna™. Simulations were carried out on aluminum terminal over aluminum wire strands using three different types of coil cross-section (trapezoidal, rectangular and circular geometry) with five turns helical coil. For the comparison cross-section (CS) area, and coil length was kept constant. The results obtained from the comparison were utilized for the fabrication of the coil. Validation of results was carried out using radial deformation and contact length between wire strands and terminal. The simulation predictions agree well with the experimental results. Some other important test results like electrical contact resistance, hardness, and pullout test were also carried out. Results show that the trapezoidal CS was the optimum geometry among the rectangular CS and the circular CS, which also shows that change in geometry, can enhance the crimping process in many parameters, which are discussed in this paper. The new outcomes of research would be helpful in determining the optimum geometry for the helical coils in similar applications.

1. Introduction

Terminal - wire crimping is a process where the cable is stripped, and the strands of wire are placed into a metal terminal. The terminal is then compressed around the wire strands to ensure good electrical connectivity and mechanical strength across joints. Crimping of wires to achieve a secure joint is one of the most critical challenges for electricity boards, automobiles, aviation, satellite and communication [1]. Modern automobiles contain several thousand crimp joints. Crimped terminals are exposed to various types of vibrations, different electrical environment, temperature gradient and the least concerned area even though most of the 60% electrical failures takes place in connector junctions [2,3]. Compression using conventional crimping tool deteriorates the material due to relaxation or partial release, which results in increasing resistivity and considerable losses in the wiring system. Crimping of larger diameter terminals is always a problem due to spring back of terminal when carried out using conventional crimping tool. Less strength of joints, poor surface finish, and cracks over the terminal is still a major hurdle in cable industries [4].

In comparison to other widely used joining techniques, like conventional mechanical crimping, electromagnetic crimping (EMC) shows interesting characteristics which result in uniform forming pressure distribution [5]. The advantage of EM process including no contact, low mould cost, no lubrication and less spring back making it more suitable for materials that are difficult to form [6]. To overcome these problems caused by conventional terminal – wire crimping process a new contactless method has been proposed in this work using EM process.

Initial work was carried out on a comparison of EM terminal - wire crimping process to conventional crimping process [1]. This paper deals with the numerical simulation, which is carried out using EM module of LS-Dyna™ software and data obtained from the experimental work. Numerical simulations were carried out on three different types of helical coils with different cross-section (CS) geometry keeping the CS area constant. For the comparison, number of turns and the total length of coil remains same so that the total inductance of the coil remains same in all the three cases. Results of the simulations were used to fabricate the coil for carrying out the experiments. The research work attempts to provide advantages in uniform terminal deformation, minimum electrical contact resistance, increased hardness number and high pullout strength.

2. Theoretical background: EM terminal - wire crimping process

A high-energy system that can discharge its energy within a very short period is required for EMC process. The system consists of a capacitor bank, which is connected, in series with the coil as shown in

* Corresponding author.
E-mail addresses: a.rajak@iitg.ac.in (A.K. Rajak), sdk@iitg.ac.in (S.D. Kore).

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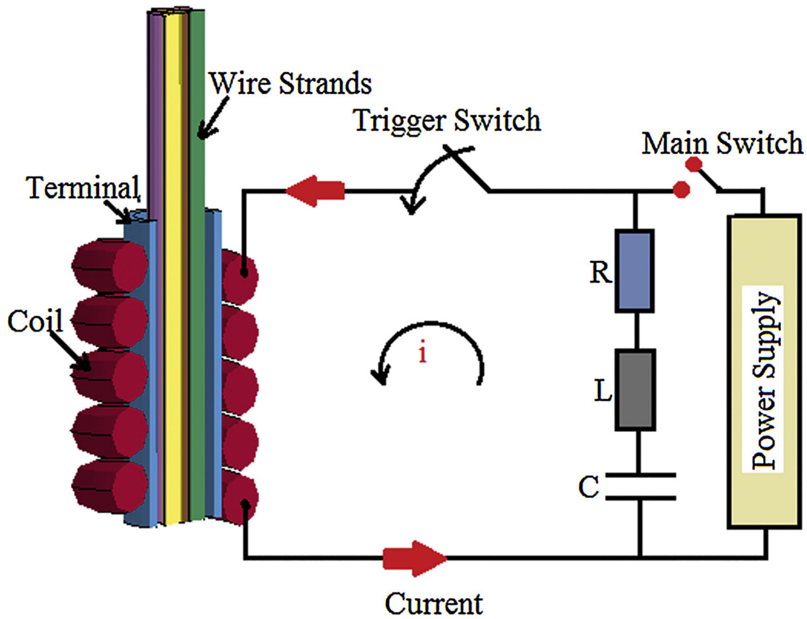

Fig. 1. Circuit diagram of EM wire crimping process.

Fig. 1. The circuit parameters are selected such that it operates in an overdamped condition [7]. A transient magnetic field is produced by passing a sinusoidal damped electric current through the coil. The transient magnetic field produced by the coil induces an eddy current in the terminal (workpiece). The magnetic field of the terminal is of opposite nature as produced by the coil. The opposing Lorentz forces between the two magnetic fields cause the acceleration of the terminal away from each other. Depending on the geometrical configuration and process parameter, crimp joint is obtained.

3. Numerical analysis

Coil with different CS was modelled and simulated in LS-Dyna™. In the numerical simulation, the EM and mechanical models were established respectively. The LS-Dyna™ software uses a link between EM field and mechanical for finite element modelling of EM terminal - wire crimping process. During the solution, the first analysis solves for the EM loading on the conductor using EM field analysis. Then second analysis uses mechanical solver to solve the dynamic response of the terminal using the result from the first analysis. The coupling between the EM and mechanical solver was used in carrying out simulations [8].

3.1. Modelling process

The explicit general contact algorithm was used for the analysis. In the general contact, the software automatically defines all the surfaces

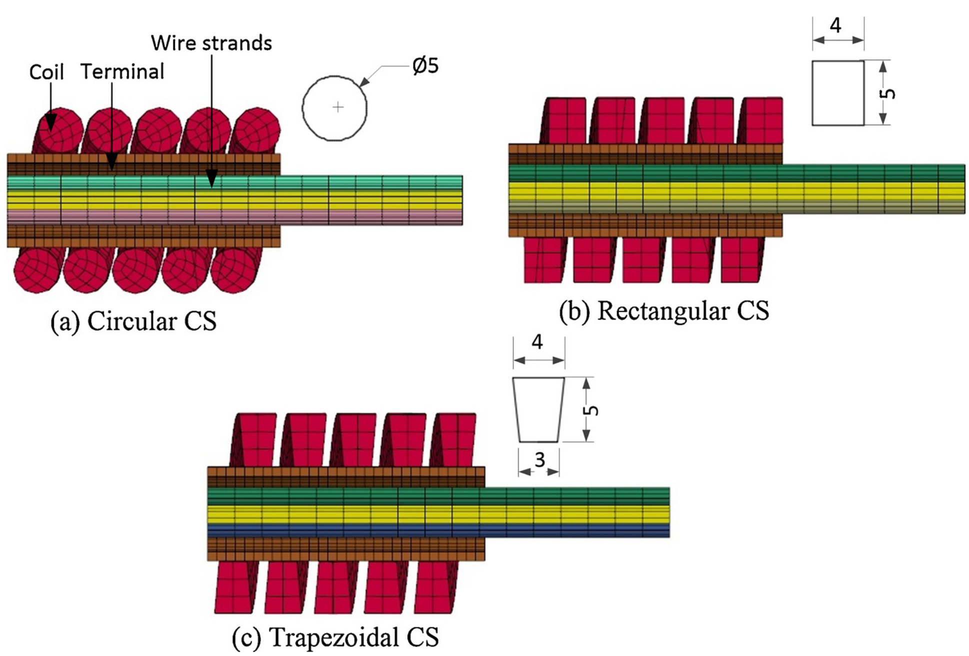

Fig. 2. Sectional CS view of the assembly with different coil geometry with the constant area, number of turns and length (Dimension in mm).