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DOCTORAL THESIS ABSTRACT

THEORETICAL AND EXPERIMENTAL CONTRIBUTIONS ON THE OPTIMIZATION OF THE PARAMETERS OF MULTI-WIRE COPPER CONDUCTORS

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Cost-effective cable manufacturing is a highly topical subject for manufacturers in the industry.

The literature research carried out reveals numerous concerns for the optimisation of the construction of electrical cables, from the research and design phase of new products, the transfer of innovative solutions into the production process and the development of quality management systems to ensure adequate product quality.

Although research on optimising cable mass is presented in the literature, it is carried out either for high- and medium-voltage cables, or for automotive cables. The mathematical modelling of the optimal number of wires of electrical cables of flexibility class 5 for household appliances and equipment, depending on mass and electrical resistance, is not studied in depth in the literature, and the method developed in this research is a scientific novelty.

The relevance of the study is supported by the experimental research carried out on a total of 35 cables, of 1.00 mm² cross-section class 5 flexible multi-wired copper conductor, each cable having 3 conductors, which were taken from seven international electrical cable companies.

Analyses of copper wire diameters and the number of wires used in the cross-section for each cable, correlated with the electrical characteristics, electrical resistance and conductivity, have shown that for the production of class 5 flexible multi-wired conductors, there is currently no method of optimising them to achieve the lowest possible mass that would allow manufacture at the lowest production cost, while ensuring that the electrical resistance of the conductors is below the values required by the standards. The optimisation method developed in this research is a scientific and practical novelty.

The optimisation method has been tested and validated in practice on a 1,00 mm^2 nominal cross-section conductor from Top Electro's current production, but it can be applied to all nominal cross-sections of class 5 multi-wired conductors.

The diagrams of electrical resistance depending on the wire diameter, for cables with a cross-section composed of 31 wires, show good accondance between the theoretical model developed and the results obtained in the experimental determination, with errors in the range $0\text{-}5\cdot10^{-2}$ Ω/km.

The conclusion is, that the practical implementation of the method confirmed the copper economy in the manufacture of conductors and the compliance of the electrical resistance within the limits required by the standard.

Quality assurance of the manufacture of new multi-wired conductors requires the application of control procedures during manufacture, analysis of cable non-conformities and their causes in order to propose measures to improve manufacturing. In an exhaustive survey of the manufacturing processes, the most frequently occurring non-conformities in manufacturing were identified, and through the study with the Pareto chart, in descending order of frequency of occurrence, are: cable diameter too small (43,03%), cable with burnt insulation surface (30,30%), cable appearance without gloss (18,18%), sheath cut (3,03%). The study of the causes of these non-conformities with the help of the cause-effect diagram allowed the formulation of the main corrective measures to eliminate them, which consist of thematic training of employees, development of infrastructure and provision of appropriate devices, improvement of machinery maintenance procedures, revision of product handling-transport-storage procedures.

Certification of compliance of 31-wire class 5 flexible multi-wire conductors of 1,00 mm² cross-section with the provisions of the standard IEC 60335 requires checks in terms of resistance to mechanical tensile and torsional stresses. The efficiency of these tests can be ensured by the use of modern digital test stands, such as the one designed and implemented in this research, which allows testing without transferring samples, reducing the total test time, reducing human errors, visualizing the effects of tensile stress on the copper conductor inside the cables, digital recording of the results with possibilities for visualization and further processing.

Mechanical tests on 20 H05VV-F 3G1,00 cords have shown that they comply with IEC 60335. The cable elongations in the tensile test range from 1,51 -1,54 mm and in the torsion test from 2,93 - 2,98 mm.

The manufacture of class 5 flexible cables with a cross-section of 31 wires of 1,00 mm² has been attested by the analysis report and the certificate of approval of the place of manufacture issued by the VDE certification body.

The originality of the thesis results from the interdisciplinary context of the studies carried out, with numerous scientific contributions of **technological, economic and managerial** importance among which the following stand out:

- I have experimentally analysed a total of 35 cables from 7 manufacturers;
- I have developed an innovative new method for determining the diameter and number of wires in class 5 flexible multi-wire conductors, which facilitates the design of new optimised conductor structures with low masses and electrical resistances required by standards;
- I have validated in practice the optimization methodology of multi-wire conductors of class 5 flexibility by implementing it at the Top Electro company in Targu Mures in the manufacturing processes of cables with 31 wires, which leads to the reduction of technological consumption of copper, a costly raw material;
- I have identified in an exhaustive research of manufacturing processes, the non-conformities that occur most frequently in manufacturing, and through the study with the help of the Pareto diagram, I have formulated the main corrective measures that lead to decrease the probability of occurrence of non-conformities;
- With the help of the cause-effect diagram I have analysed the causes of the identified non-conformities that lead to increased economic efficiency of the conductor manufacturing processes;
- I have developed a suitable laboratory infrastructure, by designing and physical achievement of a digital equipment with data acquisition board for tensile and torsional stress testing, which allows increasing the possibilities of testing the manufactured cables by digitizing the process, and visualizing the test results, as well as reducing the time of testing the samples in the laboratory;
- I have certified the product multi-wire conductor of class 5 flexibility with 31 wires to the VDE body.