S. SREMAC, P. GLADOVIĆ, M. ĐELOŠEVIĆ, B. MATIĆ, A. MATIĆ

ISSN 0543-5846
METABK 53(4) 693-696 (2014)
UDC – UDK 678.2.004.3:621.315.2=111

DEVELOPMENT OF POLYMER PACKAGING FOR POWER CABLE

Received – Prispjelo: 2013-11-29
Accepted – Prihvaćeno: 2014-04-20
Preliminary Note – Prethodno priopćenje

This paper discusses the issues of product design and the procedure of developing polymer packaging as one of the most important engineering tasks. For the purpose of packing power cables a polymer packaging has been designed in the form of drum. Packaging and many other consumer products are largely produced using polymeric materials due to many positive features. High Density Polyethylene is the type of polyethylene proposed for packaging purposes due to its low degree of branching and strong intermolecular forces. Transport and storage processes were automated based on the radio-frequency identification technology. The proposed system is flexible in terms of its possibility of accepting and processing different types of cables and other products.

Key words: polymers, amballage, cable, Radio Frequency Identification (RFID)

INTRODUCTION

In modern business conditions the procedure of product development is market oriented, since it must include all functional and market values of the product, including elements that determine its design. In this respect, the choice of material for the production of suitable products is an important factor in their manufacturing process. Product development can be directed in two main directions: developing new or improving existing products. The idea of adopting a new product is justified by market demands, i.e. whether it is a novelty on the market, socially useful, highly functional, and aesthetically and environmentally friendly with its competitive price.

Developing packaging and product's design are the most important engineering tasks. One of the approaches involves macroscopic and microscopic analysis of materials for new product development (tools for developing the packaging), allowing insight into numerous pieces of information, including: mechanism, dimensions, mass, shape, etc [1].

Namely, top-quality packaging is one of the significant product-finalization elements facilitating their placement in the market in the global packaging market reaches approximately $ 620 billion, of which one-third accounts for polymer-based packaging. The 185 million tons of annually produced and widely applicable polymer materials is the most contributed by different types of polyethylene (39 %), polypropylenes (25 %) and polyvinyl chlorides (19 %) [2]. Due to their quality and price, the increase in consumption of polymeric packaging materials is expected to show a significant growth in future.

S. Sremac, P. Gladović, M. Đelošević, B. Matić, A. Matić, Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia.

Power cables

Power cables (PC) are conductors made of soft temper copper insulated with polyvinyl chloride (PVC) with three stranded wires (Figure 1). The space between the stranded wires and the PVC material is filled with a layer of unvulcanised elastic or plastic filler and a sheath. The sheath colour is typically black.

The PC is used for distributing the power through urban networks, industrial plants, and thermal and hydro power plants. It can be laid in cable ducts, enclosed areas in the soil with the use of additional protection.

The PC is packed in drums (Figure 2) which can accommodate cable of 500 m length. Cable length toler-

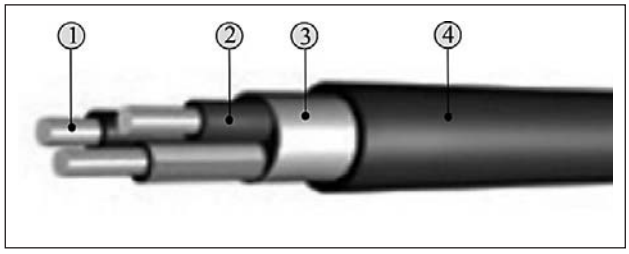

Figure 1 Product composition: 1 – Cu conductor, 2 – PVC insulation, 3 – unvulcanized tire filling and 4 – PVC sheath

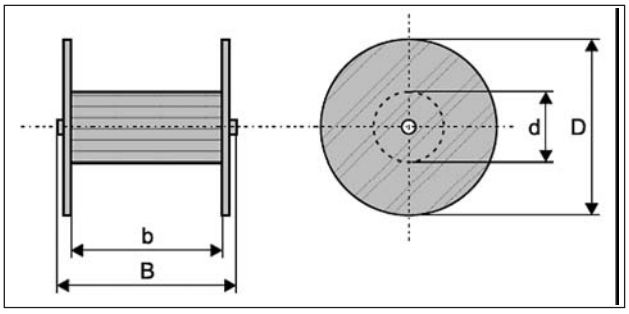

Figure 2 Design features of drums: B – drum width, b – traverse width, D – drum diameter and d – traverse diameter

ances when packed are ± 5 %. The internal drum diameter needs to be at least 20 times larger than the outer diameter of the cable, including the sheath.

PACKAGE DEVELOPMENT

Product materials

Polymers are macromolecular compounds formed by combining a large number of atoms – commonly carbon, hydrogen, oxygen and nitrogen atoms. Polymeric materials are polymers combined with some organic or inorganic compounds of small molecular mass (additives) in order to improve the properties and facilitate its processing and application. The production of packaging and many other consumer products is largely based on the use of the following polymeric materials: polyethylene PE – of low (LDPE) and high (HDPE) density, polypropylene (PP), homo and copolymers of styrene – polystyrene (PS), styrene acrylonitrile (SAN) and acrylonitrile butadiene styrene (ABS), polyvinyl chloride (PVC), polyvinylidene chloride (PVDC), polyamides (PA) and polyesters – polyethylene terephthalate (PET) and polycarbonate (PC) [3].

Common to all polymeric materials is that they have low density; they are difficult to dissolve, chemically inert and susceptible to decomposition under the influence of heat at relatively low temperatures. They are of very good technological properties, easy to mechanically shape with low consumption of work, energy and time. They do not require additional surface treatment or surface protection, while their products are coloured by adding dye concentrates. Their plasticity enables to create products of different shapes and properties with the use of a large number of processing methods.

The suggested material for making plastic packaging for the PC is polyethylene (PE). PE is a macromolecular product obtained by polymerization of ethylene. PE molecules have a flat structure with a certain amount of side chains. The content of crystalline phase depends on the degree of molecule branching. The higher the degree of molecule branching, the lower is the degree of crystalline. The specific weight of PE depends on the molecular weight, and the degree of crystalline and branching. HDPE (High Density Polyethylene) of density of 0.941 ÷ 0.960 g/cm3, and their re-granulates are types of polyethylene proposed for plastic drums. HDPE has a low degree of branching and strong intermolecular force, i.e. tensile strength. Branching is reduced by applying suitable catalysts and conditions during polymerization. HDPE has certain drawbacks (low impact strength and volatility under the influence of strong oxidants) that can be improved by introducing modifications and additives.

Packaging Design

For packaging the PC a drum-shaped polymeric packaging is designed. The material is HDPE, which is characterized by strong intermolecular force. Several types of drum-shaped polymer packaging for the PC were proposed: prefabricated drum with sharp edges, prefabricated drum with rounded edges and integrated drum with rounded edges (Figure 3).

a) b) c)

Figure 3 Types of drums for the PC: a) prefabricated – sharp edges, b) prefabricated – rounded edges and c) integrated – rounded edges

Based on the analysis of the proposed drum types, polymeric packaging has been selected with the following properties:

- it was designed according to the DIN 46395 standard;
- the packaging was made from HDPE with the possibility of recycling;
- fine finishes and colours were defined by the customer;
- adequate rigidity;
- prefabricated structure with the possibility of easy assembly/disassembly;
- joining parts with steel or aluminium fasteners;
- suitable for transporting and handling;
- weather resistant, standard and lower weight compared to wooden or metal drums;
- damaged parts are easy to replace.

For the purpose of transporting the PC a drum of following dimensions is constructed: B = 1040 mm, b = 900 mm, D = 1600 mm, and d = 800 mm. The maximum dynamic load of the designed plastic packaging is 3000 kg, while the weight of the drum itself is 240 kg. Dimensions of the drum can be adjusted during the production process to meet the customers' needs. Studies presented in [4] are important in the process of optimal structure designing. They showed that the oval hole in the packaging is suitable in terms of stability of the product, and savings in terms of material and weight.

On the outside of the drum there is a tag or panel attached indicating the following information: the name of the manufacturer or his trademark, code of the PC with factory number and the year of manufacturing, information on cable length, weight of the cable ready for delivery and its combined weight with the drum, standards according to which the cable is manufactured and tested, and the direction of rolling the drum for unwinding the cable.

A short-term storage of drums containing the PC in the open air is allowed. For long-term storage in the open air, the drum should be raised to a stand (it can be a wooden stand) and protected by an impermeable material.

The following are the positive properties of the proposed polymer packaging for the PC: low cost, very low density, high strength, low thermal and electrical conductivity, high chemical resistance, low absorption and insensitivity to moisture, non-toxicity, thermal stability and the possibility of being easily processed. Packaging made of the above polymers is resistant to temperature

changes between -40 ÷ 60 °C and is biologically non-degradable. One of the reasons for the application of these materials is that they are recyclable, preserving thereby natural reserves of raw materials. Polymer packaging is a very useful secondary raw material; by its further processing a large number of products for different purposes can be manufactured.

APPLICATION OF RFID TECHNOLOGY

Tendencies in improving packaging in terms of automation of logistic processes are directed towards the application of modern information technologies that provide significant capacity and high data-flow rate [5]. Automated systems for managing product flows provide companies with huge advantage over the competition (reduced costs, increased productivity, wider product range, and higher quality of services provided). Product identification is needed to be able to track its progress in the distribution chain; this requires planning of each stage of business process, controlling and monitoring the process, and improving business [6].

The development of information and communication technologies new opportunities have been provided for improving the transportation and storage processes, as well as the business operations [7, 8]. For these reasons, the Radio Frequency Identification (RFID) technology has been proposed for the identification of drums with PC. The application of RFID technology is the basis on which transportation and storage processes are automated, allowing daily task performance with minimum expenditure of time and human labour. It is one of the young commercial technologies, which has lately been much exploited and widely used [9, 10].

The proposed RFID system includes the following: tags in the form of discs with the possibility of introducing multiple changes to the data, handheld tag readers, antenna and appropriate software support.

For tagging the drum, a disc-tag has been proposed. The tag is situated in circular acrylic casing that protects it from external shocks. As an alternative to acrylic casing, polystyrene or epoxy resin is used. The tag is 50 mm in diameter and 2.1 mm thick, with an opening in its centre for the screw (5 mm in diameter) by which the tag is fixed to the drum. The proposed type of active tag can be read regardless of the orientation of the reader's antenna, it is equipped with its own power supply (battery) and it is possible to introduce changes to the product information. The operating temperature of the tag ranges from -40 ÷ 85 °C. The internal memory of the tag is 240 bits (for indicating the serial number of the tag) and 512 bits of user memory (for data entry on the product being tagged).

The proposed handheld reader is Motorola MC9090 – G, which has the capability of reading both RFID tags and bar codes. It allows for easy integration of the RFID technology in the supply chain management process. Wireless connectivity allows data to be available in real-time. The tag and the reader communicate at a frequency of 13.56 MHz according to the ISO15693 standard. The proposed type of reader is easy to use, enabling tags to be read quickly in various environmental conditions.

Each drum containing PC which comes to the receiving warehouse is equipped with a tag with the ability of introducing multiple changes to data. The tag is placed on the outside of the drum to avoid its damaging in case of stacking the drums on top of each other. It stores the following information: number of the work order, product ID number, basic information about the cable (cable type, cable cross-section, etc.), cable length on the drum, and the date and time when the cable was packaged. The process of receiving, storage and shipment of cables using RFID technology is shown in Figure 4.

When the tag comes to the reader's operation zone, it reads the basic information from the tag. Additional activities consist of recording on the tag the time of arrival to the warehouse, updating the company database and displaying the tag data in a list in the form of application. All activities are performed automatically. The only activity performed by man is positioning the handheld reader in the tag zone.

The process of product shipping begins when the sales clerk forwards the shipping order to the warehouse keeper. Based on the shipping order, the warehouse keeper prepares the goods for shipment to delivery. When a complete drum with a cable is shipped, the warehouse keeper compares the data read by the tag reader with the data contained in the order.

Shipping smaller quantities of cable is a rather complex task and requires a larger number of preparatory operations: measuring the cable, changing the data to the old drum's tag and loading the data into the new drum's tag. Upon the completion of measuring, the data on the old drum are updated, while the new drum is provided with a new tag if it is not already installed. When introducing changes to the data the following information are updated: number of order under which the change is carried out, the remaining cable length on the drum, and the date and time of introducing the change. The new drum to be shipped is provided with the following information: order number, product ID number, the basic properties of the cable, cable length for delivery, and the date and time of packaging.

Using the RFID technology for the purpose of packaging the PC provides with the following positive effects [11]:

- automatic product identification and tracking individual products,
- rationalization of operations in the transportation and storage processes (fast tag reading, the relatively large distance between the reader and the product tag, simultaneously reading multiple tags, etc.),
- reducing the overall cost of product distribution,
- reducing identification and data entry errors,
- it works in adverse weather conditions,
- faster delivery of goods to end-users, and
- reducing transportation-related damage, loss and theft of goods.

In addition, the RFID technology enables the availability of data on the number of stored drums, types of cables, length of cable on the drum and makes storage space easily searchable.

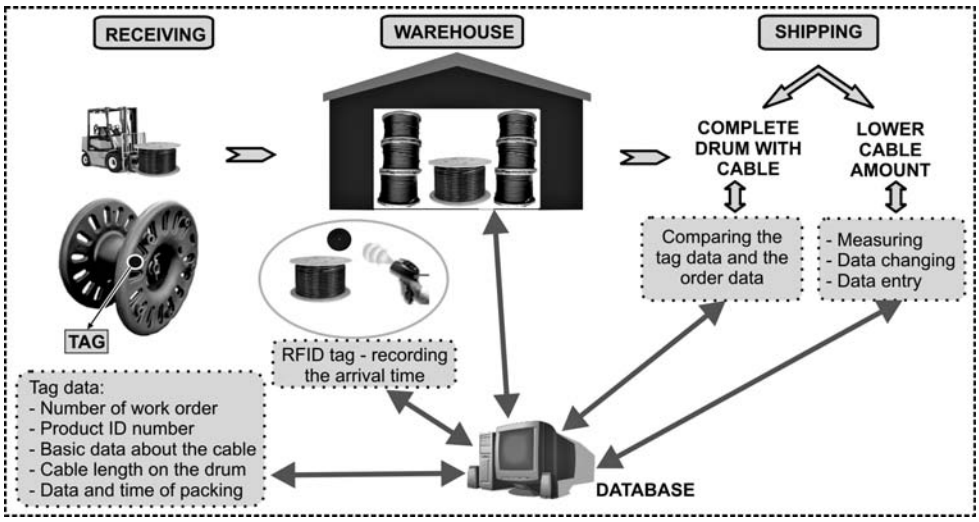

Figure 4 The application of RFID technology in cable storage

Disadvantages of using the RFID technology are high investment costs, while achieving its benefits to a maximum degree requires all participants in the supply chain to use this technology.

CONCLUSIONS

PCs were considered due to their wide application and high importance. The author has developed a polymer drum for the purpose of transporting and storing PCs. The proposed packaging is easy to adapt to packaging other sorts and types of cables. Due to their specific properties, polymeric materials have a very wide range of applications, while recyclability makes them suitable from the aspect of environmental protection and reducing the consumption of natural resources of raw materials. The final selection of the type of polymer packaging requires detailed research regarding the composition of the polymer material (ratio of the pure and the recycled granulates), as well as the form and mass of the proposed packaging.

The main reason for the application of RFID technology is to increase the productivity of the enterprise, as well as to increase the availability and accuracy of information regarding the amount of cable on the drum. The applied information technology enables the flow of goods in the PC supply chains to be managed in an efficient manner. Information collected using the proposed method is reliable, accurate and dynamic along the entire supply chain. By applying the proposed information technology all participants in the PC supply chain are enabled to fully control all flows of goods in storage and transportation processes. The proposed system is flexible in terms of possibility of accepting and processing various types of cables, as well as other products.

Acknowledgment

The authors acknowledgement the support of research project TR 36030, funded by the Ministry of Science and Technological Development of Serbia.

REFERENCES

[1] A. Antić, D. Kozak, B. Kosec, G. Šimunović, T. Šarić, D. Kovačević, R. Čep, The influence of tool wear on the chip-forming mechanism and tool vibrations, Technical Gazette, 20 (2013) 1, 105-112.

[2] S. Jovanović, J. V. Džunuzović, Pravci razvoja ambalaže od polimernih materijala, Hemijska industrija, 65 (2011) 6, 621-636.

[3] J. Tepić, V. Todić, I. Tanackov, D. Lukić, G. Stojić, S. Sremac, Modular system design for plastic euro pallets, Metallurgy, 51 (2012) 2, 241-244.

[4] M. Đelošević, J. Tepić, I. Tanackov, M. Kostelac, Mathematical identification of influential parameters on the elastic buckling of variable geometry, The Scientific World Journal, 2013 (2013), doi 10.1155/2013/268673.

[5] J. Tepić, I. Tanackov, G. Stojić, Ancient Logistics - Historical Timeline and Etimology, Technical Gazette, 18 (2011) 3, 379-384.

[6] Y. Tan, S. Takakuwa, Use of simulation in a factory for business continuity planning, International Journal of Simulation Modelling, 10 (2011) 1, 17-26.

[7] M. A. Waller, S. E. Fawcett, The Total Cost Concept of Logistics: One of Many Fundamental Logistics Concepts Begging for Answers, Journal of Business Logistics, 33 (2012) 1, 1-3.

[8] G. Roussos, V. Kostakos, RFID in pervasive computing: State-of-the-art and outlook, Pervasive and Mobile Computing, 5 (2009) 1, 110-131.

[9] P. S. Chakraborty, G. Majumder, B. Sarkar, Performance evaluation of material handling system for a warehouse, Journal of Scientific & Industrial Research 66 (2007) 4, 325-329.

[10] B. Buchmeister, D. Friscic, B. Lalic, I. Palcic, Analysis of a Three-Stage Supply Chain with Level Constraints, International Journal of Simulation Modelling, 11 (2012) 4, 196-210.

[11] S. Sremac, J. Tepić, I. Tanackov, G. Stojić, S. Kresojević, The application of RFID technology in the supply chain of energetic cables, Proceedings, 20th Telecommunications Forum TELFOR, Belgrade, (2012), 1516-1519.

Note: The responsible translator for English language is J. Šafranj from University of Novi Sad, Serbia