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RECONSTRUCTION OF LABORATORY PRESS IN ORDER TO OBRAIN RUBBER PRODUCTS BY VULCANIZATION

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Abstract: *Intensive development in field of polymer materials put on the need for laboratorz equipment for different purposes. With an increase in the number of polymer materials and with application rising, elastomers play an important role in the industry. This work describes the method of reconstruction laboratory press machine. This work describes the method of reconstruction of laboratory press machine in press machine for production of rubber parts by compression molding. Furthermore, this work provides basic information about processing technologies and rubber vulcanization. Reconstruction of laboratory press machine will enable production of samples for testing properties of different kind of rubber compound, for design and testing various tools and its will also enable design and production rubber parts.*
Key words: *Rubber press machine, vulcanozation, rubber forming, compression rubber moulding.*

Rekonstrukcija laboratorijske prese sa ciljem izrade delova vulkanizacijom gume. *Intezivan razvoj u oblasti polimernih materijala nameće potrebu raspolaganja laboratorijskom opremom rayličite namene. Sa povećanjem broja rayličitih polimernih materijala i sve većom primenom, elastomeri yauyimaju sve ynačajnije mesto. U radu je opisan način rekonstrukcije laboratorijske prese u presu za izradu delova od gume, kompresionim presovanjem. U radu su date osnovne informacije o tehnologijama prerade i vulkanizacije gume. Rekonstrukcija laboratorijskih presa će omogućiti izradu epruveta za ispitivanje svojstava rayličitih vrsta gume, projektovanje i ispitivanje različitih alata i projektovanje i proizvodnju delova od gume.*
Ključne reči: *Presa za gumu, vulkanizacija, oblikovanje gume, kompresiono presovanje gume.*

1. INTRODUCTION

Intensive development in the field of polymeric materials has led to a whole series of new products and mass production of materials of specific characteristics. Polymer materials according to the mechanical-tehnical and chemical behavior can be devided into: thermoplasts, duroplasts and elastomers materials. Discovering the vulcanization process rubber has taken a special place among present day's materials. Although, it is not a basic construction material, rubber as well as composite rubbor material have a significant utilization due to its expecional properties that are reflected in [1-3]:

- the low value of the modulus of elasticity in the initial deformation phase;
- the high value of the modulus of elasticity in the deformed state;
- high elongation at break (over 1000%);
- quick and complete return to the original dimensions after the discontinuation of the load;
- good mechanical and amortization properties;
- high resistance to wear and resistance to aggresive environments;
- impermeability to water and gases, etc.

With the increase in number of materials that can be use as rubber, the type and quantity of rubber products are growing. The raw material for rubber production is caoutchouc, which can be natural and synthetic. Caoutchouc, both natural and synthetic, has little application because it cannot meet the technical requirements of many products. In order to improve the properties of caoutchouc and to obtain the products of the corresponding properties, the caoutchouc is translated into the rubber by mixing with various additives and vulcanizing. Depending on the purpose and characteristics of the rubber products, as well as the neccessary mechanical and other properties, ingredients are added to the rubber, such as [4]:

- vulcanization agents (sulphur or other agents);
- vulcanization accelerators;
- vulcanization retarders;
- fillers;
- softeners and plasticizers;
- colors;
- anti-aging, fatigue and ozone depletion agents;
- special purpose additives.

Researches in the field of determination of rubber properties and production technology of rubber parts are very underrepesented in our country. One of the reasons is that we do not have the available and appropriate equipment for laboratory research. Generall, laboratories have only the equipment for testing the mechanical properties of metal materials. For research in the field of rubber proccesing technologies, the production of rubber parts and the design and manufacture of tools for rubber processing, it is necessary both testing equipment and machines for preparation of semi-products (mixing caoutchouc with ingredients) and machines and tools for obtaining rubber products by vulcanization.

2. FORMING SEMI-PRODUCT BEFORE VULCANIZATION

In order to obtain the product with desired shape and properties, it is necessary to know the entire technoogical flow of production. Regardless of the different properties and their application, the production of rubber parts is carried out in several stages:

- selection, acceptance, storage and preparation of raw materials;
- production of a rubber compound;
- forming a rubber compound into a product;
- vulcanization and
- control and storage of final products.

Production of a rubber products starting with forming a rubber compound. Rubber compound means caoutchouc with all ingredients to be added to obtain the rubber with the necessary properties for further shaping and vulcanization. The methods of making rubber semi-products are:

- calendering;
- exstrusion;
- molding processes;
- injection molding;
- metal bonding.

2.1. Calendering

Calendering is the rolling process of plastomers and elastomers which are applies for panels and foils of different thicknesses. The essence of the process is the multiple swiping of the product between heated rollers, so the thickness of the foil is constrantly reduced. Process is continuous and performed on calender machine and using for mass production. With multiple swiping between heated rollers which distance is changeable it is possible to produce rubber fabric and engraving, besides making sheets and foils.

2.2. Extrusion

Rubber extrusion does not much differ from the plastics extrusion (Figure 1.).

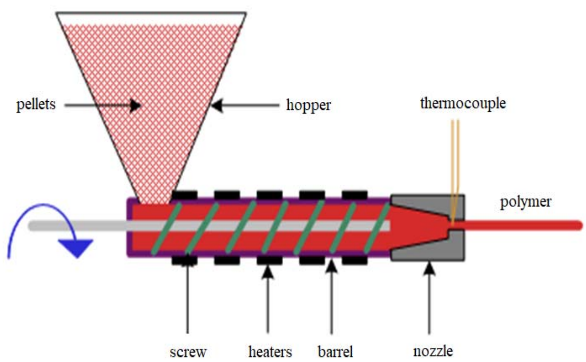

Fig. 1. Exstruder

The main difference between these two processes is the presence of vulcanization process in the production of rubber parts. In the extrusion process rubber compound of caoutchouc and ingredients is pushed through the extruder body and passes through a matrix of a certain cross section. Rubber compound can be supplиend to the extruder manually or automatically from the mixing machine. After extrusion rubber through the matrix, the vulcanization process is followed.

Straight trubes, hoses, profiles, rubber strips or coating of wire are made by extrusion process. The fundamental problem of extruding of rubber is the necessary needs for removal of air and humidity from the raw material, since the finished product can be porous or with bubbles.

2.3. Compression molding

Compression molding is a process that involves taking preforms (raw rubber material) and forming it with pressing into a final product while simultaneously vulcanizing. Preforms are placed in a mold cavity and provide a surplus of materials (from 5 to 10%). Then the tool are closed, heated and pressure is provided to ensure complete filling of mold. When the mold is filled, the excess material flows into the overflow channels, and due to te heating of the tool at the required temperature and holding a certain time on it, the vulcanization process is caried out. After the vulcanization process is completed, the tool is cooling, openning and the finished product is ejecting from the tool (Figure 2.).

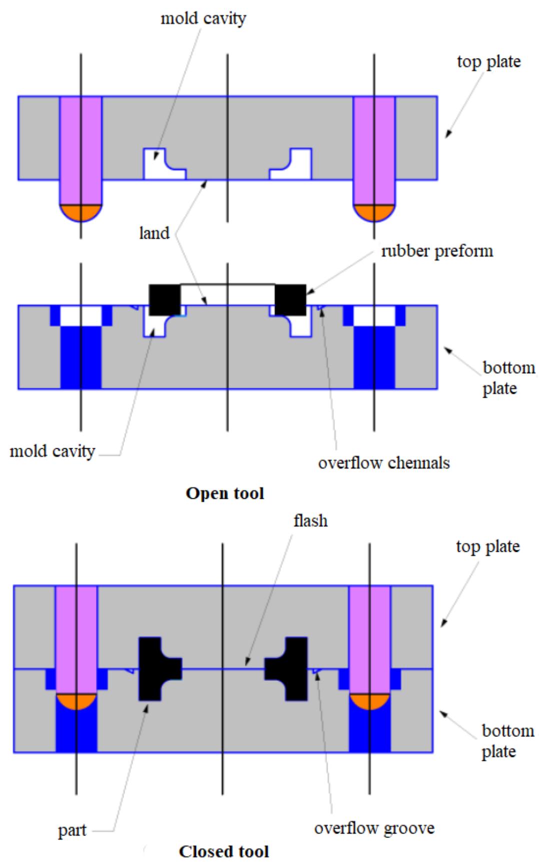

Fig. 2. Compression molding.

2.4. Transfer molding

Transfer molding as well as compression molding require prior preparation of the raw material in preforms. This method is performed using tools that have a separate chamber for material preparation. The process of transfer started by filling the chamber with the raw material, which is heating and softening in it. After that the tool is closing. In the meantime, materila which becomes soft is pressing through molding channels in the mold cavity of the tool. The product is vulcanized in the tool, and after that tool is cooling, openning and final product is ejecting from the tool (Figure 3.).

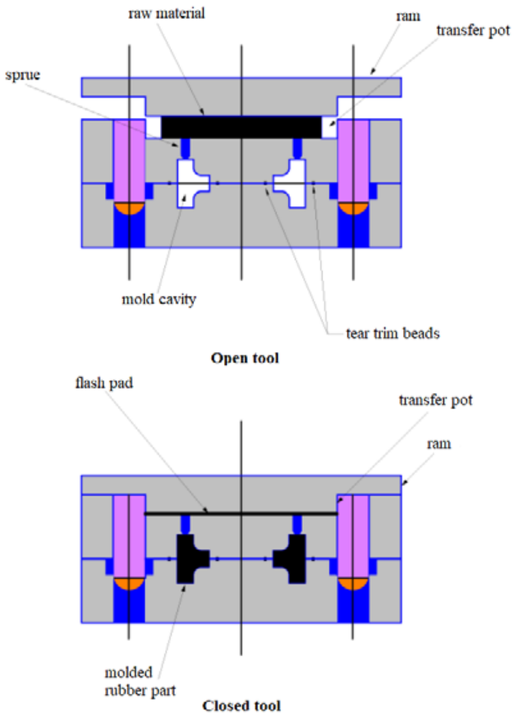

Fig. 3. Transfer molding.

2.5. Injection molding

Injection molding rubber machine is the same as machine for plastic injection molding. However, wokring with rubber compounds there are difficulties due to higher viscosity and risk of premature vulcanization.

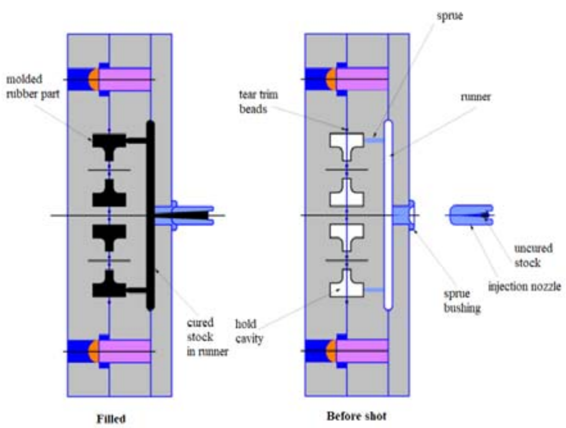

Fig. 4. Injection molding.

Injection molding process consists of several stages: Initially, material is putting into tank of the machine in the form of granules, strip, pieces or powder, from where it is driven into a cylinder that is heated by special heaters. In the second stage, the material becomes soft and under the pressure of the piston or snail is pushed through the molding channels into the mold cavity of the tool. In third stage, the tool is kept closed under very high pressure and vulcanization of rubber products take place. After that tool is cooling, openning and final product is ejecting from the tool (Figure 4.).

2.6. Rubber to metal bonding

Rubber to metal bonding process is used in many cases when it is necessary to applay rubber to metal products or to protect metal against corrosion, wear protection, vibration, etc. There are two ways of getting rubber-metal parts:

- obtaining parts by molding processes with metal inserts and vulcanization in the tools and
- coating metal by rubber material (coating of rollers, pipes, etc.) and vulcanization in autoclaves (Figure 5.).

In accordance with the specific needs, before the rubber to metal bonding process, the metal part must be cleaned from oil, grease, lubricants, etc., most often by sandblasting. In the process of coating rollers, after sandblasting process, primer with bonding agent is applied and then rollers are coating with rubber bands, which are obtained by calandering process. Thereafter, the whole product is wrepped in nylon or cotton fabric and vulcanized in an autoclave. When the vulcanization process is completed, final processing is required. Finishing is mainly done by grinding or polishing. In this way, the production of rollers for the graphics industry is performed. Sometimes, layer of ebonite is used on coated metal for good bonding [5].

Fig. 5. Examples of rubber to metal bonding.

3. VULCANIZATION

The vulcanization process is necessery for the production of rubber products. Unvulcanized rubber does not have the necessary mechanical properties, it cannot return to the original shape after a large deformation and can be very sticky. In addition, vulcanization increases the elasticity and reduces the plasticity of the material. This is mainly achieved by the formation of cross-linked molecular network (Figure 6) [6].

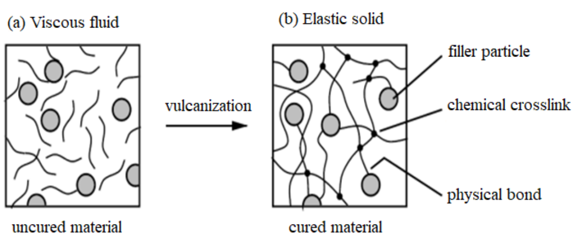

Fig. 6. Molecular model of vulcanization process.

Rubber material mainly consists of a large amount of long polymer chains, stochastically distributed and orientated in space. In the uncured state, these chains are not connected by cross-links between each other and movement between them is possible. On a microscopic basis this can be observed an inelastic (plastic) behaviour that is intentionally used during the molding process of rubber products. Nevertheless, physical links and entanglements between the molecules and links between rubber and filler particles cause some viscous and elastic effects. Therefore, it is reasonable to describe such materials as a viscous fluid. After vulcanization, in the cured state, additional chemical cross-links between the chains prevent them from extended relative movement and, thus, the ability to plastic deformation vanishes [6].

The vulcanization process taking place at certain time inteerval and can be devided into several phases (Figure 7) [4].

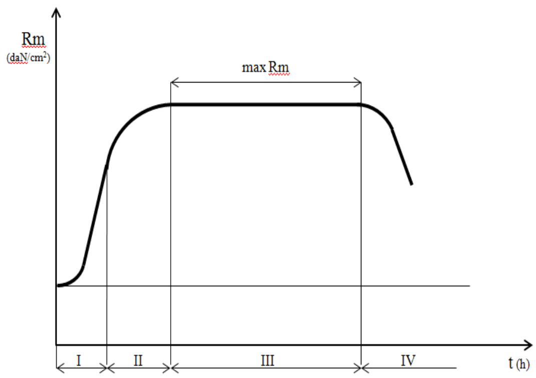

Fig. 7. Flow of the vulcanization process.

Vulcanization is never performed to reached the maximum tensile strenght, because its reaching leads to a decrease of resistance to aging. In order to achieve the best rubber properties, the vulcanization conditions for all rubber compounds are not the same [4].

Due to the formation of a cross-linked structure, the rubber becomes insoluble in any solvent and can be translated in any way into a fluid state. Therefore, it is important that vulcanization is performed after the rubber product gets the final geometrical shape. The vulcanization effects on the final rubber properties are shown in Figure 8. [7].

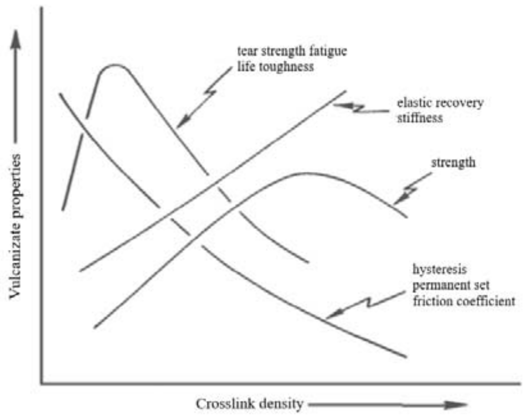

Fig. 8. Vulcanizate properties as a function of the extent of vulcanization.

Vulcanization depending on the applied method can be:

- cold vulcanization;
- vulcaniation with sulfur chloride and
- hot vulcanization.

Hot vulcanization is most commonly used in the rubber processing industry. The basic parameters of hot vulcanization are: temperature, pressure and time. There are processes with continious and non-continious vulcanization.

In continious vulcanization, the rubber profile passing through the tunnel for curing after leaving the matrix. Methods of continious vulcanization are: vulcanization in bath salt, vulcanization using fluidized beds, vulcanization in microwave ovens and vulcanization with infrared radiation [8]. The process of non-continuous vulcanization is perfoming in tools on press machines or in autoclaves (Figure 9.). In autoclaves, vulcanization of products such as conveyor belts rollers for the mining industry, printing rollers, rubber-technical goods, etc., are performed [4].

Vulcanization in the autoclave has advantages because there are not cold parts and surfaces, the products are heated equally.

Fig. 9. Autoclave for vulcanization.

4. RECONSTRUCTION OF LABORATORY PRESS MACHINE

At the Faculty of Engineering Sciences of the University of Kragujevac, for a long time there was a laboratory press for the testing of bulding materials on pressure. Since Faculty has the latest equipment for testing the mechanical properties of various materials, this press has not found adequate application. Due to that fact on the one hand and the need to intensify research in the field of polymeric materials on the other hand, the idea to reconstruct the laboratory equipment with purpose to make parts of polymeric materials was created. Moreover, the purpose of this reconstructed press will be extended to the realization of practical teaching from several subjects which include processing technologies, polymer materials, tools for making parts of polymer materials, CNC technology, etc. Figure 10. shows laboratory press machine before the reconstruction.

Fig. 10. Laboratory press before reconstruction.

The basic parts of the laboratory press are:
- trapezoidal screw with handle (to adjusting the initial distance between the work plates);
- workplates (240x240 mm);
- hydraulic cylinder;
- measuring scale;
- hydraulic valve for maximum pressure control;
- hydraulic pump.

Reconstruction was accomplished by creating individual parts, by puschasing and installing the necessary elements and commissioning test:
- removing existing work plates
- prduction of new heating workplates (220x220x45 mm) with holes for heaters and probe for temperature measurement
- production of workplate holders
- installation of heaters and probe
- instalation of new workplates and isolation (asbestos plates 20 mm thickness)
- placing the press on special stand
- replacement of existing steel hydraulic tubes with hydraulic hoses
- setting electrical instalations (switch, thermoregulator, circuit breaker) and cables
- tool production
- testing and commissioning

Before the beginning of reconstruction, manufacture and installation of necessary parts, the 3D model of the machine was made in software CATIA V5 (Figure 11).

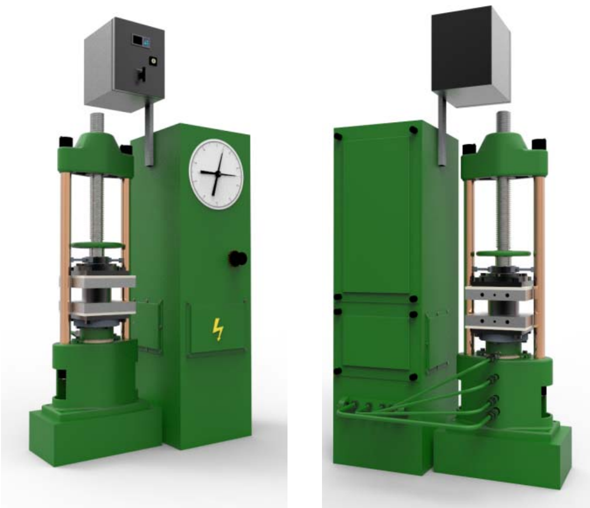

Figure 11. 3D model of laboratory press

The new heating workplates, both upper and lower, are dimension 240x240x35 mm. They have two patron heaters with power of 500W, 12 mm diametet and 220 mm long (Figure 12). Also, the probe for temperature measurement is installed in the plates (Figure 13.). Asbestos plates 20 mm thickness are installed between workplates and holders on press machine to protect the press from unnecessary heating. The probe (sensor) for temperature measurement is placed in the center of the upper workplate, just below the working surface.

Temperature measurement and setting of the required temperature is done by a thermoregulator. The thermoregulator has the task to maintain the constant set temperature of the workplates. Switching on the heaters and switching off, when the required temperature is reached , is regulated by circuit breaker installed next to the thermoregulator and the main switch in the electrobox (Figure 14.).

Fig. 12. Patron heater

Fig. 13. Temperature probe

Fig. 14. Electrobox with electrical components

The operating principle of this press machine is simple. The tool is placed between the heating workplates of the machine by which it is heated to a certain temperature. When the set value is reached, the rubber compound is inserted into the tool. Using the trapezoidal screw, the tool is closed and placed in the starting position. The necessary overpressure is provided by the hydraulic cylinder. The tool for some time in that position to allow rubber vulcanization. Then the tool is opening, and the finished rubber product is removed from the tool.

The Figure 15 presents a modified model of the machine's working space made in CATIA 3D software.

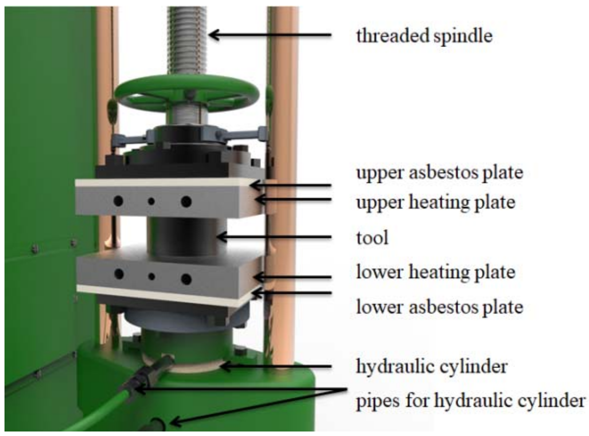

Fig. 15. Modified 3D model of the machine's working space.

Tthe appearance of laboratory press machine after reconstruction is shown in Figure 16.

The next step is commissioning of reconstructed press and checking the possibility of making rubber parts. For this, the existing tools are used (Figure 17.).

The picture shows the protective cap (35 mm diametar and 25 mm height) which is used for military purposes as a protective element. The wall thickness of the protective cap is 1 mm. Rubber compound obtained from the company „Gumi design“ from Cacak was used as the starting raw material. The vulcanization temperature was 130^0C.

Front view Rear view

Fig. 16. Laboratory press after reconstruction.

Fig. 17. Protective cap and tool for that product.

After the successful commissioning of the reconstructed press with aim to produce rubber product, a tool for manufacturing of test samples for tensile testing of polymeric materials was developed. Figure 18 shows technical draw of a samples with dimensions, and Figure 19 shows a tool model. Production of the tool and sampels of various materials with different characteristics is the next step.

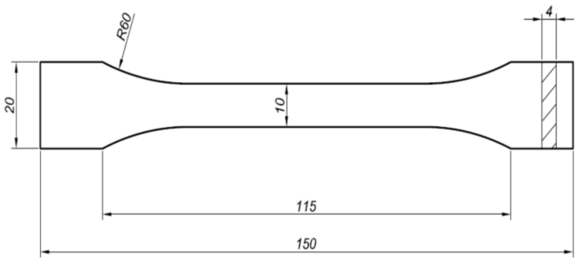

Fig. 18. Rubber samples for tensile testing.

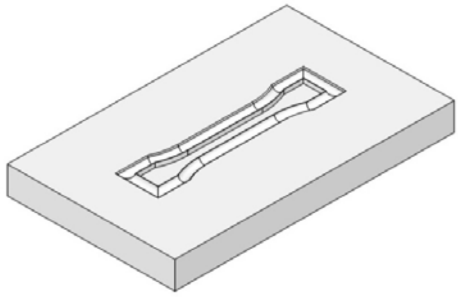

Fig. 19. Tool for making samples.

5. CONCLUSION

The presented process of reconstruction of the laboratory press in the press for obtaining rubber product has shown that in some cases with minimal investments in the existing equipment, the problems of the lack of adequate equipment for new researching can be solved.

The realized reconstruction of the press will enable research in the field of rubber processing technology, such as determining the influence parameters on the quality of the product, analyzing the ingluence of tool geometry, determining the optimal composition of the rubber compound, etc.

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