Research Article

Insulation Material Selection and Curtain Mechanism Design for Rubber Injection Molds

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(First received October 03, 2023 and in final form December 28, 2023)

Reference: Karademir, A., E., Kozan, B., Pekmezci, L. Çevik, Ü., Yıldız, A. Insulation Material Selection and Curtain Mechanism Design for Rubber Injection Molds. The European Journal of Research and Development, 3(4), 178-185.

Abstract

In this study, the selection of thermal insulation materials and the design of a mechanical insulation curtain for rubber injection molds were discussed. First, experimental tests were performed on a rubber mold to determine the most suitable insulation materials, which were mica plate, resin bonded glass fiber plate *and ceramic fiber paper. Cost and thermal performances were also analyzed for these materials. According to experimental observations ceramic paper is considered the most suitable product for curtain material. Furthermore, a new design is proposed which has a radiation curtain mechanism. It was developed for rubber presses without requiring special materials for each mold. This mechanism presents an innovative design for preventing heat transfer in this type of manufacturing process.*

Keywords: Rubber, Insulation, Molding, Hot Vulcanization, Mold Insulation, Energy Saving

1. Introduction

Rubber molding technology is constantly evolving around the world, and rubbers are now widely used in a variety of industries [1-3]. Rubber parts are vulcanized in presses of various tonnages, depending on the part geometry, weight, and rubber material, under the influence of temperature and pressure. After curing, the part is removed from the mold and the production process is repeated. The key aspect of the vulcanization process is mold design. Within the mold, the flow of rubber dough, mold sealing, part demolding, and removal without deformation are crucial. Press vulcanization is carried out using three different molding techniques, primarily based on the part geometry and material [4-6]. The increasing competitive environment in the industry requires the rapid and precise utilization of complex parts and machine systems for more cost-effective production. One of the most significant advantages of the injection method is achieving results without the need for secondary processing, including parts with complex geometries. It should be noted that a properly modeled mold will ensure more efficient production in the shortest time with minimal errors [7-10]. However, the mold technology used to produce rubber parts releases a significant amount of heat into the environment. Preventing this heat loss is crucial during the production stages. There are a variety of materials that can be used to prevent heat loss from molds. When selecting these materials, several important features are taken into account, including cost, thermal conductivity, density, workability, flexibility, and foldability. This study aimed to analyze the effect of different insulation materials for thermal isolation in rubber molds, which can increase energy efficiency. The best insulation material was selected after several experimental tests. Besides, a mechanical radiation shield design was developed for general usage for mechanical press. This study provides a valuable contribution to the field of energy efficiency in the industrial sector. The findings can help manufacturing factory to save energy and support environmental sustainability.

2. Types Of Insulation Materials

The main purpose of the investigation of thermal insulation in rubber injection molding is to determine the most suitable material among four different insulation materials: Mica plate, Resin bonded glass fiber plate, 3mm Ceramic fiber paper, and 5mm Ceramic fiber paper. The general aspects of these materials are given in Table 1.

Table 1. Properties of insulating materials

Material	Thickness (mm)	Thermal Conduction Coefficient (W/mK)	Density (g/cm^3)
Resin Bonded Glass Fiber Plate	6	0,18	1,8
Mika Plate	15	0,3	2,2-2,3

Ceramic Fiber Paper	3	0,10 -0,19	0,185
Ceramic Fiber Paper	5	0,10 -0,19	0,185

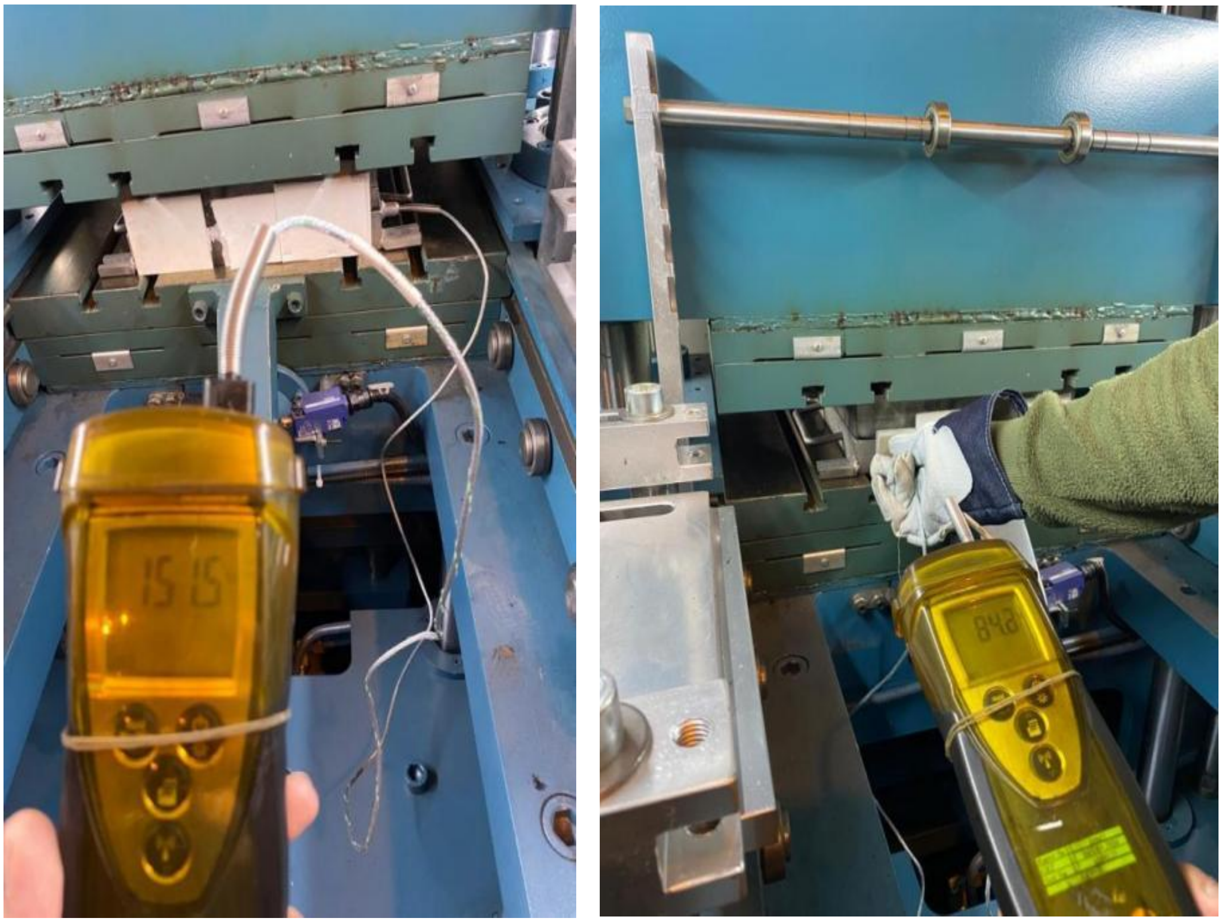

Figure 1. Non-insulated outer surface temperature and outer surface temperature of mounted ceramic plate

3. Experimental Results

In our experimental study of heat insulation in rubber injection molding, the outer surface of the mold to be worked on is cleaned of substances that prevent adhesion before being covered with the insulation material, sandblasting is applied, and it is mounted on the press machine. The mold is heated until its temperature becomes stable, and the outer surface temperature is measured with a thermocouple. Then, while the mold is covered with the insulating material, care is taken not to leave any gaps to prevent the formation of possible heat bridges. The mold's temperature is waited until it becomes stable again, and the outer surface temperature is measured again. The surface temperature was measured for each insulation.

Several experiments are carried out with these four different types of materials and surface temperatures and total heat losses are measured. The obtained data from the experiments are given in Table 2. and Table 3. as follows:

Table 2. Surface temperatures of mounted materials and the non-insulated surface

Material	Length (mm)	Thickness (mm)	Surface Temperature (^{0}C)
Non-insulated	-	-	151,5
Mika Plate	50	15	84,2
Resin Bonded Glass Fiber Plate	50	6	112,8
Ceramic Fiber Paper	50	3	88,1
Ceramic Fiber Paper	50	5	76,7

Table 3. Total heat loss by materials per square meter

Material	1m2 heat loss
Non-insulated Surface	2594,57349
Mika plate	1013,630796
Resin Bonded Glass Fiber Plate	1622,53637
Ceramic Fiber Paper 5mm	858,5020155
Ceramic Fiber Paper 3mm	1093,348004

Comparison of the material costs for a one-meter square area are given in Table 4. In these

Material	Investment Cost(TL)	Repayment Time (year)	Savings Amount (TL/Year)
Mika Plate	9231	0,695	13279
Resin Bonded Glass Fiber Plate	20071	2,458	8165
Ceramic Fiber Paper 5mm	1597	0,109	14583
Ceramic Fiber Paper 3mm	1701	0,134	12610

comparison; the investment cost, repayment time and saving amounts of the insulation materials are compared.

Table 4. Comparison of the material costs for a 1m2 area

In Table 4, energy saving comparison is given. The total savings amount is the difference between the monetary value of heat loss in an uninsulated state and the monetary value of heat loss in an insulated state. This value represents the potential annual energy savings provided by insulation.

Table 5. Energy savings by year in TL (Turkish Lira)

Material	1. Year Savings	3. Year Savings	5. Year Savings	7. Year Savings
Mika Plate	4.048	30.606	57.164	83.722
Resin Bonded Glass Fiber Plate	-	4.424	20.754	37.084
Ceramic Fiber Paper 5mm	12.986	42.152	71.318	100.484
Ceramic Fiber Paper 3mm	10.909	36.129	61.349	86.569

4. Alternative Insulation Mechanism Design in Rubber Presses

Instead of mounting insulation materials on the mold, we can reduce the energy lost by radiation by mounting a radiation shield on the press machine. However, the efficiency will be lower than mounting directly on the mold. Radiation shielding is a mechanism that is used to reduce the amount of heat transfer that occurs through radiation. In this study, a radiation shield was designed to reduce the heat transfer of a mold for a rubber injection press machine. The mold is 1100x1000 mm in size. This was done in order to ensure that the shield could be mounted to the machine and integrated smoothly. The design is made to be easily mounted to the machine and can be produced at the lowest possible cost.

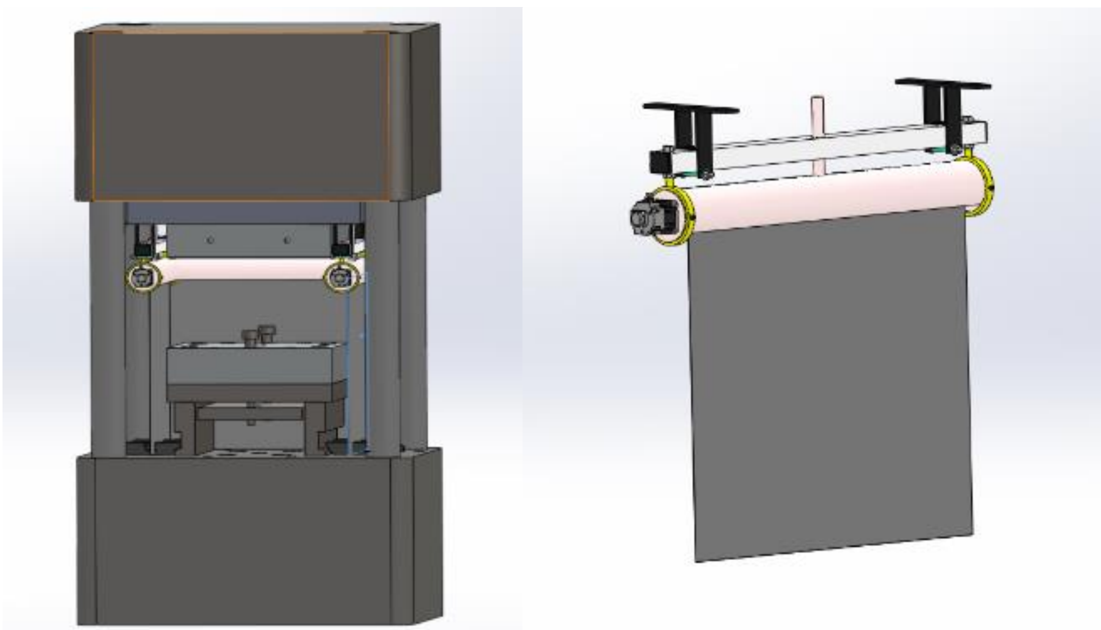

Figure 2. Installation of the radiation curtain on the machine

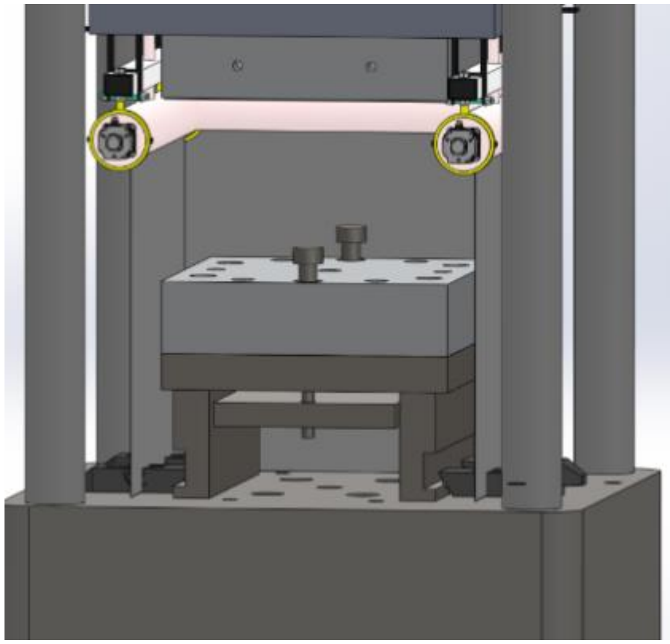

Figure 3. Mold surrounded by radiation curtain on three sides

5. Conclusion

The obtained results indicate that this study was successfully completed, introducing heat transfer systems in molds and achieving energy savings by reducing heat loss. When determining the best method, certain criteria were considered and analyzes were performed. As a result of the tests and experiments, the best insulation material was successfully selected. This material has minimized the heat loss of molds, increasing energy efficiency. In addition, the heat transfer calculations performed also confirmed that this material provides effective heat insulation. Investment cost and payback period calculations were also made. When compared to the cost of the insulation material and the energy savings, it has been observed that the payback period of the investment is within a reasonable period. This allows businesses to save costs while achieving energy efficiency. Based on the results of all analyses, a radiation shield design has been developed and ceramic paper has been chosen as the curtain material due to its low thermal conductivity, flexibility, and low investment cost. This curtain provides energy savings by significantly reducing the heat transfer of molds. With the implementation of the design, the heat loss of molds has been minimized, significantly reducing energy consumption.

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