

Study and Manufacturing of Heat Insulator for Thermoplastic Composite Propellant

Omer Elamin H. Ali ^{*§}, Nagmeldin. M. Elamin ^{†¶}

^{*}Sabighat Industrial Complex, Gama Technical Center, Sudan

[†]Defense Industries System, Advanced Industries Group, Sudan

[§]omer.ha616@gmail.com, [¶]nagmamin59@gmail.com,

Abstract

The aim of this paper is to study the possibility of localizing the manufacturing of heat insulator for thermoplastic Composite propellant which plays an important role in modern warfare. The Original heat insulator had been tested and the mechanical properties were determined to take them as a reference results for the new one in working different formulation. The heat insulation materials which used are silicon dioxide, Titanium dioxide, Antimony tri oxide, calcium carbonate and talk powder. It was seen that, the using of the above materials grand good results in the first testing stage. When the heat insulator used in the production processes some remarks were appeared, such as the flow by heat during homogenizing process. One of the formulations suggested and tested, was passed all the production processes and tests in the real product and grant excellent results compared with the Original heat insulator. The erosion rate for local insulator was 0.36mm/s while the erosion rate for the Original one is 0.37mm/s. This work proved that, the production of heat insulator for Thermoplastic composite propellants can be localized successfully.

Key words-Thermoplastic materials; Composite propellant; Insulator; Erosion rate, localization.

I. INTRODUCTION

Insulations are defined as those materials or combination of materials which retard flow of heat energy [1]. In thermoplastic materials, the very long chain-like molecules are held together by relatively weak Van der Waals forces. When the material is heated, the intermolecular forces are weakened, so it becomes soft and flexible, eventually at high temperatures it is a viscous melt. When material is allowed to cool, it solidifies again. Examples for thermoplastics are polyethylene (PE), polyvinylchloride (PVC), polystyrene, nylon, cellulose acetate, acetal, polycarbonate, poly methylmethacrylate and polypropylene [2].

There are many types of thermal isolation materials such as ceramic oxides, silica, silicon carbide, silicon nitride, asbestos, antimony dioxide, tri-chloroethyl phosphate, calcium carbonate, clay and polymer contain chlorine, bromine or fluorine like polyvinyl chloride, and polytetrafluoroethylene. Those polymers need strong flame to start burning. This major advantage cannot be found in other polymers not containing halogenic elements [3], [4], [6].



Fig. 1. Rocket motor components

A. Heat insulator forms:

Insulations are produced in a variety of forms suitable for specific functions and applications. The combined form and insulation type determine the proper method of installation. The forms most widely used are:

- 1) Rigid boards, blocks, sheets, and pre-formed shapes such as pipe insulation, curved segments, lagging etc. Cellular, granular, and fibrous insulations are produced in these forms.



Fig. 2. mixing materials



Fig. 3. Producing the insulator sheet using rolling machine.

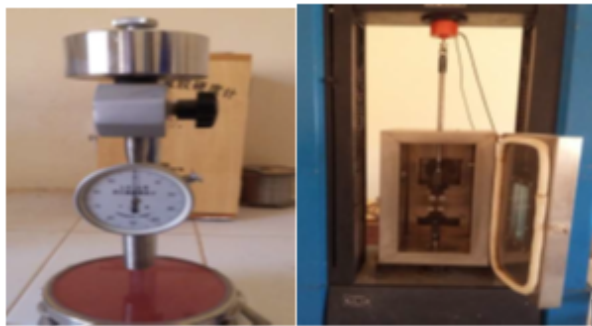


Fig. 4. Hardness tester and tensile machine



Fig. 5. Homogenizing process

- 2) Flexible sheets and pre-formed shapes. Cellular and fibrous insulations are produced in these forms.
- 3) Flexible blankets. Fibrous insulations are produced in flexible blankets.
- 4) Cements (insulating and finishing). They are produced from fibrous and granular insulations and cement; they may be of the hydraulic setting or air-drying type.
- 5) Foams. They are used to fill irregular areas and voids. Spray used for flat surfaces [1].

B. Requirements of Thermal insulator

The importance of the ingredients and method of processing can be revealed by considering the primary requirements for solid rocket motor insulation, the considerations are:

- 1) Excellent bonding of the insulator with propellant and motor case over the entire range of working temperature.
- 2) Low ablation rate (from 0.09 to 0.4 mm/s).
- 3) Sufficient tensile strength (0.5 MPa).
- 4) Porous char with good retention characteristics.
- 5) Ability to withstand mechanical and thermal stresses during storage, handling, and curing operations.
- 6) Low moisture absorption.
- 7) Good aging characteristics (minimum 10 years of shelf/useful life).
- 8) Very low outer case temperature ($\leq 150^\circ\text{C}$).
- 9) Good electrical conductivity (accumulation of static electricity) [5].

C. Advantages of insulation

The primary purpose of insulation is to prevent/minimize the thermal energy losses for the conservation of energy. However, insulation helps in several ways such as

- 1) Provides more accurate control of process temperatures and protection of the product.
- 2) Prevents condensation on cold surfaces and the resulting corrosion.
- 3) Helps in saving of energy and reduction in Green House Gases in environment.
- 4) Minimizes the formation of condensate in steam pipeline and related problems.
- 5) Provides fire protection and absorbs vibration [7].

II. MATERIALS

The materials used in this paper include two groups. The raw materials are essentially consisting of polymers (poly vinyl chloride PVC and Vinyl Chloride/ Vinyl acetate Polymer COP) and they support linking between insulation components. Also, these materials have ability to resist heat of combustion and prevent heat flow by passing through the insulator such as CaCo_3 , TiO_2 , Sb_2O_3 and Telkpowder. Some of materials help process of insulator manufacturing like Cast, and others give the insulator the elasticity property such as COP and DOP. In addition, the Termolate (TER) works as a heat stabilizer during manufacturing process.

A. Group1

Materials available in the work place such as: SiO_2 , Sb_2O_3 , PVC , COP , TiO_2 , DOP , $Di\ Octyl\ Adipate$ (DOA), and TER. These materials are expensive in the global market. They are used in this work and grant good results in the first testing steps.

B. Group2

Materials available in the local market Such as $CaCO_3$ (15m), $CaCO_3$ (20m) and Telk powder. These materials are available and produced locally and have low cost than materials imported from the global markets, beside they have good properties as heat isolation. Local heat insulation materials grand good result through all steps of research until final testing in apply of local heat insulator in real product.

III. METHODS

A. Formulation

First of all, the type of heat resistant material and the polymer type were chosen. The optimum percentage between polymer and the heat resistant materials was determined. Choosing the above parameters was done due to the compatibility with industrial processes of heat insulator and also due to the using of heat insulator in the real product.

B. Weighing process

Digital balance was used in this step. Polymer, solid materials additives, major insulating material and liquid materials, were weighed sequentially according to percentages in the formulation step. Weighing is very critical process, so it was done carefully.

C. Mixing process

When the components weighing stage finished, all components were transferred to the mixer and mixed together till all material of heat insulator had been homogenized and ready for the next step. Firstly, the polymer was put in the mixer and mixed for one minute. Then the additives were added and mixed with the polymer for 2 minutes. The major insulating material was added after that and mixed with the other components for 2 minutes. Finally, the liquid materials were added and mixed together with the other components for 2 minutes. The whole time of the mixing process was 7 minutes.

TABLE I
ORIGINAL VS. TESTED INSULATOR PROPERTIES.

Properties	Original insulator	Tested insulator
Hardness (-)	86.5°	850°
Tensile (MPa)	7.14 MPa	7.03 MPa
Elongation (%)	16.29%	17.53%
Erosion rate (mm/s)	0.37 mm/s	0.36 mm/s

D. Manufacturing process

The components were manufactured by a rolling machine contains two roll mills heated up to 1300°C, so that all components were homogenized perfectly and produce the suitable sheet of heat insulator (thickness 1mm). 250 grams of the insulator slurry were put in the rolling machine, mixed for 3 minutes and cut. Then 500 grams of the insulator were put in the rolling machine, mixed for 5 minute and cut. Finally, the sheet of insulator 1mm thickness was produced.

E. Mechanical properties measurements

Using the tensile machine and the hardness device, the mechanical properties of the new insulator such as (tensile strength, elongation, hardness and erosion rate) were tested and compared with the original heat insulator properties.

TABLE II
COMPARISON OF COST BETWEEN THE LOCAL AND THE IMPORTED INSULATOR.

No	Cost Item	Price \$
1	1 kg of raw materials	5.72
2	Working expenses	1
3	Management expenses	0.5
4	utilities expenses	0.3
5	Destruction	0.2
*	Total of 1 kg local insulator	7.72
**	Bill of 1 kg imported insulator	33.0



Fig. 6. Insulator after test in real product



Fig. 7. Outer case temperature after test in real product

F. Application of formulation in production process

The heat insulator must be compatible to all production processes through the homogenizer machine. The sheet of heat insulator was mounted with sheet of propellant up to diameter (50mm), then the internal surface of homogenizer machine (TPV50) was oiled and closed after the inserting of the product. The homogenizer was started working and the values of vacuum, pressure and temperature were recorded for 2.5 hours. Finally, the product was taken off from the homogenizer and prepared for measurements of final tests.

IV. RESULTS AND DISCUSSION

A. Results

The formulation which passed in all steps was applied in a real product and tested. Table 1 compares the properties of the original heat insulator with the new tested one. On the other hand, fig. 6 and 7 shows the shape of the insulator and the outer case temperature after the ignition in the real product. On the other hand, the cost of manufacturing of 1 kg of heat insulation locally was calculated and compared with the cost of 1 kg of that which imported from outside. Table 2 show the comparison of the two costs.

B. Discussion

From the results given in table 1, it was noticed that, there is no significant difference between the results given for the properties of the original insulator and those of the tested one. This prove that, the localized insulator can bring the same results of the original imported one. Moreover, fig. 6 and 7 show that the local insulator didnt affected by high temperatures after ignition, and the outer case remained at the same temperature after ignition as when the original insulator used.

From the cost point of view, it was seen that, the cost of the imported insulator is too high, and the manufacturing of the insulator locally can minimize the cost to more than one fourth of the imported one.

V. CONCLUSION AND RECOMMENDATIONS

The possibility and the use of manufacturing a local thermal heat insulator for thermoplastic propellants was studied carefully in this work. A sample of a localized heat insulator was manufactured and tested. The results of the mechanical and burning properties were extracted and compared with those of the original insulator used in the production line. Also, the cost of the insulator manufactured locally was calculated and compared with that of the insulator imported from outside. The following points can be concluded:

- 1) description Final formulation of local insulator grand the same mechanical and burning properties of that original standard one.
- 2) The cost of the local insulator (7.72 \$/kg) grand an economic benefit when it compared with the imported one (33 \$/kg).
- 3) The heat insulator for Thermoplastic composite propellant can be localized successfully and usefully.

A. Recommendations

for the future work, it is important to:

- 1) Study the uses of this insulator for the other types of solid rocket propellants.
- 2) Study how to facilitate manufacturing and testing steps of heat insulator and make them easier than the present method.
- 3) Study the use of local alternatives, like waste of ceramic and heat bricks factories to reduce cost of manufacturing of local heat insulator.
- 4) Study of using other type of thermoplastic polymers instead of poly vinyl chloride so as to increase safety during manufacturing stages of heat insulator.

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