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The Effect of Thermal Variation on the ROCASIN Rubber over a Predete rmined Period of Time

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Abstract - *The present paper deals with the effect of temperature variation over a given period of time on the mechanical properties of the ROCASIN (Rocket Case Insulation) rubber. Rocasin rubber is basically Nitrile Butadiene Rubber (NBR) with an acrylonitrile content ranging from 16-19% and other ingredients like silica as a reinforcement element, plasticizer etc. It is applied over the internal surface of the rocket motor case as an insulator. In this paper, an experiment is planned to be carried out on Rocasin rubber samples in two sets of operating parameters, i.e., at temperatures of 50⁰C, 65⁰C, 80⁰C, 95⁰C, and 110⁰C The samples are planned to be heated for the duration of 4 hrs and 8 hrs. and the mechanical properties like tensile strength, % elongation at break, and hardness of ROCASIN rubber samples will be evaluated and compared with the results of the mechanical properties obtained from the standard vulcanization cycle, i.e., at 120⁰C for 4 hrs.*

Key Words: Vulcanization, Insulators, Rocasin, plasticizer reinforcement, tensile strength, % elongation at break, hardness.

1. INTRODUCTION

According to the ASTM code, a rubber compound based on acrylonitrile and polybutadiene copolymer is called Nitrile Butadiene Rubber (NBR). ROCASIN stands for rocket case insulation. ROCASIN rubber is basically a thermal insulating material, applied over the internal surface of the rocket motor case. It is also used as igniter head end insulation, igniter nozzle liners, convergent liners, insulation boot, thermal boot, head end domes, and other moulded elastomeric flight components. Its main function is to protect the rocket motor case from the high heat and temperature that are generated during the burning of the propellant. The temperature is in the order of the 3000 C range [1].

The insulation buildup varies at different locations of the rocket motor casing based on the exposure of heat, the duration of heat exposure, and the thickness of insulation laid at that location. So, the vulcanization of the higher thickness of ROCASIN insulation requires pressure along with a specified temperature. The mechanical and thermal properties of the ROCASIN vary with a given set of temperatures over a specified duration of heating [2].

1.1 Vulcanization

It is a process in which the added sulphur in the ROCASIN rubber at its raw stage crosses links with the long chain of rubber hydrocarbons and creates a 3-dimensional structure that is comparatively stronger and more durable than the non-vulcanized one. The parameters which are generally used to define the mechanical properties of the ROCASIN are tensile strength, hardness, and percentage elongation. The parameters defining the thermal properties of ROCASIN are specific heat, thermal conductivity, coefficient of linear thermal expansion, and erosion rate. Density also plays an important role is the selection of ROCASIN rubber as it increases or decreases the inert weight when it goes beyond the specification.

Rocasin is vulcanised inside the hot air oven or autoclave under a predefined temperature and cycle. A normal curing time is 3–4 hours at 120°C. ROCASIN can be cured at temperatures ranging from 100 to 150 degrees Celsius.

Table - 1: Desired Mechanical properties of Rocasin

S.No	Parameters	Specification
1	Density (gm/cc)	1.19±0.02
2	Elongation (%)	600 Minimum
3	Hardness Shore ‘A	60 - 75
4	Tensile Strength (Kg/cm^2)	100 Minimum

The specification shown in the table 1.2 belongs to the samples cured at standard vulcanization cycle which is at temperature of 120⁰C for 3-4 hrs.

1.2 Types of insulating material for rocket motor casing

1. ROCASIN rubber (NBR based):
2. Ethylene propylene dine-monomer (EPDM
2. Styrene butadiene rubber (SBR)

Ethylene propylene diene-monomer (EPDM) elastomers are being tested to replace nitrile rubber in India's space and missile programs. More than a decade ago, the use of EPDM as an insulator for case-bonded solid rocket motors was investigated and shown to be practical. Due to its low specific gravity, EPDM has emerged as a unique material for a variety of applications, including insulation for solid rocket motors. EPDM rubber's major characteristics are its exceptional resistance to oxidation, ozonization, and weathering.

Styrene butadiene rubber (SBR) insulation, sometimes known as Buna-S, is made by emulsion polymerization of 75 parts butadiene and 25 parts styrene. SBR is another valid abbreviation for the styrene-butadiene rubber type. It is used in upper stage and booster rocket motors as an insulator [2].

2. Literature Review

A thorough investigation into the research conducted in the past and recent developments in the field of rocket case insulation. The literature review mainly focused on the following topics: studies on the improvement in mechanical and thermal properties of NBR by changing their ingredients or their ratio, the availability of elastomers to be used as insulators for solid rocket motors, ageing studies on NBR, special treatment on insulators or processes to enhance their mechanical and thermal properties, and other applications of NBR.

I found that there is scope to study the effect of temperature (below 120^0 C) for a given period on the mechanical properties. So, it is decided to carry out studies on the experimental samples of ROCASIN rubber subjected to the following set of temperatures and durations in hours.

Table – 3: Plan for sample preparation and experiment

1st Set of operating parameters for experiments			
S. No	**Temperature (^{0}C)**	**Duration (hrs.)**	**Sample Quantity (Nos.)**
1	50	04	06 Nos.
2	65	04	06 Nos.
3	80	04	06 Nos.
4	95	04	06 Nos.
5	110	04	06 Nos.
2nd Set of operating parameters for experiments			
S. No	**Temperature (^{0}C)**	**Duration (hrs.)**	**Sample Quantity (Nos.)**
1	50	08	06 Nos.
2	65	08	06 Nos.
3	80	08	06 Nos.
4	95	08	06 Nos.
5	110	08	06 Nos.

3. Methodology

It is planned to carry out the experiment by preparing the samples in two stages. The first stage comprises the preparation of the sample for heating inside the hot air oven. In the first stage, the size of the Rocasin rubber sheet will be selected for heating at a predefined set of temperatures for a given time period, and in the second stage, the sizing of samples will be carried out in order to meet the test standard while evaluating the mechanical properties. The hot air oven for heating the samples is shown in Fig. 1.

Fig.1 Hot air oven

3.1 Instruments Required

1. Instron UTM (Model No: 5566, Sr. No: J2936)
2. Dumbbell Shaped Die as per IS-3400 (Part-l) 1987
3. Specimen Cutting Press (Hydraulic)
4. Dial Thickness Gauge (Range: 0 – 10 mm)
5. Ro1ler Grips.
6. Desiccators with Fused Calcium Chloride (or) silica gel.
7. Hygrometer for RH measurement.
8. Shore "A" Hardness Tester (0-100).

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3.2 Sample Preparation:

a. **Sample Details for heating:**

Shape: Square
Size: 200 x 200 mm
Thickness: 2±0.2 mm

b. **Samples details for mechanical Testing**

Thickness: 2 ± 0.02 mm
Width: 6 ± 0.01 mm
Shape: Dumbbell shaped (Type-I) as per IS: 3400 (Part 1), 1987;

The hydraulic machine die set is shown in fig.2 which will be used for preparing the samples for mechanical properties evaluation

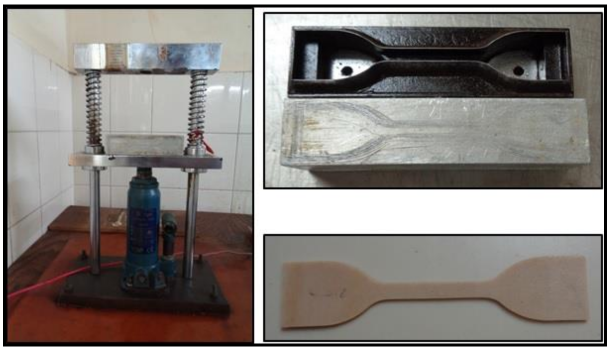

Fig.2 Hydraulic press, die set and rocasin sample

c. Sample Conditioning

Samples prepared for mechanical testing is required to keep inside the desiccators in order to remove the moisture present in the Rocasin samples.

Fig.3 desiccators for conditioning rocasin sample

Fig.2 Experimental set up (UTM)

3.3 Operational parameters for testing

Parameters	Value	Parameters	Value
Grip distance	60 mm	Gauge length	33 mm
Test speed	500 mm/min	Grip pressure	roller grip
Sample conditioning	Kept for 48 hrs in desiccators over fused calcium chloride		

4. Conclusion:

This review paper deals with the experiments on the rocasin rubber to be carried out at different sets of temperatures for four and eight hours, respectively, to evaluate its mechanical properties so that a set of data can be generated showing the effect of temperature on the various parameters of mechanical properties. That data obtained can be utilised to establish a new vulcanization cycle or to help in rocket motor processing if the mechanical properties obtained by experiments fall within the specified range for a solid rocket motor at temperatures below 120^{0}C.

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