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Aerospace components made by Polymer material

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Cover Page Footnote

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Aerospace components made by Polymer material

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***Abstract*— The aerospace and aviation industry have fasted growing industries on a global scale. Reliable aircraft demands many top rubber components. These rubber components must-have high performance and endurance properties, since they will be exposed to a range of extreme weather conditions, such as excessively hot or cold temperatures, and different types of oils and gases. Rubber products are becoming more famous because of their durability under extreme environmental conditions and cost-effectiveness. The rubber used for aircraft must be of high quality, and this factor is most important in the production of the necessary parts. To study the effect of all compounding ingredients while optimizing compound design and conforming to the various specification requirements and to study the effect of aging, generally, rubber is tested at three different stages viz. Unvulcanised rubber, vulcanized rubber, and finished product.**

Keywords- Aircraft Components, Rubber; Polymer, Testing

I. INTRODUCTION

Rubbers or elastomers are materials that have unique properties known as elasticity in simple terms it means that this material can be easily deformed by a weak stress and upon removal of stress it returns to almost its original shape. Rubber is broadly divided into two groups:

1. General-Purpose Rubber: It includes Natural Rubber, SBR, BR, IR constitute almost 80% of total rubber used.
2. Special Purpose Rubber: As the name suggests, has some special properties such as resistance to oxidation, heat weathering, ozone, oils, fuels, chemicals, etc.

Types of special Rubbers

A. R-Group: Rubbers are in double bond in the main chain.
B. M- Group: Rubber Which has a saturated main chain.
C. O- Group: Rubbers and Oxygen atoms in the main chain.
D. Q- Group: Silicone Rubbers
E. T- Group: Rubber has Sulphur in the main chain.
F. U- Group: Polyurethane Rubber

A. R-Group: Rubbers are in double bond in the main chain.

NR: Natural rubber (polyisoprene)
BR: Butadiene Rubber
CR: Chloroprene (Neoprene)
IR: Isoprene Rubber
IIR: Isobutylene-Isoprene Rubber (Butyl Rubber)
SBR: Styrene Butadiene Rubber
NBR: Acrylonitrile Butadiene Rubber (Nitrile Rubber)
HNBR: Hydrogenated Nitrile Rubber
BIIR: Bromo Butyl Rubber
CIIR: Chloro Butyl Rubber

B. M- Group: Rubber Which has a saturated main chain.

ACM: Acrylic Rubber
CM: Chlorinated Polyethylene
CSM: Chlorosulfonated Polyethylene
EAM: Ethylene Acrylate Copolymer
EPM: Ethylene Propylene Copolymer
EPDM: Ethylene Propylene diene terpolymer
EVM: Ethylene/Vinyl Acetate Copolymer
FKM: Fluorocarbon Rubbers
FFKM: perfluoro elastomers

C. O- Group: Rubbers and Oxygen atoms in the main chain.

CO: Epichlorohydrin Rubber
ECO: Copolymer of Epichlorohydrin and ethylene oxide.

D. Q- Group: Silicone Rubbers

MQ: Silicon Rubber with the methyl group
VMQ: Silicon Rubber with methyl and vinyl group
PVMQ: Silicon Rubber with methyl, vinyl, and phenyl groups
FVMQ: Silicon Rubber with methyl, vinyl, and fluoro groups

E. T- Group: Rubber has Sulphur in the main chain.

Polysulphide Rubber

F. U- Group: Polyurethane Rubber

AU: Polyester urethane rubber

Ranking of special characterized rubber on Heat & oil resistance (as per ISO/TR 8461)

Sr. No	Heat Resistance	oil Resistance	Heat & oil Resistance
1	FKM	FKM	FKM
2	VMQ	NBR	ACM

3	ACM	ECO	ECO
4	ECO	ACM	CSM
5	EPDM	CSM	-
6	CSM	CR	-
7	NBR	-	-

Sr. No	Heat Resistance up to	Elastomers
1	100 degrees Celsius	AU/EU/NR/OT/SBR/PNR
2	125 degrees Celsius	CR, NBR, X-NBR
3	150 degrees Celsius	CO, ECO, EPDM, EVM, CM, CSM, X-IIR, HNBR
4	175 degrees Celsius	ACM, EAM, PNF
5	200 degrees Celsius	FVMQ
6	225 degrees Celsius	VMQ
7	250 degrees Celsius	FKM

II. PROCESSING OF RUBBER COMPONENTS

Raw rubber goes to Weigh Up compounding as per formulation chart. And then transferred to the Mixing mill. For Mixing Two Roll Mixing Reel is used. By using different types of chemicals such as plasticizers, curing agents, Colour Pigments, Filler materials, Coolants are mixed with Raw rubber to form synthetic rubber sheets. This sheet further goes for testing. Rubber compounding means incorporating rubber ingredients into a rubber mixture so it is evenly dispersed, then the rubber mixture is called a rubber compound. The mill aids in two main steps of rubber processing - mastication and mixing. Mastication is when the raw polymer is sheared and broken down to create an easier flow. This allows for better incorporation of materials, which leads to the mixing component when the other materials for a compound are added.

To create a rubber compound on a mill, a raw polymer, or base polymer, is needed. The polymer can be several things, including natural rubber, such as SMR CV, SMR 20, SMR L, or a variety of synthetic rubbers such as nitrile (NBR), ethylene propylene diene monomer (EPDM), butyl, polychloroprene (CR), Polyisoprene (IR) and others. The raw rubber after being masticated, in which normally for natural rubber, other ingredients needed to be compounded into the raw polymer either on a mixing Banbury Kneader or other rubber mixing machine then pass to two roll mills for dispersion and sheeting out for rubber compound that is suitable for molding dimension. Rubbing compounding also can be mixed on two roll mills by sequentially adding the ingredient and folding, cut and rolling the rubber to mix. This process creates rubber that can be used to create products.

Ingredients added to make a rubber compound include oils, fillers, and accelerator, which usually includes sulphur or peroxide, and may also include a metal oxide either as an activator such as zinc oxide, in some cases as filler, and also as an activator. After mixing, a compound is removed from the mill in a large sheet and then molded into its desired product.

After mixing rubber sheets are formed and then it is further transferred for Inspection. For inspection purposes, they made some inspection tools with rubber sheets like dumbbells, cylinders, sheets. By using these components inspecting procedure takes place. The main purpose of the test is to ensure the complete curing and also that the material composition is identical with that of the approved rubber compound. The sample size during this testing is usually restricted to 3 percent of a batch. Testing at this stage is mainly to assess the suitability as well as consistency of the test, which are sensitive to the degree of vulcanization and change in the composition of rubber compounds. As an example, the following are the few important tests that pertain to rubber sealing rings. Tensile Strength, Elongation at break, Hardness/ Apparent hardness, Compression set, Swelling, Density, Material Identification, Traceability. The Temperature and duration are to be decided based on the service temperature and type of rubber being used for the application.

Following rubber ingredients used in the rubber industry:

- **Natural Rubber**
- Synthetic Rubber : PBR (Cisamer) 1220/01, SBR - 1502/1712/1783, NBR: PVC (70:30) (50:50), NBR: PVC (KNB-35L), EPDM RUBBER, Chloroprene Rubber (B-30/ B-100),Silicone Rubber ,EVA, Process PBR,Process SBR, Process Neoprene

- **Reclaimed Rubber**
  White Reclaimed 92%/85%/50%, Black Rubber Compound, Whole Tyre 2*/3*/ SF, Tube, reclaim (Natural/ Butyl), EPDM Reclaim

- **Crum Powder**
  Natural Crum (30 & 40 Mesh), Nitrile Crum (30 & 40 Mesh), EPDM Crum (30 & 40 Mesh)

- **Carbon Black**
  HAF N-330, FEF N- 550, GPF N- 660, SRF N- 774

- **Silica**
  Aerosil, Precipitated Silica (Sipernat 22 S), Precipitated Silica (Tray Dry), Precipitated Silica (Spray Dry), Ultrasil VN3 Equivalent Grade 175

- **Waxes**
  Paraffin Wax (Super/ Medium/ Cheap), Microcrystline Wax (White/ Yellow), Carnauba Wax (Red/ yellow/ Black)

- **Colors & Pigments**
  Titanium Dioxide (Anatase/ Rutile), Pigment (All Colors), Silicone Color Masterbatch

- **Oxides** Zinc Oxide (White Seal), Zinc Oxide (Imported 98%), Calcium Oxide, Magnesium Oxide, Red Oxide

- **Activators**
  Stearic Acid (Godrej / V.V.F)

- **Resins**
  Gum / Wood Resin, Petroleum / CI Resin, Phenolic Resin

- **Sulfur Powder**
  Yellow Sulphur Powder, Insoluble Sulphur (OT Sulphur)

- **Accelerators**
  MBT, MBTS, CBS, TMTD, ZDEC, ZDBC, NOBS (MOR), ETU (NA-22), F, ZMBT, TBBS, DPG

- **Flame Retardants**
  CPW (Chlorinated Paraffin Wax)

- **Antioxidants**
  SP(Small), SP(Big), SP(E), TDQ, ZMBI, 6PPD

- **Glycols**
  PEG-400, PEG-4000 H, DEG (Small), DEG (Big)

- **Solvent**
  Mek, Toluene, Xylene Orthxy
- **Factiees**
  Brown – G SB, Softice G -, Brown G – 50, Nitrile G, Sonu G. Asp, White GL

III. TESTING

A. Introduction

To study the effect of all compounding ingredients while optimizing compound design and conform to the various specification requirements and to study the effect of aging, generally, rubber is tested at three different stages viz. Unvulcanized rubber, vulcanized rubber, and finished product. The details are elaborated on below.

B. Un-vulcanized rubber

At this stage, testing is concerned with the measurement of rubber processing parameters such as initial/ minimum viscosity, induction time, scorch time, optimum curing time, curing rate, etc. Additionally, marching or reversion characteristics of rubber can also be confirmed, which indicates the increase or decrease in physical properties. All these processing parameters are generally measured by using the Rheometer. In this equipment about 3-to-4-gram rubber compound is placed between static and oscillating discs which are tightly closed by pressure. The resistance offered in oscillation due to vulcanization of rubber compound is then measured. By Rheometer, viscosity is measured in terms of torque, which changes as the vulcanization progress concerning the time at a particular temperature. During the operation of the Rheometer, initially, torque decreases as the rubber charge is heated up and then progressively increases as the cross-linking in the rubber compound gets initiated. Reading of the automatically plotted graph gives all the above-mentioned information. In addition to the above, plasticity which is defined as easy to deformation of the material on application of load, viscosity/ molecular weight as well as a characterization to confirm saturation/ un-saturation and base of rubber are other properties that are measured on raw rubber.

Raw rubber properties are useful while deciding the type quantity of various compounding ingredients required to be incorporated in the rubber compound.

C. Vulcanised rubber

At this stage following tests are carried out

1) Short Term Stress/ Strain tests, which include
   - Tensile strength
   - Elongation at break
   - Tensile set at break
   - Hardness test

2) Permanent set test
3) Resistance to liquid test
4) Heat ageing resistance test
5) Weather resistance test
6) Low temperature

D. Finished products

The main purpose of the test is to ensure the complete curing and also that the material composition is identical with that of the approved rubber compound. The sample size during this testing is usually restricted to 3 percent of a batch. Testing at this stage is mainly to assess the stability as well as consistency during the manufacturing of a product. In this testing, emphasis should be to include the tests, which are sensitive to the degree of vulcanization and change in the composition of rubber compound, as an example, the following are a few important tests that pertain to rubber sealing ring:

a. Tensile strength
b. Elongation at break

c. Hardness/Apparent hardness
d. Compression set
e. Swelling
f. Density
g. Material identification

The Temperature & duration are to be decided based on the service temperature and type of rubber being used for application. It is recommended that the variation in the results of the batch acceptance test should always be compared with the test results obtained at the time of evaluation/ approval of material. Generally, statically quality control data should be made available for comparison.

E. TEST METHODS & SIGNIFICANCE

At the time of indigenous development of various rubber compounds, physical-mechanical property measurement is the main criteria to accept or reject the developed material before subjecting it to further end use evaluation. Russian manufacture's site after confirming of physical-mechanical properties. Because of this, it is felt necessary to discuss in brief all such tests that are carried out at the time of development of indigenous rubber compound.

1. SPECIFIC GRAVITY (DENSITY)

Specific Gravity is normally abbreviated to SG and is the ratio of the weight of a given substance to the weight of an equal volume of water at a specified temperature. For rubber sheeting, this is generally expressed as the **Weight Per Square Metre Per mm Thickness**. The SG of a solid rubber will vary according to its formulation and polymer type.

2. ELONGATION

Elongation or strain is the extension between benchmarks produced by a tensile force applied to the test piece and is expressed as a percentage of the original distance between the marks.

3. **TENSILE STRENGTH**:

It is maximum tensile force due to stretching a test piece.

4. HARDNESS

Hardness is the resistance to deformation of material surface on the application of applied load. It is a resistance to penetration deformation.

Dead load Tester: Which measure Hardness in IRHD (international of Rubber Hardness Degree)

Micro Hardness Tester: Measured for low thickness Rubber products like

O Ring, Profiles Etc.

Durometer: it Measures Hardness in Shore- A for shaft Rubber & Shore-D for hard rubber Such as Plastics, ebonite, etc.,

5. Oil Swelling:

The change in the volume of rubber articles is due to the absorption of oil or other fluid.

6. OZONE RESISTANCE:

Ozone testing is a method used to determine a rubber or elastomer's resistance to ozone degradation. The elastomer samples are placed in a special chamber that exposes them to ozone at concentration and duration specified by a testing specification or standard. A sample that does not stand up to the effects of ozone exposure will crack at the surface and sometimes break in two.

7. FROST RESISTANCE:

Frost resistance is nothing but the ability for elastic recovery at specified sub-zero temperatures after releasing the compression load. The rubber compound is used for low temp. application.

8. FLEX CRACKING TEST

Flex-crack resistance is the ability to withstand several flexing cycles without experiencing the occurrence of surface cracks as a result of stress.

9. CONFIRMATION OF BASE RUBBER

The reverse engineering technique is used to identify base material.

10. INSPECTION OF ASSEMBLY

Finished items are required to comply with the relevant specification for the particular type of items, The items shall be inspected & tested for compliance with the requirements. Assembly lines accommodate a wide variety of parts. A missing part or an assembly defect may affect product performance and in the worst case could result in an accident. Each assembly step requires an inspection to ensure that the correct parts have been used and that they meet tolerance requirements. Items are tested as per relevant manufacturing & overhaul technology of aero-engine/aggregate.

11. Functional test:

Carried at customers end as per relevant application

12. Endurance test

Endurance testing refers to tests typically done to find out whether an application can withstand the processing load it is expected to have to endure for a long period.

IV. EXPERIMENT NO: 1

Nitrile-based rubber compound.

Sl. No.	Recipe	Phr
1.	NBR Raw Polymer	100
2.	Sulfur	1
3.	ZNO	5
4.	C.I.Resin	4
5	Anti-oxidant	1
6	Anti-degradants.	1.5
7	ST.ACID	1
8	M.wax	0.5
9	Process Aids	0.5
10	Carbon SRF	65
11	Carbon FEF	66
12	Plasticizer	26
13	Primary accelerator	1
14	Secondary accelerator	1
PRESS CURING TEMP./TIME		150 deg.c/10mints
POST CURING TEMP./TIME		-----N/A-----

Physical-mechanical properties of above rubber compound

SR. NO.	PHYSICAL PROPERTIES	RESULT OBTAINED
1	Tensile Strength in kg/cm2	109.67
2	Relative Elongation at Break%	226.33
3	Relative Residual Elongation after a rupture in %	04%
4	Hardness shore "A"	79
5	Relative Residual deformation on compression test at 20% at 150°C for 24 hours in hydraulic oil media.	23.00%
6	Change in Volume after seasoning at 150 deg.C for 24 hours in hydraulic FH-51oil media	24.02%
7	Density gm/cm3	1.26

PROPERTIES:

1. Excellent Fuel & Oil Resistance.
2. Good temperature Resistance Upto 45 deg.C to +120 deg. Resistance.
3. Good Processability & Good abrasion resistance.
4. Fuel & Oil resistance is directly proportional to the content of acrylonitrile.

Typical Products:

1. O-Rings & Seals.
2. Gasket, Bushes.
3. Fuel Tanks.
4. Diaphragms.
5. Hoses & metal bonded parts etc.
6. Oil –resistance Pipes
7. Aircraft & Missile Wire Insulation.
8. Automotive transmission belts.

END-USE OF MATERIAL

Material approved for manufacturing of MiG-series aircraft components

such as sealing rings, gaskets, bonded valves,

This rubber compound is suitable to use in hydraulic oil media.

Figure 1. Nitrile Rings

V. EXPERIMENT NO. 2

Silicone rubber is an elastomer consisting primarily of a chain of molecules known as a siloxane bond (-Si-O-Si-). This chain is effectively silicone rubber's "backbone," to which a variety of organic chemical groups can be added, altering its mechanical and material characteristics.

Silicone base rubber compound.

SR. No.	Recipe	Phr
1.	Silicone raw rubber	100
2.	Heat stability modifier	2.5
3.	Peroxide	1.25
4.	Red colour pigment	3.50
Press curing temp./time Post curing temp./time		170 deg. C/10 mints. 200 deg.c/04 hours.

Physical-mechanical properties of above rubber compound

SR. NO	PHYSICAL PROPERTIES	RESULT OBTAINED
1	Tensile Strength in kg/cm2	65.33
2	Relative Elongation at Break %	190.33
3	Hardness shore "A"	78
4	Relative Residual deformation on compression test at 20% at 200°C for 24 hours in air media	23.50%
5	Density gm/cm3	1.38

PROPERTIES:

1. Very Low Compression Set Over -120F to 500F
2. Excellent High-temperature Resistance.
3. Excellent Low-temperature Resistance.
4. Excellent Electrical Properties.
5. Poor Strength.

Typical Products:

1. Air & oxygen Pressure Regulator Diaphragms.
2. Engine Starter Hose.
3. O-Rings & Seals.
4. Aircraft & Missile Wire Insulation.

END-USE OF MATERIAL

The Indigenous rubber compound is approved for manufacturing of MiG series of aircraft components such as profiles, gaskets, and packing.

Photographs of our products

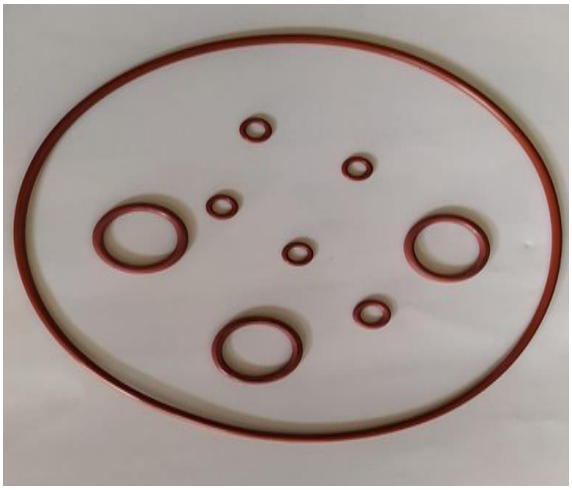

Figure 2. Silicone Rings

VI. CONCLUSION

Aerospace industry required rubber components with high performance and endurance properties for gaskets and packing because they will be exposed to a range of extreme weather conditions, such as excessively hot or cold temperatures, and different types of oils and gases. By experiment 1, results shows that the nitrile-based rubber compound is having an Excellent Fuel & Oil Resistance. Good temperature Resistance up to 45 degrees Celsius to +120 degrees Celsius. Resistance Good Processability & Good abrasion resistance. and Fuel & Oil resistance is directly proportional to the content of acrylonitrile this type of rubber component uses in fighter jets such as sealing rings, gaskets, bonded valves, this rubber compound is suitable to use in hydraulic oil media. By Experiment 2, the silicone base rubber compound having Very Low Compression Set Over -120F to 500F, Excellent High-temperature Resistance. Excellent Low-temperature Resistance. Excellent Electrical Properties. The Indigenous rubber compound is approved for manufacturing of MiG series of aircraft components such as profiles, gaskets, and packing.

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