Common Causes Of Failure In Elastomers ….

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Failure

Why do we need to know how rubber materials fail?
Rubber Failure – Where Is The Knowledge?

- When failures occur, those involved understandably do not wish to publicise the occurrence.

- Diagnosticians investigating failures are often prevented from disclosing the details due to the restraints of their contracts.

- For these reasons failure diagnosis activities are very often covert.

- Opportunities for learning from previous mistakes is limited.

- Knowledge and skills required to diagnose failure not generally freely available.
Understanding Failure – How Can It Help?

- Prevent future failures by understanding the cause and applying lessons learned.
- Avoid the costs associated with product failure.
- Avoid loss of reputation.
- Avoid expensive litigation costs.

Failure Is Expensive!
Common Causes Of Rubber Component Failure
Rubber Failure – Human Causes

Reason for Failure

- Material misselection and poor specification: 45%
- Poor material process: 20%
- Poor product design: 20%
- Product abuse: 15%
- Product abuse: 15%

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Rubber Failure – Service Related Causes

Common Service Related Causes Of Failure

- Chemical
- Heat
- Fatigue
- Abrasion
- Tear
- Set
- Ozone

Note: UV attack can be an issue with elastomers
Failure

Human Causes
Human Causes

1. Incorrect Material
Human Causes – Incorrect Material

Material Selection Is No Simple Task!

- Successful material selection requires a judicious scientific approach in order to evaluate the requirements of the application.

- Need to match the application to the properties of the material.

- Incorrect material selection is one of the most common causes of failure.
Failure

Human Causes

2. Poor Product Design
What do we need to consider when in the design stage?

- Select the most appropriate material
- Understand fully the service conditions
- Understand the expected lifetime of the product
- Is the application dynamic or static?
- What stresses and strains can we expect in service?
- What will the product be in contact with or exposed to?
- What are the material’s property limits?
- How are they affected by the design?
Human Causes

3. Poor Material Processing
Human Causes – Poor Material Processing

Don’t Engineer-In Product Failure!

• Correct and appropriate material processing is a key factor in the product life cycle.

• Even if we select the correct materials, and design the right rubber compound, all is lost if processing is poor.

• We need to consider material processing from start to finish.
Human Causes

4. Product Abuse
Human Causes – Product Abuse

- Product abuse accounts for approximately 15% of all rubber component failures.

- It can result from many factors such as:
  - Product designers not understanding their materials fully.
  - Inappropriate use.
  - Excessive use.
  - Deliberate damage
  - Users who do not understand the limitations of the products they use.
Human Causes – Product Abuse

Example – Hot Water Bottle

Product abuse can be dangerous!
Human Causes – Product Abuse

Example – Engine Mount & Truck Tyre

NR

Engine Mount

NR/BR

Diesel

Truck Tyre
Service Related Failures
Service Related Failures

1. Chemical Attack
There are a large number of chemical agents that can degrade elastomers.

The severity and effect depends on the chemical agent and the chemistry of the elastomer being attacked.
When considering an elastomer for an application, we need to be aware of any contact media that can cause the following to occur:

- Polymer chain scission leading to molecular weight reduction.
- Increased cross linking of the matrix.
- Polymer chain modification as a result of cyclisation, chlorination or other chain modifications.
Examples of chemical attack:

Degradation of a butterfly valve seal by chlorine containing species
Examples of chemical attack:

Degradation of a NR/CR pipe expansion joint by metal ion accelerated thermo-oxidation.

$\text{Cu}^{2+}$
Service Related Failures

2. Heat
Effect of Heat:

- Thermal degradation is highly complex, depending on the material exposed and the contact media. There is no single diagnostic effect.

- As the temperature increases, the rate of reaction of rubber degradation processes also increases.

- This principle applies to elastomers operating in oxygen environments, but also to rubbers exposed to other degrading chemicals or environments.

- Excessive exposure to heat leads to a deterioration in material properties, and ultimately chemical degradation of polymer itself.
Example of the effect of heat:

SBR rubber shock absorber:

• Internal heat build up.
• Not visible externally
• Thermal degradation
• Reversion
Service Related Failures
3. Fatigue
What is fatigue?

- A Function of the Polymer
- Time related
- Related to compounding
- Related to duty/service
- Can be affected by design
- Micro cracks start at flaws in the material
- Cracks propagate through the material leading to ultimate failure

Fatigue cracking in a cycle handlebar grip
Service Related Failures

4. Abrasion
What is abrasion?

- It is a highly complex process.
- Often loosely described as ‘wear’.
- Abrasion involves the removal of rubber from a component through contact with another surface.
What is abrasion?

- Abrasion is a function of the polymer, compound and service.

- Types of abrasion are:
  
  **Abrasive** - Hard asperities cutting the rubber
  
  **Fatigue** - Dynamic local stress
  
  **Adhesive** - Transfer of rubber onto another surface
Service Related Failures

5. Tear
What is tearing?

Tearing initiates at weak points with the material.

Two processes are involved:
- Tear initiation
- Tear growth

Critical in highly stressed components:
- Tyres, bushes, tank pads

Tearing is:
- A Function of the Polymer
- Compounding
- Processing
- Duty
- Design
Service Related Failures

6. Set
What is set?

- A Function of the Polymer
- Compounding
- Duty
- Design
- A permanent deformation
- Can occur in tension or compression
- Leads to reduced sealing force in sealing applications.

Tension maintained for a period of time and then released

A permanent set – termed tension set
Examples of compression set:

- Tap washer
- Soft drink bottle seal c.1918
Service Related Failures

7. UV Attack
Service Related Failures – UV Attack

Unsaturated elastomers can be attacked by Ultraviolet light unless they are protected. Those susceptible include:

Natural Rubber (NR)
Synthetic Polyisoprene (IR)
Butyl rubber (IIR)
Polybutadiene (BR)
Styrene-butadiene Rubber (SBR)
Nitrile Rubber (NBR)
Hydrogenated Nitrile Rubbers (HNBR)

Saturated elastomers such as EPDM are more resistant, but still affected in strong sunlight
Service Related Failures – UV Attack

- Carbon black used as a filler in rubber compounds can act as a UV screen, but it is never completely effective in preventing attack.

- Titanium dioxide can be added to light coloured compounds as a UV screen, but it is expensive especially when used at filler loadings.

- Tinuvin P can be added as an absorber of UV light.

2-(2H-benzotriazol-2-yl)-p-cresol - hydroxyphenyl benzotriazole
Service Related Failures – UV Attack

- Initially - a surface effect.
- Chalkiness and mud cracking on light coloured articles
- Increasing exposure - attack depth increases and bulk physical properties change.
- Faster bulk effects in transparent items
Service Related Failures – UV Attack

Examples of UV Attack
Service Related Failures

8. Ozone Attack
Service Related Failures – Ozone Attack

- Atmospheric or electrically generated ozone affects unsaturated polymers.

\[
\begin{align*}
\text{O}_3 & \quad \text{C} &=& \text{C} \\
& & + & \text{C} = \text{O} \\
& & \quad & \text{O} = \text{C}
\end{align*}
\]

Polymers strongly affected: Natural rubber, Polybutadiene, Styrene-butadiene rubber, Nitrile rubber.
Polymers affected: Butyl
Resistant polymers: EPDM, Silicone, Fluoroelastomers, Polychloroprene
Service Related Failures – Ozone Attack

- Ozone is a naturally occurring gas, present in the atmosphere at concentrations of 0.5 - 2 pphm.

- Ozone can be generated by electrical equipment, and is often present in concentrations up to 50 pphm.

- Ozone is also present in higher concentrations in polluted urban environments.
Example of Ozone Attack:

- A basketball exposed to the atmosphere for a number of months.
- Material is under strain.
Example of Ozone Attack:

• A golf club grip.
• Material is under strain, cracks at 90° to the strain direction.
Thank-you for your attention

Gary S. Crutchley
is part of the Polymer Consultancy group at Smithers Rapra.

The company provides a complete range of services inclusive but not exhaustive of:

- Polymer failure diagnosis
- Polymer analysis
- Polymer materials and product testing
- Design services: Materials selection FEA, Mould flow,
- Long term design data generation and accurate lifetime predictions services to the performance of a part.

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