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Silicone Hose with Braiding Technology

Sonal B. Prajapati[*1], Prof. Rupande N. Desai[2]

[*1, 2]L.D. College of Engineering, Ahmedabad, India

sonalchem20@gmail.com

Abstract

Silicone Rubber is a specialty synthetic elastomer that provides a unique balance of chemical and mechanical properties required by many of today's more demanding industrial applications. Because of its relative purity and chemical makeup, silicone rubber displays exceptional biocompatibility which makes it suitable for many health care and pharmaceutical applications.

However, Braiding is probably the most common and traditional method of reinforcing hose. Braiding machines were available in France and Germany as early as the middle of the l9th century for braiding textiles used for rope and clothing products. Compared to many organic elastomers, silicone rubber offers superior ease of fabrication resulting in high productivity and cost effectiveness for extended service reliability. Here, We are going to combine properties of silicone with braiding technology to make a well suited hose to industrial applications.

Keywords:

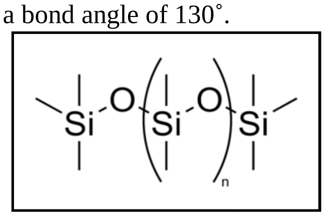
Introduction

Silicone rubber is an elastomer (rubber-like material) composed of silicone—itself a polymer—containing silicon together with carbon, hydrogen, and oxygen. Silicone rubbers are widely used in industry, and there are multiple formulations. Silicone rubbers are often one- or two-part polymers, and may contain fillers to improve properties or reduce cost. Silicone rubber is generally non-reactive, stable, and resistant to extreme environments and temperatures from −55 °C to +300 °C while still maintaining its useful properties. Due to these properties and its ease of manufacturing and shaping, silicone rubber can be found in a wide variety of products. From its original development in the 1940's using a laboratory Grignard process, to its final commercial form today, silicone rubber excels in such areas as:

- High temperature stability
- Low temperature flexibility
- Chemical resistance
- Weatherability
- Electrical performance
- Sealing capability

Structure

Polysiloxanes differ from other polymers in that their backbones consist of Si-O-Si units unlike many other polymers that contain carbon backbones. Polysiloxane is very flexible due to large bond angles and bond lengths when compared to those found in more basic polymers such as polyethylene. For example, a C-C backbone unit has a bond length of 1.54 Å and a bond angle of 112˚, whereas the siloxane backbone unit Si-O has a bond length of 1.63 Å and a bond angle of 130˚.



The siloxane backbone differs greatly from the basic polyethylene backbone, yielding a much more flexible polymer. Because the bond lengths are longer, they can move farther and change conformation easily, making for a flexible material. Polysiloxanes also tend to be chemically inert, due to the strength of the silicon-oxygen bond. Despite silicon being a congener of carbon, silicon analogues of carbonaceous compounds generally exhibit different properties, due to the differences in electronic structure and electronegativity between the two elements; the silicon-oxygen bond in polysiloxanes is significantly more stable than the carbon-oxygen bond in polyoxymethylene (a structurally similar polymer) due to its higher bond energy.

Classes of Silicone Rubbers

MQ, or polydimethylsiloxane (PDMS), denotes a polymer in which two methyl groups are bound to the siloxane backbone.

VMQ stands for a polydimethylsiloxane in which a small number of methyl groups have been replaced by vinyl groups.

PVMQ stands for a VMQ in which a small number of methyl groups have been replaced by phenyl groups.

FVMQ stands for a VMQ in which a small number of methyl groups have been replaced by trifluoropropyl substituents.

Industrial Classifications

There are three main industrial classifications of silicone rubbers:

High Temperature Vulcanising (HTV) – Sometimes called heat curable, these are usually in a semi-solid gum form in the uncured state. They require rubber-type processing to produce finished items.

Room Temperature Vulcanising (RTV) – Usually come as a flowable liquid and are used for sealants, mould making, encapsulation and potting. These materials are not generally used as conventional rubbers.

Liquid Silicone Rubbers (LSR) – Sometimes called heat curable liquid materials, these materials are processed on specially designed injection moulding and extrusion production equipment.

Manufacture

Silicones can be mixed/compounded using mixers of mills. However, due to the low viscosity close-fitting scrapers and cheek plates need to be used to ensure complete mixing. Forming can be carried out by conventional techniques such as injection moulding, extrusion and compression moulding. Care must be taken to take into account relatively large curing shrinkages and to avoid entrapped air.

Curing is generally rapid for most grades and followed by a post cure treatment in an air oven at 200-250°C, for a period of 4-24 hours. This process serves to improve properties and remove residual peroxide products.

Hose Manufacture

A hose is a reinforced, flexible conduit used to move materials from one point to another or to transmit energy. It is flexible to accommodate motion, alignment, vibration, thermal expansion and contraction, portability, ease of routing, and ease of installation.

Most hoses are made up of three elements:

(1) A tube

(2) Reinforcement

(3) An outer cover.

Silicone Tubing

Silicone tubing is made by extrusion of the above compounded elastomers, known as high consistency silicone rubbers (HCR). These thermoset materials are available as two-part products:

- Base plus a peroxide, usually in the form of a paste (or “masterbatch”) for the peroxide initiated products, or
- Part A and part B for the Pt catalysed products.

In both cases, the two components are mixed at the point of use, for example using a two-roll mill, before extrusion at room temperature followed by continuous curing in high temperature ovens.

Standard rubber extruders with water cooling and roller feeds can be used to fabricate silicone rubber.

Reinforcement

Reinforcement can be textile, plastic, or metal, alone or in combination, built into the body of the hose to withstand internal pressures, external forces, or a combination of both. The type and amount of reinforcing material used depends on the method of manufacture and on the service requirements. Methods of applying these reinforcements are braid, spiral, knit, wrap, and woven.

1 Braid Reinforcement

Braiding is probably the most common and traditional method of reinforcing hose. Braiding machines were available in France and Germany as early as the middle of the l9th century for braiding textiles used for rope and clothing products.

Braiders are described as vertical or horizontal depending on the direction the tube progresses through the machine during braiding. The two major classifications of braiders are tubular or “maypole” type and rotary type.

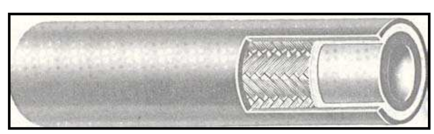


Figure 1. Single ply braided hose

1.1 Maypole Type

As the name implies, braid is formed from multiple carriers each carrying a reinforcement package traveling in a serpentine maypole fashion generally with a two over-two under pattern. The common carrier varieties available are 20, 24, 36, 48, and 64. They are utilized in vertical or horizontal, single or multiple deck arrangements.

Vertical set-ups are normally a maximum of two decks for convenience and handle non- mandrel or flexible mandrel hoses up to 1-1/2" ID. For vertical braiding, the tube is fed into the braider from underneath, passing through the centre of the unit where the braid is applied and then over a rotating capstan wheel designed to pull the tube through the braider at a specified rate so the braid is applied at the optimum design angle. For non-mandrel style products, an air cushion is often used inside the tube to prevent collapse at the braid point. The vertical braider is the oldest fashioned style with little recent advancement. Output speeds are about 30% less than the latest horizontal maypole braider innovations.

Horizontal braider equipment advancements have been substantial in the last 15 years. Improvements for tensioning wire and textile, as well as larger capacity packages, have provided significant improvements in hose output and quality, especially for wire braid products. The most common horizontal arrangements are 20, 24, 36, or 48 carriers in two or three deck combinations for handling hose up to 4" ID in flex or rigid mandrel constructions.

Flow of the tube through the braider is similar to vertical style, except caterpillar pull units instead of capstan wheels are more common. Figure 2 shows a typical modern unit.

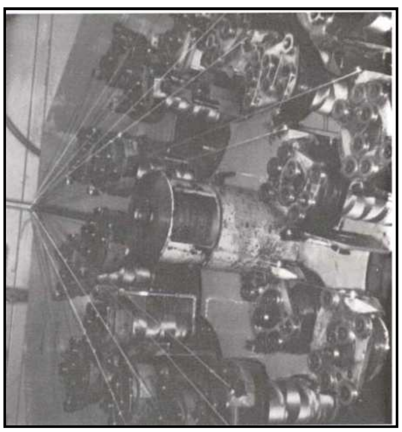


Figure 2. Modern unit of Horizontal braider

Rotary Type

The term rotary braider applies to units where the carriers holding the reinforcement package are fixed on two counter-rotating decks and do not move in and out in a serpentine path like the maypole type. The braiding pattern is achieved by deflecting the reinforcement strands from the outside deck under and over two carriers on the inside deck, repeating the motion continuously during rotation. Because of the simpler travel of the carriers, output speeds can be as much as 200% faster than an equivalent may pole type. Common arrangements are available in 20, 24, 36, 48 carriers, vertical and horizontal, one-, two- or three-deck setups for both textile and wire reinforcement.

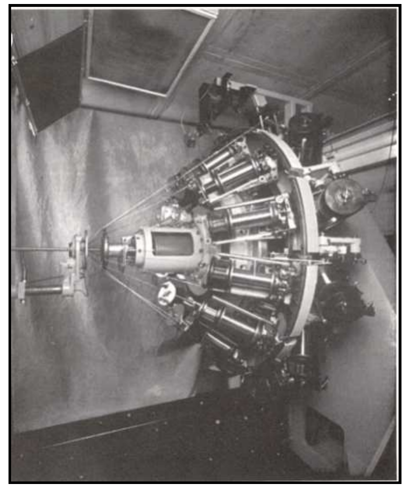


Figure 3. 24-carrier horizontal rotary style unit

This method of hose manufacture is mainly used for smaller bore hose, up to around 50 mm internal diameter, particularly for medium to high pressure applications, such as automotive brake hose. In this process, the inner tube is extruded onto a suitable mandrel and then passes through the braiding head.

Depending on the bore size and the application, an outer layer of rubber may be extruded onto this braid; for the higher rated burst strength hoses, a second layer of braiding and further cover of rubber may subsequently be applied.

Neutral Angle

From Figure 4, the braid angle, θ is given by:

$$\tan\theta = \pi D/L$$

The pressure in the hose, *P*, exerts forces in the longitudinal direction of the hose, *H*, and in the 'hoop' or radial direction, *V*. When the resultant of these two forces, *R*, is at an angle equal to the braid, the 'neutral' angle is achieved, so that:

$$\tan\theta = V/H$$

From analysis of the forces exerted by the pressure:

$$H = P\pi(\tfrac{1}{2}D)^2 = \tfrac{1}{4}(PD^2\pi)$$

$$V = \tfrac{1}{2}(PDL)$$

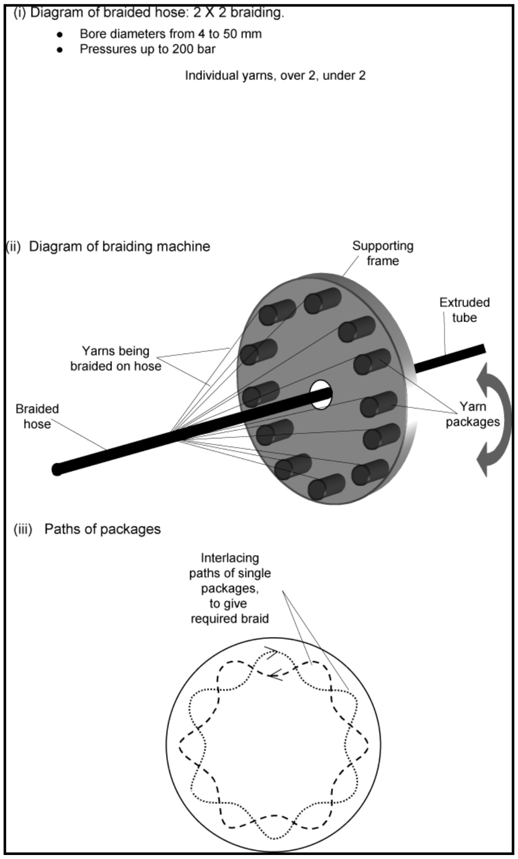


Figure 4. Braided hose

Thus, for tan θ to equal *V*/*H*:

$$\tan\theta = \frac{\frac{1}{2}(PDL)}{\frac{1}{4}(PD^2\pi)}$$

$$L = \frac{\pi D}{\tan\theta}$$

And on substituting for *L*:

$$\tan\theta = \frac{2(PD^2\pi)}{PD^2\pi\tan\theta}$$

Which reduces to:

$$(\tan\theta)^2 = 2$$

Hence,

$$\theta = 54^\circ\ 44'.$$

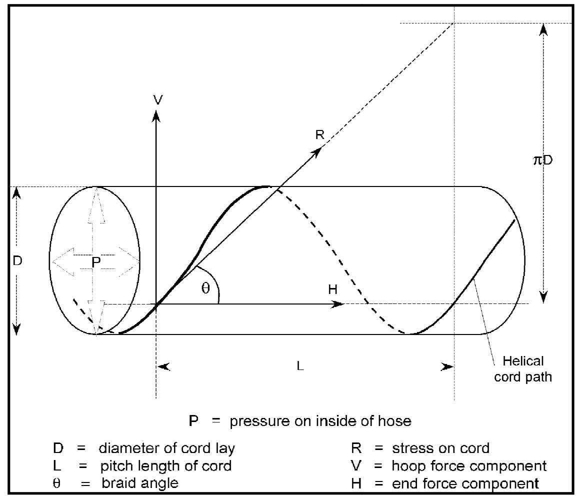


Figure 5. Derivation of the neutral angle

When it is required actually to measure the braid angle of a hose, this is calculated from measurements of the diameter and the pitch length of the helix, as shown above.

Hose Design and Construction

The most important design features of a hose is in its carcass (The fabric , cord and/or metal reinforcing section of a hose as distinguished from the tube or cover) construction. The various textiles used, together with safety factors have to be considered, but the angle of application of the textile reinforcement together with the bursting pressures achieved are of paramount importance in hose design. With regard to the angle of application of a textile yarn or cord to and around a hose lining tube, generally speaking the designer aims at obtaining the so called neutral angle, which mathematically is calculated to be $54^{o}44'$. This is the angle at which there is no movement of hose, under internal pressure, either in hose length or diameter, assuming no elongation of the reinforcement. The movement of a hose can be predicted when the angle of application is different to the neutral angle.

When the braid angle is higher than neutral:

1. The hose will increase in length.
2. Its diameter will decrease.

When the braid angle is lower than neutral:

1. The hose will shorten in length.
2. Its diameter will increase.

Summary

The siloxane backbone differs greatly from the basic polyethylene backbone, yielding a much more flexible polymer. Because the bond lengths are longer, they can move farther and change conformation easily, making for a flexible material. With the good silicone properties, Silicone Braided hose excels in High temperature stability, Low temperature flexibility, Chemical resistance, Weatherability, Electrical performance.

The various textiles used, together with safety factors have to be considered, but the angle of application of the textile reinforcement together with the bursting pressures achieved are of paramount importance in hose design. The following conclusions have been made concerning the advantages of the braiding technology: Braiding technology enables near-net-shaped fiber preform to fabricate automatically. It enables automatic production system causing the cost to reduce. Also, helps to improve the impact properties by arranging the braid layers in which braiding patterns are arranged to optimize. In last, braiding technology enables the fiber and resin hybrid structure to construct which cause to improve the impact properties.

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