PENFLEX

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Hose Flexibility: A Complex Calculation

Assemblies that transfer corrosive media at various temperatures, from very low cryogenic temperatures to temperatures as high as 1500°F, often under pressure and usually subject to some form of motion—be it flexing, vibration or fatigue—require metal hose. There's simply no other material suitable for such applications.

The ability of a metal hose to bend in response to static or dynamic movement without deforming is one of its key characteristics. It's also perhaps the one that's most difficult to understand given the number of inputs that ultimately determine how a hose will bend.

The context in which flexibility is discussed can be cause for further confusion. We could be talking about how easy a hose is to bend, how acutely it may be bent, or even how many cycles it can go at a certain pressure.

It's no surprise then that explanations of hose flexibility are prone to oversimplification. In this bulletin, as we discuss flexibility, we are referring to how large or small a hose can be bent as well as how easy it is to bend that hose.

The oft overlooked role of hose geometry

There is a common misperception that the corrugation forming process (i.e. mechanical, hydroforming, etc.) determines how flexible a hose is. But that's too easy. Rather, it is the geometry of the hose that dictates just how flexible it will be.

While the corrugation forming process does impact wall thickness—and variations in wall thickness are a result of all forming processes—it is important to highlight that the forming process itself does not determine hose flexibility.

When we say hose geometry, we are referring to these characteristics:

- **Inside diameter (ID).** ID is the distance between opposite points inside the hose.
- **Outside diameter (OD).** OD is the distance between opposite points outside the hose.
- **Wall thickness.** Base metal thickness plays a role in the eventual thickness of hose wall.
- **Corrugation width.** This is the width of an individual corrugation.
- **Corrugation count.** Also called the pitch, this is the distance from one corrugation to the next or the number of corrugations per foot.

Additional characteristics to consider in hose assemblies

When considering braided hose assemblies, braid design is an additional variable. When we say braid design, we are referring to its construction which includes the following properties.

- Number of bands of wires or number of carriers
- Number of wires per band
- Diameter of the wires
- Angle of the braid from longitudinal axis

Material selection: The part mechanical properties play

Changes in the mechanical properties of the strip or wire used to make braided hose affect the force needed to bend a hose, and thus impact its flexibility. When we talk about these mechanical properties, we are referring to:

- **Tensile strength.** Ability to resist tension, or the forces that elongate a hose.
- **Temper.** Delivered though heat treating, temper refers to the toughness of a hose, or its ability to absorb energy without fracturing.
- **Elongation.** Amount of strain a hose can experience before failure.

Increases in tensile strength, temper and elongation increase the force required to bend a hose, thereby reducing flexibility.

For example, a high nickel, high tensile material such as Inconel 625 ™ requires more force to bend than stainless steel. On the other hand, Monel 400 ™ has a lower tensile strength and requires less force to bend than 321 or 316L Stainless Steel.

When considering flexibility from this perspective alone, we could say that Monel 400 ™ hoses are likely to be the most flexible, followed by 321 or 316L Stainless Steel hose and finally by Inconel 625 ™ hoses.

Hose flexibility: A complex calculation

All of the attributes listed above play a role in the flexibility of a hose or braided hose assembly, and each one must be taken into consideration individually as well as collectively when designing the right solution for a particular application.

For instance, if all else remains the same, increasing wall thickness will decrease flexibility. Alternatively, decreasing wall thickness will increase flexibility.

However, increasing wall thickness can be offset by increasing the corrugation count, or increasing the OD—or both—to retain flexibility. Of course, all these characteristics are limited by the ranges within which changes can occur.

If a wider corrugation is desired to reduce the metal content and thus the cost of a hose, a thinner wall hose can be used to retain flexibility and further reduce weight per foot. These changes, however, reduce burst pressures and the hose will fail earlier than a heavier hose when subjected to the predicted penetration of the media.

The important point to keep in mind is that design of a braided hose is always a matter of optimization, and the effects increasing or decreasing one of the above characteristics can be offset by other changes to the design to achieve the goal set for a particular hose.

To learn more about the impact of operation conditions like bend radius and internal pressure on flexibility, take a look at Engineering Bulletin #140 on the topic.

For any questions regarding metal hose flexibility, please contact us here.