# Measuring Radial Force

Blockwise Engineering LLC
www.blockwise.com

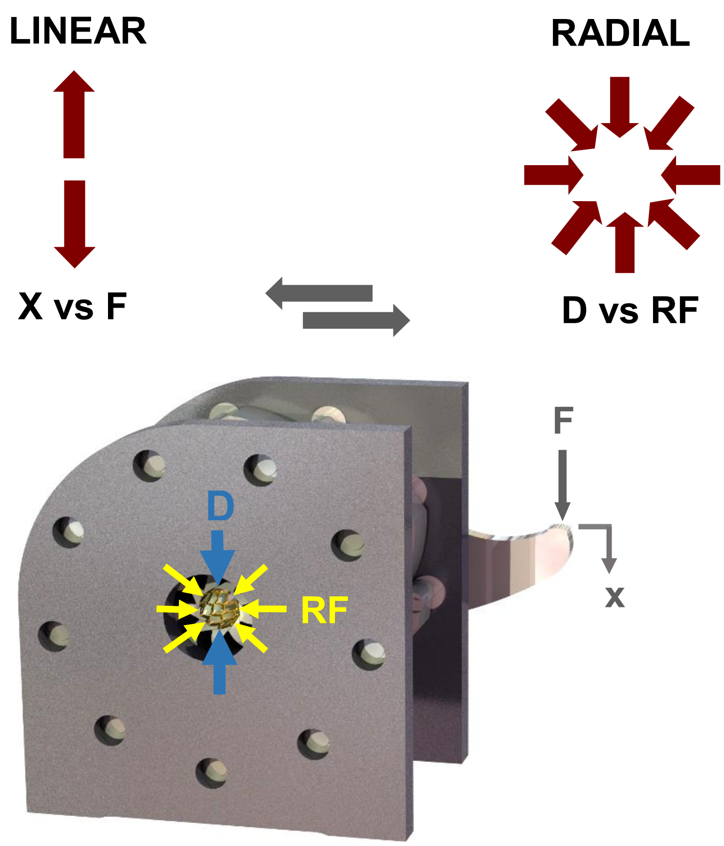
The radial force applied by a radial compression mechanism (or a "crimping head") to a product (such as a stent) is usually measured by a linear force transducer that senses the force applied by an actuator. The measured diameter of the opening can be easily verified using pin gauges, but the measured radial force is not so easily verified because "radial force gauges" do not exist.

Therefore, a trusted relationship between actuator (linear) force and radial force must be developed. Conservation of energy provides one method. (Another method is to use free-body diagrams to analyze force vectors.)

Assumptions in this analysis:

- The mechanism's friction is neglected
- The friction between the dies and the product (such as a stent) is neglected
- The product (stent) is modelled as a circular-cylindrical thin-walled tube

Most radial compression mechanisms convert linear motion at the actuator to radial motion at the product.



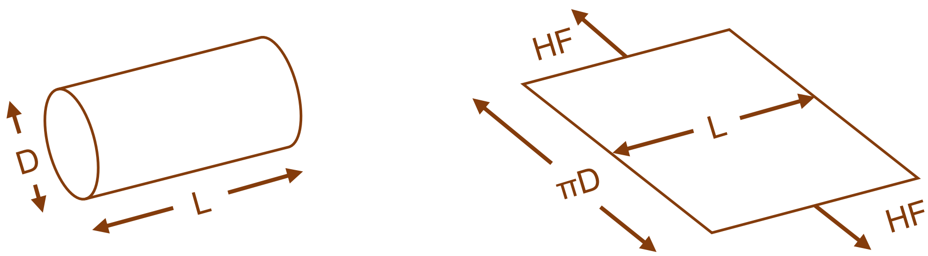

Typically the displacement x and the force F are measured, and the diameter D and radial force RF are calculated.

When the actuation arm is move a little bit (slowly), conservation of energy says that the work done on the arm F * dx equals the work done by the dies on the product. We assume that the work strains the product in the hoop direction.

Imagine that the thin-walled product is cut along one wall, lengthwise, and laid out flat

# Measuring Radial Force

Blockwise Engineering LLC
*www.blockwise.com*




Work in = Work out. For a small change in diameter dD:

$$F \times dx = HF \times \pi \times dD \qquad (1)$$

The hoop force is related to the radial force by the well-accepted relationship:

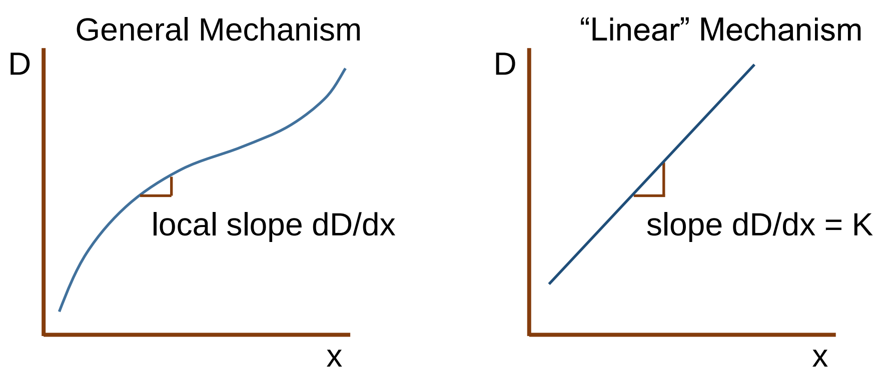
$$RF = 2 \times \pi \times HF \qquad (2)$$

which is derived in Blockwise document number R862. (See also, for example, Cabrera et al "Understanding the requirements of self-expandable stents for heart valve replacement: Radial force, hoop force and equilibrium", Journal of the Mechanical Behavior of Biomedical Materials, Volume 68, April 2017, Pages 252–264)

Combining the equations (1) and (2):

$$RF = \frac{2}{\left(\frac{dD}{dx}\right)} \times F \qquad (3)$$

The functional relationship between diameter D and actuator displacement x depends on the design of the mechanism, and may not be linear. But for most imaginable mechanisms it is a smooth function; then the value of dD/dx is the local slope of the function.




For the general mechanism, the relationship (3) is valid at any diameter, but the proportionality between RF and F varies depending on the diameter.

The better mechanisms are specifically designed to linearize the relationship between diameter and actuator stroke, so that the slope has a single value, "K", independent of diameter. Then RF can be calculated as

$$RF = \frac{2}{K} \times F \qquad (4)$$

All of Blockwise's radial compression mechanisms for stent crimping or radial force testing employ a linearized design, and Blockwise publishes the values of K for each model of mechanism.