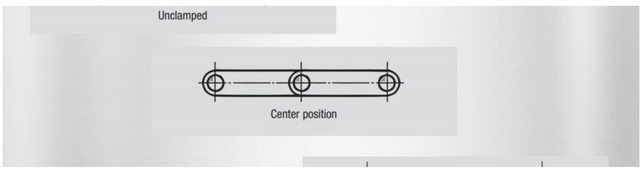
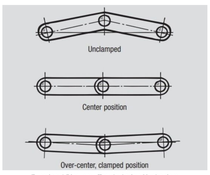
How to Calculate Applied Forces on Toggle Clamps



Do you know how to calculate exerting or clamping force and holding capacity for toggle clamps?

In this article we will take a closer look at:

How Toggle Action Force Factors Function



Functional Diagram - Toggle Action Mechanism

Toggle action clamps operate through a linkage system of levers and pivots. The fixed-length levers, connected by pivot pins, supply the action and clamping force.

The maximum exerting or clamping force developed in any toggle action clamp is attained when the three pivot points of the mechanism are in a straight line. While theoretically true, there is no allowance for vibration and intermittent load conditions found in industrial applications. Such conditions would soon unlock an improperly designed clamp.

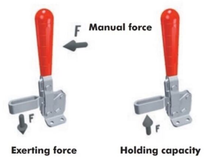
The proper amount of over-center travel to produce maximum holding force and yet ensure positive locking is a carefully calculated and controlled dimension developed by years of experimentation and experience.

Each clamp is rated with its **holding capacity**, the maximum load or force the clamp will sustain in the closed and locked position without permanent deflection.

Exerting forces applied as the clamp closes are less than the holding capacity and are dependent on variables such as the position of the operator's hand on the handle; the amount of force applied; and the position of the spindle on the bar.

This article explains how to calculate exerting or clamping force and holding capacity.

What is Exerting or Clamping Force and Holding Capacity?



When selecting clamping products for your workholding solutions, a clear distinction must be made between **exerting forces** and **holding capacities**. Here are the essential features.

Exerting or Clamping Force

Manually operated clamps have several variables which determine the actual exerting force. Among these variables are:

> **The force exerted on the handle by the operator.**

> **The point on the handle where this force is applied.**

> **The mechanical advantage in the linkage.**

> **The point on the work holding bar where the force will be measured. As a general rule, the mechanical advantage available ranges from 2:1 to 10:1.**

Holding Capacity

The **holding capacity** of toggle clamps is usually determined by actual tests. It is defined as the maximum amount of force that may be applied to the work holding bar, in the closed position, without creating permanent deformation of the clamp components. This maximum force is measured at a point closest to the base and diminishes as the spindle approaches the end of the bar. The ratings for holding capacity are typically maximum and should not be exceeded. These values include a safety factor.

How to Calculate Exerting or Clamping Force?

The table below depicts holding capacity (HC) and clamping force (EF) data for a typical manual clamp. The **clamping force (EF)** is expressed as a ratio of the **force applied to the clamp handle (AF)**. In this example, either 10:1 or 5.3:1 depending upon the position of the clamping point on the clamp arm. That is, at position X1, the maximum clamping force (EF) that can be generated is 10 times the force that is applied to the clamp handle or a 10:1 ratio.

Examples:

Example #1 - Find the force (AF) the operator would have to apply to the clamp to generate a clamping force of 90N [400lbf.] at the end of the clamp arm (X1).

If: **AF = EF ÷ 10**

Then: **AF = 90N (400lbf.) ÷ 10 = 9N [40lbf.]**

Example #2 - What is the maximum clamp force that can be generated at X2 if the operator is only able to apply 5N [23lbf.] to the clamp handle?

If: **EF = AF x 5,3**

Then: **EF = 5N [23lbf.] x 5,3 = 26,5N [120lbf.]**

How to Calculate Holding Capacity?

The holding capacity (HC) ratings shown in the table are relative to the pivot point of the clamping arm. This is useful in estimating the holding capacity at an intermediate clamping point along the arm, or a point beyond the length of the standard clamping arm.

Examples:

Example #1 - Find the maximum holding capacity if the clamping point is 40mm [1.5in.] from the front of the base of the clamp.

Step 1 – find the clamping distance from the clamping point to the pivot point

Xc = 40mm + X = 40mm + 40,5mm = 80.5mm

Step 2 – express the holding capacity as a moment

M = X1 HC1 = 49,5mm x 4450N = 220275 N mm

Step 3 – calculate the holding capacity at XC

HC = M ÷ Xc = 220275 ÷ 80,5 = 2736N [615lbf.]

Example #2 - Find the maximum holding capacity if the clamp arm is extended by 25mm [1in.] **(follow steps 1-3 above)**

Xc = 25+X2 = 25 + 99,5 = 124,5mm

M = X2 HC2 = 99,5mm 2090mm = 207955 N mm

HC = M ÷ Xc = 207955 ÷ 124,5 = 1670N [375lbf.]

Summary

While many types of clamps are used in jigs and fixtures, the most commonly used are toggle clamps. They are available in manual, pneumatic and hydraulic versions and come in a wide variety of configurations, sizes, and holding capacities.

Regardless of how they are operated, the primary feature of *toggle clamps* is that they lock in position securely, are quick acting and can be quickly turned on or off by an operator.

One of the most important criteria for selecting toggle clamps for your workholding solutions is how to calculate exerting or clamping force and holding capacity. The formulas are easy to understand and apply. Most toggle clamp manufacturers provide data tables that assist the workholding designer.