## Step 1: Establish Key Geometry from Shaft Properties

In machine design problems where a square key is specified without direct dimensions, its sizing defaults to standard proportional proportions. For a square key, the width (b) equals its thickness (t), defined as one-quarter of the shaft diameter (d):

$$b = t = \frac{d}{4}$$

Given a shaft diameter (d = 130 mm = 0.130 m):

$$t = \frac{0.130\ m}{4} = 0.0325\ m$$

## Step 2: Calculate the Key's Resisting Compressive Force ($F_c$)

Bearing stress ($S_c$) acts across the longitudinal flank of the key. Because a square key is split equally between the shaft keyseat and the hub keyway, only half of its total thickness (t/2) is subjected to compressive crushing forces against the shaft. The effective bearing area ($A_c$) is:

$$A_c = \left(\frac{t}{2}\right)L$$

Where the key length (L) is 150 mm = 0.150 m. Using the bearing stress limit ($S_c$ = 400 MPa = 400,000 kPa), we find the maximum allowable tangential crushing force ($F_c$) at the shaft surface:

$$S_c = \frac{F_c}{A_c} = \frac{F_c}{\left(\frac{t}{2}\right)L}$$

$$F_c = S_c\left(\frac{t}{2}\right)L = (400,000\ kPa)\left(\frac{0.0325\ m}{2}\right)(0.150m) = 975\ kN$$

## Step 3: Determine the Tangential Force at the Pulley Rim ($F_{pulley}$)

For a rigid assembly, the internal torque sustained by the shaft-key interface must balance the external mechanical torque applied at the outer rim of the pulley:

$$T_{pulley} = T_{key}$$

$$F_{pulley}\left(\frac{D_{pulley}}{2}\right) = F_c\left(\frac{d}{2}\right)$$

$$F_{pulley}(1.8\ m) = (975\ kN)(0.130\ m)$$

$$F_{pulley} = 70.417\ kN$$

Notice that the force required to crush the key inside the shaft hub (975 kN) is nearly **14 times higher** than the force required at the rim (70.4 kN). This difference highlights the principle of mechanical leverage. Because the pulley has a wide diameter (1.8 m) compared to the narrow shaft (0.13 m), small force inputs at the rim convert into massive, destructive forces at the center axis.

**Keys as Intentional Safety Fuses:** In power transmission design, keys are often engineered as "mechanical fuses." It is much cheaper and easier to replace a sheared or crushed key than it is to replace a warped drive shaft or a broken pulley hub. Designers intentionally specify key materials that will fail at predictable thresholds to shield more expensive system components from sudden overload spikes.