A roll must have sufficient overall strength to withstand the rolling forces and resulting stresses it will be subjected to during its service life. During rolling a roll will be exposed to multiple stresses including:

i. Shearing stress – torque applied to the drive interface of the roll will result in stress at the drive palm and clamp grooves of work rolls.

ii. Bending stress – Roll separating forces cause deflection of the roll stack that results in stress being developed in the barrel face to journal radii of back up rolls and work rolls in the case of 2-high mills. Modern shape control systems will typically apply bending to the work roll to alter its effective crown with resulting bending stress being created.

iii. Axial stress – resulting from abnormal cross rolling, bearing fixtures and shape control systems will result in stresses forming at clamp or ring grooves.

It is important both for the roll maker and the roll user to understand the magnitude of these stresses so that the roll material and manufacturing method can be chosen to ensure the finished roll will possess the required mechanical properties to withstand these stresses. A factor of safety of 2 to 3 times for the roll materials strength over that of the maximum predicted stress is typically applied to allow for fatigue as well as unknown factors such as corrosion or mechanical damage within highly stressed areas.

Care should be taken by the roll user whenever modifications to a mills design and operation occur such that higher rolling forces result that will increase the stress applied to a roll. An assessment of any existing roll design with these new stresses is recommended. Where the factor of safety is considered insufficient then a modification to the roll material and or re-design of the roll should be considered.

A few regularly used examples of long hand stress calculations are shown below
1. Bending Stress.

The bending stress resulting at the barrel face to journal radius within the journal of a work roll can be calculated using the following equation:

\[
Bending \ Stress \ S_b = \left(\frac{P \times L \times 32}{\pi \times d^3}\right) \times K_t
\]

Where:
- \(P\) = load
- \(L\) = lever arm length
- \(d\) = roll neck diameter
- \(D\) = barrel diameter
- \(r\) = fillet radius
- \(K_t\) = stress intensification factor

The stress intensification factor \(K_t\) can be determined by looking up the following values on the table seen in figure 1.

Fillet radius to journal diameter ratio \(= \frac{r}{d}\)

Barrel diameter to journal diameter ratio \(= \frac{D}{d}\)

![Figure 1](image-url)
2. Shear Stress

The shear stress resulting in the clamp groove of a journal can be calculated using the following equation:

\[ \text{Shear Stress } S_s = \left( \frac{16 \times T}{\pi \times D^3} \right) \times K_t \]

Where:
- \( T \) = torque
- \( d \) = groove diameter
- \( D \) = journal diameter
- \( r \) = fillet radius in groove
- \( K_t \) = stress intensification factor

The stress intensification factor \( K_t \) can be determined by looking up the following values on the table seen in figure 2.

Groove fillet radius to groove diameter ratio = \( \frac{r}{d} \)

Journal diameter to groove diameter ratio = \( \frac{D}{d} \)

![Figure 2](image-url)
3. Finite Element Stress Analysis

Stress calculations such as those shown above have for many years allowed for the stress at any single given location to be determined. While these calculations have been found to be reliable the ever increasing complexity of modern mill roll design makes the application of this method challenging. In recent year’s computer modeling and finite element stress analysis has been adopted by Union Electric Steel for its roll stress analysis. This method allows for the calculation of stress values at all points across a roll allowing for areas of concern to be highlighted and where necessary design changes can be recommended to the mill builder or end user and changes in manufacturing process can be made to increase the roll materials strength.

An example of some of the results obtained from finite element analysis of a roll are shown below.

Back up roll model showing the mesh and location of the bending load to be applied.
Stress values will be calculated for each nodal point
Von Mises stress plot for a back up roll with bending load applied

Model of a work roll with for analysis under torque load.
Von Mises stress plot for a work roll with torque load applied