CATEGORY: **SPALLING**

TYPE: **SUB-SURFACE INITIATION - CONTACT STRESS (CRUSHING)**

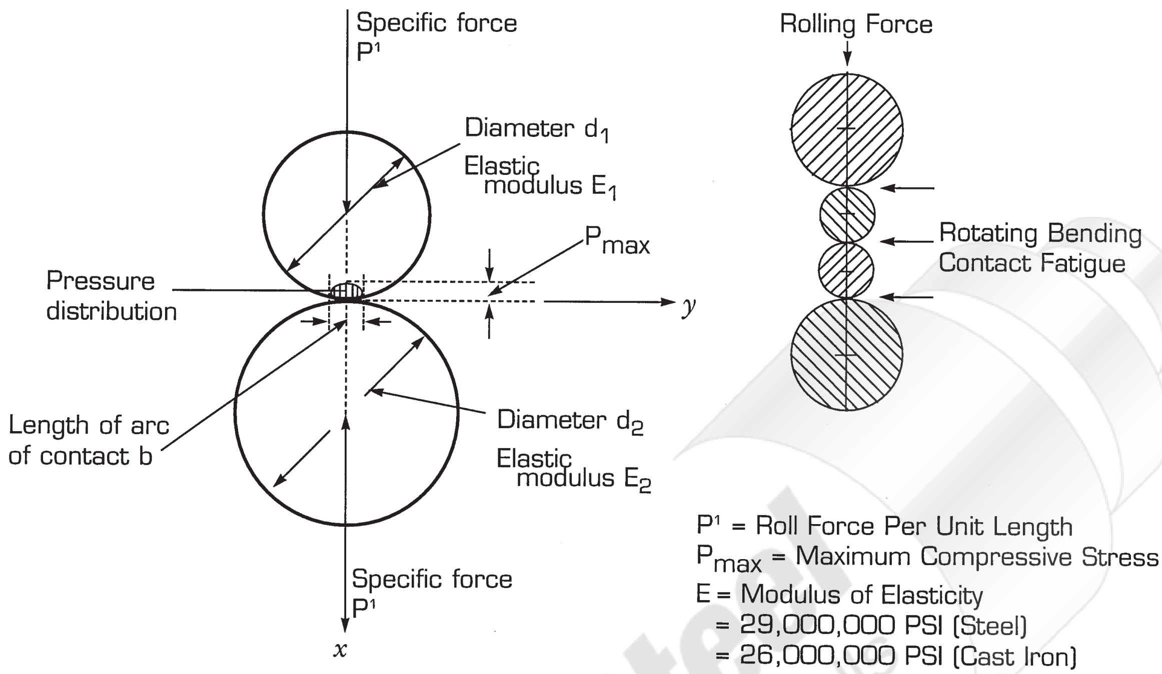
GENERAL MECHANISM

Due to the applied mill load and the localized flattening of the rolls at their contact point, the maximum resultant shear stress (commonly referred to as "Hertzian Stress") is located at a short distance below the roll surface (Figures 1 and 2 illustrate the stress condition). Cracks at multiple locations can initiate and propagate at that sub-surface location when the Hertzian Stress exceeds the compressive strength of the roll. This can occur via two modes:

(1) Instantaneously; by a sudden increase in the Hertzian Stress. This occurs when work rolls wrap, skid or stop suddenly. The Hertzian Stress increases dramatically and can easily exceed the compressive strength of the roll. Sub-surface cracks can then form instantaneously and with further cycling of rolling stresses, propagation via a fatigue mode can occur and spalling is probable. In extreme cases of excessive contact stress, subsurface cracks can both initiate and propagate to spalling instantaneously.

(2) High Cycle Fatigue Fracture; this mode of sub-surface crack initiation occurs more commonly in back-up rolls and usually occurs without mill incidents. Typically, this type of fatigue fracture is described as a "crumbly" type spall that manifests from cracks that initiate beneath the roll surface over time. This is readily explainable by a typical S-N fatigue graph where the number of cycles to failure is on the order of 1 million. Repeated application of stress lower than the inherent material strength of the roll can lead to crack initiation if the number of stress applications is sufficient. High cycle contact stress fatigue spalls initiate in many locations within the stressed area as very small cracks oriented parallel to the tangent of the roll surface. Repeated cycling of stress then propagates these cracks toward the surface until spalling occurs. In some cases, the contact stress fatigue cracks can begin to propagate radially and circumferentially, forming a fatigue "wreck" path and spalling is inevitable (See Spalling - Surface Initiation). A number of factors contribute to produce contact fatigue spalls including: length of time in the mill, stock removal, rolling pressures and work roll to back-up roll diameter differential.

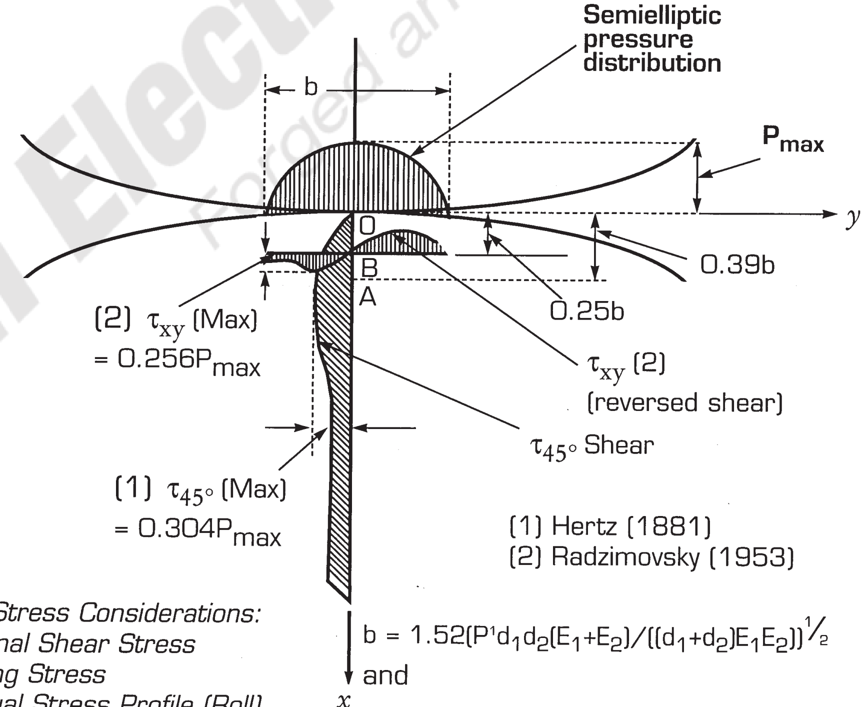
STRESS DISTRIBUTION
(Work Roll - Back Up Roll Contact Zone)



P^1 = Roll Force Per Unit Length
P_{max} = Maximum Compressive Stress
E = Modulus of Elasticity
= 29,000,000 PSI (Steel)
= 26,000,000 PSI (Cast Iron)

FIGURE 1 (ref. 2)

STRESS DISTRIBUTION
(Work Roll - Back Up Roll Contact Zone)



(1) Hertz (1881)
(2) Radzimovsky (1953)

Additional Stress Considerations:
Torsional Shear Stress
Bending Stress
Residual Stress Profile (Roll)

$b = 1.52(P^1 d_1 d_2 (E_1+E_2)/((d_1+d_2)E_1 E_2))^{1/2}$

and

$P_{max} = 4P^1/(\pi b) = 0.83(P^1 E_1 E_2 (d_1+d_2)/((E_1+E_2) d_1 d_2))^{1/2}$

FIGURE 2 (ref. 2)