CATEGORY: ROLL SURFACE INDICATIONS

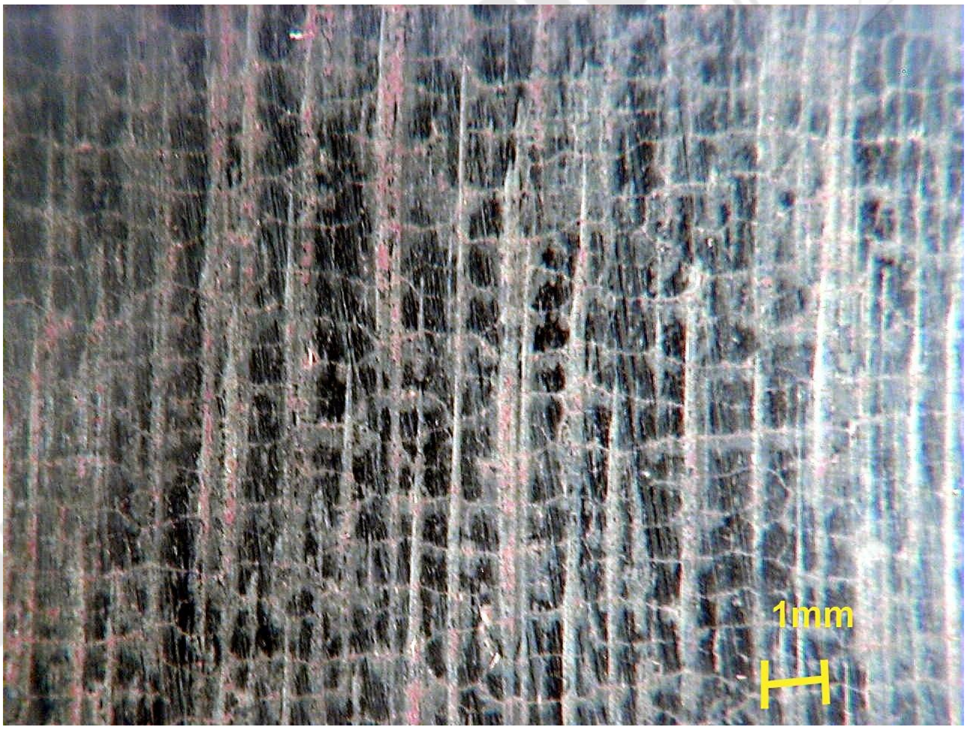
TYPE: FIRE CRAZING

AFFECTS: WORK ROLLS (HOT MILLS)

CHARACTERISTICS

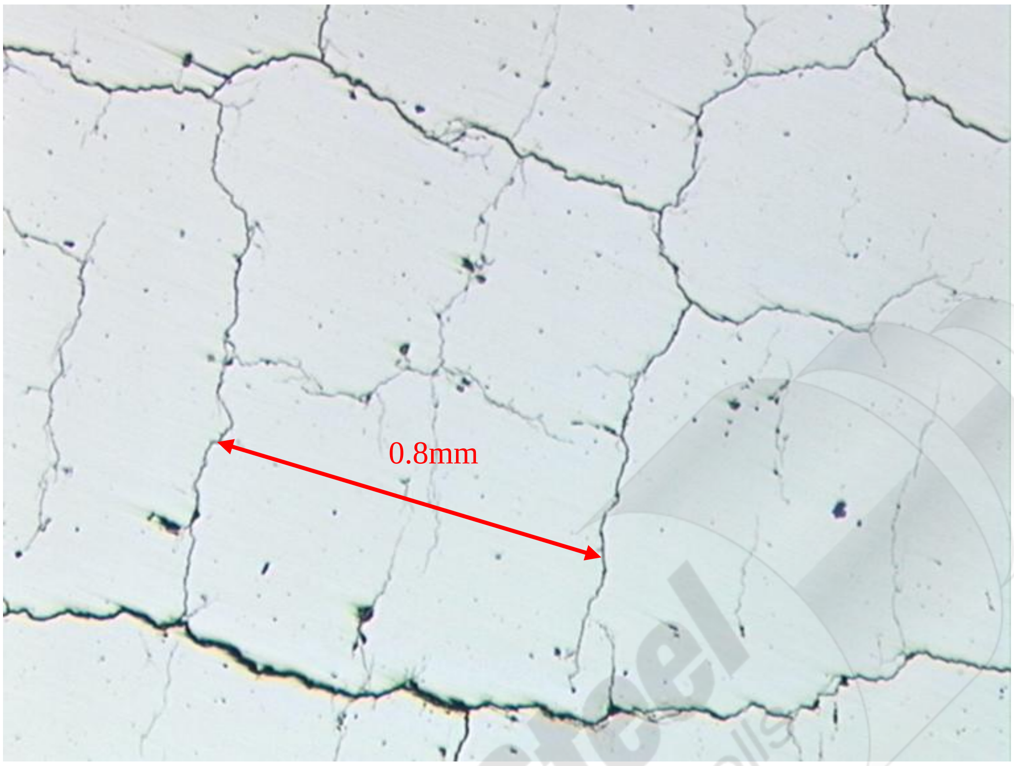
Fire crazing typically only occurs in hot strip applications and is defined as a uniform cellular network of alternating longitudinally and circumferentially aligned cracks at the barrel surface area contacted by the hot strip or bar. The cracks form a repeating pattern with a spacing or cell size typically less than 5mm between each crack. Fire craze cell size is generally largest in the first stand of the mill decreasing incrementally toward the final stand of the mill.

EXAMPLE

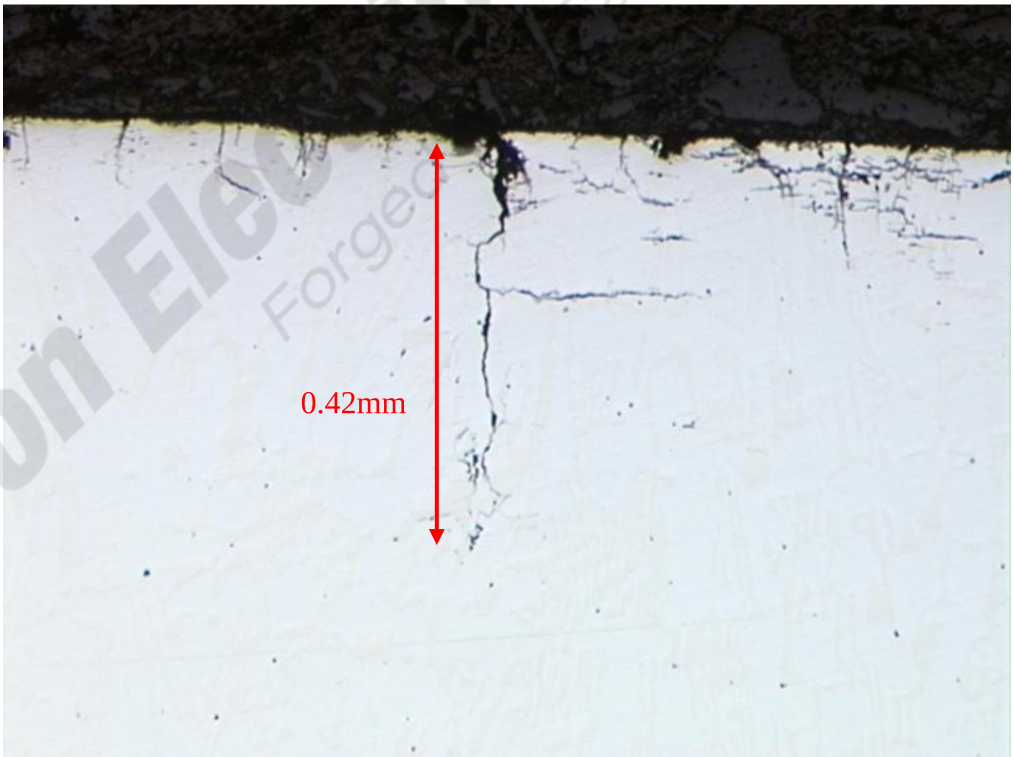


Example 1

Fire craze cracking at the barrel surface of a high chrome iron work roll



Example 2
Fire craze cracks seen at x 50 magnification



Example 3
The same area of fire craze cracks as in example 2 is shown in cross section

GENERAL MECHANISM

Fire crazing manifests during thermal expansion of the barrel surface material during contact with the hot strip or bar and subsequent contraction during quenching in the cooling water (thermal fatigue). As the surface layer is heated in contact with the strip and expands it is restrained by the underlying parent material and surrounding cooler material resulting in the generation of a localized compressive stress at the barrel surface. When this stress exceeds the hot compression strength of the material yielding will occur. When this same area is then exposed to mill cooling water rapid contraction of the surface layer occurs and a resultant tensile stress is generated. Fire craze crack formation results when this stress exceeds the tensile strength of the material.

The size of the fire craze cell is determined by the mechanical and physical properties of the roll material and the magnitude of the stresses developed at the surface. Stress magnitude is determined primarily by the surface and sub-surface temperature differential determined by contact time between the roll surface and the product and subsequent water quench. In the first stand of the mill the strip temperature is highest, roll speed is lowest, roll to strip contact time as well as cooling time are longest. The stress developed within the surface is highest and a larger fire craze cell size will result.

PREVENTION

Fire crazing is a normal byproduct of the rolling process. The severity of the fire crazing must however be controlled both by the selection of the correct roll material properties for a given mill stand and by grinding and inspection at the end of a rolling campaign. Inadequate management of fire crazing can initiate or aid in the formation of other surface defects such as thermal pitting (see section II.B) and banding (see section II.C)

MECHANISM IN DETAIL

Fire crazing manifests during normal hot strip mill operation when thermal expansion and re-tempering of the barrel surface material occurs during contact with the hot strip or bar and subsequent contraction during quenching in the cooling water.

During mill operation, each point of the roll surface that makes contact with the strip is exposed to heating to a very short distance below the roll surface. The resultant expansion that occurs to this heated layer is restricted on all sides by the cooler roll material surrounding it. This restriction to the roll materials expansion results in the generation of a localized compressive stress within the heated area. When this same area is then exposed to mill cooling water rapid contraction of the surface layer occurs and a resultant tensile stress is generated. The repeated heating and quenching occurring during each roll revolution and cycling between compressive and tensile stress states results in crack formation once a critical number of stress cycles has been achieved and is known as thermal fatigue.

The resultant tensile stress can be compounded even further when the temperature of the surface layer exceeds the tempering temperature used during roll manufacturing. The tempering temperature is set to establish the roll hardness. In general, the higher the tempering temperature, the lower the roll hardness. If contact with the strip surface results in a temperature that is greater than what was used during manufacturing, then re-tempering will occur in a non-uniform and uncontrolled way. During tempering and re-tempering, contraction occurs with increasing temperature which will be additive to the contraction that will also occur due to rapid water spray cooling. This contribution to the material contraction will result in an increase in the residual tensile stress generated during cooling. The greater the difference between maximum roll surface temperature attained and the tempering temperature used during roll manufacturing, the greater the tensile stress that will be generated during the cooling portion of the thermal cycle.

The size of the fire craze cell is determined by the mechanical strength and physical properties of the roll material and the magnitude of the stress cycle developed at the surface (all of which are also effected by the rolls tempering temperature). The magnitude of the stress cycle is determined primarily by the surface and sub-surface temperature differential determined by contact time between the roll surface and the product, the tempering temperature of the roll used during roll manufacture and the effectiveness of the subsequent water quench. In the first stand of the mill the strip temperature is highest, roll speed is lowest, roll to strip contact time as well as cooling time are longest. The magnitude of the stress cycle developed within the surface is highest and a larger fire craze cell size will result.