

CATEGORY: ROLL SURFACE INDICATIONS

TYPE: INCLUSIONS

AFFECTS: WORK ROLLS AND BACK-UP ROLLS (HOT MILLS and COLD MILLS)

CHARACTERISTICS

Inclusions are characterized as entrapped foreign materials that can be metallic or non-metallic within the parent roll material. They can range in size, quantity and distribution depending on the source. Metallic inclusions can appear as bright or grey indications in relation to the surrounding roll material or may not be visually detectable at all, however most forms of metallic inclusions that are present at the roll surface can be detected using eddy current inspection. Non-metallic inclusions are surface or subsurface indications that are typically comprised of moulding or casting materials (such as sand, refractory, flux, slag, etc). In some instances the included material can fracture and fall out leaving a residual hole, however in most cases some or part of the included material usually remains (especially true for non-metallic inclusions).

Both metallic and non-metallic inclusions can affect the surface quality of the strip especially for rolls in the last stand. Included material may wear at a different rate from the parent metal or fall out and result in a low spot, a high spot or a residual hole on the roll (most metallic and non-metallic inclusions wear at a faster rate than the parent metal resulting in low spot in the roll barrel surface). This low spot, high spot or residual hole can then be imprinted on the strip surface which may not be able to be rolled out in the following stands.

EXAMPLE



Example 1

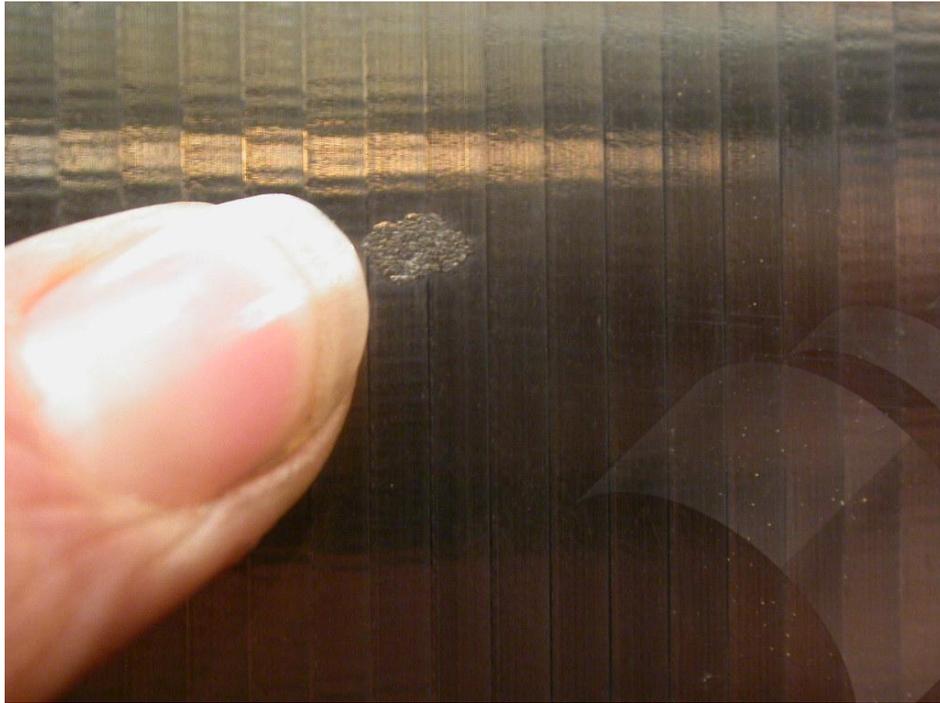
Bright inclusion made up of partially dissolved ferro-alloy at the barrel surface of a work roll. Cracks have started to form around the area of diffusion that will ultimately result in the inclusion falling out leaving behind a hole.

X10 magnification



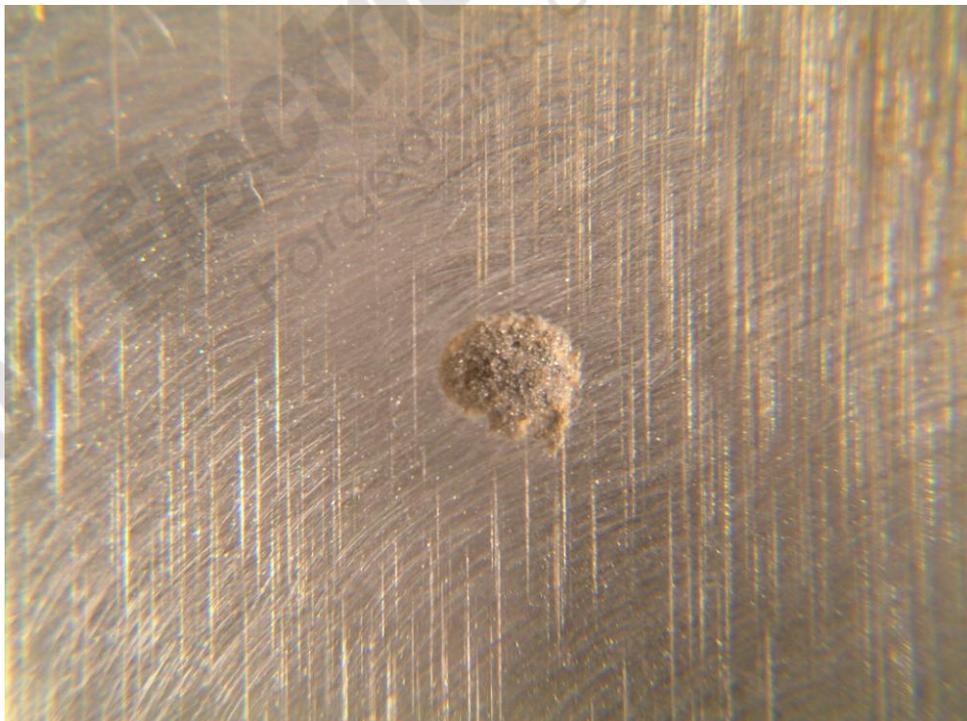
Example 2

Bright, metallic inclusion at the surface of a work roll. Some darker areas consisting of flux can be seen surrounding the main inclusion.



Example 3

Inclusion at the surface of a work roll exposed during machining.



Example 4

Cavity left by included material that has now broken out from the roll surface.

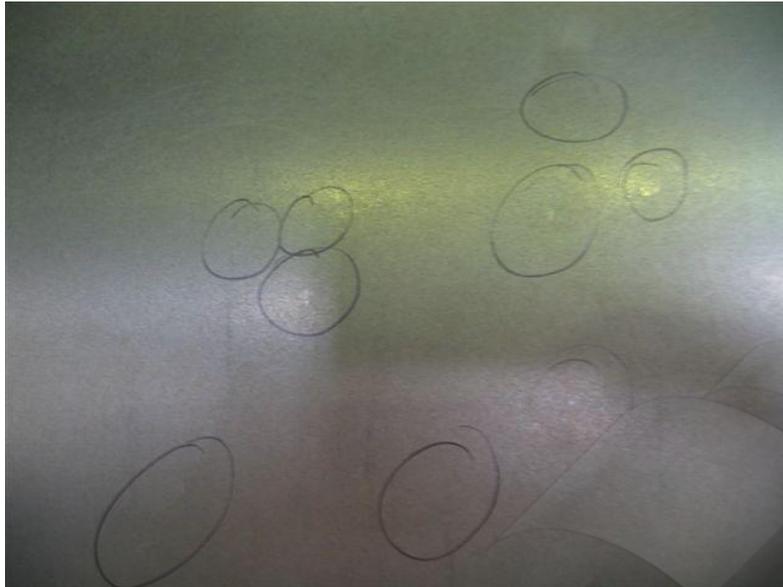


Figure 5

Bright areas at the barrel surface of a work roll after rolling. These bright areas consist of included high carbide material.

GENERAL MECHANISM

Inclusions are defined as foreign exogenous materials that are introduced during the casting of a roll (i.e. solid objects that are not the same material as the parent metal). During the centrifugal casting process the included foreign material is typically spun out toward the barrel surface at a rate dependant on its difference in density compared to the main bulk of the roll material. The included foreign material can be metallic in nature but of a different chemical make up to that of the roll material or non-metallic material such as ceramics, slag and flux from the mold or casting process. As such metallic inclusions when present are more often close to the surface of a new diameter roll and rarely present at greater depth.

PREVENTION

The presence of exogenous inclusions at the barrel surface of a roll are unlikely to result in serious or catastrophic failure, however they may result in surface quality issues for the rolled strip. Inclusions are the responsibility of the roll manufacturer and as such the roll maker should:

- It is the roll manufacturer's responsibility to ensure that process control measures are in place to ensure that all charge materials are fully melted and homogenized within the melt and to prevent the introduction of foreign materials in to the melting, tapping, casting or solidification process.
- Carry out inspection prior to shipment of a roll to ensure the barrel surface and the working layer where possible is free from an exogenous inclusion. Non-metallic exogenous inclusions above a given size should be readily detected by eddy current and ultrasonic inspection methods.

MECHANISM IN DETAIL

Inclusions that are visually detectable are normally exogenous in nature. Indigenous inclusions, which are inherent in the iron and steel making process, require the aid of a microscope for detection and can be classified according to their composition (sulfide, aluminate, silicate or oxide).

An exogenous inclusion occurs when a foreign body (metallic or non-metallic) is entrapped within the roll material during solidification.

Metallic exogenous inclusions are primarily one of two main types:

- un-melted charge materials - these can be either hard and wear resistant or soft and wear prone compared to the parent metal
- un-melted roll material - foreign globules of roll material (can be a different chemistry from the parent metal) which is introduced from improper in-house cleaning practice (ladles, floor debris, etc) which can either be hard and wear resistant or soft and wear prone compared to the parent metal

Non-metallic exogenous inclusions are primarily moulding or casting materials (sand, refractory, flux, slag, etc) that are either not properly removed during slag-off, are introduced from improper in-house cleaning practice, or breakdown of the moulding materials prior to solidification.

If foreign material is present during the casting of centrifugally cast rolls, the centrifugal forces react with the density difference between the foreign material and the liquid metal which either forces the foreign material to the outside diameter of the roll or toward the centerline. Foreign materials that are denser than the liquid metal become forced to the outside diameter of the roll which can then become exposed when the roll is machined to final diameter or during the early stages of the roll life (rarely present at greater radial depths).