Safety Precautions for Roll Spalling Events

Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

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Work roll and backup roll failures are dangerous events that occur in the mill and roll shop environment. Roll failures pose a serious risk of injury or death to personnel and can cause significant damage to equipment and property. Procedures must be in place to protect personnel and to reduce the risk of injury during the handling and inspection of work and backup rolls.

Acoustic emission testing is a key component of risk assessment during the inspection and monitoring of rolls subjected to conditions that may lead to their failure. Acoustic emission testing is a simple nondestructive testing technique that can determine if any active propagation of internal or surface cracking is taking place in the roll.

Roll Failures

Roll failures are generally governed by the stress state of the roll. When the stress levels are higher than the yield stress of the material, cracks will develop, and any existing cracks located at the surface of the roll or at internal defect sites will propagate. Some examples of the mill rolling events that can cause localized overloads at the roll surface or at locations internally in the roll that generate and propagate cracks are:

- Mill stops (fire cracking and high thermal stresses).
- Strip welding.
- Tail whip (slap).
- Strip edge or tail end crimping (pinching).
- Skids.
- Mill wrecks.
- Mill alignment issues.
- Excessive mill forces.

These events can initiate roll spalling or catastrophic failure. Fig. 1 shows a roll barrel that has been damaged by a high-stress mill incident. A ribbon fatigue or "cat's tongue" fracture band ultimately propagated from that initiation site until a large explosive surface spall occurred.

Thermal stresses from temperature gradients, either from roll contraction during cooling after use in the mill, or from roll expansion from heating, can also drive crack propagation that leads to failure. It is necessary to perform acoustic emission testing within the first 24 hours of bringing a roll inside from either a colder storage area or after unloading a roll from a shipping truck or railcar to detect potential activity during the expansion of the roll from heating.

Whenever a roll is subjected to one of the previously listed high-stress mill events or is involved in any other event that leaves visible cracks or other markings on the roll, the roll needs to be placed either under a blast blanket or in a designated quarantine area inside a specially designed metal container referred to as a spall box or "bomb box." These protective covers will contain any ejected material in the event of a roll failure.

When removing the roll from service, safety precautions need to be in place to minimize risk to the personnel handling the roll. The surrounding area needs to be cleared of personnel and then caution signs, lights or tape used to cordon off the area. Spall curtains or spall blankets should be used to protect the crane operators and personnel moving the roll.

Spall boxes are designed to cover the roll barrel and are open at the

Figure 1

Surface damage caused by a high-stress mill accident (a) and stress conditions propagated a fracture band until explosive spalling of the roll barrel surface (b).

roll necks, so the chocks do not have to be removed before placing the roll in the spall box. Fig. 2 shows a roll, still in the chocks, covered by a spall box with ejected roll material on the ground. After the roll is placed in the spall box, acoustic emission testing is performed on the roll to detect if any cracks are actively propagating.

Acoustic Emission Testing

Acoustic emissions are defined as transient elastic waves generated by the rapid release of energy from localized sources within a material. In the case of rolls, the energy generating the transient elastic waves are released by crack propagation or fracturing of the roll material under the influence of a stimulus of external, residual or thermal stresses. The acoustic emission waves emanate in every direction from the source until reaching the surface. If a piezoelectric acoustic emission sensor is coupled to the surface, the surface displacement (often on a nanometer scale) is converted into an electric signal that can be measured and recorded by the acoustic emission instrument.

Acoustic emission signals recorded by the sensors are displayed by the instrument in the shape of a sinusoidal waveform. When the peak amplitude of a signal waveform is higher than a set threshold amplitude, a hit is recorded. With correct timing parameters configured in the instrument, each acoustic emission signal from the roll will be counted as one and only one hit. The integrated area under the waveform is the energy. Hits and energy are the best ways to measure acoustic emission activity in a roll and are used as criteria for the passing or failing of an activity monitoring test. A diagram of acoustic emission testing is shown in Fig. 3.

The procedure for acoustic emission testing is relatively simple and straightforward. While the roll body is covered by a spall box or blanket, the acoustic

Figure 2

A roll, still in the chocks, covered by a spall box with ejected roll material on the ground.

Figure 3

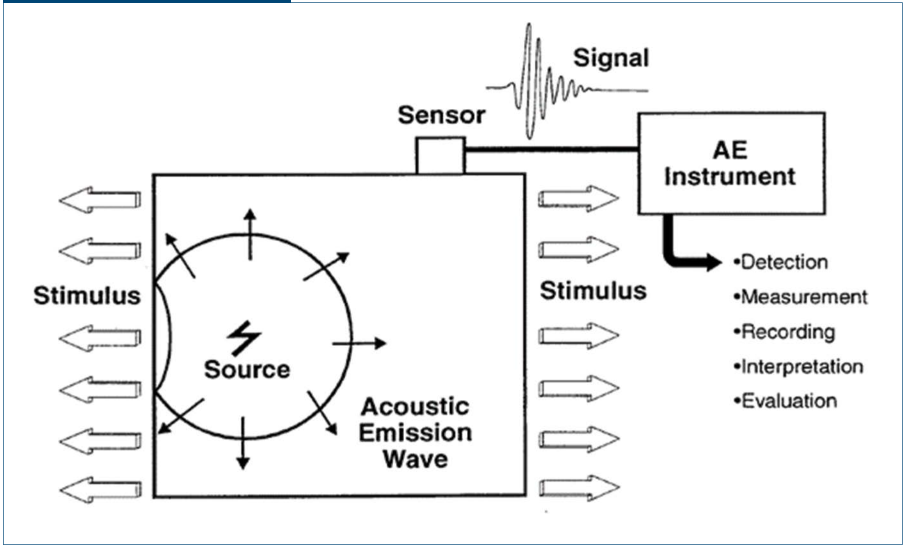


Diagram of acoustic emission testing (adapted from T.A. Tamutus, R.K. Miller and A.A. Pollock, "Roll Test Procedure Using Acoustic Emission," Mistras Group Inc., 2010).

emission sensor is placed on the end of the roll with a flat surface. A major advantage of acoustic emission testing compared to other non-destructive evaluation methods, such as ultrasonic testing, is that acoustic emissions can be detected at a remote location relative to the source. This means that it is possible to detect acoustic emission activities occurring anywhere in the roll barrel with a sensor attached to the roll end. Vacuum grease or ultrasonic gel is used as a couplant to maximize the transfer of energy from the roll to the sensor, and the sensor is held in place on the roll by a magnetic clamp. Two sets of calibrating pencil lead break tests are performed, one at 6 inches from the sensor and one at the opposite end of the roll. The recorded amplitudes from these tests are checked against previously recorded reference values for that specific design of roll. If the values are close, the acoustic emission instrument is said to be checked and considered calibrated. The roll monitoring test is then performed for one hour.

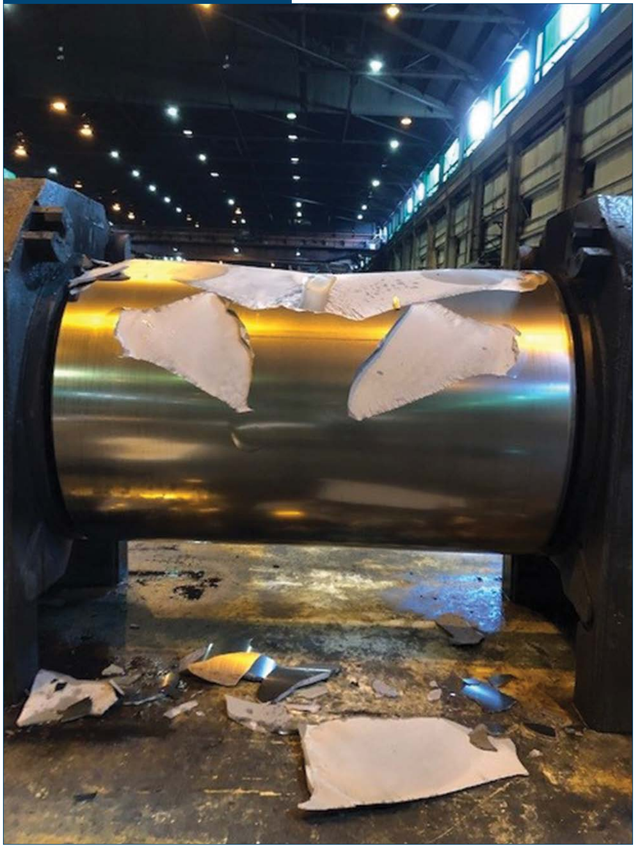
After the results are recorded and the file saved, the sets of pencil lead break tests are repeated, and if the amplitudes are close to what was previously measured, the results of the roll monitoring can be considered valid.

Threshold values of acoustic emission sum energy and hits should be determined for the test passing or failing criteria. For a zero tolerance program, there must be zero hits in the hour of monitoring for the roll to pass the test. The roll should remain situated inside of the spall box until the number of hits during monitoring is below the background noise level.

Roll Inspection and Disposition

Rolls can be active for days, weeks or even months. Once the roll passes acoustic emission testing and is declared inactive, other non-destructive techniques such as ultrasound, eddy current and dye penetrant testing can be used to locate any surface and internal defects. Fig. 4 shows the spalled roll with the spall box lifted for roll inspection after being declared inactive after passing the acoustic emission monitoring. The spall box did an excellent job of keeping mill personnel, equipment and property safe by containing the material that was ejected from the roll.

Figure 4



Example of a spalled roll with the spall box lifted for roll inspection after being declared inactive after passing the acoustic emission monitoring.

Once the inspection is complete, the roll can be dispositioned. If the roll is to be repaired by grinding, caution must be taken because stresses generated by both temperature changes and the grinding itself can change the internal stress state which may cause crack propagation to start again. Because of this, there should be protective barriers in place to protect grinding personnel. If the roll is to be scrapped, the roll should be secured with steel bands and then covered with a spall blanket throughout the entirety of the transportation to the scrapping destination.

In summary, a safety plan must be in place to address the risk of explosive work roll and backup roll failures due to high stresses caused by either temperature gradients or rolling mill accidents. It is important to reduce the risk of injury or death of mill personnel by having procedures in place that address when a roll should be removed from service, how to safely handle rolls that have been exposed to high-stress events and are at risk for active crack propagation, and how to use acoustic emission testing as a safety check so that no roll handling or grinding personnel are exposed to the danger of a roll undergoing active crack propagation.

Acknowledgment

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References

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2. T.A. Tamutus, R.K. Miller and A.A. Pollock, "Roll Test Procedure Using Acoustic Emission," Mistras Group Inc., 2010. ✦