Elastic springback in plates on equipment

Mines safety bulletin no. 172

1. Background

The results of a fatality investigation have highlighted potential hazards that may exist in plates that have been indented during operations or otherwise.

Plates on equipment, other than the excavator bucket involved in the incident described below, can pose similar hazards. Indentation is a major contributing factor to elastic springback potential. Other factors may play a role too.

While this incident occurred with a quench and tempered steel wear plate, similar hazards may exist with other metallic and non-metallic materials (e.g. stainless steel, fibre glass, mild steel, aluminium or plastic).

The purpose of this safety bulletin is to provide information that may help reduce the risk to persons working on or near plates with springback potential.

2. What happened

A boilermaker was using an air carbon arc gouging process to remove an external wear plate from an excavator bucket. The plate unexpectedly sprang up approximately 1200 mm. About midway in this upward movement, it struck the boilermaker on his forehead, fatally injuring him.

3. Equipment description (See figures 1 & 2)

The main bucket structure is made of structural steel and covered with internal and external wear liner plates. The liner plates are consumables and depending on their condition are removed and replaced from time to time.

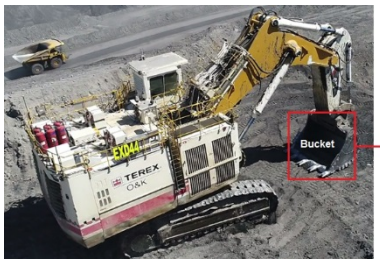

Fig. 1A – Excavator


Fig. 1B – Bucket in workshop


Fig. 1C – Sprung plate

4. Other incidents

The hazard of elastic springback is not limited to excavator buckets. From anecdotal and other evidence, related incidents were found:

- In two similar but separate incidents, workers were struck while removing indented sections near the rim of rear dump truck trays.
- Violent elastic springback was observed during the removal of an under-tub wear plate from a dragline. The plate had probably been indented when the dragline was walked over an uneven surface.
- A worker was hit while removing a wear liner plate (push pad) from a dozer blade.

5. Causes of elastic springback

More than one factor can cause elastic springback in plates. These factors can be present alone or in combination with others.

The factors discussed below were not necessarily all present in the plate involved in the excavator bucket incident. They are discussed as they may be present in other configurations:

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5.1 Misshape

If the wear plate does not match the profile of the structural plate, the installer needs to force it in position using techniques such as dogging and wedging. Once it's welded or bolted in position, the dogs and wedges are removed. The residual stresses remain for as long as the welding or bolting holds the plate in position.

5.2 Welding (see figure 2)

As the molten weld metal cools after welding, it shrinks. If the parent material is constrained, forces are applied to it which may present as distortion and/or elastic springback.

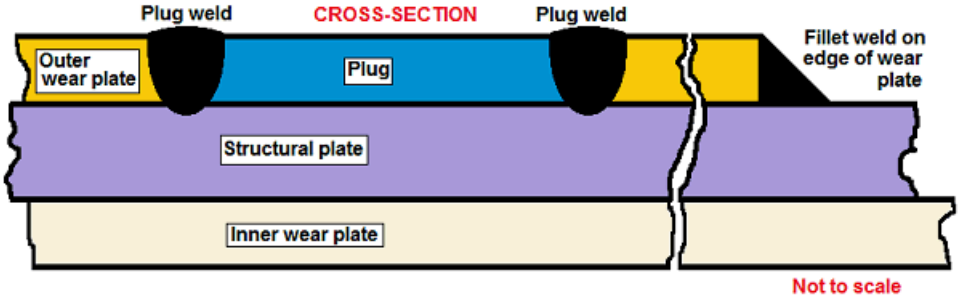

Fig. 2 –Sketch of cross-section through welds, plugs and plates

5.3 Wear

When a plate is bent or rolled, it is plastically deformed. One surface is under compressive residual stress, while the opposite is under tension. When it is newly rolled, the opposing residual stresses are in balance and maintain the desired shape of the bent plate.

During operation, one surface wears away, disturbing the balance and contributing to elastic springback potential.

5.4 Indentation

If a plate is impacted or permanently indented during operations, the strain and stress profile is likely to be affected. There are different configurations:

- For a profiled (e.g. rolled) plate, if the magnitude of indentation is sufficient, the material yields in the opposite direction, effectively cancelling or reducing the residual stresses needed to maintain the plate profile. This contributes to elastic springback potential.
- Where the impact is severe enough to cause yielding, the plate permanently elongates (stretches) on the opposite side to the impact. The elongated material tends to lift up the plate and contribute to elastic springback.
- Multiple, overlapping indentations may have had a cumulative effect, depending on their relative positioning.

A plate can be indented even if it is closely supported by a hard and strong backing material. An unsupported or weakly supported plate will however indent more than a supported one for the same impact force.

For the plate involved in this incident, indentation was the primary contributor to elastic springback.

5.5 Poisson expansion

As a plate is being indented during operations, it compresses in the through-thickness direction. This causes the material to expand in all directions within the plate plane; a phenomenon called Poisson expansion.

On the opposite surface to the indenter, the plate is strained in tension. The Poisson expansion adds to this and simultaneously increases the springback potential.

5.6 Dirt ingress

For layered plates, such as the structural and wear plates involved in this incident, dirt can affect the stress profile.

In this incident, dirt entered the space between the structural plate and the wear plate during operations. It entered after some of the welds had cracked and also after the wear plate had worn through. The process of dirt entering was accelerated by the actions of the excavator. Note that the dirt did not contribute to the initial cracking of the plate.

The presence of dirt increases the extent of deformation during impact. It also contributes to the stress profile as it tends to wedge the plates apart.

6 Recommendations

6.1 Awareness

Persons working with plates should be made aware of elastic springback potential and the associated hazards.

6.2 Detection

Because there is no practical way of predicting the amount of stored energy (if any), work should be planned on the assumption that spring back is going to occur.

The following tell-tale signs may indicate springback potential:

- Indentations
- Deformed material due to ingressing dirt
- Cracking
- Wear
- If, during installation, excessive force was needed to position a plate before welding or bolting it to the rest of the structure
- Quench and tempered steels (often used as wear plates) have a high yield point and consequently a higher elastic springback potential
- Larger plates typically have a higher springback potential.

Strain gauges can be used to determine the level of residual stresses in a plate. Their application is an elaborate process and probably not practical in most cases.

6.3 Design

Long wear plates were fitted around most of the outer surface of the bucket involved in the incident. This was a modification of the original equipment manufacturer's design where multiple smaller plates were used.

The original design had much less springback potential because using several wear plates instead of one large one will reduce the amount of stored energy that has to be controlled at any one time during removal. (Compare Fig. 3 with Fig. 1B)

In general, for the purposes of controlling elastic springback potential, designs with multiple smaller wear plates are recommended.

Fig 3. – Alternative wear package with multiple plates

6.4 Controlled release

When an installed plate is being removed, measures should be in place to release it in a controlled and systematic manner. This applies to both gouging and unbolting.

Before the first fastening element (welding, bolting or other) is removed, assess whether the remaining elements will have enough strength to contain potential springback energy.

If there is doubt about the integrity of the original fastening elements, extra welding or replacement of the original bolts should be considered.

6.5 Safety and Health Management System (SHMS)

All of the above should be practised within an appropriate SHMS that includes (but is not limited to) elements such as risk assessment, change management, training, supervision and a system to keep and disseminate safety information about similar earlier jobs.