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joining & cladding

Solutions Flash
Economic and Effective Hardfacing Strategy for Ground Engaging Tools (GETs) and Cutting Edge Shrouds

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Today’s situation

Ground engaging tools, commonly referred to as GETs, and cutting edge shrouds encompass a broad range of equipment used for mining, construction and agriculture. These components are made from high-strength steels; but because of the very nature of their intended purpose, they benefit from hardfacing to resist abrasion, impact and extend service life.

Hardfacing solutions using GMAW (Gas Metal Arc Welding) to apply a blend of tungsten carbide (WC) in a nickel- or iron-based matrix are well known for GETs. Often, a mild steel wire is used and tungsten carbide pellets are dropped into the weld pool. Solutions using PTA (Plasma Transferred Arc) welding or laser cladding are also quite well-known. Here, the WC is pre-blended in appropriate ratios with a nickel-alloy powder in advance of deposition onto the substrate. All of these strategies result in similar performance and can provided the needed wear resistance.

However, the above strategies often chosen as a “one size fits all” approach with little regard for the type of service the GETs encounter and the wear and/or failure mechanisms common to a particular site. The wrong hardfacing choice could result in less than optimal productivity and cost benefits, and, in some cases, result in accelerated failure of GET teeth. In the later case, the net outcome is an increase in operational costs for the time that the equipment is out of service and the repairs that must be done to restore the teeth.

Clearly, hardfacing strategies that consider the service environment are needed.

Figure 1. GETs come in many sizes and shapes, such as the bucket wheel excavator shown here. They can also encounter many different types of operating environments. The best hardfacing strategies will take these factors into account.

Our solution

Our portfolio of hardfacing materials are designed to protect GETs in different service environments. Through the use of our unique Scoperta™ rapid alloy development process, we formulate new compositions from a totally different viewpoint.

Our Scoperta process uses a high throughput computational metallurgical process to evaluate millions of candidate alloy compositions. Potential candidates are then experimentally evaluated using an advanced screening process where both properties and alloy microstructure are measured. The combined Scoperta computational and experimental approach allows us to rapidly design compositions with much better in-service properties than conventional empirically-based methodologies.

For GET applications Metco Joining & Cladding has developed materials that:

- Can be applied using conventional welding processes such as GMAW, PTA or laser cladding
- Provides the long-lasting protection needed to extend the service life of GET components when different mechanisms are of concern such as:
  - High abrasion
  - High impact
  - GET failure due to crack propagation of the hardface into the substrate

With our tailored approach, users of GETs can choose an appropriate hardfacing strategy that best suits their service environment, thus optimizing productivity and reducing overall maintenance costs.

Solution description and validation

1. Hardfacing considerations

When utilized properly a relatively small quantity of hardfacing material can substantially increase the operational lifetime of even the largest GETs. However, if not applied properly, the hardfacing may not deliver substantial increased life. In the worst case scenario, hardfacing can lead to accelerated failure. Two variables should be considered when designing a GET hardfacing solution:

1. Matching the hardfacing alloy to the service environment
2. The pattern of the applied hardfacing

1.1 Alloy selection

Selection of the hardfacing alloy centers around one key performance metric: does the hardfacing alloy crack. A cracking alloy will typically be more abrasion resistant, but increases the potential for chipping and crack propagation into the substrate that ultimately results in failure of the entire tooth.

1.2 Wear and hardfacing patterns

The wear pattern is the second key variable to consider as it governs the evolving shape of the GET as it wear away. While there are potentially many ways to design the weld pattern, one should consider avoiding application of the hardfacing beyond the axis of bending in the tooth.

2. Trials with cracking hardfacing

The trial discussed here was performed at a North American hard rock gold mine where GETs frequently broke when hardfaced. This mine did not use WC–based hardfacing because it results in accelerated tooth failure leading to a net increase in operational costs.

2.1 Other trials

During subsequent, independent trials where WC is typically used in standard operation, the WC-hardfaced GETs broke prior to wearing away at an approximate ratio of 1 to 3. Note that welding a cracking hardfacing onto a GET will always decrease the structural integrity. An existing crack in the hardfacing will act as a stress riser in the tooth that can grow under cyclic loading. This is further aggravated by the presence of a heat affected zone in the GET substrate.

2.2 Trial methodology

For the gold mine trials, an iron-based alloy known for high abrasion resistance was utilized as the hardfacing material.

Eight GETs were welded (one complete bucket shovel). All eight GETs exhibited different degrees of failure in service with some completely failing. The eight GET components were analyzed to understand the wear and failure mechanism.

2.3 Results and analysis

Figure 2 shows the extreme case where the majority of the GET area broke off with only a small portion of the original hardfacing remaining. Figure 3 shows a schematic highlighting the proposed failure mechanism, whereby cracks present in the as-welded hardfacing extended over time into the substrate until rapid fracturing and failure of the GET occurred.

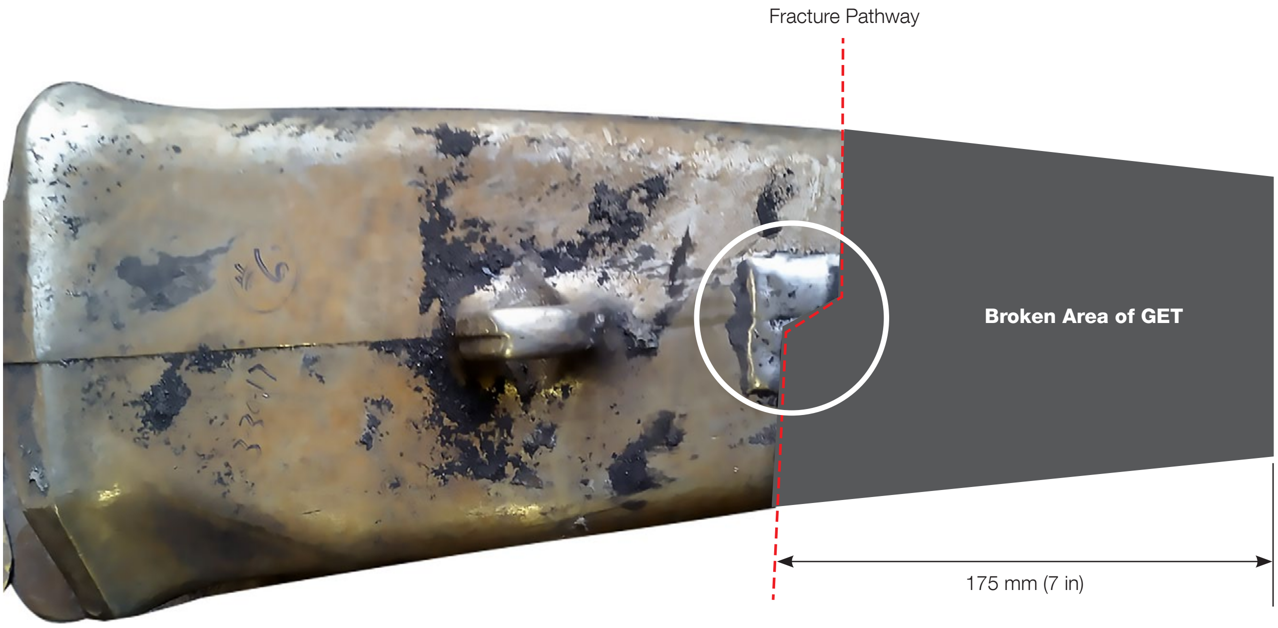

Figure 2. GET failure after service using a cracking hardface..

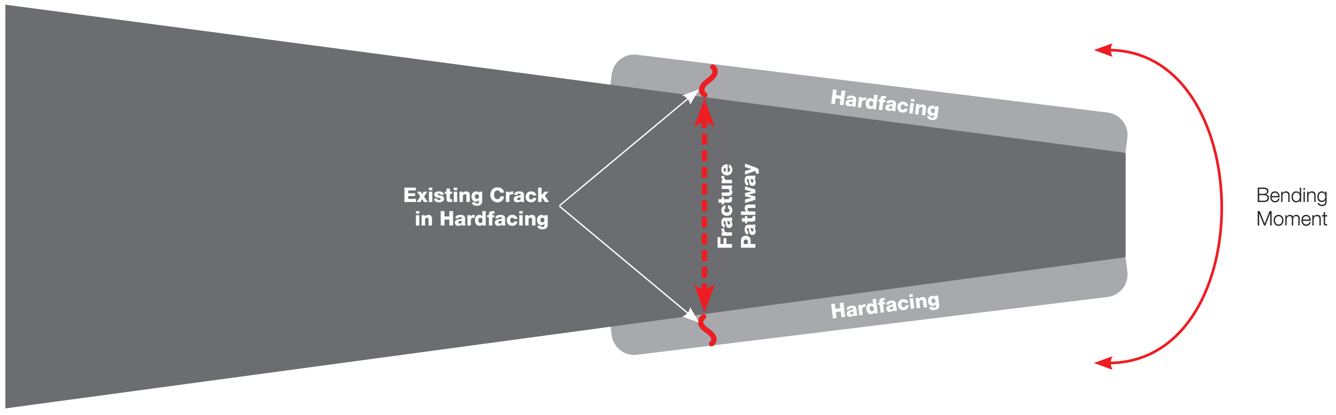

Figure 3. Schematic showing the fracture pathway originating from cracks in the as-welded hardfacing which propagate into the GET substrate.

One GET was removed from service prior to complete failure and a detailed analysis of the crack growth was performed (Figure 4) to verify the proposed failure theory. Figure 4A shows a top view and Figure 4B shows a cross-section of the GET front face.

Cracks are highlighted in yellow for emphasis. Figure 4 shows that several cracks have grown from the hardfacing into the GET substrate. In particular, Figure 4B shows how the crack growth will likely propagate into the GET substrate and lead to large-scale failure.

While the GET shown in Figure 2 fractured during service, it is likely that the GET shown in Figure 4 was about to fracture and fail.

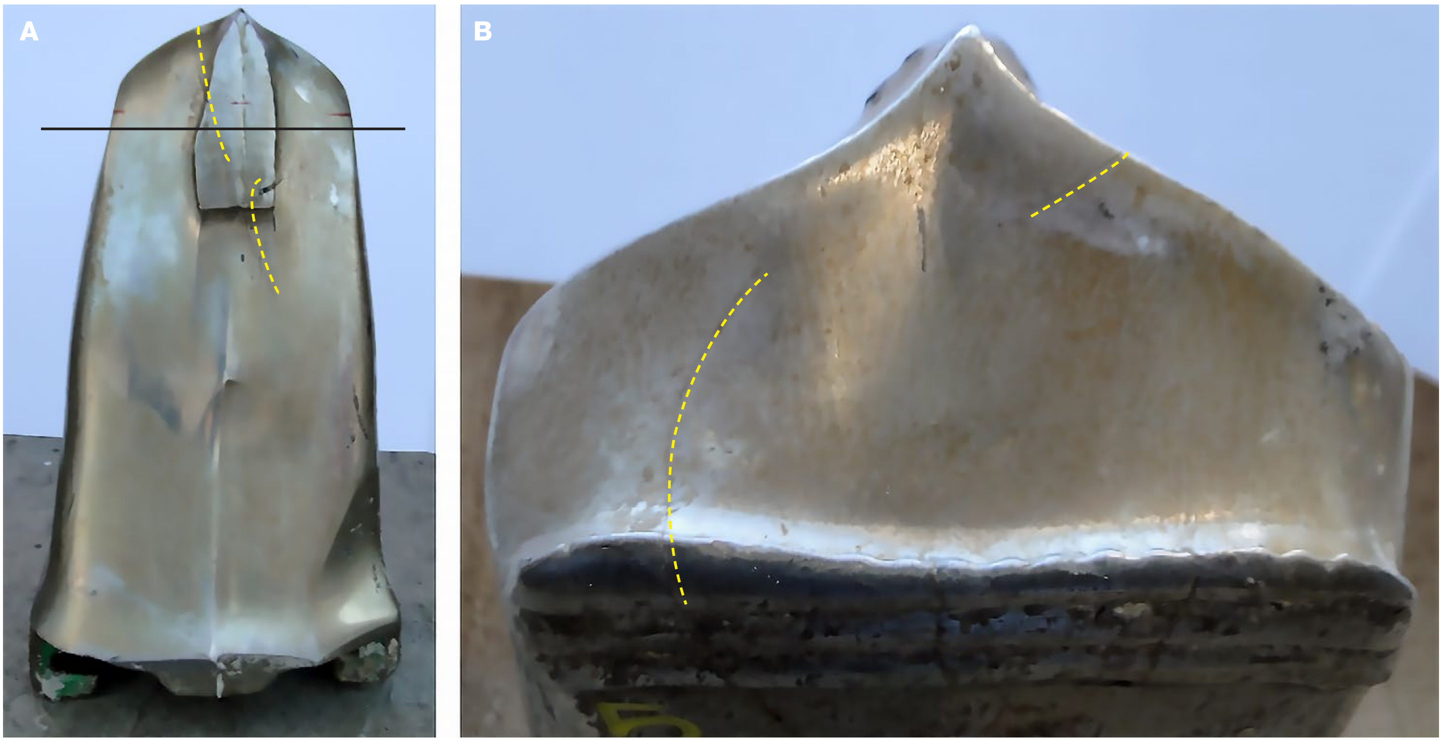

Figure 4. GET after service with cracking hardfacing that has been taken out of service before full fracture allowing for analysis of crack growth behavior. Cracks are highlighted with a yellow dashed line. The solid black line highlights where the GET was sectioned for further wear analysis. **A**: Top view. **B**: Cross-sectional view of the front face.

3. GET wear mechanisms

Critical to extending the life of a GET requires a good understanding of the balance between maximizing abrasion resistance and minimizing the embrittling effect of the hardfacing. To better quantify this balance, a detailed analysis of the worn GETs from the gold mine field trial was conducted.

The GET shown in Figure 4 was cross-sectioned along the solid black line as presented in Figure 4A. Utilizing a contour gauge, the cross-sectional area of the worn GET was measured and compared with the original unworn cross-section at the same location. That analysis is shown in Figure 5 which compares the worn GET (Figure 5A) to an unworn GET (Figure 5B) as well as a overlay of the worn over the unworn cross-sections (Figure 5C).

Areas where the hardfacing remains are completely unworn in comparison to the bulk of the tooth. For a quantitative comparison, the tooth middle (an area containing hardfacing) wore less than 1 mm (0.04 in) whereas the tooth edge (an area where no hardfacing was applied) wore about 25 to 30 mm (1 to 1.2 in). The bottom of the GET, which contained hardfacing across the width, exhibited little to no wear.

4. Undercutting

The vast difference in abrasion resistance between hardfacing materials and the GET substrate creates an undercutting wear mechanism that is highlighted in Figure 6.

Figure 6A shows an interior view of a GET where some hardfacing is still present. As highlighted via the dotted red line, the hardfacing is actually proud in relationship to the substrate directly underneath due to the differences in wear resistance between the two neighboring materials.

It is proposed that this undercutting behavior is the dominant wear mechanism is hardfaced GETs whereby the underlying substrate wears away until the hardfacing is exposed. Eventually, the exposed hardfacing material will crack off and the undercutting wear will begin again. This behavior is simplified in the schematic shown in Figure 5B highlighting a crack which will lead to spalling of the exposed hardfacing at the location where the GET substrate has been worn away.

ASTM G65 lab testing of the hardfacing material and GET substrate confirm the prodigious difference in wear resistance with the hardfacing being roughly 20-times more resistant. Furthermore, the GET substrate softens to a depth of about 10 mm (0.4 in) below the interface due to the welding process itself, which results in an additional 30 % decrease in wear resistance.

As it is the undercutting mechanism that giverns the wear behavior of the GET, the overall abrasion resistance of the hardfacing material is of lesser importance. As long as the hardfacing material is more wear resistant that the GET

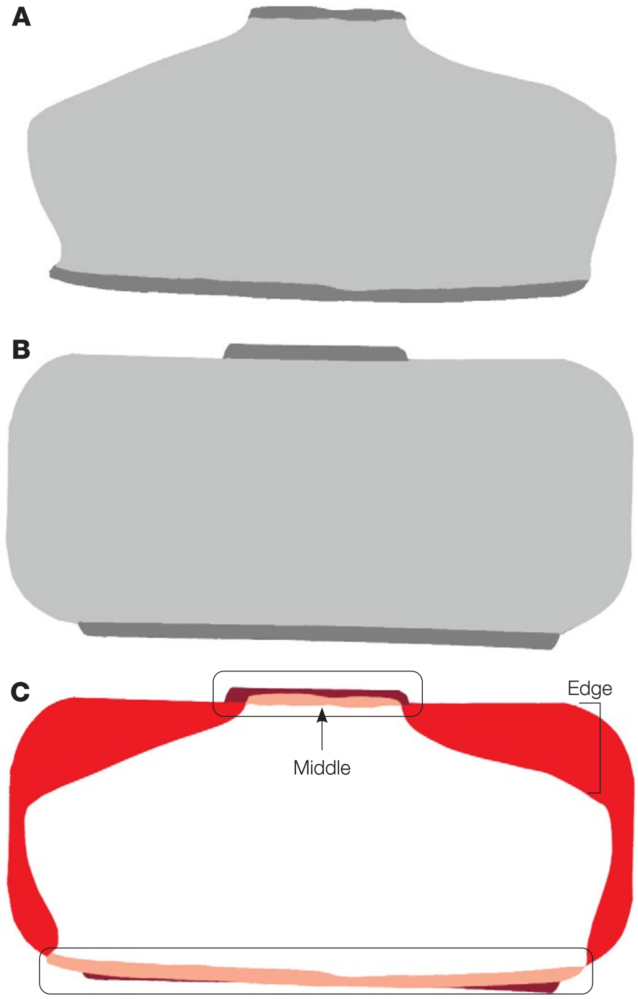

Figure 5. Cross Sectional Analysis of GETs. **A**: Worn GET. **B**: Unworn GET. **C**: Cross-section of worn GET overlaid onto cross-section unworn GET for direct comparison.

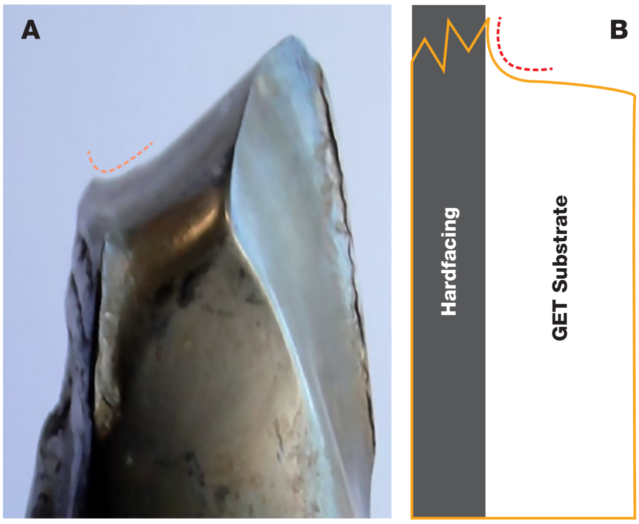

Figure 6. A: Photograph of undercut GET. **B**: Schematic highlighting the undercutting wear behavior in GETS, where the dashed red line highlights the undercut profile in both cases.

substrate, this undercutting mechanism will dominate irrespective as to whether the hardfacing material is 5-times or 500-times more abrasion-resistant than the GET substrate.

5. A better solution with a non-cracking hardface

Metco 8247 is a non-cracking hardfacing material proven to be highly suitable for GET applications.

Metco 8247 is an iron-based composite wire that easily applies using standard GMAW equipment. It forms very fine, homogeneously dispersed titanium carbides during the weld processing as shown in Figure 7, thus ensuring a consistent wear resistance throughout the deposit. Not only will Metco 8247 weld as a crack-free deposit, it is quite tough and resistant to cracking during service.

Deposits of Metco 8247 are 5-times more abrasion resistant than the GET substrate with only 0.2 to 0.4 g loss in ASTM G65A testing.

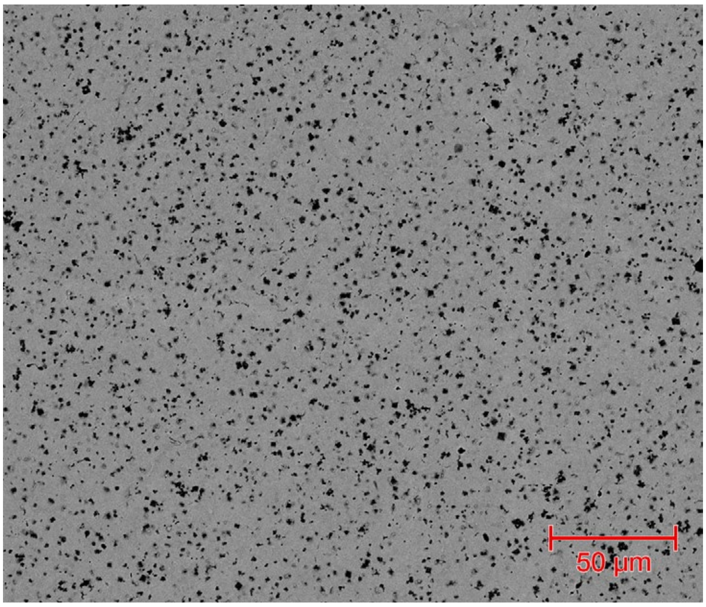

Figure 7. Typical crack-free, as-welded microstructure of Metco 8247. Note the homogeneous distribution of the very fine carbide hard phase (black)

6. Trials with Metco 8247 hardfacing on GETs

A second set of trials were performed at the same gold mine using Metco 8247 as the hardfacing material on GETs of the same size, geometry and substrate composition.

This trial was deemed a success, as the hardfaced teeth lasted 1.5- to 2-times longer than the teeth without hardfacing, and remained roughly 40 mm (1.6 in) longer than adjacent teeth without hardfacing (Figure 8B). The 2-times increase in GET lifetime through utilization of hardfacing with aligns with several other trials where Metco 8247 was used as the hardfacing material.

More importantly, none of the GET teeth hardfaced with Metco 8247 exhibited any fracturing nor had to be pulled from service as a result of failure.

Figure 8. Trials using Metco 8247, a non-cracking hardfacing, GETs in service. **A**: Close-up of hardfaced GET. **B**: Comparison of hardfaced and unhardfaced GETs. White arrows highlight the hardfaced GETs. Notice that the hardfaced GETs are longer and less worn, attesting the the abrasion resistance of Metco 8247.

Summary

As the size, shape and service conditions for GETs varies widely; therefore, the information from trials presented here are provided as an example. However, from these results:

- Hardfaced GETs will last longer than GETs without hardfacing
- GETs with a cracking hardface will result in GET failures resulting from crack propagation from the hardface into the substrate. For the trial discussed here, this was exhibited at a ratio of 1 failure out of every 3 GETs in service
- Such failures require that the GET is repaired or replaced, resulting in additional downtime and maintenance costs
- The predominate wear characteristic for GETs is undercutting, where the less wear-resistant substrate undercuts the more wear-resistant hardface
- The undercutting characteristic is so dominant that generally speaking, as long as the hardface is more wear-resistant than the substrate, the amount of wear resistance is of secondary importance
- The use of a wear-resistant, non-cracking hardface, such as Metco 8247, can eliminate GET failure

The economic comparisons of using unhardfaced GETS versus GETs hardfaced with a cracking deposit versus GETs hardfaced with a non-cracking deposit are summarized in Figure 9. This clearly shows the economic benefits of using a non-cracking hardface material such as Metco 8247.

Metco Joinng & Cladding has also developed Metco 8233, which solves similar issues for manganese-steel GETs.

To further protect your surface mining equipment, we have excellent solutions for wear plate applications.

Please contact us for more information regarding Metco 8233, Metco 8224 and Metco 8226. We will help you determine the best solution for your specific operating conditions.

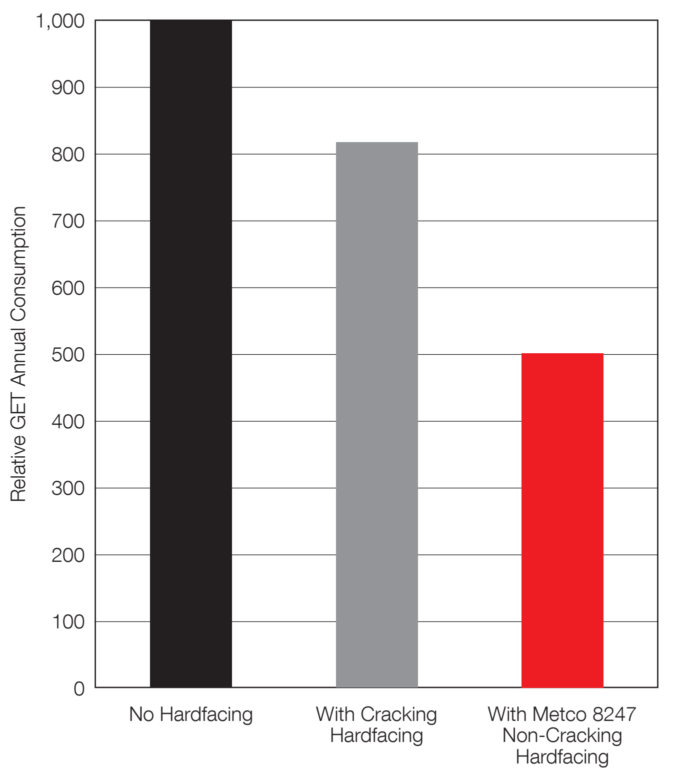

Figure 9. Relative, normalized comparison of annual GET consumption considering various forms of hardfacing. Without hardfacing, GETs will wear as a result of abrasion and crack as a result of impact. With a traditional hardfacing, the abrasion issue may be mitigated, but a crack in the hardface as a result of impact will propagate into the GET causing failure, which can actually crack at a higher rate than unhardfaced GETs. Using Metco 8247, both abrasion and impact are mitigated, and the hardfacing does not crack, leading to the highest-performing and most cost-effective hardfacing strategy available on the market today.

Customer benefits using Metco 8247

Effective

- Long-lasting, abrasion-resistant hardfacing material with good toughness that is ideal for GET applications
- Welded properly, Metco 8247 applies crack-free and resists cracking in service, eliminating GET failure due to propagation of hardface cracks into the substrate
- Deposited microstructure exhibits very fine carbides homogeneously distributed ensuring consistent protection throughout the deposit

Efficient

- Easily applied using standard GMAW equipment that can be applied on-site or in-shop
- One-component welding application — no need to 'drop in' carbide during welding, ensuring a consistent, reliable deposit

Economical

- Reduces GET consumption by 50 % as a result of effective wear protection and reduction of GET failure
- Inexpensive to apply and readily available
- Applies with a relatively smooth surface finish, greeatly reducing post-weld machining or finishing

Eco-Friendly

- Welds with low smoke and spatter providing a safer, cleaner environment for weld applicators

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