# Increasing Belt Life Performance and Maximizing Production Time in Powdered Metal Sintering Operations

Cory J. Bloodsworth
Cambridge Engineered Solutions, Cambridge, MD USA

Stephen L. Feldbauer, Ph.D.
Abbott Furnace Co., St. Marys, PA USA

## Abstract
Woven wire mesh belts are an ongoing cost associated with the operation of a continuous powdered metal sintering furnace. The life of a T314 stainless steel belt operating in one of these units is typically measured in months. A belt pretreatment to extend the life of the belt and address one failure mechanism has been developed and tested. Initial results have demonstrated a 25% increase in belt life and an overall reduction in downtime that is typically in excess of 18%. The mechanism associated with this failure, the belt pretreatment, and subsequent test results are described and reviewed.

## Introduction and Statement of Problem
Type 314 stainless steel woven wire belts are widely used to convey products through the final sintering stage in powdered metal production lines. Although the life of a wire mesh belt is very dependent on the loading, furnace conditions, furnace atmosphere, and temperature, it is not uncommon to measure the life of a belt in months. As a result, facilities that regularly work with the woven wire mesh belts in these applications have become quite proficient at replacing belts with minimal cool-down of the furnace and subsequent lost production time. Unit temperatures are typically reduced to below 1500ºF (815°C), and the new belt is fed into the unit as the old belt is being removed. Once completely installed, the temperature is ramped-up as quickly as possible and the unit is restored to service. This process is repeated as necessary throughout the many production lines of today's PM production facilities. Over the years, belt designs have steadily improved to permit higher production rates with less downtime for maintenance and overall longer belt life. Recent belt designs such as Knuckleback™ by Cambridge Engineered Solutions have been shown to allow higher product throughput rate by utilizing a flattened spiral wire and a reverse bend knuckled and welded edge. Following extensive tests, we have seen favorable results that show improvements of over 50% increased production. While Knuckleback™ offers significant improvement in throughput and value in optimal furnace conditions, there is still a need for additional improvements. From the standpoint of the belt, there have been and remain typically two problems associated with the frequent installation and use of new belts in the sintering furnace units: absence of a proper break-in period for the belt, and lack of sufficient de-lubing of the products. It can be shown that these two problems are closely related.

It is generally accepted that for woven metal mesh belts to perform optimally, they should be subjected to a break-in period that could span up to 1-3 days. During that time, the belt is allowed to 'soak' while moving slowly through the conveyor as the temperature within the unit is gradually and incrementally increased. This is thought to be an advantage both from a mechanical and metallurgical standpoint. Dimensionally, the belt can slowly adjust to maintain proper seating of the mesh and crimp wires, which promotes more even loading across the belt width along with improved articulation. But perhaps more importantly, free of any special atmosphere, a slower controlled break-in period can be used to promote the formation and growth of an oxidation layer on the belt surface that can provide an important means of surface protection for the belt. Conversely, without the proper belt break-in period for a new belt, the result can be and often is a reduced service life. PM production facilities generally accept this as a "fact of life" in their industry as typically none can really afford the extended production line downtime associated with a lengthy break-in period for a new belt after it has been installed.

Closely associated with a lack of a proper belt break-in for a new belt are the issues associated with incomplete removal of the lubricant from the parts. Again, for reasons tied to increased production rates, many PM parts are not fully de-lubed prior to the sintering stage of the overall process. If the lubricant exits the parts at a temperature above 550ºC (1020°F), soot (carbon) from the lubricants naturally develops and collects inside the sintering furnace. A portion of the soot is carried out of the unit as a result of the motion of the belt. However, a significant percentage of that material is known to collect along the edges of the furnace where it will reside until some steps are taken to physically remove it. This is not thought to impair the process or detrimentally affect the product. However, the presence of this additional carbon positioned along the edges of the belt is believed to cause weld embrittlement to the belt, eventually resulting in broken welds and frayed belt edges, (Figure 1). Once this starts to occur, the belt will naturally develop excessive camber and/or uneven stretch across the width which creates difficulty in articulation around the support and drive rollers. Additional credibility is given to this line of thinking from experience that indicates that most belts of this type generally begin to fail along the edges first, the result of broken welds.

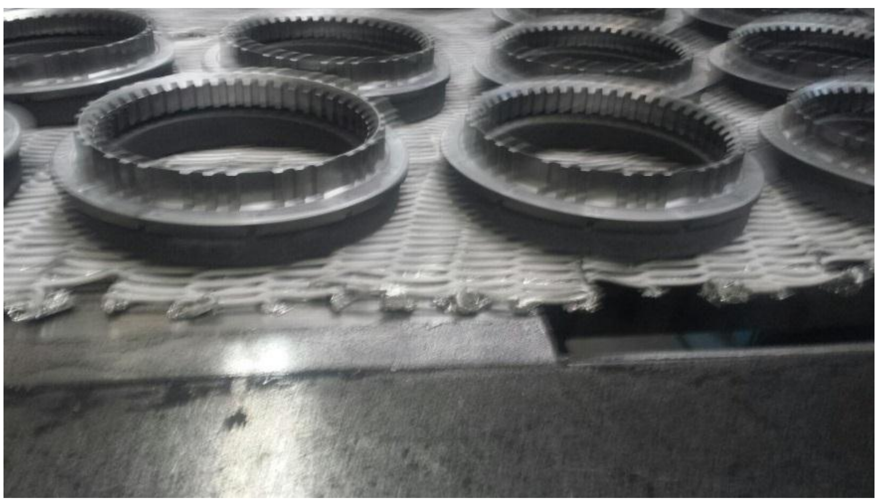

**Figure 1. T314 Stainless Steel Woven Wire Belt with Frayed Edges**

In this whitepaper, we intend to show that by subjecting the T314 woven wire mesh belt to a simulated break-in period under specifically controlled parameters, a measureable increase in the typical service life of the belt in a sintering furnace can be realized. Increased belt life is directly translatable into reduced downtime, increased production, and belt cost savings.

## Discussion of Proposed Solution

Based on the premise that neither adequate belt break-in nor de-lubing of the PM products prior to the sintering stage of the process will typically take place, we have taken the step of subjecting new belts to a type of controlled break-in process prior to shipping them to the customer. We have named this product variation the "Platinum" belt. Under a tightly controlled and proprietary process, each belt is essentially pre-oxidized before being installed. The process is carried out in an electric furnace with no artificial atmosphere. Belt sections are subjected to a specifically defined set of temperature 'soaks' in order to build a protective layer of natural oxidation on the surface of the wires. This oxidation layer is most important along the belt edges where the welds are located (and also correspondingly where the highest concentration of free carbon is located). Due to the presence of an artificial atmosphere within the sintering furnace, this oxidation is not able to completely and adequately form; therefore, the belt never gains the benefit of that protection.

The metallurgical argument behind this is fairly straightforward. T314 stainless steel wire in an un-oxidized state operating in a high-heat environment along with excess carbon from heating petroleum-based lubricants experiences a certain amount of carbon diffusion into the surface. This effect is concentrated along the edges of a welded belt where it seems that much of the excess carbon is allowed to collect within the furnace unit. At temperatures between 650ºF and 815ºF, (340ºC to 435°C), carbon is known to diffuse into the welds (areas of the belt within the heat-affected zone created during welding), and bind with chromium to form chromium carbides ($Cr_{23}C_6$) creating an embrittled structure. In high nitrogen furnace atmospheres, it is thought that chromium carbonitrides (CrCN) also form in addition to chromium carbides. Both act to constrain grain movement, some of which is necessary for normal belt operation, though clearly the biggest detrimental impact is from the chromium carbides. Under normal circumstances, the formation of chromium carbides and resulting weld sensitivity can and will cause intergranular corrosion of the material; however, in high-temperature and reducing furnace atmosphere applications such as the sintering furnaces, restricted grain movement (essentially material embrittlement) can lead to grain separation (localized cracks) and the eventual breaking of the welds. This then becomes the major concern. Broken welds quickly lead to frayed belt edges, and thus it only a matter of time before the belt must be replaced.

By subjecting the belt to series of heat 'soaks' under controlled conditions in an oxidizing atmosphere, a protective layer of chromium oxide ($Cr_2O_3$) forms on the surface of the wire and welds. We refer to this as a pre-oxidation step in the belt manufacture (Figure 2).

This chromium oxide layer sufficiently binds the chromium on the surface of the wire effectively prohibiting it from interacting with the available free carbon typically found inside the sintering furnaces. It is critical to perform the pre-oxidation process within a furnace that is clean from carbon in order to avoid the unintended forming of chromium carbides in the material. This is especially critical at the temperature soaks at or near 650°C (1200°F). Also, temperature soaks near 815°C (1500ºF) must be avoided so as not to subject the material to the formation of 'green rot' oxidation on the surface of the wires.

**Figure 2. Belt inside of Treating Oven**

**Results**

Field test results in actual PM sintering furnace operations have shown a significant increase in average belt life for pre-oxidized belts as compared to those that have not undergone that process. As shown in Figure 3, a typical T314 belt service life will average some 60 days. But results from using pre-oxidized belts within the same furnaces and process indicate an extended belt service life of 75+ days, or about a 25% increase in belt life. Results have also shown a decrease in production downtime of more than 18% attributable not only to fewer belt replacements, but also reduced belt and conveyor maintenance.

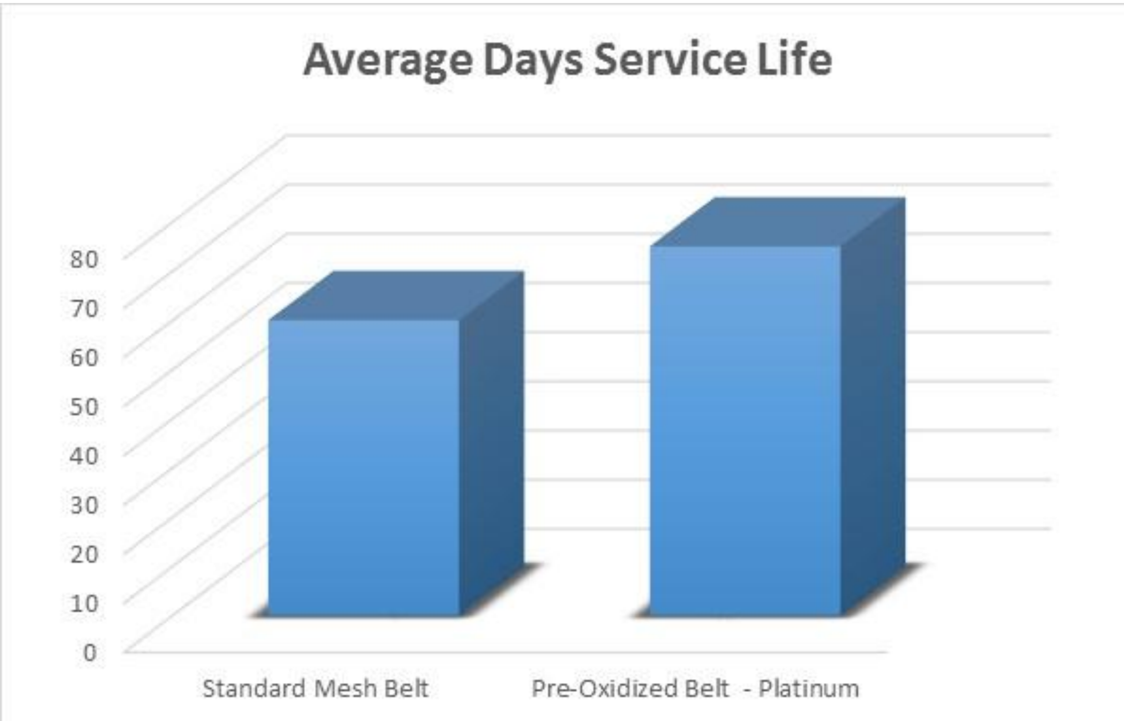


**Figure 3. Comparison of Belt Service Life for Treated vs. Un-Treated Belts**

The belts that undergo this step prior to installation often still fail in a manner not unlike those that have not been pre-oxidized. During operation, the belt typically sustains some damage to the oxide layer from which it does not recover. As a result, it is expected that some sections of belting will still develop broken welds, which begins the process by which the belt becomes unusable. However, the effect of the applied oxide layer seems to be sufficient in delaying the onset of the inevitable.

It should be noted that the additional costs associated with the pre-oxidation process essentially limit its cost-effective application to wider belts only. Due to the lower purchase cost point for narrower belts, an overall 25% increase in belt life does not sufficiently offset the added costs for pre-oxidizing the belts prior to installation. The chart below (Figure 4) indicates a cost benefit for belts that are approximately 24” wide and wider. However, it should be stated that this breakeven analysis does not include any cost savings associated with reduced production downtime as has been previously discussed.

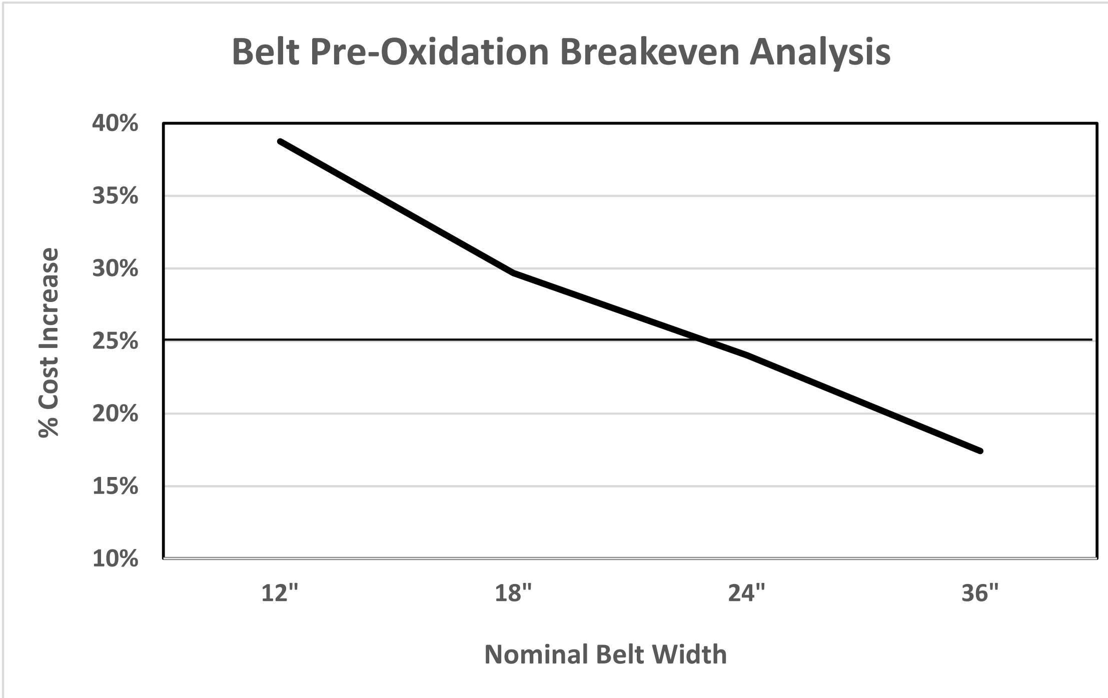


**Figure 4. Breakeven Analysis for Pre-Oxidized Belts**

## Summary

Pre-oxidizing the belts effectively replaces the desired break-in period which is not typically practical for any company operating a powdered metal sintering furnace line. Yet this step still provides the benefits normally associated with that process, especially for units that must operate without sufficient de-lubing of the PM parts. The additional life gained by using a pre-treated belt can mean an additional $15-20k in production uptime for a single sintering line without making any other changes in the equipment or the process of today's typical high production line.