Steel belts for sulphur forming

Tom Smith of IPCO Germany GmbH discusses the history of steel belts in product cooling and forming and new grades of steel that the company has developed to deal with corrosion issues.

The steel belt journey began in 1901 when a conveyor made from a hardened solid strip steel was used for transporting scrap material from a Swedish saw mill. Originally, this strip steel was used for band saws in the lumber industry. Then, thanks to an upgrade in the rolling mills, much longer and wider strips could be produced and the idea came up to use the material as a conveyance medium.

During these early days, applications for steel belts were mainly limited to conveying products from one point to another and the same hardened carbon steel grade used for saws sufficed. However, as industrial development around the world drove the need for steel belts with qualities other than simple strength and wear resistance, the first stainless steel belt was introduced in 1931. This cold rolled stainless material, containing 17-20% chromium and 8-13% nickel, opened the doors to a host of new and exciting applications in the food, chemical and fertilizer industries, where good corrosion resistance, ease of cleaning and protection from contamination were all-important. Eventually, the thermal properties of steel belts were recognized and the first ‘process belt’ was born.

The pioneering company behind these innovations is today known as IPCO (formerly Sandvik Process Systems), and the company has gone on to become a world leader in the manufacture of carbon, stainless and now duplex steel belts. IPCO steel belts are now used around the world for applications as diverse as baking cookies; pressing wood-based panels such as MDF and OSB; freeze-drying instant coffee; casting thin pharmaceutical films; sintering, and even the wind tunnel testing of racing cars at full speed.

One area in particular – the solidification of chemical melts – has seen steel belt-based cooling come to be accepted as the default process solution for many product types, from A (alkane sulphonate) to Z (zinc stearate), with products in between including bitumen, hot melt adhesives, pesticides, resins, rubber chemicals, and of course sulphur. This in turn has driven continuing improvements in belt technology: the more advanced the application, the greater the need for flatness, straightness and the ability to operate at ever greater speeds and temperature fluctuations.

A steel belt might appear to be a relatively simple product but engineering the qualities into the belt necessary to deliver the required performance is a lengthy and exacting process. Today’s steel belt manufacturing requires a whole series of production steps in order to remove unwanted characteristics of cold rolled steel such as camber and ‘loose’ areas providing tighter tolerances for thickness, flatness, surface roughness and straightness. The process includes the following steps:

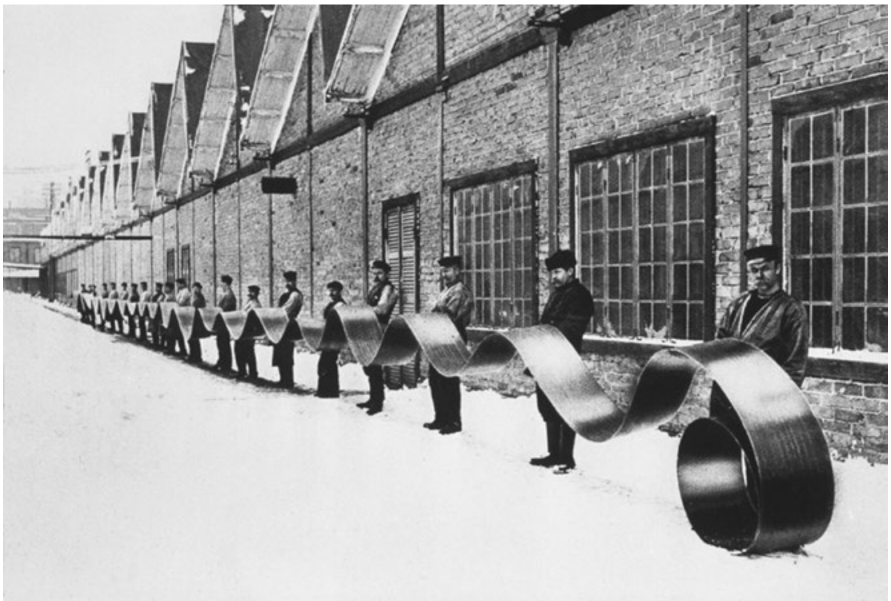
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Fig. 1: A hardened, solid strip steel belt from the early 1900s.

Oxide scale removal

The high temperatures required to hot roll the steel into coils results in surface oxidation that manifests itself in the form of a scale that causes a rough surface. This oxide scale must be removed prior to cold rolling. This is accomplished by a combination of mechanical scale breakage and an acid bath treatment known as pickling. With each subsequent process after pickling, the surface area of the steel is increased while the cross section is reduced until the material is cold rolled into a finished strip.

Cold rolling

Cold rolling requires high pressures since it does not have the softening benefits of the high temperatures used in hot rolling. Therefore, special rolling mills are required to perform cold rolling. For a steel belt, the

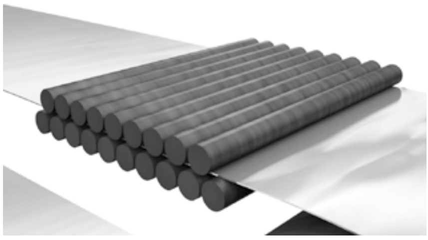

Fig. 2: Belt levelling.

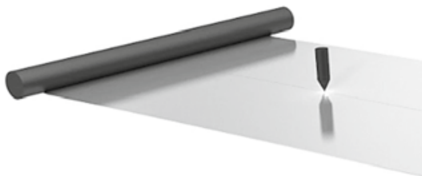

Fig. 3: Longitudinal welding.

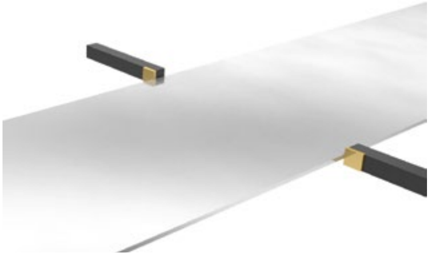

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Fig. 4: Edge treatment.

cold rolled coil must meet certain flatness and straightness specifications. However, the cold rolled coils have varying degrees of long centres and differing compressive and tensile stress patterns throughout the cross-section of the material that need to be levelled in order to meet final tolerances.

Belt levelling

Belt levelling, also called flattening or trueing, corrects the shape of the cold rolled coil so that the resulting belt is flat and straight. During levelling, the varying internal stresses in the coil are balanced throughout the belt, reducing the risk of belt deformation (the belt losing shape) during operation or heat exposure.

To better explain the concept of levelling, it is necessary to point out what it is that causes a belt not to be straight or flat. If one side of the coil is longer than the other side, the coil will not be straight or run true; this is a condition called camber. To correct the camber, the short side needs to be elongated until it reaches the length of the longer side. To complicate the situation, the longer 'loose' areas and shorter 'tight' areas are not uniform throughout the coil. Belt levelling is considered to be more of an art than a science, and a great deal of knowledge and skill is required to identify these tight areas and how to level them out to match the loose areas in the steel belt.

Welding

The maximum width of a steel belt depends on the limits of the hot rolling equipment in steel mills. Up until relatively recently, the maximum single width steel belt was 1,500 mm wide. However, in 2005 the first 2,000 mm wide single width material became available; this was a significant development as it enables 33% more forming capacity over the narrower 1,500 mm.

It is possible for multiple belts to be longitudinally welded together to create a wider belt, but for many applications the cost of producing these longitudinally welded belts will be prohibitively expensive. For some markets though (e.g. bake ovens, industrial presses, paper mills), the benefits of a wide belt far outweigh the cost and IPCO regularly produces such belts.

Edge treatment

Most belts are slit down from a wider coil and the edge cutting and treatment steps in production are crucial to prolong the belt life. Since the belt edge is cut square, it must be machined to a smooth rounded surface to eliminate any sharp corners or burrs.

When a steel belt is in operation, the belt edges can be exposed to high stresses from belt tensioning and tracking or from possible pulley misalignment. Rounded belt edges help to withstand these stresses. If the edge of the belt gets nicked or burred during operation, it should be immediately retreated and reduce the risk of edge cracks developing. Also, to avoid abrasive damage, anything that may come into contact with a steel belt (i.e. support idlers, product scrapers, etc.) should either be rotating, or made of a softer material than the steel belt grade.

Belt systems need to be inspected regularly – ideally daily – to make sure that the belt is not in danger of damage in any way. In addition, a more detailed inspection should be performed on a quarterly or biannual basis, the frequency depending on the criticality of the operation and whether or not the belt operates around the clock.

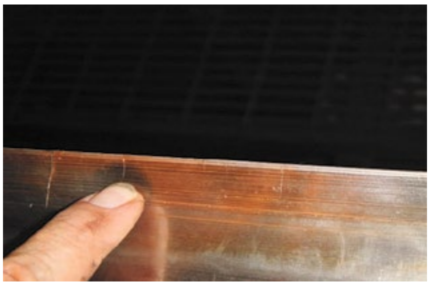


Fig. 5: Edge cracks developing.

If a crack develops and is noticed in time, it can be repaired on site by a qualified technician. Also, thanks to the repairability of the steel belt materials, if an area has extensive damage, a section of steel belt can be removed and replaced with two intermediate welds.

Sulphur processing

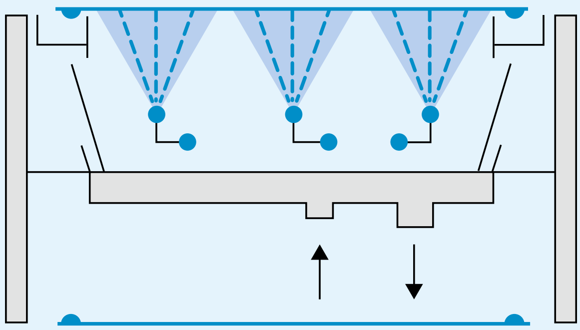
IPCO steel belts are widely used across the oil, gas and chemical industries and one of the most important applications in this particular field is sulphur processing. The company's experience in this area extends back to 1951, when they installed the first continuous sulphur slating line at an oil refinery in Mexico. Such was its success that the company has gone on to design, manufacture and install more than 700 steel belt-based Sulphur forming machines around the world, producing either slates or pastilles.

The forming or solidification process works by delivering molten sulphur onto a continuously running stainless steel conveyor belt. Cold water is sprayed onto the underside of the belt and the excellent thermal conductivity of the steel allows the heat of the Sulphur melt to be transferred to the cooling water as it is conveyed along the system, resulting in a solid formed Sulphur for safe and convenient transportation to end users. The recirculated cooling water is collected in tanks and returned to a water re-cooling system; at no stage does the water contact the sulphur (see Figure 7).

PHOTOS: IPCO

Fig. 6: Sulphur slates and pastilles

Fig. 7: **Cross-section of a steel belt cooler**



Source: IPCO

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Fig. 8: A steel belt cooler producing sulphur pastilles.

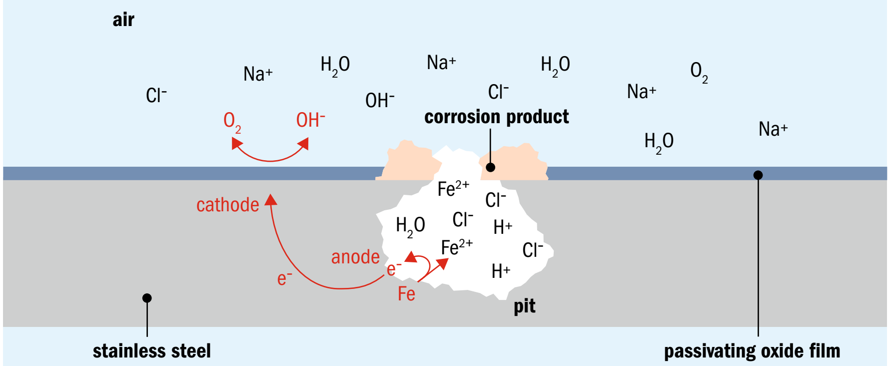
IPCO's designations of steel belt grades will be described in the remainder of this article. For clarity, the IPCO designation of the steel grades gives an indication of both the tensile strength of the steel and the type of steel. The numbers are used to indicate the approximate tensile strength of the steel belt in megapascals (MPa). Letter symbols are used to designate the following steel types:

C = Carbon steel
S = Stainless steel
A = Austenitic steel
M = Martensitic steel
F = Ferritic steel

For example, IPCO grade 1200SA is an austenitic stainless steel with a tensile strength of approximately 1,200 MPa; whereas, 1400SAF is a duplex steel stainless steel made up from a mix of austenitic and ferritic steels with a tensile strength of approximately 1,400 MPa. For universal familiarity, the European standard steel number is shown in parentheses after each steel belt grade designation.

Historically, a standard austenitic steel belt – IPCO grade 1200SA (1.4310) – has been used for sulphur forming. However, plants installed in warm regions and near seawater are exposed to high levels of airborne chlorides and moisture that combined with elemental sulphur can result in pit corrosion of the steel belts and, eventually, lead to the development of edge cracks. Pit corrosion occurs when the passive layer on the stainless-steel surface is locally broken down by halide ions, such as by chloride ions, in a neutral or acidic environment. As a result, pitting and crevice corrosion can propagate at a high rate, causing corrosion failure in a short time. While pits in a steel belt appear to be small holes in the surface, the actual corrosion below the surface can be much greater (Figure 9).

Fig. 9: **An example of pit corrosion below the surface**



Source: IPCO

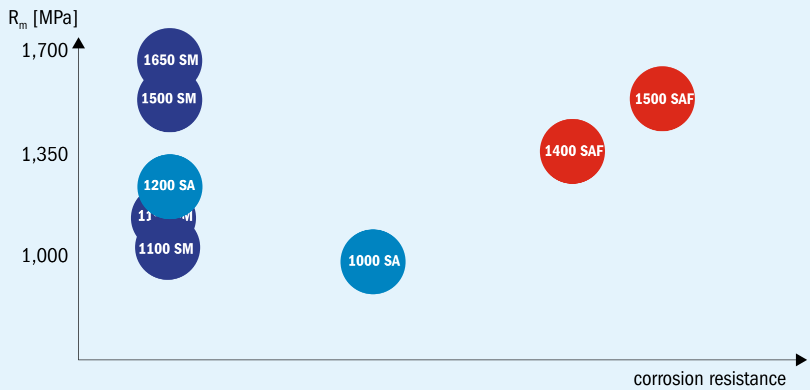
IPCO 1400SAF

In order to tackle this challenge, IPCO has recently introduced a steel belt made of duplex stainless steel that offers significantly greater resistance to chlorides and wet sulphur contact corrosion. Most of the sulphur recovered these days is from oil and gas refining and many refineries are located near seaports for ease of exportation. IPCO grade 1400SAF (1.4462) is a steel grade that is highly alloyed of the elements chromium, molybdenum and nitrogen, which provides enhanced reinforcement of the passive layer of the surface. This makes it ideal for use in Sulphur plants that are located close to salt water, especially in countries where ambient temperature can reach 30-40°C.

To make a rough ranking of different stainless steels, the PRE (pitting resistance equivalent) formula is used, PRE = % of Cr + 3.3 x % of Mo + 16 x % of N. IPCO grade 1400SAF has a PRE of 35, in comparison IPCO 1200SA has a PRE of 18 and IPCO 1000SA (1.4401) has a PRE of 24. The higher the PRE value, the better the resistance.

Stress corrosion cracking (SCC) is a brittle failure mode caused by the combined effect of mechanical stress in a corrosive environment and normally at elevated temperature. SCC is often initiated by a localized corrosion attack (pitting or crevice attack). Standard austenitic stainless steels containing less amounts of molybdenum are more sensitive to SCC than other types of stainless steels. The 1400SAF grade has a very good resistance to stress corrosion cracking due to its duplex microstructure of austenite and

Fig. 10: **Steel belt grades tensile strength versus corrosion resistance**



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ferrite where the ferrite phase is the continuous phase. Also, the material has a low carbon content and thereby a high resistance to intergranular corrosion.

Reference installations are proving that the 1400SAF duplex steel is much more resistant to corrosion from high chlorides in the presence of wet sulphur with belts running much longer than the standard 1200SA stainless steels without signs of pit corrosion or cracking. While sulphur installations away from sea water have seen great success for decades with the 1200SA steel grade, IPCO is standardising on its 1400SAF duplex steel for all sulphur installations from now on since other airborne chlorides could be present in any location.

IPCO has continued development and is also now also able to offer a 'super duplex' grade 1500 SAF (1.4410) for installations where chloride levels are particularly high or there is a risk of hydrochloric acids coming into contact with the steel belt. The diagram left shows how IPCO's different steel belt grades rate for tensile strength and corrosion resistance.

The SM grade belts shown in the diagram are all martensitic precipitation-hardened stainless steels. These martensitic grades have a thermal conductivity that is comparable to the austenitic grades, but the thermal expansion is much lower. This makes the precipitation-hardened steel less sensitive to thermal strain and buckling caused by uneven temperatures. However, they are more sensitive to pitting than the austenitic grades, even in solutions of a relative low chloride content, and are not recommended for processing sulphur-based products.

While mechanical forces remain to be the most common cause of damage to steel belts, IPCO continues to develop new steel grades like the 1400SAF duplex steel to resist damage that can be controlled, like corrosion, to prolong the life of steel belts.