Leslie David, Dunlop, UK, explains how both ozone and ultraviolet light can dramatically shorten the working life of conveyor belts, and considers how fertilizer manufacturers can protect against these effects.

No matter what price you pay, the reliability and longevity of conveyor belts will ultimately dictate their cost. There are many things that determine the level of maintenance they require and their working lifetime. The incessant abrasive action of the materials being conveyed, the impact damage caused by heavy, sharp lumps of rock being dropped onto conveyor belts, or the ripping and tearing caused when a rock or other foreign object becomes trapped and penetrates the belt, are all scenarios recognised as the norm.

However, what is not well known are two other inescapable factors that have a huge influence on the operational lifetime of a rubber conveyor belt. Those factors are ozone (O_3) and ultraviolet (UV) light. Contrary to common misconception, the damage that can be caused is extensive and not limited to higher altitudes or sunny climates. Although it is relatively easy to make rubber that is resistant to the effects of O_3 and UV, in an effort to minimise the sale price, more than 90% of all conveyor belts sold in Europe are not ozone and UV resistant. Ironically, this practice actually increases the cost to the end user.

From protector to destroyer

One of the first design considerations that engineers should take into account when working with rubber are the effects of ozone. Almost all of the rubber used in conveyor belt manufacturing is synthetic. This is because different mechanical properties and characteristics can be specifically created

CRACKING UP

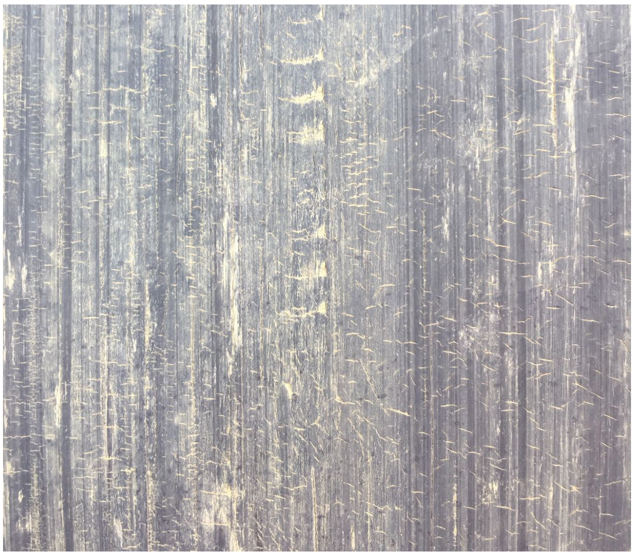

Figure 1. Ozone cracks in the surface of the rubber.

Figure 2. Pollution problems – fine particles of dust penetrate the cracks and are then discharged (shaken out) on the return (underside) run of the belt.

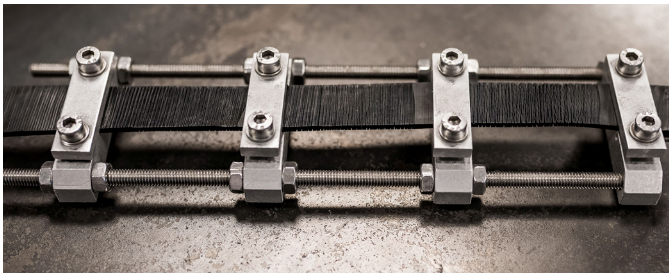

Figure 3. The cracks are always orientated at right angles to the strain axis.

Figure 4. Transversal cracks deepen under the repeated stress of passing over the pulleys and drums.

depending on what the rubber will be used for and the working environments it will be subjected to.

Ozone (O_3) occurs naturally in the upper atmosphere. It is formed continuously by the action of solar UV radiation on molecular oxygen (O_2). At high altitude, ozone acts as a protective shield by absorbing harmful UV rays. Wind currents carry O_3 to the atmosphere at the Earth's surface. However, at low altitude, O_3 becomes a pollutant. Ground level or 'bad' O_3 is not emitted directly into the air but is created by the photolysis of nitrogen dioxide (NO_2) from sources such as automobile exhaust and industrial discharges. This is known as ozonolysis.

Ozonolysis

Ozonolysis is the reaction that occurs between the molecular structure (double bonds) and O_3.

The scientific explanation is that the immediate result is the formation of an ozonide, which then decomposes rapidly so that the double bond molecule is split. The critical step in the breakdown of molecular chains occurs when polymers are attacked. The strength of polymers depends on the chain molecular weight or degree of polymerisation. The longer the chain length, the greater the mechanical strengths, including the highly important tensile strength of the rubber. By splitting the chain, the molecular weight drops rapidly. There comes a point when very little strength remains and cracks starts to form. Further attacks occur inside the freshly exposed cracks, which continue to grow steadily until they complete a 'circuit' and the product separates or fails.

Exposure is inescapable because even tiny traces of O_3 in the air will attack the molecular structure of rubber. It increases the acidity of carbon black surfaces with natural rubber, polybutadiene, styrene-butadiene rubber and nitrile rubber being the most sensitive to degradation. Although the first visible sign is when cracks start to appear in the surface of the rubber, depending on the level of O_3 resistance that has been built into the rubber compound, the process of ozonolysis effectively begins when the conveyor belt leaves the production line.

Although the variability of weather, airflow patterns, seasonal changes, and the level of emissions and climatic conditions do mean that O_3 concentrations can differ from one location to another, the fact is that ground level O_3 pollution is ever-present and therefore its effects should never be underestimated.

A partner in crime

To make matters worse, 'bad' O_3 has a partner in crime that also has a seriously detrimental effect on rubber. UV light from sunlight and artificial (fluorescent) lighting accelerates rubber deterioration because it produces photochemical reactions that promote the oxidation of the rubber surface resulting in a loss in mechanical strength. This is known as 'UV degradation'.

Ironically, the rapid decline in the O_3 layer in the upper atmosphere over the past several decades is allowing an increasing level of UV radiation to reach Earth's surface. Continuous exposure is a more serious problem than intermittent exposure, since attack is dependent on the extent and duration of the exposure. As would be expected, the problem is worse in hot and sunny climates but even in the most moderate of environments, the problem is ever-present and, as with O_3, it would be foolish to underestimate the damage it causes.

Figure 5. Dunlop's ozone testing cabinet.

Figure 6. Samples are checked for cracking at two-hourly intervals.

Figure 7. Some rubber disintegrates within hours.

Hidden effects

O_3 cracks form in rubber that is under tension. This is sometimes referred to as 'dry rotting'. It is important to bear in mind that the amount of tension (critical strain) needed is only very small. Even a belt that has not yet been fitted on a conveyor has a certain amount of intrinsic tension. The cracks are always oriented at right angles to the strain axis.

The dynamic stress that a conveyor belt undergoes while in operation is considerable. O_3 attack occurs at the points where the strain is greatest.

The repeated action of the mechanical stress of the conveyor belt and the frictional process from the idler means that the rubber molecular chain will break to form what scientists refer to as a 'free radical'. This triggers the oxidative chain reaction that forms a chemical process, which mechanically breaks the molecular chain and activates the oxidation process and which magnifies a whole range of more obvious problems such as the ability to resist abrasion.

Stress magnification

At first glance, having small cracks in the surface rubber may not seem to be a big problem, but over a surprisingly short amount of time, the rubber becomes increasingly brittle. Transversal cracks deepen under the repeated stress of passing over the pulleys and drums. The O_3 continues to attack so the cracks will steadily grow until catastrophic failure occurs. Cracks often present other potential risks such as scrapers catching on them and tearing off parts of the cover. Re-splicing can also become increasingly difficult over time as the adhesion properties of the rubber diminish.

Yet another 'hidden' problem is that moisture seeps into the cracks. This then penetrates down to the actual carcass of the belt. In multi-ply belts, the fibres of the weft strands of the plies expand as they absorb moisture, which in turn causes sections of the carcass to contract (shorten) as the weft strands pull on the warp strands of the ply. This can result in tracking problems, which can be difficult to pinpoint, and which no amount of steering idler adjustment can compensate for. Last but not least, there can also be significant environmental and health and safety consequences because fine particles of dust penetrate the cracks and are then discharged (shaken out) on the return (underside) run of the belt.

The damage is preventable

Damage caused by O_3 and UV is almost entirely preventable thanks to the use of modern technology. Several years ago, Dunlop were among the first in the world to make use of new technology that enabled the effects of O_3 to be tested and measured. Dunlop equipped its laboratory in Drachten in The Netherlands with the very latest O_3 testing equipment and introduced mandatory testing to EN/ISO 1431 international standards for all Dunlop rubber products. The same testing regime was applied to samples of belts made by other manufacturers.

As a direct result, special additives that act as highly efficient anti-ozonants and protect against the damaging effects of O_3 and UV became an essential ingredient in all Dunlop rubber compound recipes without exception. Unfortunately, few belt manufacturers make use of these anti-oxidant additives.

EN/ISO 1431 testing

To scientifically measure resistance to O_3 in accordance with the EN/ISO 1431 test method, samples are placed under tension (e.g. 20% elongation) inside an O_3 testing cabinet and exposed to highly concentrated levels of O_3 for a period of up to 96 hours (at 40°C, 50 pphm and 20% strain).

Samples are closely examined for evidence of cracking at two-hourly intervals and the results are carefully measured and recorded. Experience has determined that in order for the rubber to be regarded as adequately resistant, the pass criteria needs to be that the rubber sample does not show any signs of cracking within the 96-hour period.

Swept under the carpet

Despite its crucial importance, O_3 and UV resistance is very rarely, if ever, mentioned by belt manufacturers and suppliers and remains a subject that is swept under the carpet. This is because so much of the market is dominated by those trying to undercut their competitors on price. Anti-ozonant additives are not cheap and therefore, in the pursuit of a price advantage, are simply not used. A more sinister aspect of the non-use of anti-ozonants is that for a great many belt suppliers, anything that prolongs the working life of belts is not good for business.

As mentioned previously, more than 90% of belts tested in Europe fail the EN/ISO 1431 test. Worse still, in the majority of cases, the cracks start to appear as early as six to eight hours within the target time of 96 hours. In fact, it is not uncommon to see rubber samples completely disintegrate within a few hours. Typical 40 and 60 Shore sheeting and skirting rubber seems to be even worse.

Because of the sheer size of industrial conveyor belts, it is common practice amongst manufacturers and distributors to store rolls of belting in the open air. Belts can often be held in stock for long periods, sometimes for several years, before they are eventually dispatched and ultimately put to use. During that time, they are vulnerable to the ever-present effects of O_3 and UV radiation. A number of conveyor belt users have reported that surface cracking could be seen at the time of delivery.

No hiding place

O_3 can be found everywhere. Even 'normal' air can have up to 0.01 ppm of O_3. The addition of electrical equipment or lighting can increase the ppm level even further. There is no hiding place. The importance of having conveyor belts that are resistant to the damage caused by O_3 and UV can no longer be ignored. Unless conveyor operators start insisting on having belts that are O_3 and UV resistant, then the vast majority of belt manufacturers and suppliers will continue to ignore the issue and continue to supply belts that start to deteriorate from the moment of creation.

For all buyers of rubber conveyor belts, an absolute pre-requisite when buying any type of belt is that it is fully resistant to the effects of O_3 and UV. It is important to always insist on certification that confirms that the belt you are being offered is fully resistant to O_3 and UV in accordance with the EN/ISO 1431 test method, because without this essential property, the belt will almost certainly need to be replaced far sooner than necessary. WF