# WORLD COAL®

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Figure 1. Hardening of a chain.

# CHAINS: THE PRIORITY

**Kazimierz Hanuszkiewicz, Capital Group FASING Plc, Poland,** discusses how the adjustment of mechanical properties can increase the durability and lifetime of a plow chain in extreme performance conditions.

Coal plows are being used more and more often in mines of thin and medium coal seam. The plow body is conveyed by a continuous loop chain (also called a drive chain), which allows for the plow to move along the longwall. It is bidirectional and travels at speeds three times higher than the speed of the AFC chain. In the latest plow system developments, the remote control plays the major role and allows for unmanned operation. Chains that draw plow body (in both gliding and base-plate type) operate in very extreme performance conditions, as they move inside chain guide ducts at speeds of almost 4 m/sec.

Uneven seam and unsteady movement of the longwall mining system cause a constant disalignment of chain guide ducts. It results in strong friction of chain links against the duct walls, particularly at vertical and horizontal contraflexure points. Such continuous, strong and intense rubbing of chain links and high value stress on the duct – which guides the chain at high speeds – creates high temperatures on the upper layers of the link surface.

Propagation of microcracks towards the internal link structure at the time of the chain's operation results in fracture over a relatively short period of chain use. Its lifetime amounts to tens of thousands of minutes of effective work (up to four months since the start-up).

The research and development work carried out by FASING Group is focused primarily on extending the chain's life. Such methods include:

- The modification of the chemical composition and micro additives of vanadium, tungsten and titanium to increase mechanical properties (improvement of strength and yield point).
- The multi-stage induction heat treatment to obtain the smallest grain structure, an increase of absorbed energy in Charpy impact strength testing and fatigue resistance with reference to DIN 22252:2012-07 standard.
- The reduction of the friction coefficient between chain links and chain guide duct surface.

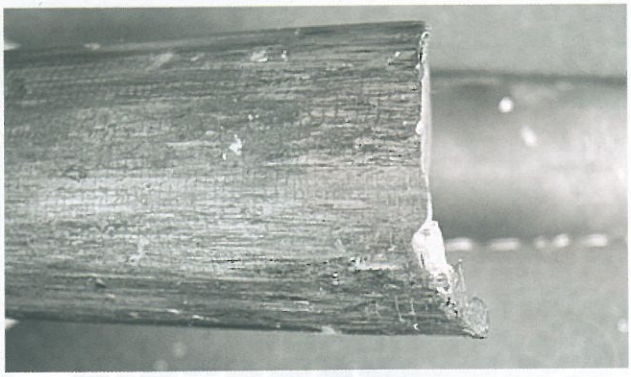

Figure 2. Microcracks of grinding martensite.

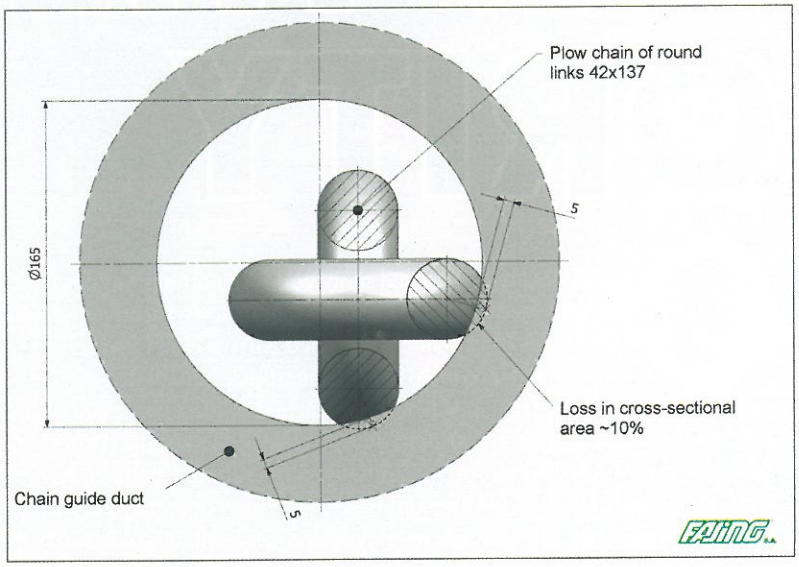


Figure 3. Material loss in cross sectional area of links.

## Research and development works

### Modification of chemical composition

In the plow chain production process, the best steel is used under the requirements of the DIN 22252: 2012-07 standard. It is the steel grade 23MnNiMoCr54 according to DIN 17115: 2012-07 standard. To improve the strength parameters of the said steel grade, which directly determine the chain's mechanical properties, FASING Group orders bars for plow chain manufacture with reference to its own Specification of Requirements, that include adjusted values of element content in chemical composition and microalloy additives: vanadium, tungsten and titanium.

### Multi-stage heat treatment

In order to achieve the optimal mechanical properties of a chain, FASING has established a five-stage heat treatment which involves normalising (homogenisation), hardening, annealing and double tempering the chain on a computer-controlled induction heat treatment line.

This meticulous heat treatment allows for the hardness to be distributed evenly on straight link sections that are exposed to the risk of friction martensite (aiming for lowest possible value of ~340 HBW), and for the link crowns to resist wear and sprocket indentations (hardness value up to 390 HBW).

Modification of highly optimal (HO) steel chemical composition and aforenamed heat treatment results in obtaining the most fine grain structure (100% of grains are size '10'). It gives the required mechanical properties that have been originally in a concept stage of the research project and later included in FASING Technical Requirements for plow chains 38 x 137 and 42 x 137 of over 900 MPa in strength. Basic mechanical properties are presented in Table 1 and compared to the ones of DIN 22252: 2012-07 standard.

### Reduction of friction coefficient

The main reason behind the damage of the plow chain is friction martensite, which appears at the time of intense abrasion on a chain guide duct surface. This happens when the chain is drawn by a plow at a high speed. Hard martensite is exposed to microcracks and through the crack propagation, it leads to chain fracture during plow operation.

Martensite creation may be significantly reduced or eliminated by the following means:

- Maximisation of the area on link straight sections where low value hardness is present.

**Table 1. Parameters of plow chains made by FASING as compared to DIN 22252 standard requirements**

| Chain size d x t (mm) | Test force (kN) | Elongation under test force (%) max | Breaking force (kN) | Elongation at fracture (%) | Working force (kN) | Charpy V-test (J) | Fatigue resistance (cycles) |
|---|---|---|---|---|---|---|---|
| Fasing 42 x 137 | 1660 | 1.4 | 2400 | 17 | 1560 | 95 | 110000 |
| DIN 22252 42 x 137 | 1660 | 1.6 | 2220 | 14 | 1380 | 57 | 70000 |
| Fasing 38 x 137 | 1360 | 1.4 | 1960 | 17 | 1250 | 95 | 110000 |
| DIN 22252 38 x 137 | 1360 | 1.6 | 1820 | 14 | 1130 | 57 | 70000 |

- Application of double protective agents in time of chain entering the duct: coating FAS-Zn-M, FAS KBP 50/00/22 and FAS-AN-S (Fasing trade names).

### Protective agents

Coating FAS-Zn-M –I entry protection: this is a highly protective, anti-corrosive and lubricating agent based on zinc and its compounds. It forms durable, elastic coating that is resistant to wear and creates the lubricant effect in link contact areas. Furthermore, it decreases friction and wear values by reducing friction coefficient up to ~$\mu$ = 0.08 in. plow ducts.

Coating FAS-KBP-50/00/22: this is a protective, anti-corrosive and lubricating agent, which is a multi-component coating based on special tectyl, containing water-resistant medium, and prevents damping and condensation corrosion. It creates protective layer which is resistant to wear, i.e. reduces friction.

Once the chain moves with a high speed inside the guide ducts, both horizontal and vertical links come into contact with the internal duct surface.

Despite the coating application, the chain link surface is subject to significant wear over time. In the case of non-application of entry protective agent, the material loss in chain links may reach up to 10%.

In addition, if chain guide ducts are not aligned, conveyor plates may get damaged as well. The degree of duct wear may be observed by comparing the as-new duct condition with the damaged guide duct.

Therefore, the effective method to reduce wear of chain links and eliminate the occurrence of grinding martensite is the application of so-called 'entry protection II'. It includes simultaneous use of special lubricant FAS-AN-S and constant spraying of water to operating chain.

Application of these entry, protective coatings that reduce friction coefficient between links and guide ducts translate directly into longer durability and performance life of a mining plow.

## Conclusion

Longwall extraction of low and medium coal seams below 1.8 m (71 in.) is most efficient when applied with coal plows. In comparison to the shearers the coal output may be even 40% higher in the case of plow systems. Moreover, the machine body is much shorter than the shearer's, so it is possible to plow more undulating seams. Their design and structure is simple, which directly translates into their longer lifetime. The main elements that are subject to high level of wear are: bits, drive chain, sprockets and sliding members of the plow body.

Figure 4. Damaged guide duct.

The state of a plow chain significantly affects operations and coal production in underground mines. In comparison to the armoured face conveyor chain it has a much shorter lifetime. The previously mentioned actions should be introduced in order to gain economic benefits. Moreover, frequent plow chain replacements are difficult, tiresome and dangerous. WC