RELIABLE HIGH PERFORMANCE CENTRAL CHAIN FOR BUCKET ELEVATORS

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PRESENTS THE DEVELOPMENT OF A NEW RELIABLE HIGH PERFORMANCE BUCKET ELEVATOR CENTRAL CHAIN.

In the cement industry and other bulk solids handling industries, reliable conveying machinery and equipment is essential to achieve high productivity and avoid unexpected plant shutdowns. An optimum ratio of operational capacity to energy consumption, e.g. of modern high performance vertical roller mills or roller presses for grinding of raw materials, clinker and cement, is achieved by

Figure 1. Photographic images of broken outer links of bucket elevator central chains with old design.

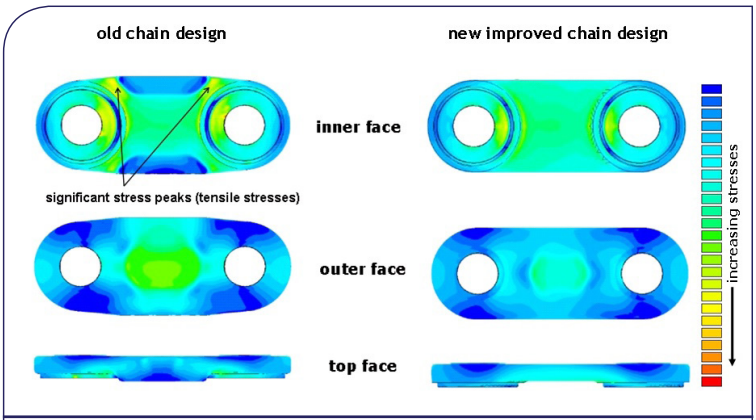

Figure 2. Von Mises equivalent stresses on the inner links of the old and the new improved chain link.

uniform and undisturbed feeding. Increasing feeding rates require bucket elevators with higher capacities and, hence, heavy duty bucket elevator chains with the highest tensile strength, wear resistance and fatigue strength.

Achieving these demands requires a fundamental knowledge of chain technology and material science, as well as the availability of the best material qualities and state-of-the-art manufacturing technologies. This article summarises the development of a new reliable high performance bucket elevator central chain. The development has been performed on the basis of long term experiences and by applying modern finite element analysis tools.

State of the art bucket elevator central chain technology

In the past decades HEKO Ketten GmbH (HEKO) and its enterprise KoWey GmbH & Co. KG (KoWey) have become a reliable partner for bulk solids handling industries with the delivery of bushed conveyor chains and correspondent equipment for high performance bucket elevators. The entire chain production of HEKO's high performance bucket elevator central chains is performed by applying state-of-the-art manufacturing technologies. Most of the components are manufactured in HEKO's production plants. HEKO chains are made from high quality steel grades with European origin.

Chain manufacturing

The main characteristics of HEKO's high performance bucket elevator central chains are:

- CNC machined pins and bushes with the highest tolerances in diameter, parallelism and roughness.
- CNC machined bores in link plates to provide continuous high press fit between bushing/pins and chain link plates and to guarantee a straight non twisted chain.
- Case hardening of bushes by applying state of the art vacuum heat treatment technology (carburisation in vacuum chambers and quenching in helium atmosphere) to achieve highest wear resistance and still maintaining a tough core.
- Quenched and tempered pins with induction hardened surface to maintain highest resistance against abrasive wear and retaining a tough core.

The drop forged link plates of HEKO's high performance bucket elevator central chains are made of boron alloyed, quenched and tempered steel. Drop forging with subsequent quenching and tempering is essential to achieve the best ratio between tensile strength and chain weight.

Ordinary chain design

For applications with increased abrasive wear HEKO provides bucket elevator forged link chains with labyrinth sealing.

The buckets are fixed to the chain by drop forged angular brackets fitted to elongated chain bolts by means of loose fits.

The drop forged inner and outer link plates are bearing on the shoulder of the drive ring after a certain run-in period. This so called '3-point bearing' of each individual chain link (bearing of bushing and chain link plates) should reduce the bearing pressure on the bushing outer lateral surface and, hence, the wear of the bushing.

The bearing of the inner and outer chain link plates on the drive rim shoulders led to the requirement of reinforced contact areas on the drop forged link plates.

The above mentioned ordinary bucket elevator central chain design is well established in different kinds of high capacity applications and industries all over the world. Hence, the question is: Why has HEKO further developed this central chain design?

Motivation for improvement of central chain design

Theoretical considerations

Undoubtedly, the additional bearing of the inner link plates on the shoulders of the non-toothed drive ring led to significantly reduced bearing pressure on the bushing lateral surface and, hence, to reduced bushing wear. The additional transverse load of the inner links is compensated for and no additional lateral bending will occur on the inner link plates due to the mechanical stiffness of the bushes.

However, in the case of the outer link plates, the situation is totally different. The pins will be deformed under load leading to a deformation of the forged link plates. Due to the fact that the forged link plates have a reduced flexibility in the region of the labyrinth sealing and in the region of the reinforced contact areas, the only region where such an outer link plate can flex is the very small gap between the labyrinth sealing and reinforced contact area. This, in turn, will lead to alternating increased tensile stresses on the inside of each outer link.

This situation will be amplified if the reinforced contact surfaces of the forged outer link plates come into contact with the drive ring shoulder and the lateral movement of the reinforced contact areas is hindered.

Experiences of plant operators

In the past few years plant operators reported frequent chain fractures on bucket elevator central chains with the above mentioned old design, i.e. drop forged chain link plates with labyrinth sealing and reinforced contact surfaces. In each individual case the cause of the chain failure was a fracture of the drop forged outer link in transition to the reinforced contact area.

HEKO's conclusion

As a result of the above mentioned findings and plant operator experiences HEKO decided to modify the above mentioned old chain geometry in order to maintain a reliable and fatigue durable high performance bucket elevator chain family. Thereby, the good properties of the old chain design have been combined with new approaches to maintain long service chain life.

Improved high performance bucket elevator central chain

Requirements specification for the development

The development of a new modified high performance bucket elevator central chain with drop forged link plates has been performed on the basis of the following requirements specification:

- Retention of 3-point bearing of the inner links on the drive rim shoulders after a certain run-in period.
- Engineering of the outer link plates as pure tension plate to avoid 3-point bearing of the outer links and, hence, to avoid fatigue strength reducing alternating tensile stresses.
- Maintaining 100% compatibility to old chain:
  - Labyrinth sealing of the chain link joint.
  - Connection size of angular brackets and buckets.
  - Identical dimensions and quality of pins and bushes.
  - Drop forged link plates.
  - Minimum breaking load from 1.250 to 1.950 kN.

In the improved chain design the 3-point bearing is limited to the inner links only by introducing optimised geometry of the reinforced contact areas. The drop forged outer link plates are engineered as pure tension plates with optimised geometry to avoid contact with the shoulder of the drive rim.

Finite element (FE) analysis of the old and the new improved chain design

The old chain design and the improved chain design have been converted into a 3D finite element model.

In Figure 2, the comparison of the von Mises equivalent stresses on the outer links of the old and the new improved chain design are shown. The modified geometry of the drop forged outer link plate leads to a reliable homogenisation and reduction of the stress distribution by avoiding significant alternating tensile stress peaks induced by bending of the chain pins under load.

Moreover, by avoiding the reinforced contact areas, superimposed tensile stresses induced by inevitable small discontinuities in the transition to the reinforced surfaces of the old chain design resulting from the manufacturing process, like e.g. tensile stress peaks due to link plate distortion caused by drop forging and heat treatment or permissible discontinuities in forging surface due to increased wear of the forging die, will be eliminated reliably.

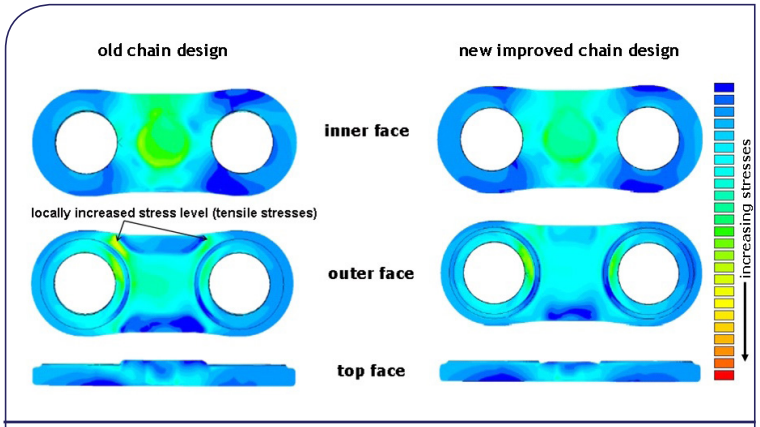

Figure 3. Von Mises equivalent stresses on the inner links of the old (left) and the new improved (right) chain link design.

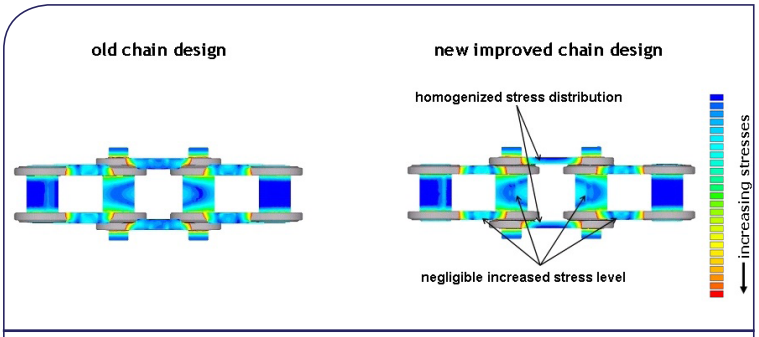

Figure 4. Comparison of von Mises equivalent stresses on link and bushing bearing between old (left) and new improved (right) high performance bucket elevator central chain design.

In Figure 3, the resulting von Mises equivalent stresses on the inner links of the old and the new improved chain design are shown. In comparison to the old inner chain link geometry the new improved geometry leads to a significant reduction of the stress levels in the transition to the reinforced contact areas.

Additionally, the influence of the modified 3-point bearing to the bearing pressure between bushing and drive rim has been investigated in order to avoid premature wear of the bushes. In Figure 4, a comparison of the von Mises equivalent stresses on the lower side (in contact to the drive rim and drive rim shoulders) of the chain link plates and the bushing is shown.

The improved chain design yields a homogenised and reduced stress distribution at the outer links. Moreover, avoiding bearing of the outer link plates do not lead to a significant increase of the bearing pressure on the inner link contact areas and bushes. Consequently, the new improved high performance bucket elevator chain is as durable against abrasive wear of the bushes lateral surface as the old chain.

Summary and conclusion

HEKO/KoWey have developed a new high performance bucket elevator central chain family with drop forged chain link plates, labyrinth sealing and reinforced contact surfaces by applying modern finite element analysis. This development has been encouraged by customers reporting of frequent chain fractures on bucket elevator central chains with the above-mentioned old design. In each individual referred case the cause of the chain failure was a fracture of the drop forged outer link in transition to the reinforced contact area.

The new improved chain design is characterised by avoidance of the so-called 3-point bearing of the outer chain links, i.e. avoidance of outer chain link plates bearing on the drive ring shoulders. The results of a comparative finite element analysis show that the stresses on drop forged inner and outer chain link plates of the new improved chain design are significantly lowered and homogenised yielding increased chain reliability and chain fatigue durability. Moreover, the avoidance of the outer link plates bearing on the drive ring shoulder yields no limitations in chain bushing durability against abrasive wear.