Cost reduction for conveyor systems through self-adjusting chain wheel

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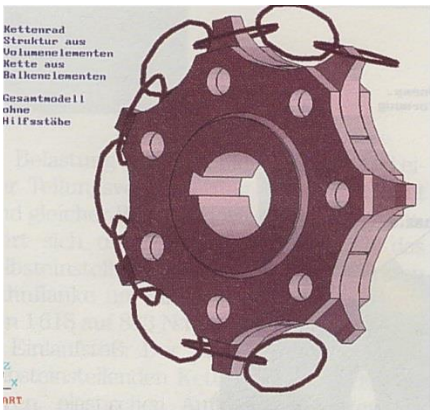
Current energy costs let expenses for the production and manufacturing of round link chains reach a very high level. Apart from that these machine components, that tend to be used often as drive chains in hoisting and conveying engineering solutions, wear out rather quickly. An alternative is offered by a patented chain wheel which uses elastic teeth to achieve a better distribution of the acting loads resulting in a drastic reduction of chain and wheel wear.

Introduction

Operators of modern conveyor systems which are based on chains (**Fig. 1**) have to take into account that chains and chain sprockets are subject to wear. Due to this wear, chains and chain sprockets require regular fitness-for-service reviews and, if necessary, they need to be replaced. High wear rates, therefore, result in a frequent replacement of the chains and the chain sprockets which inevitably leads to frequent conveyor system downtimes which in turn results in considerable loss of production and maintenance costs for the plant operator, an aspect that also needs to be considered beforehand in the engineering phase of a conveyor system.
The actual design of a modern drive chain is based on a construction of the Frenchman A. Galle from 1829 which over the years has been standardized or normed, respectively, as Gall chain. In the course of several technical advancements the chain and, in particular, the corresponding chain sprocket have been further improved. The target of construction always was a reduction of wear in order to extend service life. For instance, current bush roller chains are equipped with rotating rollers on the pins in order to reduce the friction forces between chain and the chain sprocket. In the course of development, the optimal tooth form for chain sprockets has been determined and adopted in different standards. Round link chains can be surface-hardened up to a hardness depth of 10 to 20 percent of the diameter to counteract premature wear.



1: Modelling of the system chain / chain sprocket

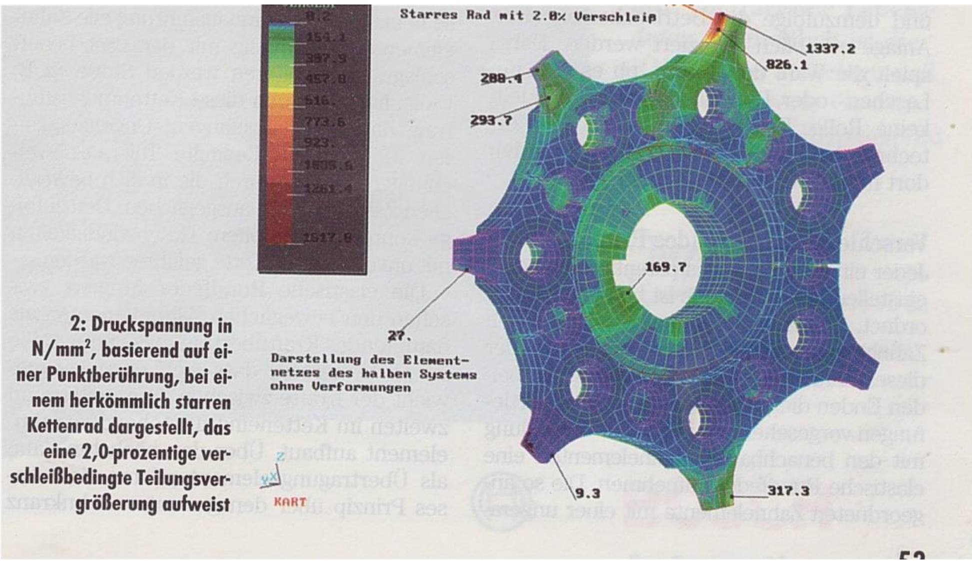
Chain sprocket structure of volume elements
Chain of beam elements

Overall model without auxiliary members

Cause of wear

With respect to the force transmission system chain/wheel we can conclude that wear is essentially caused by
- the force transmission from the chain wheel to the chain;
- longitudinal forces acting on the chain and the respective elongation of the chain links,
- irregular pitch tolerances caused by inaccuracies in manufacturing and
- meshing shocks caused by the chain hitting the chain sprocket (polygon effect, impact acceleration, etc.)

In summary, the largest source of wear can be identified inside the subsystem chain/drive wheel because the actual conveying distance practically does not produce any relative motion of the chain links which could essentially cause wear. Therefore, the main reason for the wear of the chain and the chain wheel lies in the torque transmission from the wheel to the chain. Only the first three teeth of the chain sprocket which are meshed with the chain transmit the complete traction force of the chain. This means that the share received by each individual tooth also depends on the state of wear of the chain in terms of elongation and tooth flank wear. In other words: the wear of chain and chain sprocket in turn results in a less efficient force transmission of the individual meshed teeth which, in turn, results in a higher wear rate. This wear process, once started, spreads continuously and gains speed until the chain sprocket and the chain become unserviceable. In **Fig. 2** you see an illustration of the compressive stress in N/mm2 based on a single-point contact acting on a rigid standard chain sprocket with a pitch extension of 2 percent due to wear. As expected, inadmissiby high compressive stress acts on two or three teeth of the chain sprocket; the wheel is wearing off.



Rigid wheel with a wear rate of 2,0%

2: compressive stress in N/mm2, illustrated on the basis of a single-point contact with a conventional rigid chain sprocket with a pitch extension of 2 % due to wear

Illustration of the element grid of half the system without deformations

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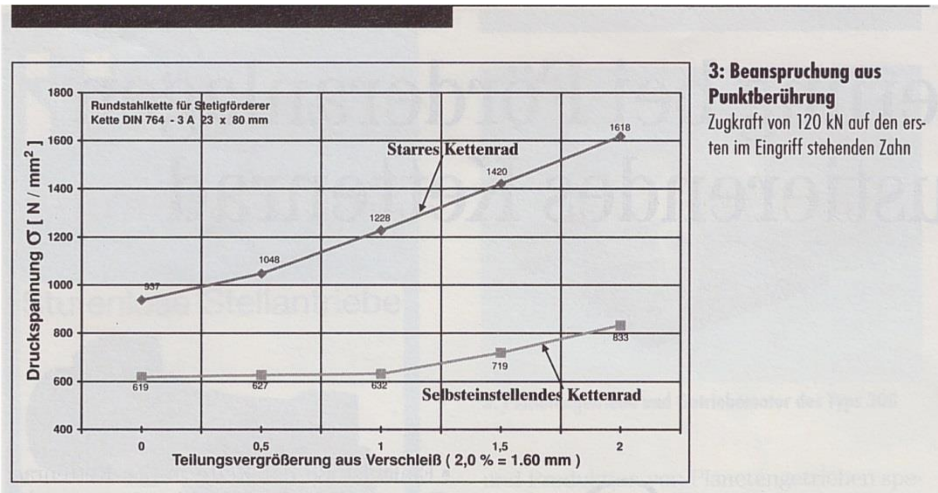


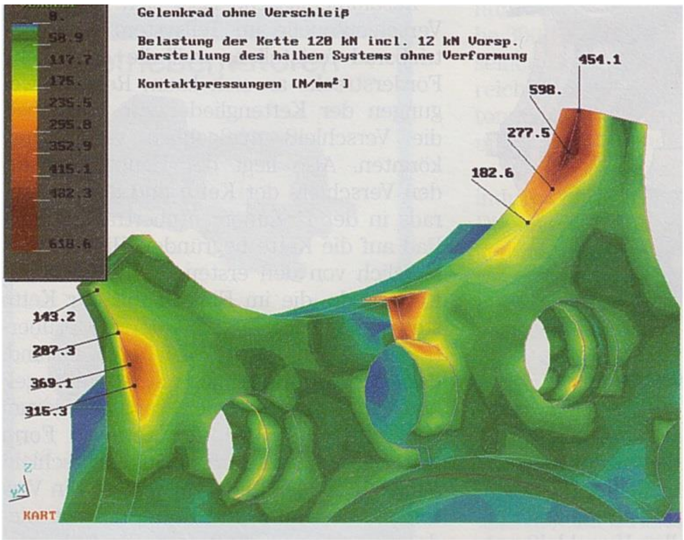
3: Stress resulting from single-point contact
Traction force of 120 kN acting on the first meshed tooth

Round steel chain for continuous handling equipment
Chain DIN 764 – 3A 23 x 80 mm
(technical data see diagram)

Rigid chain sprocket
self-adjusting chain sprocket

compressive stress

pitch extension due to wear



4: Load without wear
Articulated wheel without signs of wear

Chain load 120 kN incl. 12 kN pre-tensioning
illustration of half the system without deformation

Contact pressure (N/mm2)

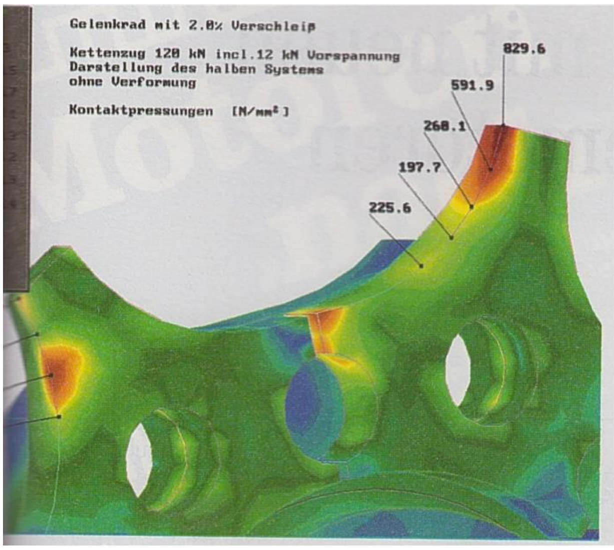
Self-adjusting chain wheel reduces wear

In an attempt to counteract the described negative wear effect without having to replace the entire chain/drive wheel system, various manufacturers use replacement wheels with a wider pitch in order to be able to keep in use at least the stretched or only partly worn chain, respectively. Apart from the considerable expenditure of time and money that comes hand in hand with the disassembly and reasssembly, the effects of wear will persist.
The application of the „self-adjusting chain wheel“ (patent number DE 4317461 C2) can considerably reduce wear and, consequently, also the operating costs, no matter if we talk about bush roller chains or round link chains. Both are frequently used in hoisting and conveying engineering and are specially designed for the highest demands.

Principle of minimizing wear

Every single tooth of the patented self-adjusting chain sprocket is flexibly arranged. Every tooth element is characterized by a pin located under the tip of the tooth which allows the tooth element to pivot in its bearing. Both ends of the tooth element provide indentations which in conjunction with the neighbouring tooth elements accommodate an elastic spiral spring. The so arranged tooth elements with an uneven number of teeth therefore form a radial and solid sprocket with, in itself, flexible tooth elements which are able to execute small „tilting movements“ and transmit these to the neighbouring teeth. Now, if a force acts on any of the teeth, the flexible arrangement generates a torque on the tooth element which is transmitted by means of the elastic spiral springs to all subsequent teeth – all the way through to the first tooth element under load. It is

the „endless balance“ principle where *all* tooth elements participate in the force transmission. Contrary to the conventional, rigid and unyielding chain sprocket with only three teeth significantly participating in the force transmission, all tooth elements of this innovative chain sprocket design are uniformly loaded. Moreover, impacts (e. g. meshing shocks) are offset and absorbed by this chain sprocket design; inaccuracies such as tolerance variations due to manufacturing reasons are compensated by the tooth elements that are flexible in themselves. Therefore, it is possible to run the system at a higher speed and without any modifications to the chain.
The elastic spiral spring acts as cushioning force transmission element between the flexible tooth elements. It is rated such that a balance of the forces is established between the first and the second meshed tooth element. The following tooth acts as transmitting element so that the principle spreads across the entire sprocket.



5: Load with wear

Articulated wheel with a wear rate of 2 %

Chain load 120 kN incl. 12 kN pre-tensioning
illustration of half the system without deformation

Contact pressure (N/mm2)

As a result, an equilibrium of forces is established on the chain sprocket in operation so that both chain and chain sprocket face considerably less wear (**Fig. 3**). From Fig. 3 we can conclude as follows:
1. Load *without* wear (**Fig. 4**): For a chain sprocket with seven teeth that is subject to a traction force of 120 kN – resulting from the torque – and a pre-tensioning of 12 kN, the compression stress on the first tooth flank is reduced by the self-adjusting chain sprocket by a factor of 1.5 or from 937 to 619 N/mm2, respectively (please compare Fig. 3).
2. Load *with* wear (**Fig. 5**): If we have a pitch extension of 2.0 percent and the same load as in point 1, the compressive stress on the first tooth flank is

reduced by the self-adjusting chain sprocket by a factor of 1.9 or from 1618 to 833 N/mm2, respectively (please compare Fig. 3).
3. Meshing shock: the meshing shock on the self-adjusting chain sprocket is almost completely compensated by the elastic inner structure of the chain sprocket – or even completely absorbed by the spiral spring.
4. Tolerance variations: the tolerance variations of chain and chain sprocket that are due to manufacturing factors are offset and compensated by the flexible tooth elements. This compensation on the chain sprocket is particularly important in the case of chain conveyors which are operated with two parallel chains such as, for instance, in underground mining applications.

Conclusion

The use of the patent „self-adjusting chain wheel“ provides unique advantages to the operators of conveyor systems. For instance, round link chains without surface hardening can be used – providing the same service life. The production of surface-hardened round link chains requires the use of large amounts of energy. Without surface-hardening the purchasing costs will be reduced by approx. 50 percent. Apart from that the maintenance of the chain sprocket is possible at a very low cost and without disassembling the chain. On the whole, considerable energy and cost reductions can be realized with this innovative product.