A PLANETARY UPGRADE

LUKAS STEINER, WIKOV, CZECH REPUBLIC, DEMONSTRATES HOW IT IS POSSIBLE TO FIGHT OPERATION COSTS IN CEMENT PLANTS.

Are gearboxes driving central ball mills a reliable part of cement plants or do they lead to wrinkles on the foreheads of maintenance managers? How do they influence the operation costs of the plant? These questions are not only in the minds of cement plant managers – equipment manufacturers also deal with these topics. Their aim is to distinguish themselves in the market by means of products that are able to meet such challenges and become equipment that cement plants can rely on.

Uninterrupted ball mill operation, reduced energy costs, lower maintenance. These are three goals of cement plants and a primary task for gearbox manufacturers. The answer to meeting the target can be correctly designed planetary gearbox.

Despite the protests of cement plant staff about the complexity of a planetary gearbox and the demanding nature of eventual repair in contrast with the good old parallel shaft gearbox that is easy to service, there are aspects that speak for a planetary solution. The goals of cement manufacturers are obvious – the higher efficiency of the drive reflected into reduced energy costs, resulting in lower CO_2 emissions and reliability contributing to continuous mill operation and reduced maintenance costs.

Cement manufacturing is highly energy intensive. Indirect emissions are produced by burning fossil fuels to heat the kiln. Kilns are heated using coal, natural gas or oil and the combustion of these fuels produces additional CO_2 emissions, just as they would in producing electricity. This represents approximately 40% of cement emissions. The

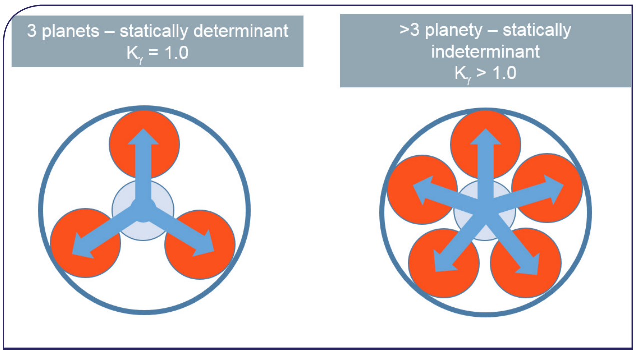

Figure 1. Power-split in a planetary stage with three and five planets.

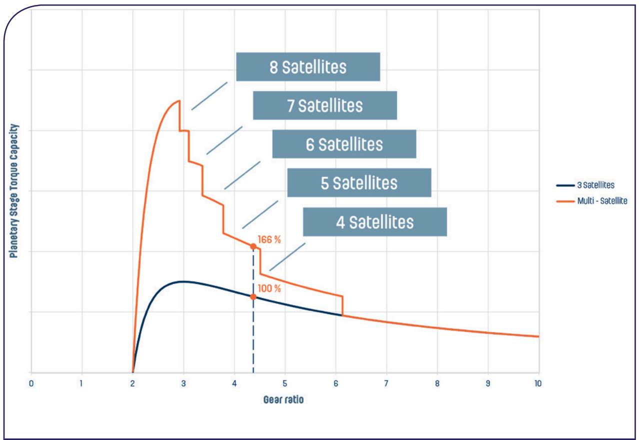

Figure 2. Single planetary stage capacity vs. number of satellites.

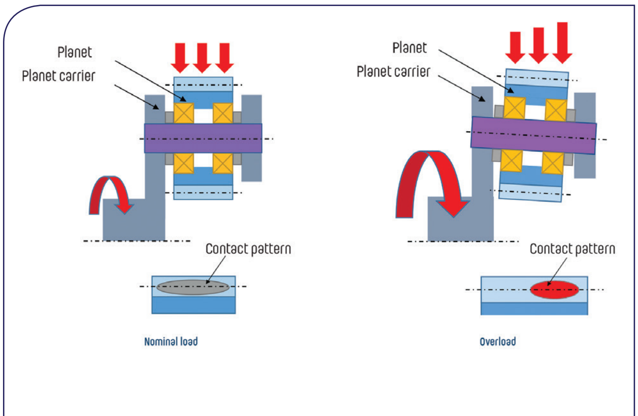

Figure 3. Conventional planetary stage.

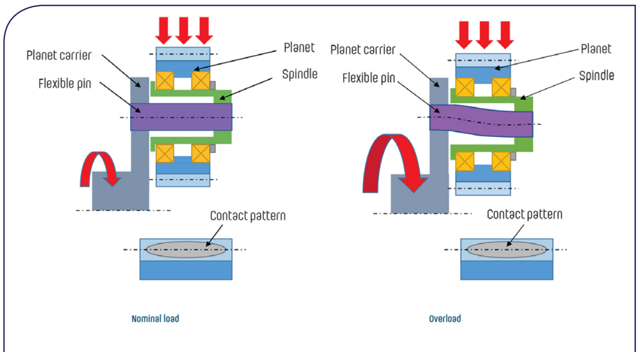

Figure 4. Flexible pin planetary stage.

electricity used to power additional plant machinery, and the final cement transportation, represents another source of indirect emissions and accounts for around 10% of the industry's emissions.

The planetary gearbox is a solution that can help cement manufacturers effectively reduce emissions, while it helps to achieve significant savings at the same time. A planetary gearbox can typically achieve 1% higher efficiency compared to parallel shaft execution, so it represents a 10 kW reduction on losses per 1 MW drive. Considering 24 hours of mill operation 350 days a year, this equates to about 84 000 kWh of saved energy. With the EU-28 electricity prices for industrial consumers during the second half of 2015 averaging €0.119 per kWh, we can reach savings of €9996 per drive in a year. Further savings can be achieved during acceleration phases due to significantly lower moment of inertia of planetary gearboxes compared to parallel shaft ones.

This saving, multiplied by years of operation, makes a strong argument for investing in a planetary gearbox. The planetary gearbox represents a very robust solution with excellent power to weight and size ratio. Gearbox durability is maintained at the same level or even increased while the overall size and weight are significantly reduced. There is a clearly visible cross-industrial trend for a shift from parallel shaft gearboxes to planetary ones, as those can offer reduction in terms of size, weight and cost with no compromise in the performance. In the gearbox market, planetary gearboxes are experiencing the most rapid growth.

Planetary gearboxes have been around for decades, and still most of the arrangements rely on a traditional design approach with three planets mounted in a rigid carrier. Such a solution offers improvements over parallel shaft gearbox arrangements as described above. Further development of such concept needs to be considered though, as there is potential for further significant improvement in all key aspects.

Achieving higher power/torque density by using more than three satellites in one planetary stage is a well known approach. By adding more planets, the power/torque is split into more paths (Figure 1), and while using the same size gearing and keeping the overall dimensions, an increase in power/torque capacity can be achieved.

A theoretical comparison of a single stage capacity based on the number of planets and gear ratio is shown in Figure 2. It can be seen that the five planets gear stage has 166% of the capacity of the three planets design.

However, if a conventional rigid carrier is used, problems caused by key component deformations from both internal and external loading, manufacturing tolerances and behaviour under various operation loads may occur, as the load may be unevenly distributed between planets, and the life of overloaded components, e.g. gears and bearings, can be significantly reduced.

There are limitations in such an approach though. The traditional three planet arrangement, where one member is kept free (floating, e.g. the sun gear), is statically determinant. That means equal power split between planets is always assured. When more planets are added, the system becomes indeterminate and very sensitive to manufacturing tolerances, as well as deformations in the system. Manufacturing tolerances can be compensated in some ways by tighter tolerances as well as careful part selection during assembly, though this means additional cost. The traditional approach to coping with deformation is to make key components stiffer, and less prone to deformation – increased size, weight and cost are the penalty.

The approach applied by Wikov is different. Rather than fighting with deformation, Wikov uses it for better functionality and durability of the system. Such an approach allows for small, light gearboxes.

The key technical feature in the Wikov design is flexible pin technology. This technology offers increased lifetime of gears and bearings, shock loads resistance and compact design. Adding controlled flexibility into the system compensates for structural deflections and manufacturing errors and high power density can be achieved in a safe way using multi-satellite arrangement.

In the case of conventional planetary stages (Figure 3), the stiffness, as well as gear micro geometry, can be well optimised for a nominal torque under both gear contact patterns and the load sharing between planets is good. However, in case of unexpected overload in terms of torque or external force applied on the gearbox, deformation in the structure leads to an uneven gear contact pattern as well as planet bearing loading. One side will be loaded more than the other one. Both gear and bearing life is compromised as any unbalance in the system leads to local overloading and potential risk of failure.

Using a flexible pin planetary stage (Figure 4), the extra flexibility allows the planet to float under load in a limited manner. The double-cantilever arrangement of the pin means that the planet stays parallel to both the sun and annulus gear. Equal planet bearing load sharing, as well as an even gear contact pattern, is achieved for various loads including overload.

If the flexible-pin is used in a fairly harsh application with uncontrolled shock loads and significant overloads, there may be a risk of exceeding the allowable stress in the flexible pin, which can lead to a potential failure. Wikov introduced an overload stop to prevent such a state through a controlled reduction of movement under extreme conditions while still maintaining load sharing.

Planetary gearboxes are regularly used with roller presses where the presence of the flexible pin provides trouble-free operation in case of unexpected shock loads. Although the potential risk of shock loads is less frequent with ball mills than roller presses, the implementation of the planetary gearbox with flexible pin technology is justified as it increases the gearbox capacity and can be used to reduce the size of the gearbox. This decreases the initial capital expenditure, lowers emissions and increases operation safety, resulting in lower cumulative costs with multiple years of operation.