WHITEPAPER

ROLLER MILL DRIVE

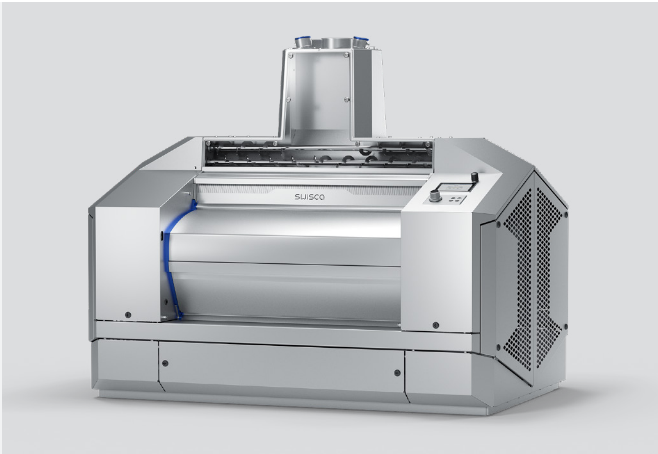
ROLLER GRINDING AS A QUANTUM LEAP

The crushing of cereal grains has historically been accomplished through pressure and shearing. Approximately 27,000 years ago, grinding stones were first employed for this purpose. Utilizing an oscillating motion of the grinding stone against a stationary surface, the grain trapped in between could be effectively processed.

In many subsequent developments, the principle of maintaining one grinding surface stationary while the other moves relative to it was preserved. This is achieved, for example, through a horizontal or vertical pair of disks, a cone with a counterpart, or a roll with an adjacent counter surface. In all these variations, the stationary mating surface doesn‘t actively engage in the grinding process; it primarily absorbs forces without undergoing movement. This paradigm shifted with the advent of roller grinding in the 18th century.

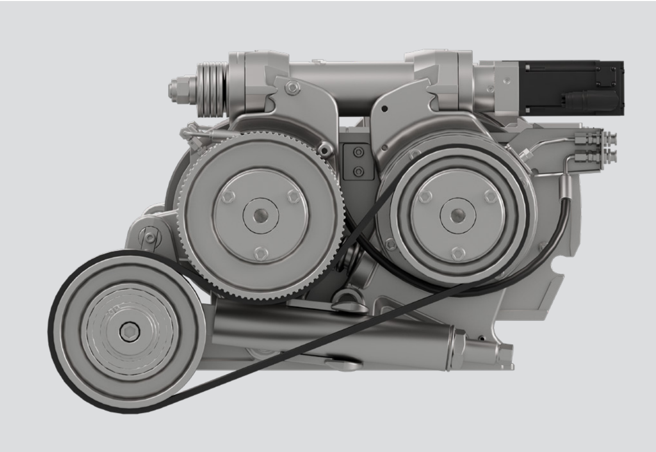
The hand-operated lathe mill is an invention originating from the Ibero-Celtic region. Fragments of millstones made of basalt lava were discovered in a Celtic hilltop settlement dating back to the 7th century BC, alongside remnants of spelt, emmer, and barley.

In modern roller mills like SWISCA‘s ROMIL, the stability and precision of the grinding gap are ensured through servo-controlled gap adjustment and a robust roll assembly. While manual operation remains essential, it is now facilitated through the use of a touchscreen and an electronic handwheel.



The movement of the previously stationary counter surface was recognized to offer several advantages. By configuring it as two parallel, counter-rotating rolls operating at distinct speeds, pressure and shear could be precisely controlled as influential variables, independently and purposefully. This setup enabled enhancements such as increased throughput and desired selective grinding. Thanks to many other parameters, multi-stage, sophisticated grinding processes were developed.

From the perspective of machine manufacturers, one aspect of roller grinding stands out: the „overdrive,“ which refers to the coupling of the two roll speeds. The technically straightforward design, consisting of two differently sized intermeshing spur gears at one end of the roll pair, represents an ingenious solution. In the configuration typical for grain roller mills, the slow roll must always be braked to maintain the desired speed ratio. However, if the grinding speed ratio remains constant, the considerable braking force applied to the slow roll can be efficiently transferred back to the fast roll via spur gears.



The technical simplicity and high efficiency of the traditional belt drive are advantageous for energy-efficient roller mills. In the SWISCA roll assembly shown on the left, a tensioning aid ensures the correct belt tension without the need for remeasurement or readjustment.

In a typical roll pair, the fast roll is powered by an electric motor, which in turn drives the slow roll through the material in the grinding gap. The overdrive mechanism prevents the slow roll from reaching the speed of the fast roll and redirects the braking power back to the fast roll. Consequently, a significant amount of mechanical power is effectively circulated.

Measurements indicate that the braking power on the slow roll is notably high in comparison to the power introduced into the roll assembly. On smooth passages, this braking power typically exceeds the grinding power by a considerable margin. Therefore, it is paramount that this excess power is efficiently transferred back to the fast roll.

The rolls become tense due to the ground material and the overdrive. A torque ratio can be calculated from the measured torque on the rolls, which typically falls within a certain range under typical operating conditions for roller mills. The influences on this torque ratio are complex. The braking power is determined by the speed ratio and the above torque ratio:

– The lower the speed of the slow roll compared to the fast roll, the lower the required braking power.
– The greater the tension between the rolls, the greater the required braking power.

Of course, the above does not address the effective grinding power, which is the power converted as the difference between the drive and braking power in the grinding gap.

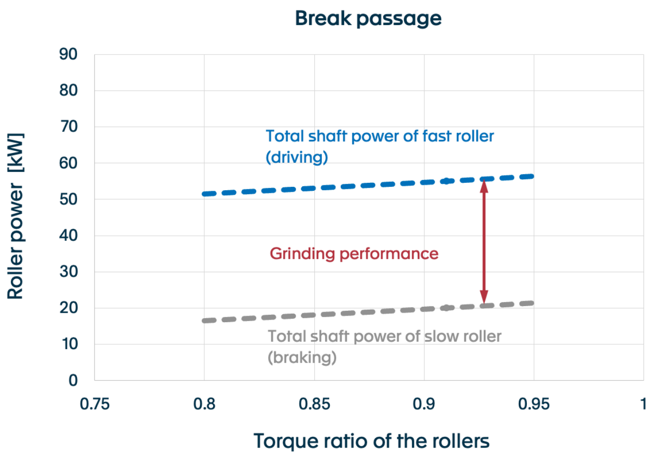
DEGREE OF FREEDOM AND EFFICIENCY

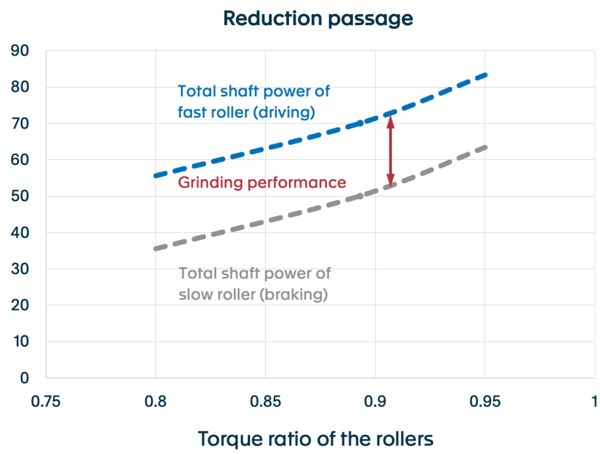
Pressure can be easily varied during operation by means of a variable grinding gap. Conversely, varying shear, generated by altering the speed ratio during operation, comes at a high cost. This can be achieved by feeding back the braking power with associated losses and/or through a technically complex machine design. As a result, the flexibility gained through a variable speed ratio has often been overlooked, optimized only for specific processes and kept constant for the majority of operations.

EXPLANATIONS WITH EXAMPLES

Given two typical, well-utilized passages:

	Break passage	Reduction passage
Speed ratio fast roll / slow roll	2.5	1.25
Required grinding capacity in the grinding gap	35 kW	20 kW
Total shaft power o of fast roll (driving)	55 kW	70 kW
Total shaft power of slow roll (braking)	20 kW	50 kW





The difference between the total shaft power of the fast roll and that of the slow roll determines the required grinding performance within the grinding gap of the break / reduction passage.

The comparison of the two passages indicates that the performance of the reduction passage surpasses that of the break passage, despite its lower grinding capacity. Of course, this also applies analogously to less heavily utilized passages.

In 8-roller mills, which are often used in the first and second break passages, the product falls directly from the upper roll pair into the grinding gap of the lower rolls.

VARIABILITY VS. ECONOMIC EFFICIENCY

Nowadays, the simplest method to incorporate a variable speed ratio during operation is to equip each roll with its own motor and link the corresponding frequency converters in the intermediate circuit This individual roll drive can be configured as a direct drive or as a remote motor with belt drive. In such a system, the braking power from the generator-driven motor of the slow roll is dissipated from the system and reintroduced via the motor on the fast roll. Consequently, the motor on the fast roll must be chosen considerably larger than in a roll package with a fixed speed ratio.

For the example given above, this means, for instance:

	Roll pack with fixed overdrive		**Roll pack with individual roll drive**	
	Break passage	Reduction passage	Break passage	Reduction passage
Drive power	1 × 37 kW	1 × 22 kW	2 × 55 kW	2 × 80 kW

The drive power of the roll package with individual roll drive must be significantly higher than that of the roll package with fixed overdrive.

ABSOLUTE POWER LOSSES

Based on the previous examples, the power losses are now being estimated. It should be noted that even if very high efficiencies are deliberately assumed for the individual roll drive, a very clear picture still emerges:

	Roll pack with fixed overdrive		Roll pack with individual roll drive	
Drive	IE3 asynchronous motor (mains operation) with belt drive on fast roll		– Two identical permanent magnet synchron synchronus motors with converters. – Converter coupled in intermediate circuit.	
Overdrive	Belt overdrive			
Break passage	Full load (100%)	Partial load (60%)	Full load (100%)	Partial load (60%)
required grinding power	35 kW	21 kW	35 kW	21 kW
Efficiency levels	Drive: 89%	Drive: 86%	Motors: 95%	Motors: 95%
	Overdrive: 97%	Overdrive: 97%	Converter: 98%	Converter: 98%
Total power loss*	4.9 kW	3.7 kW	5.5 kW	3.3 kW
Reduction passage	Full load (100%)	Partial load (60%)	Full load (100%)	Partial load (60%)
required grinding power	20 kW	12 kW	20 kW	12 kW
Efficiency levels	Drive: 88%	Drive: 86%	Motors: 95%	Motors: 95%
	Overdrive: 97%	Overdrive: 97%	Converter: 98%	Converter: 98%
Total power loss	4.3 kW	3.1 kW	8.6 kW	5.2 kW

* The power losses refer only to drive components.

The power losses are greater with the single-roll drive because they occur at a higher power level. If a toothed belt with correspondingly better efficiency were used in the conventional drive, the power losses would be lower in any case.

FOR THEY KNOW NOT ALWAYS WHAT THEY DO...

In order to fully utilize the degree of freedom in a roll assembly with a single roll drive, the rated torques or rated power of the components must be sufficiently high. This aspect should not be underestimated. Conversely, there is no need to worry about the generally unknown power flow with fixed overdrive. If the power transmission from the fast roll to the product to the slow roll is high, then the overdrive power is high, resulting in more power being circulated. This does not impact the required drive power and the typical assumptions for power requirements (kW per t/h) used in calculations.

However, this is not the case with the single roller drive. The intricate power transmission in the grinding gap directly affects the required drive and braking power and the selection of component sizes, as the power must be entirely extracted and reintroduced electrically into the assembly. Incorrect drive and braking power can result in reduced throughput, the need to decrease grinding work, or the inability to maintain the optimal speed ratio for the process.

VARIABILITY IN MILLS

In a grain mill, there are numerous break and reduction passages where a variable speed ratio during operation may not be beneficial. However, variability can be advantageous for specific passages to enable the production of specialized products. For instance, this could include a grist passage where, in extreme cases, the fluting position (back/back to cutting edge/cutting edge) is changed, or a smooth passage where a notably high shear is desired with a high-speed ratio.

<table>
<tr><th></th><th>Roll pack with fixed overdrive</th><th>Roll pack with individual roll drive</th></tr>
<tr><td>Speed ratio</td><td>Constant</td><td rowspan="2">Variable within the limits of the installed torques or outputs</td></tr>
<tr><td>Speed level</td><td>Variability possible with additional frequency converter</td></tr>
<tr><td>Technical expenditure</td><td>Minimal</td><td>2 larger motors, 2 frequency converters, shielded cables</td></tr>
<tr><td>Elektrical power</td><td colspan="2">Equal absorbed power, with differing power dissipation</td></tr>
<tr><td>Efficiency</td><td>High efficiency: high braking energy is mechanically fed back directly to the fast roll</td><td>Critical, as additional components are present and are subjected to higher power loads</td></tr>
<tr><td>Space requirement</td><td>Compact design limited:
– two floors (motor under floor)
– longer overall length (motor on floor)</td><td>Depending on concept:
– e.g. with direct drive → very compact
– as a single roll drive via belt → large space requirement</td></tr>
</table>

Comparison between the roll pack with fixed overdrive and the roll pack with individual roller drive.

If the variability of the speed ratio is required to produce special products, this can be easily implemented in selected passages with individually assigned drives. However, it's important to note that the roll package with individual drives incurs significantly higher energy losses.

CONCLUSION

SUMMARY

Energy efficiency can be achieved through the optimization of the mill diagram and the use of energy-efficient machinery. The recovery of energy, which must first be added to a system, leads to poorer energy efficiency. The power losses are greater with individual roller drive, as energy recovery for this application is not energy efficient.

If the variability of the speed ratio is required for the production of special products, this can be easily implemented for selected passages with individually assigned motors. The technical simplicity and high efficiency of the traditional belt drive transmission are advantageous for an energy-efficient roller mill. In combination with modern product level control and feeding, as well as precise adjustment and stability of the grinding gap through robust roll packages, an overall energy-efficient milling process can be achieved. For technical systems, only the required energy in a suitable form should generally be supplied for optimal energy efficiency.

The trend towards process optimization with sustainable machines in the milling industry not only saves costs and supports millers in their work. Innovativesolutions optimize energy-efficient and food safe processes and thus the work of the operating personnel.

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