REVIEW NO.157

The FLSmidth ATOX mill - history, features and performance

Reprint of article published
in Global Cement and Lime Magazine, March 2005.

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FLSmidth

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The FLSmidth Atox mill - history, features and performance

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The original FLSmidth Atox mill has its origins in the 1920s, although the only thing that is common between the early mills and those of today is the name 'Atox.' The first of the new series of Atox mills were commissioned in the early to mid-1980s for grinding coal and raw materials. Some of the larger mills were prone to mechanical problems, and throughout the late 1980s and the 1990s a series of innovations and improvements were applied to the design of the mills. These optimised Atox mills are now found world-wide.

In the beginning of the nineteen twenties, FLSmidth introduced a new vertical roller mill on the market under the registered name 'Atox.' This first generation of the Atox mill, however, was of a design entirely different from today's modern Atox mill. The old design (Figure 1) was abandoned a long time ago and only the name remains in the Atox mill offered today.

Through the 1970s, FLSmidth co-operated with Gebr. Pfeiffer AG of Germany enabling FLSmidth to manufacture and sell MPS vertical roller mills for grinding of raw materials. However, for various reasons the co-operation between the two companies was terminated around 1980 and FLSmidth started to develop the new Atox roller mill.

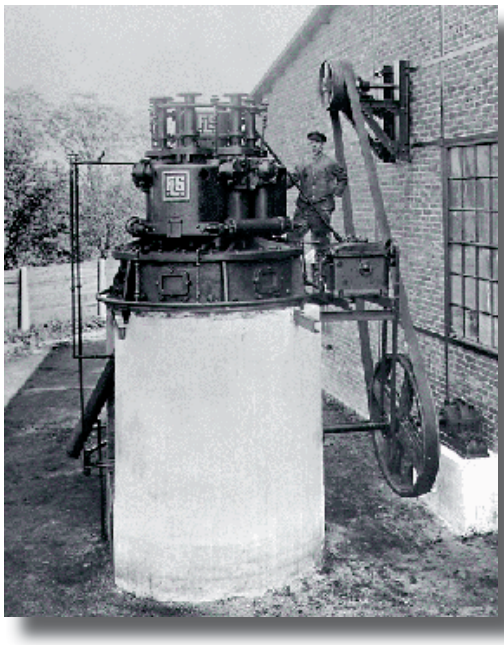


Figure 1, above: An old design Atox mill from the 1920s. Figure 2, below, The modern design concept of the Atox mill.

The first new Atox mills for grinding of coal and raw materials were commissioned through 1983 to 1985 and they performed reasonably well in terms of operation. However, they were not without problems as far as mechanical performance was concerned. In particular some of the large size raw mills suffered from various mechanical problems.

FLSmidth allocated the necessary resources to analyse the problems, identify the causes of the problems and develop solutions to the problems encountered. Through the mid-1980s all problems were analysed, the causes of the problems were identified and solutions to the problems were worked out. The problems addressed and the solutions to those problems are described in this article.

Since January 1988, FLSmidth has sold more than 100 Atox raw mills, all including the design improvements made through the mid-1980s. More than 50 of these Atox raw mills have been successfully commissioned and are generally operating without any significant problems - mechanically as well as in terms of process.

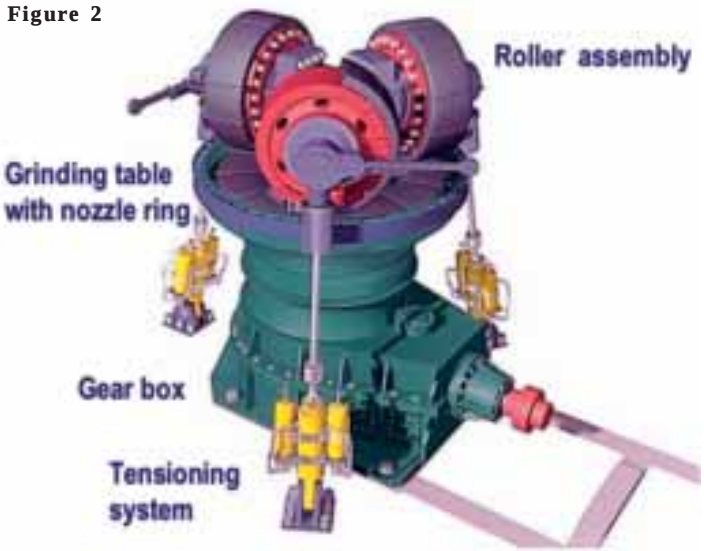
The Atox raw mill today is regarded as a well-performing mill in every respect, which is reflected in a high market acceptance and a corresponding growing market share for the Atox raw mill.

Atox mill design concept

The grinding table of the Atox mill (Figure 2) has a flat, horizontal grinding track encircled by an adjustable dam ring and an adjustable nozzle ring equipped with an air guide cone. The dam ring is made of stacked bolted-on segmented rings and is simply adjusted by adding or removing one or more segmented rings. The height of the dam ring determines the depth of the grinding bed on the table.

The roller assembly is kept centred on the grinding table and prevented from rotating by three torque

Figure 2



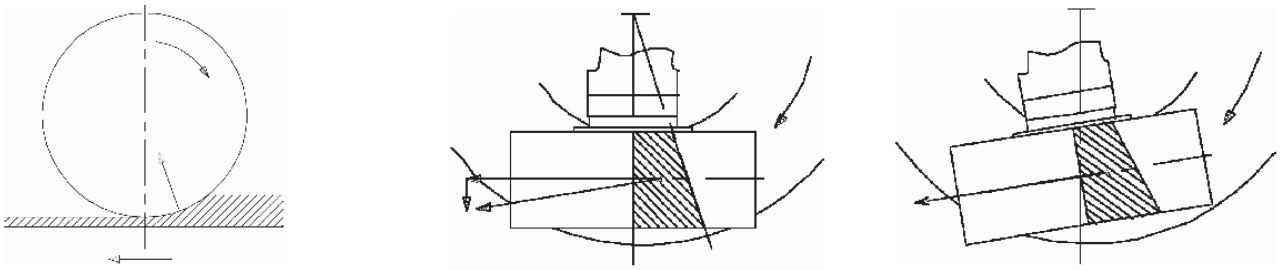


Figure 3. A, left: Reaction force from grinding bed. B, middle: Conventional design. C, right: Design with toe-in.

rods attached to the mill housing through rubber dampers. The grinding pressure is exerted hydraulically through three pull rods attached to the outer ends of each roller shaft. By this unique roller suspension the grinding forces are transmitted by the tension rods directly into the foundation.

Design advantages

With the grinding track being horizontal and the centre of gravity of the roller system only moving vertically, all impact forces and dynamic reactions are mainly vertical and therefore easy to accommodate.

The extremely low mass of the roller suspension system means low inertia and thereby low dynamic forces. In case of excessive vibrations of the roller system, the lower inertia also limits the dynamic loads on the grinding table and thrust bearing in the gear box as well as on the surroundings.

During grinding, the force of reaction on the roller is located in front of the vertical line below the roller shaft, see (Figure 3a). In that position, however, the velocities of the roller and the table have different directions, (see Figure 3b), if the roller is placed traditionally, resulting in significant axial loads on the roller bearing.

Due to a patented toe-in of the rollers of the ATOX mill, the axial load is eliminated, (see Figure 3c), and the roller bearings are thus only exposed to well defined radial load ensuring significantly longer life of the spherical bearings.

Segmentation of wear parts (Figure 4) means low risk of cracking; therefore extremely wear resistant wear parts for both rollers and table can be used. Roller segments can be reversed enabling high material utilization to be achieved also in case of uneven wear. The roller wear segments can easily be reversed inside the mill, i.e. without taking the rollers out of the mill. The separator reject cone is provided with a rail and trolley for that purpose.

Figure 4: Segmented and 'oversize' rollers mean low risk of cracking, easy segment reversal and a coarser mill feed.

The ATOX mill has rollers with a larger diameter compared to the diameter of the table than most other vertical roller mills. Larger roller diameter permits operation with a proportionally thicker grinding bed, and this is less critical as regards uneven wear and foreign bodies in the mill feed. The rollers of larger diameter further allow a proportionally coarser mill feed, which reduces the requirement on pre-crushing.

The roller suspension system of the ATOX mill permits the hot gas inlet section to be designed virtually without restrictions to the airflow below the grinding table and, further, to be fitted with an oversize nozzle ring. In consequence the standard ATOX mill can operate with the extra amount of gas required by specially wet or easy to grind materials. It is not necessary to involve a larger mill size just to accommodate the air flow - only the nozzle ring and the separator must be adapted to the higher airflow.

The ATOX mill is of a very compact design, involving a space-saving arrangement of inlet ducts and, further, crane access for service is required in only one position. The mill is thus easy to fit into a constricted space. The very compact design of the ATOX mill offers a correspondingly low cost of foundation and mill building in case of clients demand for the latter.

Mill design development

Major improvements and re-design of critical components took place during the mid-1980s to eliminate the problems encountered with the first ATOX mills in operation. Further development and optimisation has been made to enhance the reliability and performance of the mill. The following is an outline of the most significant improvements made, leading to the current design of the modern ATOX raw mill.

The axial thrust bearing supporting the grinding table and the grinding force has been changed from a proper hydrostatic bearing to a more reliable hydrodynamic/semi-hydrostatic bearing of segmented design

Figure 5: Segmented hydrodynamic/semi-hydrodynamic axial thrust bearing

(Figure 5). (Only hydrodynamic for small mills). All the thrust pads are immersed in an oil bath.

The design grinding pressure has been increased to raise mill capacity and the roller bearings have been enlarged to match the higher grinding pressure. Lubrication of roller bearings has been changed from grease lubrication to circulating oil lubrication with continuous oil filtering and conditioning.

The design of the grinding table has been changed from a T-profile to a Y-profile (Figure 6) for enhanced rigidity and better fixation of table segments. An improved tensioning system including tension rods with pre-stressed bolted connections instead of fatigue-prone threaded joints has also been introduced.

The three-flap sluice has been replaced by a simple rotary sluice that effectively keeps the ingress of false air to a minimum and furthermore provides a virtually constant material flow to the mill. To prevent build-up of sticky material, the rotor is provided with a wear-resistant rubber lining. The sluice is provided with a circular outlet flange, so it can always be aligned with an incoming belt conveyor. Sluices of latest design are provided with removable cylinder walls for easy maintenance.

The first ATOX mills introduced in the early 1980s were supplied with static separators - simple and sturdy separators, but at that time considered adequate for the application. After thorough analysis of the performance of the mills and in particular of the separators it was concluded that - after all - the efficiency of these separators was inadequate. It was consequently decided to replace the static separator with a modern, dynamic and efficient separator - the FLS RAR Separator.

In 1998 L.V.Technology developed a concept for upgrading existing vertical roller mills. An upgrading project based on the LVT concept addresses three key areas: the separator; the air velocity through the mill; and the air nozzle ring and air guide cone. In 1999 FLSmidth signed an exclusive co-operation agreement with LVT to market this upgrading concept. An amendment agreement was signed in 2001 allowing FLSmidth to use and market the LVT concept also for new ATOX mills.

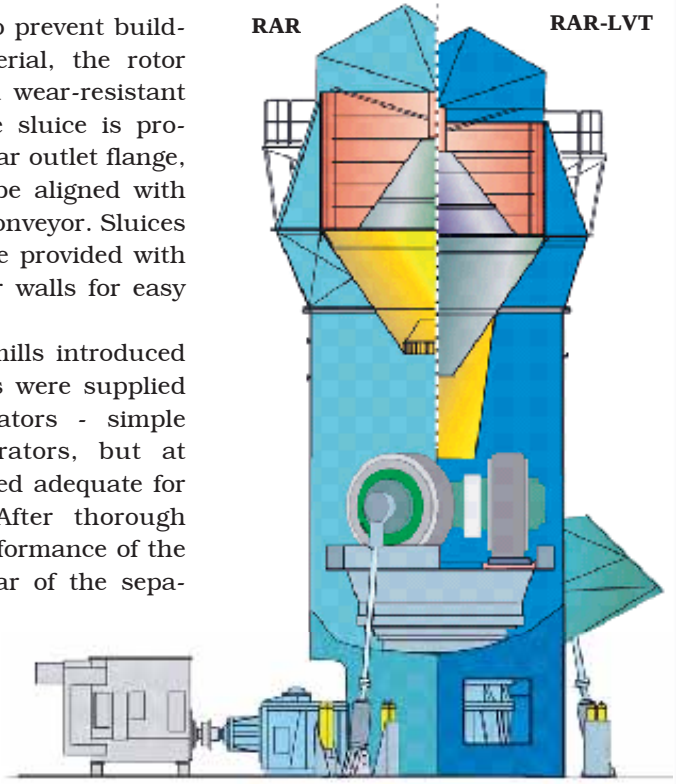


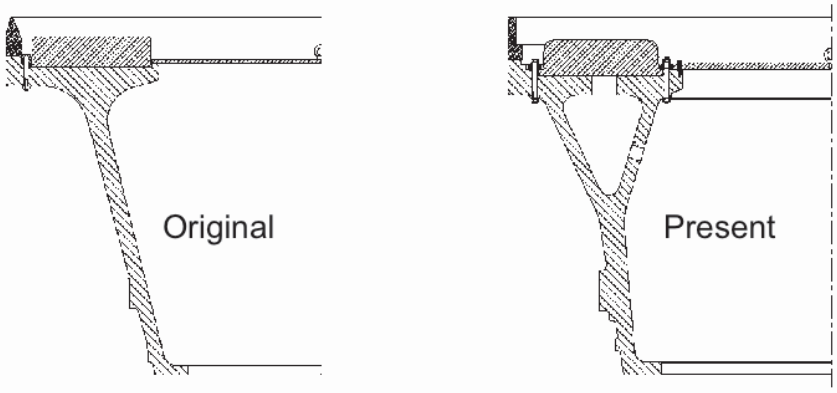
Figure 7: Comparison between the FLS RAR and FLS RAR-LVT separators.

In such a case, the RAR separator modified by use of LVT design concept has a larger rotor D/H ratio, a larger radial air velocity through the rotor, a new suspension of the reject cone and a filling mantle for increased air velocity in the mill housing (Figure 7).

The grinding efficiency of an ATOX with RAR-LVT typically appears to be some 5-10% better than that of an ATOX mill with RAR separator. Since the RAR separator even without LVT concept is a very efficient separator, the advantage of using LVT concepts in the RAR-LVT design is significantly lower than benefits achieved by LVT upgrades of other vertical roller mills.

Until recently water injected on the grinding table for stabilisation of mill operation was introduced through pipes above the nozzle ring. The water pipes and their wear protection were thus exposed to heavy wear from the material accelerated upwards of the nozzle ring. In new ATOX mills, however, the water injection will be provided via the central part of the roller suspension system (figure 8) and the wear of the water injection pipes will thus be eliminated or at least be reduced significantly.

Figure 6: Change in grinding table profile from T to Y, for enhanced rigidity.



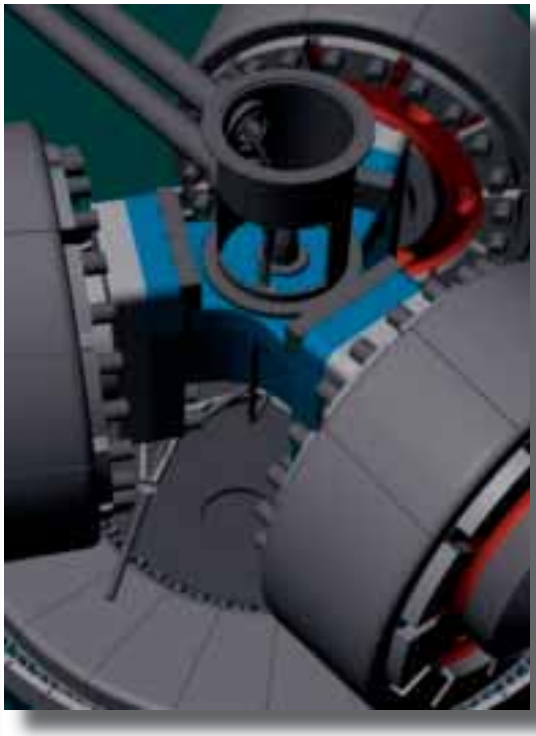


Figure 8: Water injection provided via the central part of the roller suspension system: water of previously-used water injection pipes is eliminated.

ATOX raw mill performance

More than 50 ATOX raw mills are now in operation grinding and drying a very wide range of raw materials including raw materials that are highly abrasive or very sticky. Some of the mills grind very dry raw materials with a moisture content of less than 1%, while others grind very wet raw materials with more than 18 % moisture. Likewise, the grindability of the mill feed materials varies within a very wide range; from less than 3kWh/t to more than 11kWh/t. The mills have in all cases produced a raw meal of a fineness suitable for kiln operation; whether with a sieve residue of less than 5% or more than 20% on a 90μm sieve.

Irrespective of mill feed properties and requirement for product fineness, proper and stable operation has been attained. Table 1 shows performance figures for a number of ATOX raw mills operating with raw materials representing a wide range of properties.

The feed material for the ATOX 30 mill in Chile has a moisture content of less than 1% and, further, there is a very limited supply of water available for water injection. Vertical roller mills have been claimed to be unsuitable for such applications. Nevertheless, with a slightly reduced speed of rotation of the grinding table, the mill performs quite well even without water injection.

The raw materials for the ATOX 35 mill in Brazil are extremely easy to grind. The capacity of this mill is therefore very high compared to the mill size. The high capacity and the moisture content in the raw materials require an above-standard air volume through the mill. The mill is simply adapted to such a situation by being provided with an oversize nozzle ring and an oversize separator.

Part of the mill feed to the ATOX 37.5 mill in England is introduced to the mill as slurry, which increases the moisture content in the mill feed material to around 17%.

The ATOX 50 mill in China represents a case of very hard-to-grind raw materials.

It is significant that all four mills have complied with the guaranteed performance, which in fact is characteristic of virtually all ATOX raw mills commissioned so far.

Table 1: Performance comparisons between ATOX mills grinding raw materials.

Plant location	Chile	Brazil	England	China
Mill size	ATOX 30	ATOX 35	ATOX 37.5	ATOX 50
	Achiev./Guar.	**Achiev.**/Guar.	**Achiev.**/Guar.	**Achiev.**/Guar.
Production, t/h	**114**/100	**294**/245	**183**/165	**351**/320
Feed moisture	**<1**	**7**	**17.2**/17	**2.6**
Product moisture	**0.3**/0.5	**0.5**	**0.3**/1.0	**0.3**/0.8
Product fineness				
%>90μm	**9**/10	**16.4**/18	**8.7**/10	**12**/12
%>0.2mm		**2.2**/2.8	**0.6**	
Spec. energy Cons.				
Mill (kWh/t)	**6.1**	**2.7**	**8.8**	**10.2**
Mill+separator	**6.2**	**2.9**/4.5	**8.9**	**10.8**
Mill+sep+fan	**13.5**/16.2	**8.6**	**15.4**	**19.3**/20.1
Water injection m^3/h	**0**/1.2	**0**	**0**	**10.3**

Figure 9: Raw coal enters via a double feed screw that also serves as an air sluice.

ATOX for coal grinding

The ATOX coal mill was designed and further developed concurrently with the ATOX raw mill. In terms of basic design concepts, the ATOX coal mill is identical to the ATOX raw mill and this also applies to the separators for the two applications. However, some components of the ATOX coal mill are obviously designed or adapted with particular reference to coal grinding applications.

The raw coal enters the mill via a double feed screw that also serves as an air sluice (Figure 9). Self-cleaning is achieved by

a cutting action of the two rotating screws, which enables the handling of sticky materials with high moisture. An airlock is achieved by consolidation of the feed material at the outlet end of the screw feeder as the screws are without flights in the outlet end section.

In the case of bigger-size coal mills, reversal and replacement of roller wear segments is easily carried out inside the mill, as is the case for ATOX raw mills. Reversal or replacement of roller wear segments for smaller-size mills normally takes place outside the mill. The whole roller assembly is pulled out on a special trolley and serviced on the platform in front of the mill.

Coal mill performance

More than 50 ATOX mills are now in operation, grinding and drying various types of solid fuels like anthracite, pet-coke, ordinary bituminous coal and lignite. Dependent on the type of fuel and in particular on its content of volatile matter, the fuel is ground to a fineness in a range from less than 3% to more than 20% residue on a 90μm sieve.

The content of volatile matter in the fuel is not only reflected in the product fineness, but also in the layout of the coal grinding plant. In case of high volatile fuels like lignite and most bituminous coal, the layout must be prepared for inert operation, using exit gases from the kiln preheater to dry and convey the material through the mill.

Mills exclusively grinding low-volatile fuels like anthracite or pet-coke may operate under non-inert conditions using excess air from a clinker cooler for drying and conveying purposes.

Examples of performance figures for ATOX coal mills grinding various types of solid fuels are shown in the Table 2, below.

The mills grinding anthracite and pet-coke are provided with a variable speed motor, to ensure that optimum grinding conditions can always be attained even when grinding to high fineness.

Some ATOX coal mills are supplied for alternate grinding of two or more types of fuel; typically pet-coke and ordinary bituminous coal.

An example of performance figures for such a mill is shown in Table 3, above.

Mill: ATOX 17.5	Guarantee/Design	Achieved	Achieved
	Coal, pet-coke	Coal	Petcoke
Capacity, t/h	15	16.1	15.3
Product SR %>90μm	10	6.8	5.9
Product mositure %	1.5	0.8	0.9
Feed moisture %	12	4.0	7.5
Spec. Eng. cons. kWh/t			
Mill		10.4	12.3
Separator		0.5	0.6
Fan		10.0	11.0
Mill + Sep. + Fan	26.0	20.9	23.9

Table 3: Performance figures for an ATOX 17.5 mill grinding more than one kind of solid fuel.

Conclusion:

- The ATOX mill grinds coal and raw materials of a very wide range of properties.
- Virtually all ATOX mills sold and commissioned have fulfilled the guaranteed performance.
- After redesign of some basic components and current development and optimisation, the modern ATOX mill now presents itself as a very reliable and well performing mill, reflected in its pronounced position in the market for vertical roller mills.

Table 2: Comparison of ATOX mills grinding solid fuels.

Type of Fuel	Anthracite	Pet-coke	Lignite
Location	Vietnam	El Salvador	Thailand
Mill size	ATOX 27.5	ATOX 25	ATOX 27.5
	Achiev./Guar.	**Achiev.**/Guar.	**Achiev.**/Guar.
Production t/h	**40.3**/40	**28.1**/27	**48**/45
Feed moisture %	**10**	**12.7**/10	**25**
Product moisutre %	**1**/1	**0.8**/0.9	**7.5**/10
Product %<90μm	**4.3**/5	**2.8**/3	**18**/18
Product %<0.2mm	**0.2**		1
Spec. Eng. cons. kWh/t			
Mill	**9.7**	**12.8**	**16.7**/13
Separator	**1.3**	**0.7**	**1.8**
Mill fan	**12.0**	**14.9**	**15.2**
Total	**23.0**/29.1	**28.4**/36.2	**30**/31
Water injection m^3/h	**2.1**	**0**	**0**

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