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Design of a typical Autogenous Mill: Part-II

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ABSTRACT

The special characteristics of the Autogenous mill are stated, and a suitable type of model for the mill is presented. An Autogenous Milling defined as used in this study; the term Autogenous milling means a process in which the size of the constituent pieces of a supply of rock is reduced in a tumbling mill purely by the interaction of the pieces, or by the interaction of the pieces with the mill shell, no other grinding medium being employed. The definition thus covers both 'run-of-mine' and 'pebble' milling, the only difference from the mathematical modeling viewpoint being that the feed to the first has a continuous, and the second a non-continuous, size distribution

Introduction

Over the past twenty or thirty years, mathematical modeling of ball and rod mills has been widely investigated, and reasonably satisfactory models are now available. The Autogenous mill has, however, received very little attention in this respect, and in view of the increasing importance of this type of mill, the Julius Kruttschnitt Mineral Research Centre in the Department of Mining and Metallurgical Engineering, University of Queensland, in 1970 commenced a programme of research into mathematical modeling of the Autogenous mill.

Special Characteristics of the Autogenous Mill Autogenous milling differs fundamentally from non-Autogenous milling in two respects. (1) Size reduction occurs by two main modes, namely the detachment of material from the surface of larger particles (referred to as 'abrasion') on the one hand, and disintegration of smaller particles due to the propagation of crack networks through them (called 'crushing') on the other. Abrasion and crushing breakage overlap on the size scale. This contrasts with non-Autogenous milling, in which only crushing breakage, however caused, is regarded as significant. (2) The grinding parameters of the Autogenous mill load are not independent of the mill feed; the load is continually generated from the feed, and its parameters therefore depend directly on those of the feed. These two characteristics must be specifically included in the model of the Autogenous mill (George, 1947). A special development is the Autogenous or semi Autogenous mill. Autogenous mills operate without grinding bodies; instead, the coarser part of the ore simply grinds itself and the smaller fractions. To semi Autogenous mills (which have become widespread), 5 to 10 percent grinding bodies (usually metal spheres) are added. Autogenous and semi-Autogenous mills are designed for grinding or primary crushed ore, and are the most widely used in concentrators globally. Autogenous mills are so-called due to the self-grinding of the ore: a rotating drum throws larger rocks of ore in a cascading motion which causes impact breakage of larger rocks and compressive grinding of finer particles. It is similar in operation to a SAG mill as described below but does not use steel balls in the mill. Also known as ROM or "Run of Mine" grinding.

Autogenous Mills operate, mechanically, similar to the ball mill. They differ in the media they use to break or grind the ore. Autogenous Mills use large particles of ore instead of steel or other balls for grinding media. Autogenous mills use large pieces of ore as grinding media. The grinding is facilitated in Autogenous mills by attrition with limited grinding by impact.

For an ore to successfully grind autogenously, the ore must be competent, and it must break along grain boundaries at the desired product size. Another requirement is that the finer sizes should break easily and should be removed from the mill; otherwise, there will be a critical size buildup. Autogenous grinding has two advantages such as it reduces metal wear and eliminates secondary and tertiary crushing stages. Thus it offers a savings in capital and operating costs. Autogenous mills are available for both wet and dry grinding. The diameter of Autogenous mills is normally two to three times the length. The ore charge is usually 25 to 35% of the mill volume. Autogenous mills have grate discharges to retain the coarse grinding media in the mill (Andrew et al., 2000).

Metal Emptying Operation

Metal pieces are separated from the bath, which are basically too heavy to be carried up by the conveying airflow and remained inside the mill body. So during grinding operation, the un-grind able metal contents inside the Autogenous Mill are gradually increased. The feeding flow rate is decreased proportionally in order to maintain constant load inside the Autogenous Mill. Once this feeding flow rate reaches the predefined low level, the feeding line is automatically stopped and an alarm system calls for emptying the operation. After rotation of about 30 minutes without bath feeding but with air sweeping, the metal becomes dust and the Autogenous Mill is stopped. Then, the movable spout feeder is moved backwards from the Autogenous Mill. In place of it, a special metal butts extractor is moved forward in the Autogenous mill. The Autogenous Mill is restarted, the lifted metal pieces go out of this extractor and it is used as a collecting spoon. Those metal

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pieces are then discharged on the belt conveyor fitted with a magnetic separator. It takes about 5 minutes to get the Autogenous mill emptied out of tramp metal. Then the above extractor is moved backwards and the feeding spout is set again in operating position into the Autogenous Mill. Thereafter, the grinding operation can start again at its maximum capacity. The frequency of emptying sequence is usually scheduled as once to twice a week. It can reach up to once a shift in case of high metal content in the bath from cleaning station. This emptying operation is carried out without any dust pollution. Bath is taken out from raw bath silo by the reciprocating feeder to belt conveyor, which in turn feeds to the Autogenous Mill. The ground product is extracted from the mill by air sweeping effect, generated by main exhaust fan of Air Sweeping System. The air driven suspension directly goes through a bag filter. The solid material is collected in the screw conveyor (below bag filter), which feeds a double-deck vibrating screen to separate following fractions: 1) Over 40 mm scraps are rejected to a scrap bin, 2) 10 to 40 mm fraction is recycled back by gravity to the mill-feeding conveyor and 3) -10 mm to + 10mm fraction of crushed bath is conveyed to airlift vessel through a set of belt conveyors. The mill in the process circuit will be suitable for operating with a bath temperature of 85°C. During grinding time, the un-grind able products accumulate in the Autogenous Mill, thus progressively reducing its production capacity and the speed of reciprocating feeder. The pressure drop of the mill is monitored by a dedicated control loop (by power / amperage of mill) in order to maintain the constant mill load. When the mill is full of un-grind able products, the speed of reciprocating feeder reaches a preset low speed alarm value and then the emptying operation is called. The same message can appear if the mill outlet gate is clogged. The flow of sweeping air through the mill is measured by a flow meter located in the stack at fan outlet. A control loop maintains this flow constant by acting on the inlet damper position of the fan. This flow set point may be modified by the operator in order to adjust the size distribution of ground products. A lower airflow will deliver a finer product and a higher airflow a coarser one (Mevlut et al., 2006).

Materials and Methods:

The specifications for the design and developed Autogenous Mill are given below:

Table 1: Autogenous Mill specifications

Equipment	**Autogenous Grinding Mill (Size: 3900x1450x50mm)**
Type	Air Swept Discharge
Capacity	Rated- 20 TPH, Design- 30 TPH
Feed Material	Anode Bath for Aluminium Smelter
Bulk Density	1.8 – 2 T/Cu m
Desired Product Size	100% < 5 mm 95% < 3 mm 30% < 74 microns
Gearing Ratio	9.16
Pinion speed	150 rpm
Material Characteristics	Very Abrasive
Auxiliary Systems	Tramp Metal Butts Extractor with Feed Launder Movement Device and Dust collection Outlets Access Doors Main Driving Mechanism and Motor (150 kW- 1500 rpm) Inching Drive with Motor (3.7 kW- 1500 rpm) Lubrication System
Mill Shell	3900 mm diameter inside liners 1250 mm length inside liners
Mill Operating Speed	16.37 rpm
Design Mill Charge	45 % by volume maximum

Fig.1 shows the complete designed Autogenous mill. The total Autogenous mill is consists of some of the critical major assemblies like Mill body assembly, Driving gear and pinion assembly, Spout Feeder Assembly, Outlet Duct Assembly, Babbit Bearing Assemblies, Metallic Butt Extractor Assembly, Drive Base Assembly. These are discussed in brief in the following sections.

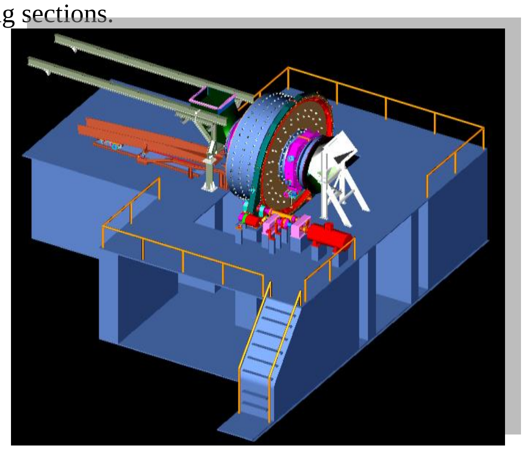

Fig 1: Complete designed and developed Autogenous mill

Mill Body Assembly

It consists of all together 17 items and the weight of whole unit is approximately 2 Tons. It is made of steel and rubber materials.

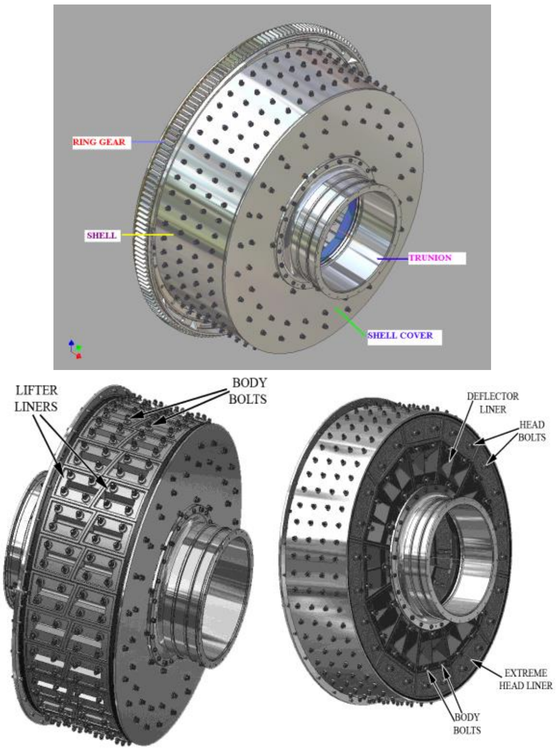

Fig 2: Mill Body of Autogenous Mill

It is located and arranged on the thrust trunnion bearing and free trunnion bearing. A mill body has two trunnions bearing assemblies for supporting left side and right side trunnion bearings. There is a disclosed system for sensing and controlling the mill load in a grinding mill. The system includes a load cell located in the region of the mill, which is subjected to axial thrust forces developed during mill operation as reaction force. The load cell senses the thrust forces and provides output signals representative of the values of the thrust forces. The system further includes a load controller, which is responsible for the output signals to determine the charge load of the mill and for providing control signals to the mill in order to control entry of materials into the mill.

The shell of the mill body assembly is a drum type structure mounted to rotate about a horizontal axis extending longitudinally through the bore of the drum structure (Fig.3). The shell usually includes an inlet end through which ore is fed into the structure and an outlet end through which the milled ore is discharged. The outlet end often includes a screen, which allows only the smaller fragments of ores, than a predetermined size, that is to be discharged from the drum structure. The bore is usually lined with an interchangeable liner because of the high abrasive forces present in the shell. The liner prevents the drum mantle itself from becoming worn out.

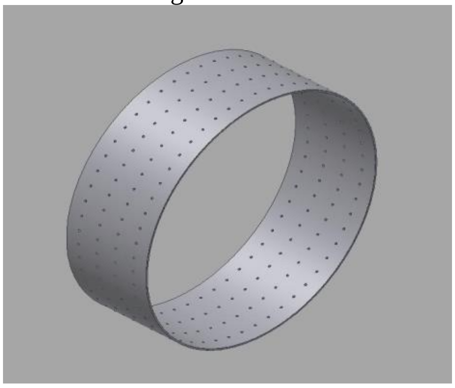

Fig.3: Shell of a mill body

Discs are the end covers of the shell as shown Fig. 4. They have holes drilled in them to carry the liners. They carry the extreme headliners and deflector liners on them. Because of the high abrasive forces acting on the discs, they are lined with the interchangeable liners. The liners prevent the shell itself from becoming worn out, as a result of the abrasive forces and when the liners are worn out, new liners can replace them. One of the disks has a ring gear welded to it at its periphery, which is connected to the gear mechanism for providing the mill body with a uniform circular velocity for self-attrition.

Table 2.5: Material Speciation of Discs

Material	Specification
Steel plates for pressure vessels	S 235J2G3 According to NF EN 10025/1993 (BS: 4360-40D) (IS: 8500 - 1991)

Driving Pinion and Gear Assembly

This is the main driving system of the mill. The ring is fitted peripherally at one side of shell body of the mill and the pinion at an angle of 20 degree (pressure angle of the gear profile) is engaged with the gear. The rotation of the pinion occurs in such a way that the pinion load always acts against the gravity to reduce the bearing load at the mill. The driving pinion and gear assembly has been shown in Fig.4 while the block diagram of main power transmission system has shown in Fig.5.

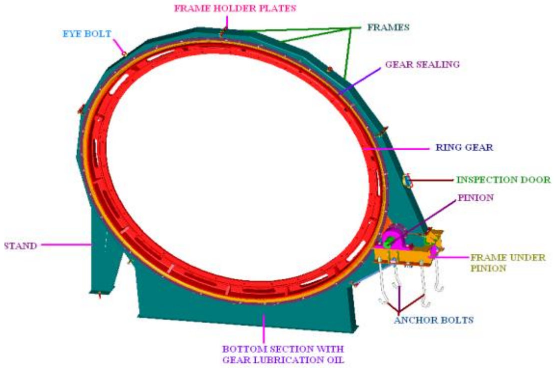

Fig 4: Driving Pinion and Gear Assembly

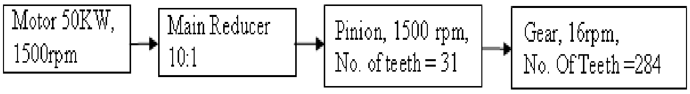

Fig.5: Block Diagram of Main Power Transmission

Spout Feeder Assembly

Spout feeder (Fig. 6) is the inlet duct of the material for the Autogenous Mill shell. It slides on an I-Section beam during maintenance work and engages with trunnion during the feeding operation. At the time of butts extracting, it is removed from the trunnion and slides on the mill.

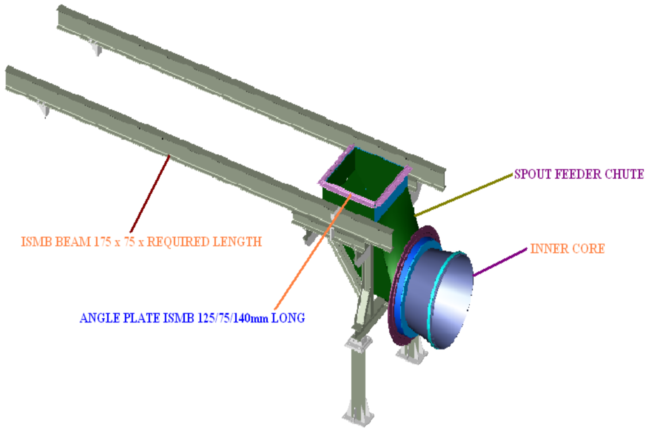

Fig 6: Sprout Feeder Assembly

Outlet Duct Assembly

The outlet duct assembly (Fig.7) comprises of Discharge cone, Mesh, Liners, Beam structure, Outlet duct and Coupling discs. The outlet duct is prepared by surface development work. The diameter of cone is 1080mm. The height of A.G Mill centre line and the outlet duct centre line is 918mm. A sheet plate of thickness 0.10mm to 10mm thick plates are used at the perimeter of outlet chute. The cone structure is made by using different plate sizes and it is assembled with the discharge cone assembly. The major function of the outlet duct is to filter the particles with desired size with the help of exhaust fan, which is fitted with motor damper. It is then allowed to enter in a process bag filter.

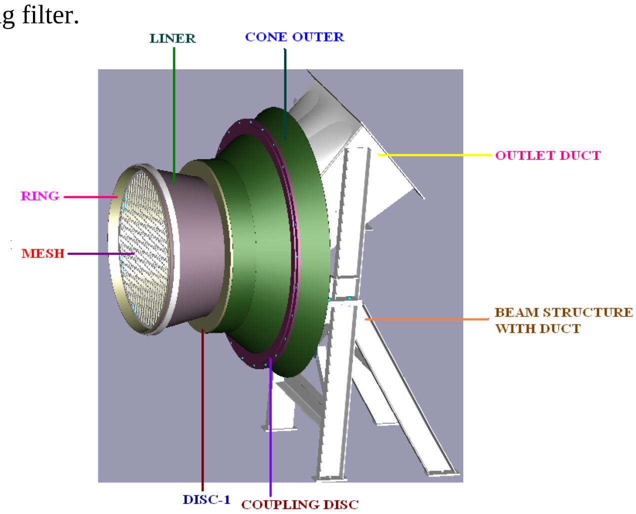

Fig 7: Outlet Duct Assembly

Babbit Bearing Assemblies

The babbit bearing assemblies (Fig.8) consists of Bearing pedestal weldment, Bearing liner assembly, Slide base weldment, Bearing cap weldment, Oil wiper assembly, Trust plate, Inspection cover weldment, Hand hole cover weldment and Oil level indicator. Babbit bearing is cast and placed on the support plate. A tube like structure is prepared inside the Babbitt bearing as it is required to pass the coolant into the pipe for cooling the bearing. This is fitted over both the trunnions for carrying the load. The outer diameter of trunnion is 1600mm and inside diameter of the bearing is similar to the outside diameter of the trunnion. The width of the bearing is 170mm. Trunnion carries two oil rings at both the sides of its web and the oil rings are to be immersed in the oil tank to carry the oil for lubrication of the bearing.

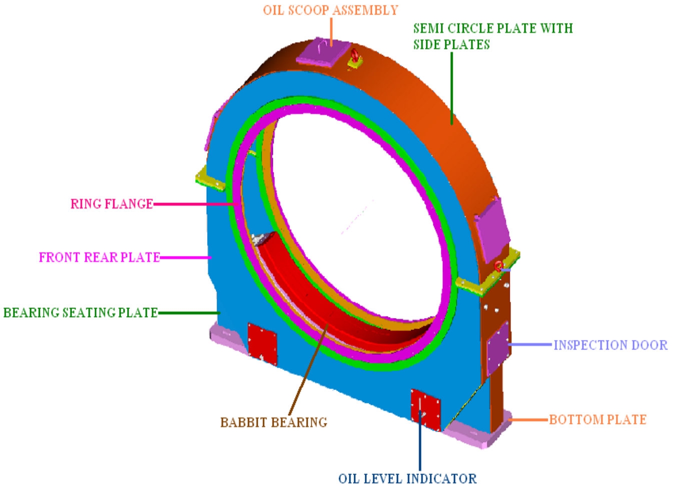

Fig 8: Babbit Bearing Assembly

Metallic Butt Extractor Assembly

It (as shown in Fig.9) consists of many different parts like Spout and Motor base, Stationary Shaft, Roller (free), Driving Shaft, Horizontal Rail, Inclined Rail, Drum Assembly, Chain Guard, Taper Roller Bearing, and Grease Nipple. The major function of the metallic butt extractor is to remove ungrind material of the mill by using inching motor and its accessories. The drum is rotating with low speed (i.e. 16.37 RPM) inside the mill. Spout and motor is entered with the help of horizontal and inclined rail. Drive is given to spout feeder with the help of motor. The stopping extractor is fitted at one end of the inclined rail to stop the spout and motor. The ungrind material is collected and it is dumped outside the mill. Grinding process will continue until the required size of grind particles in the A G Mill. Chain guards with mesh are used for protecting the motor. A steel rope is wounded on a roller for restricting the motion of spout and motor drive.

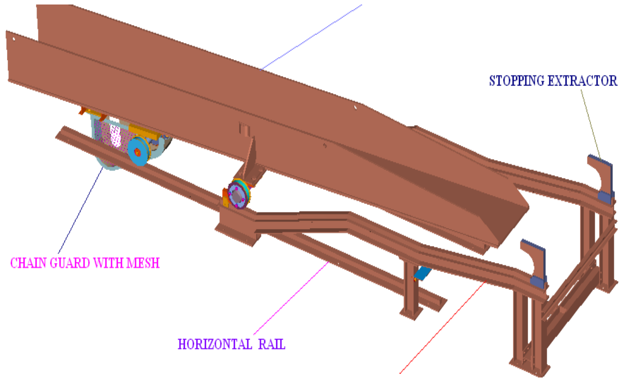

Fig 9: Metallic Butt Extractor

Drive Base Assembly

The drive base assembly as shown in Fig.10 is consists of Main Motor, Main Reducer, Geared Coupling with 800 Spacer, Auxiliary Reducer, Break and Auxiliary Motor etc. The main function of the motor is to give the drive to main reducer with reduction ratio of 10:1. The speed of the pinion is 150 rpm and the ring gear speed is 16.37 rpm. Ring gear is connected to mill body unit with hexagonal headed bolt, nut & washer. The total unit rotates with the help of motor of power 150KW. By using motor power material is to be grinded to the required size. The size reduction of bath is obtained by impact and attrition work.

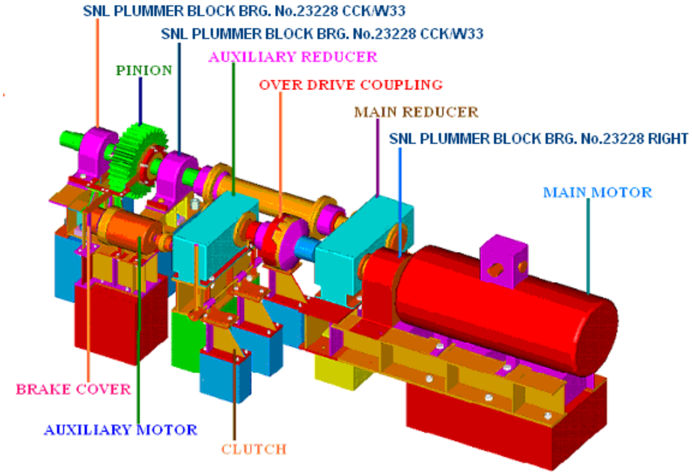

Fig 10: Drive Base Assembly

Conclusions

An Autogenous Milling has been designed based on the customer need and presented in this paper. Here, the term Autogenous milling means a process in which the size of the constituent pieces of a supply of rock is reduced in a tumbling mill purely by the interaction of the pieces, or by the interaction of the pieces with the mill shell, no other grinding medium being employed. The two main character of an Autogenous Mill e.g. size reduction which occurs through the detachment of material from the surface of larger particles (referred to as 'abrasion') and the grinding parameters that are dependent of the mill feed; has been specifically included in design of the Autogenous mill.

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