GROSS POWER CALCULATOR

General

This model uses the equations from Morrell's 1993 PhD thesis: "The Prediction of Power Draw in Wet Tumbling Mills". The model is also described in detail in the book "Mineral Comminution Circuits Their Operation and Optimisation" which is available from the Julius Kruttschnitt Mineral Research Centre.

The model predicts the gross power, which is also called the motor input power. This is not the same as the so-called "power at pinion", which is slightly lower than the gross power and relates to the power as measured at the shaft which drives the pinion gear in a gear-and-pinion drive. Apart from in pilot-scale mills, the power at pinion is never directly measured in full scale operating mills but is estimated from the gross power by assuming a variety of losses across the motor and gearbox. Published literature contains a variety of estimates of what these losses are. In pilot-scale mills, where it is possible to directly measure these losses it is found that proportionately they are relatively high and can be as much as 20% of the gross power. However, in full scale mills these losses are proportionately much smaller. A reasonable working estimate to use in the case of gear-and-pinion drives would be 6-7%, ie the estimated power at pinion would be about 6-7% lower than the gross power draw. Gearless drives (also known as wrap-around motors) are quite different to gear-and-pinion drives. They do not have gears or pinions and hence the term "power at pinion" is not relevant to them. With these drives the literature normally refers to the "power at shell" in stead. Once again the literature contains a variety of estimates of what the losses are in these drives between the motor input and the power at the shell. A reasonable working estimate to use in the case of gearless drives would be 3-4%, ie the estimated power at shell would be about 3-4% lower than the gross power draw.

The model was originally developed using a data base of 76 operating mills to validate its accuracy. These data were published in Morrell's thesis and are reproduced in Tables 2-4. Since that time (1993) the data base that the model has been tested against has increased to over 150. AG/SAG mills in the data base are up to 40ft in diameter and ball mills are up to 26ft in diameter. The measured gross power draws from these mills are plotted against the model predictions in Figure 1. As indicated by this data base the accuracy of the model (1 standard deviation) is 4.6%.

How to Use the Model

Inputs to the model are made in three windows, viz:

Mill Type – available options to choose from are Autogenous (AG), Semi-autogenous (SAG) or Ball mills. When "AG" is chosen the ball filling option in the Contents Data window is automatically set to zero and cannot be changed. When "SAG" is chosen all input options are available. When "Ball" is chosen the total filling option is automatically set to the same value as the ball filling value and cannot be changed manually. These are all conditions dictated by the model for it to work correctly.

Design Data – this covers mill dimensions, speed of rotation, whether the mill has cone ends and type of discharge mechanism. Dimensions can be input in either metric or imperial units by the use of the drop-down menu. The mill diameter input relates to the inside-shell dimension. The model actually requires the inside liner diameter and hence the liner thickness must also be input. The required length to be input depends on whether the mill is an overflow or a grate discharge machine. In all cases AG and SAG mills are grate discharge and ball mills are mostly overflow (a few, however, are grate discharge). In overflow mills the belly length inside liners, which is what the model requires to be input, is very close to the flange-to-flange length. In grate discharge mills it is the length as measured from the inside face of the grate to the inside face of the feed end head liner. Note that in much published literature and many equipment suppliers documentation an “Effective Grinding Length” is often quoted and is often abbreviated to “EGL”. Beware of what this actually refers to, as its definition varies as there is not a universally accepted definition. In some cases it will be similar to the belly length inside liner dimension that the model requires. However, there are cases, usually related to AG/SAG mills, where the quoted EGL may refer to the flange-to-flange length. If the mill has conical ends then the angle of the cones needs to be input. If there are no cone-ends then zero degrees for the cone angle should be input. Note that the model assumes that both ends of the mill are the same. Figures 2-4 provide a general guide as to the definitions of the various dimensions. If you are in doubt the best course of action is to refer to an engineering drawing of the mill.

Contents Data –the model requires inputs of the liquid and ore specific gravities as well as % ball filling, % total filling and the % solids by weight of the discharge slurry. The ball filling relates to the volume (including voids) that the balls occupy when the mill is completely ground out, ie there is no ore in the mill. This volume is expressed as a % of the total mill volume. Note that these figures should be calculated and input to the model for the cylindrical part of the mill only, as this simplifies the required calculations by the user. If the mill has cone ends the model automatically calculates the volume of the cone ends as well as the volume of balls/rock in the cone ends from the cylindrical section data that the user inputs. In SAG mills the total filling relates to the combined rock and ball volume (including voids), whilst in AG mills it relates just to the rocks (including associated voids). The total filling can only be determined accurately in an operating mill by carrying out what is known as a crash stop. In this case the mill is effectively tripped when in operation. The feed ore will automatically stop and any feed water not stopped automatically is also immediately turned off. Measurements are then taken from within the mill. Pictures of the insides of an AG mill and a SAG mill which have been crash stopped are shown in Figures 5 and 6 respectively. Accurate measurements of the ball filling can only be made after the mill is ground out. In this case the mill is operated with the feed turned off until all of the ore has exited the mill. Measurements of the ball level within the mill can then be made. Figure 7 shows an example of the balls in a mill after a grind-out.

“Cautionary Tales”

The axiom “garbage in – garbage out” very much applies here. The model has been developed from data that have been carefully measured and if used properly will give accurate predictions. The model is most sensitive to the dimensions that are input as well as the ball and total filling values. Hence if the user is comparing the model’s predicted power to an existing mill’s actual power and approximations of these input parameters are used then it is quite possible that the predicted and actual power draws will not match very well – don’t blame the model for this!

To ensure that the user does not input values that are outside of the range that the model has been validated with, limits have been set for all of the input cells and a warning message will appear if the user attempts to input values outside these limits. These limits are as detailed in Table 1.

Table 1 – Model Limits

		Ball Mill		AG/SAG Mill	
		min	max	min	max
DESIGN DATA					
diameter inside shell (m)		0.9	7.9	1.8	12.2
belly length inside liners (m)		1.5	12.2	0.5	9.6
liner thickness (mm)		51	152	51	152
diameter inside shell (ft)		3	26	6	40
belly length inside liners (ft)		5	40	1.5	31.5
liner thickness (inch)		2	6	2	6
fraction of critical speed		0.6	0.82	0.5	0.9
cone angle (deg)		0	26	0	15
CONTENTS DATA:					
ore sg		2.6	4.5	2.6	4.5
liquid sg		1	1.24	1	1.24
ball filling of cylindrical section(%)		20	48	0	25
total filling of cylindrical section(%)		20	48	10	40
% solids by weight of discharge slurry		0	77	0	78

It should also be remembered that power draws indicated in the control room of a concentrator may not necessarily be motor input power. Particularly with more modern plants it is common to find that the power draw indicated in the control room has been adjusted in some way, eg the power draw shown may be motor input power less various estimates for motor, drive train and bearing losses to arrive at a an estimate of the power that may be going directly into the grinding process.

Finally it should be noted that the phenomenon of slurry pooling is not explicitly covered in the version of the model on this website. However, the structure of Morrell's model has been designed to accommodate it and in an advanced (unpublished) version of the model the volume of excess slurry (slurry pool) is predicted from mill design and slurry flow data and its impact on power draw is then predicted. Slurry pooling causes the power draw in AG and SAG mills to be lower than a mill without a slurry pool. This phenomenon results in overflow mills usually drawing less power than grate discharge mills that are operating without a slurry pool. This is because by definition overflow mills operate all of the time with a slurry pool. Some idea of how much slurry pooling in an extreme case can cause the power draw of an AG/SAG mill to drop can be gauged by switching the discharge mechanism choice in the model from grate to overflow when predicting the power draw of an AG/SAG mill.

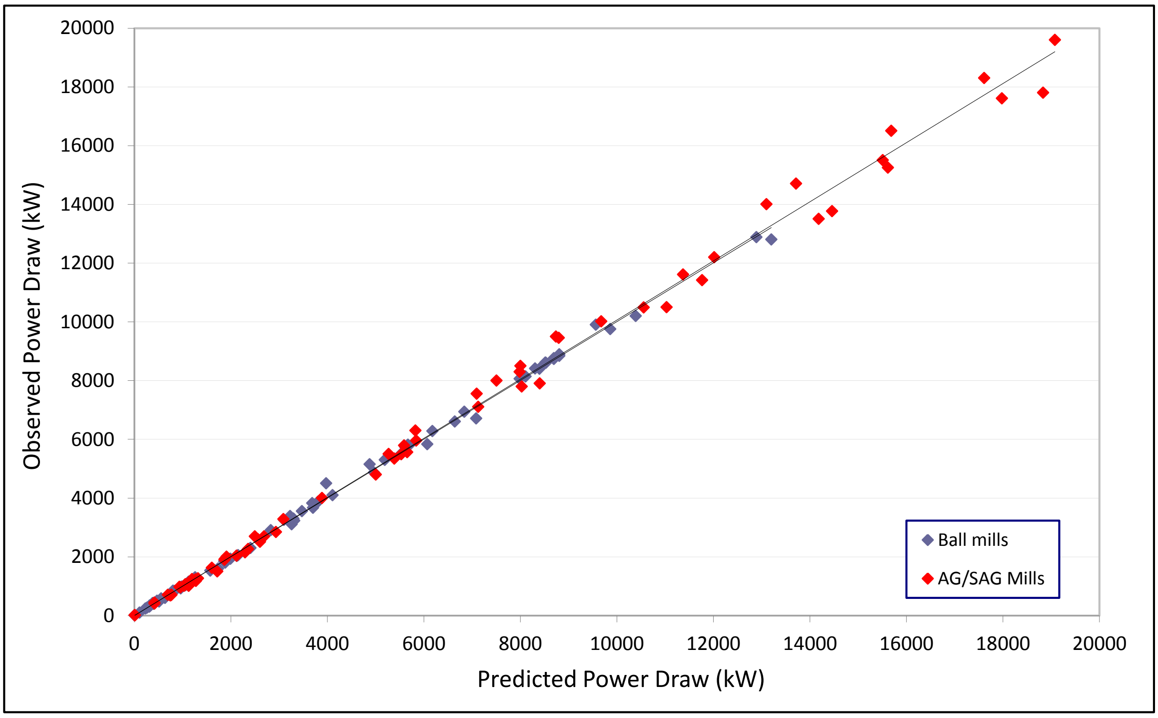

Figure 1 – Measured vs Predicted Motor Input Power

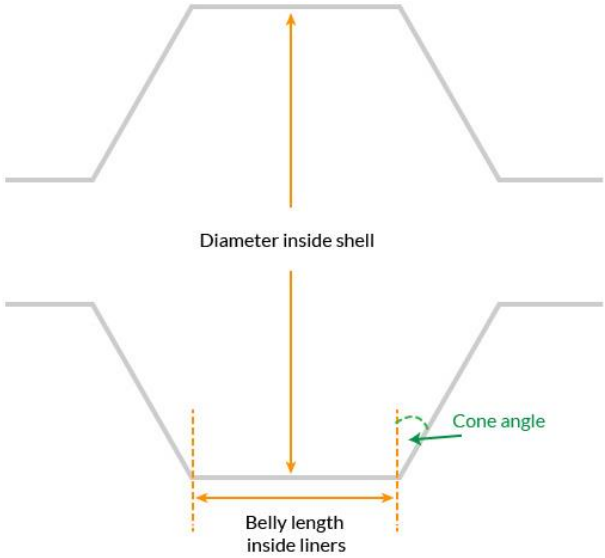

Figure 2 – Overflow Discharge Mill

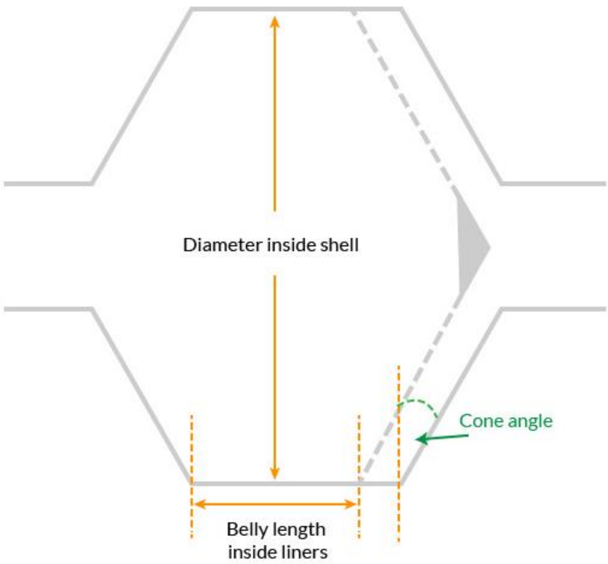

Figure 3 - Grate discharge mill

Figure 4 – Lifter/liner

Figure 5 – Crash Stop of AG Mill

Figure 6 – Crash Stop of SAG Mill

Figure 7 – Balls in a Mill After a Grind-out

Table 2 – Ball Mill Data from Morrell's PhD Thesis

Discharge Mechanism	Diameter Inside Liners(m)	Length (Belly) (m)	Length (C/line) (m)	Mill Speed (fr.crit)	Ball Filling (%)	Total Filling (%)	Ore sg	Gross Power (kW)
Overflow	4.41	6.10	6.10	0.74	35	35	4.10	1900.00
Overflow	2.30	4.20	4.20	0.82	36	36	2.70	299.00
Overflow	2.65	3.40	3.40	0.77	36	36	2.70	334.00
Overflow	2.52	3.66	3.66	0.67	35	35	2.70	265.00
Grate	1.73	2.44	2.44	0.68	35	35	2.70	97.00
Overflow	3.48	4.62	4.62	0.71	39	39	2.70	834.00
Overflow	3.54	4.88	4.88	0.76	42	42	2.70	1029.00
Overflow	4.12	5.49	5.49	0.75	45	45	2.70	1600.00
Overflow	4.38	7.45	7.45	0.75	30	30	2.70	2026.00
Overflow	5.29	7.32	7.32	0.70	40	40	3.20	3828.00
Overflow	4.80	6.10	6.10	0.69	40	40	3.00	2498.00
Overflow	3.05	4.27	4.27	0.70	40	40	4.50	580.00
Overflow	2.60	3.70	3.70	0.69	40	40	4.50	347.00
Overflow	3.05	4.27	4.27	0.73	45	45	3.90	600.00
Overflow	3.50	4.42	4.42	0.74	35	35	2.75	820.00
Overflow	4.87	8.84	8.84	0.72	27	27	2.60	2900.00
Overflow	4.87	8.84	8.84	0.75	30	30	2.60	3225.00
Overflow	4.87	8.80	8.80	0.75	31	31	2.60	3104.00
Overflow	5.33	8.54	8.54	0.72	34	34	2.60	4100.00
Overflow	3.04	3.05	3.05	0.82	45	45	3.50	475.00
Overflow	2.29	2.74	2.74	0.83	44	44	3.50	235.00
Grate	1.70	2.70	2.70	0.81	40	40	2.70	103.00
Overflow	3.55	4.87	4.87	0.72	40	40	2.80	970.00
Overflow	3.50	4.75	4.75	0.75	42	42	2.80	921.00
Overflow	0.85	1.52	1.52	0.71	40	40	2.90	10.00
Overflow	0.85	1.52	1.52	0.71	20	20	2.90	6.80
Overflow	4.75	6.26	6.26	0.77	28	28	2.68	2050.00
Overflow	3.85	5.90	5.90	0.77	30	30	2.80	1300.00
Grate	2.64	3.66	3.66	0.70	43	43	2.80	420.00
Overflow	4.12	7.04	7.04	0.70	38	38	2.60	1800.00
Overflow	4.10	5.92	5.92	0.75	34	34	3.10	1525.00
Overflow	4.35	6.56	6.56	0.70	40	40	2.72	1850.00
Overflow	3.48	6.33	6.33	0.75	34	34	2.70	1150.00
Overflow	3.83	4.83	4.88	0.61	31	31	2.60	842.00
Overflow	4.68	5.64	5.64	0.72	48	48	2.80	2300.00
Overflow	4.73	7.01	7.01	0.60	32	32	2.80	1840.00
Overflow	5.34	8.69	8.69	0.73	28	28	3.20	3669.00
Overflow	5.34	8.69	8.69	0.73	26	26	3.20	3549.00
Overflow	5.34	8.69	8.69	0.73	24	24	3.20	3385.00
Overflow	5.34	8.69	8.69	0.73	23	23	3.20	3251.00
Overflow	3.87	6.34	6.34	0.69	27	27	4.60	1075.00
number	41	41	41	41	41	41	41	41
mean	3.73	5.58	5.58	0.73	35.25	35.32	3.03	1539.34
sd	1.23	2.15	2.15	0.05	6.79	6.80	0.55	1223.53
min	0.85	1.52	1.52	0.60	20	20	2.60	6.80
max	5.34	8.84	8.84	0.83	48	48	4.60	4100.00

Table 3 – SAG Mill Data from Morrell's PhD Thesis

Discharge Mechanim	Diameter Inside Liners(m)	Length (Belly) (m)	Length (C/line) (m)	Mill Speed (fr.crit)	Ball Filling (%)	Total Filling (%)	Ore sg	Gross Power (kW)
grate	7.73	3.46	3.46	0.70	11	11	2.60	1800.00
grate	6.50	2.42	3.02	0.75	6	21	3.64	1228.00
grate	4.35	4.85	4.85	0.75	12	29	2.60	1045.00
grate	7.05	3.45	3.45	0.72	12	33	2.65	2239.00
grate	7.05	3.45	3.45	0.72	12	12	2.65	1500.00
grate	5.30	7.95	7.95	0.71	18	30	2.80	3284.00
grate	4.05	4.60	4.60	0.76	8	26	2.70	688.00
grate	4.05	4.60	4.60	0.76	7	7	2.70	440.00
grate	4.05	4.60	4.60	0.76	6	32	2.70	687.00
grate	4.05	4.60	4.60	0.76	6	34	2.70	706.00
grate	6.51	2.44	2.44	0.71	3	16	4.10	972.00
grate	1.80	0.59	0.59	0.75	6	27	2.74	14.80
grate	9.59	4.27	5.86	0.75	14	14	2.60	5790.00
grate	9.59	4.27	5.86	0.75	19	31	2.60	7900.00
grate	9.59	4.27	5.86	0.75	17	30	2.60	7100.00
grate	8.39	3.26	5.00	0.80	14	18	2.68	4000.00
grate	4.12	5.02	5.02	0.75	22	22	2.70	1012.00
grate	4.12	5.02	5.02	0.75	22	33	2.70	1225.00
grate	4.16	4.78	4.78	0.89	10	38	2.70	1063.00
grate	3.90	5.10	5.10	0.78	25	34	3.35	1175.00
grate	5.08	6.82	6.82	0.66	12	31	2.85	2000.00
grate	5.05	5.99	5.99	0.77	17	21	2.68	2035.00
grate	5.82	5.65	5.65	0.81	13	33	2.80	2840.00
grate	5.80	5.65	5.65	0.81	10	27	2.80	2600.00
grate	3.85	5.69	5.69	0.48	12	12	2.80	424.00
grate	7.23	3.00	3.00	0.75	11	16	2.72	1920.00
grate	7.09	2.74	2.74	0.75	11	21	3.10	1900.00
grate	6.26	2.50	2.50	0.71	5	21	2.70	1200.00
No.	28	28	28	28	28	28	28	28
mean	5.79	4.32	4.57	0.74	12.16	24.25	2.82	2099.49
sd	2.01	1.52	1.55	0.07	5.67	8.52	0.34	1946.55
min	1.80	0.59	0.59	0.48	3	7	2.60	14.80
max	9.59	7.95	7.95	0.89	25	38	4.10	7900.00

Table 4 – AG Mill Data from Morrell's PhD Thesis

Discharge Mechanim	Diameter Inside Liners(m)	Length (Belly) (m)	Length (C/line) (m)	Mill Speed (fr.crit)	Total Filling (%)	Ore sg	Gross Power (kW)
grate	7.10	2.43	3.47	0.72	10	3.57	703.00
grate	7.10	2.43	3.47	0.72	12	4.60	1009.00
grate	6.49	2.25	2.48	0.75	27	4.00	1240.00
grate	6.49	2.25	2.48	0.75	19	4.00	960.00
grate	5.11	5.18	5.18	0.73	24	4.20	1264.00
grate	1.80	0.59	0.59	0.75	25	2.74	12.50
grate	9.50	4.40	6.40	0.75	31	2.90	5490.00
number	7	7	7	7	7	7	7
mean	6.23	2.79	3.44	0.74	21.11	3.72	1525.50
sd	2.35	1.53	1.90	0.01	7.78	0.69	1799.05
min	1.80	0.59	0.59	0.72	10	2.74	12.50
max	9.50	5.18	6.40	0.75	31	4.60	5490.00