Hammermill grinding rate and energy requirements for thin and conventional hammers

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Vigneault, C., Rothwell, T.M. and Bourgeois, G. 1992. **Hammermill grinding rate and energy requirements for thin and conventional hammers**. Can. Agric. Eng. 34:203-206. Two hammermill hammers of different thickness were compared in a commercial feed mill using the existing equipment. Comparison of specific energy consumption and grinding rate were done. Lifetime evaluation was attempted. The results showed that a 13.6% saving in specific energy consumption and an increase of 11.1% in grinding rate can be obtained by using a thin hammer without affecting the quality of the ground material. However, the lifetime of the thin hammers was very low and difficult to predict. These thin hammers tended to fracture resulting in damage to the surrounding equipment.

L'effet de l'épaisseur des marteaux utilisés dans une moulange sur l'efficacité énergétique et sur leur taux de production a été évalué en comparant des marteaux de deux épaisseurs différentes. Des essais ont aussi été faits pour évaluer la durabilité de ces marteaux. Les essais ont été effectués dans une meunerie commerciale en utilisant des équipements existants. Les résultats ont démontré une réduction de l'énergie spécifique de 13.6 % et une augmentation de la productivité de 11.1% grâce à l'utilisation des marteaux plus minces sans affecter la qualité du matériel moulu. Toutefois, la durée de vie des marteaux plus minces est plus courte et difficile à prédire. Ces marteaux ont tendance à se briser prématurément et à endommager les équipements périphériques.

INTRODUCTION

The grinding rates and energy requirements for the hammermilling process are influenced by a number of variables. These variables include the characteristics of the grains, the screen, the aspiration system, the hammer type and condition, and the feeding method of the hammermill (Kuprits 1967). Very little information concerning these effects was found in the literature. Published data on the specific energy and the specific energy ratio for different hammer thicknesses are summarized in Table I.

Work reported by Agriculture Canada (1971) revealed that comparative grinding efficiencies for different thicknesses of hammers change with hammer tip speed (Table II). At the lowest speed tested, 3.18 mm hammers ground more efficiently than 1.59 mm hammers, but this relationship did not persist over the entire speed range. The increase in energy consumption was amplified as the tip speed was increased. Unfortunately, the reference did not give screen diameter or resultant particle size.

Average particle size and tip speed are known to be inversely related, i.e. a higher tip speed results in a finer grind, all other things being equal (Rothwell and Southwell 1986). However, results presented by Pfost (1976) did not show any effect of the hammer tip speed on grinding quality of the grain. Since the two hammer types were not exactly the same length, the comparison of the thicknesses of the hammers, on an energy and economic basis, should take into account the effect they have on the grinding quality of the grain.

A smaller cross sectional area and thus a thinner impact zone suggest a more uniform cutting action by the thinner hammers versus the standard hammers. This would suggest less energy consumption since inertial effects are lessened and more milling is conceivably achieved by shearing and cutting. There was some published information related to this field (Pfost 1976). Unfortunately, some data, particularly regarding hammer lifetime, were not included. No information was found in the literature regarding wear rates, although Pfost (1976) advised that the usual practice is to replace the hammers when grinding rates drop to about 80% of the

Table I: Specific energy and relative energy efficiency resulting from the use of different hammer thickness in a hammermill.

Hammer thickness (mm)	Specific energy ($kW{\bullet}h{\bullet}t^{-1}$)	Relative energy efficiency (%)	Reference
8.00	9.5	117	Pfost (1976)
6.35	8.1	100	*
3.18	6.5	80	*
1.59	5.5	68	*

*Pfost (1976), Agriculture Canada (1971), CFIA (1978)

Table II: Specific energy consumption for grinding corn across a 2.38 mm hole diameter screen using different hammer thicknesses and hammer tip speeds (Agriculture Canada 1971).

Hammer thickness (mm)	Hammer tip speed (m/s)		
	54	71	86
	Specific energy consumption (kW•h•t^{-1})		
6.35	4.6	6.5	12.9
3.18	3.7	5.6	11.0
1.59	3.9	4.8	7.6

original values obtained when the hammers are newly installed.

The objectives of this project were to evaluate the lifetime of hammers of two different thicknesses and compare their effect on the efficiency and the grinding rate of the hammermilling process and the quality of the ground material.

MATERIAL AND METHODS

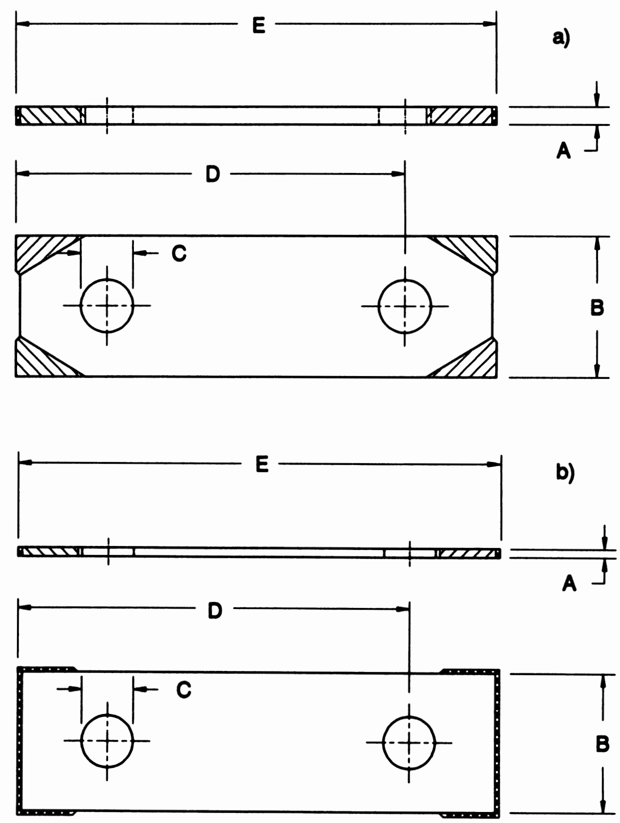
The comparisons of the energy, grinding rate and durability characteristics of hammermill hammers 3.18 mm and 6.35 mm thick were made using the Schutte 1080 (Schuttle Pulverizer, Buffalo, NY) hammermill specified in Table III. One hammer set of each type was composed of 64 hammers, installed onto rods which were mounted on the hammermill rotor. Diagrams and dimensions of each hammer type are given in Fig. 1 and Table IV, respectively. The thin hammers were slightly longer (179.4 mm) than the standard hammer (176.2 mm). The hardened material was covering the edge and sides of each of the four corners of the standard hammers, but only the edges (actual grinding face) of the thin hammers (Fig. 1).

Paired tests were conducted, one using standard hammers and one using thin hammers. In each test, two lots of corn drawn from the same silo were ground. The corn was conveyed into the hammermill system at a rate such as to operate at a peak hammermill motor current of approximately 100 A. Fineness analysis, using the technique specified by ASAE Standard S319.1 (ASAE 1989), was performed on samples of ground product taken during each trial. The electrical energy consumption was determined by taking energy readings on a kW•h meter connected to the hammermill motor starter.

Table III: Hammermill specifications

Model	: Schutte 1080
Motor	: 93 kW, 550 V
Aspiration fan	: Negative aspiration across screen
	: Fan motor 3.7 kW, 550 V
Grinding chamber diameter	: 590 mm
Rotor speed	: 3600 rpm
Hammer tip speed	: 111 m/s
Screen type	: Punched screen, 30% open area
	: 2.78 mm hole diameter

Lifetime tests were concurrently initiated for the two hammer types. Corn, barley, alfalfa pellets, and wheat were ground with the two hammer types. Little deviation in the ratio of materials used during the lifetime tests was anticipated and it was felt that the results would be reasonably comparable.



A = thickness, B = width, C = hole diameter, D = hole position and E = length.

Fig. 1: Schematic of a) standard and b) thin hammer used in hammermill.

RESULTS AND DISCUSSION

Specific energy and grinding rate comparisons for hammers

Results for the four sets of comparison tests using lot size ranging from 9.5 to 15.9 t are given in Table V. The grinding rate of the hammermill using the thin hammers was significantly higher ($F_{1,3}$ = 14.84, P = 0.031) compared to the standard type of hammers. On average, the thin hammers required 86.4% of the specific energy required with the standard type. This result is slightly higher than the specific energy ratio of 80% presented in Table I. The average grinding rate increased by 11.1%. This reduction of the specific energy would translate into an annual electricity saving of 63 000 kW•h which represents a reduction of the operation cost of approximately $3000 per year for a typical feed mill (35 000 t/y of ground material). Furthermore, the increase of the grinding rate results in an increase of the annual production of the hammermill or a reduction of its operating time.

The quality of material ground, expressed in terms of particle size ($F_{1,3}$ = 0.04 , P = 0.86) and geometric standard deviation ($F_{1,3}$ = 0.38, P = 0.58), were not significantly different for the two hammer types.

Table IV: Hammer specifications of standard and thin hammer types related to Fig. 1.

	Standard hammer	Thin hammer
	Dimensions (mm)	
A	6.4	3.2
B	50.8	50.8
C	19.1	19.1
D	142.9	146.1
E	176.2	179.4

Hammer lifetime

Mill maintenance staff estimated lifetime of standard hammers to be 3600 t. This was confirmed when all four faces of the standard hammer were judged to be spent in an inspection after 3601 t, 80% of which was corn.

Failure of a thin hammer occurred on the second day of testing after only 267 t of material (90% corn) were ground. Failures of new sets of thin hammers occurred again on the second and third days and the hammer life test was terminated. Failures were costly both in down time, and replacement of damaged screens.

Thin hammers were used successfully in another model of hammermill in the same feed mill. It was speculated that the reason for failure was due to the hammer striking a bolt head protruding through the screen. This was not confirmed.

CONCLUSIONS AND RECOMMENDATIONS

The energy and grinding rate advantages derived from the use of the thin (3.18 mm) hammers compared to the standard (6.35 mm) hammers were clearly evident in the results, which indicated a 13.6% specific energy conservation and a 11.1% grinding rate increase potential.

The measurement of the thin hammer lifetime was not possible due to premature hammer failure. Further experiments are needed to determine the causes of failure and if necessary improve the fabrication process to produce thin hammers having acceptable lifetimes.

ACKNOWLEDGMENT

This analysis was conducted using the data collected by Rothwell and Southwell (1986). Their project was funded by Agriculture Canada under the ERDAF program.

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Table V: Results of the test for hammer thickness effect evaluation.

Test No*	Specific energy ($kW{\bullet}h{\bullet}t^{-1}$)	Grinding Rate ($t{\bullet}h^{-1}$)	d_{gw} avg.# particle (µm)	S_{gw} std.+ deviation (µm)
S1	12.4	7.2	507	1.74
T1	10.2	8.4	491	1.73
S2	10.8	8.8	505	1.74
T2	10.0	9.2	503	1.71
S3	12.5	7.9	499	1.71
T3	10.4	9.4	497	1.77
S4	11.3	8.3	527	1.64
T4	10.0	9.1	554	1.67
S average	11.8 a$^{\Delta}$	8.1 b	510 a	1.71 a
T average	10.2 b	9.0 a	511 a	1.72 a

$^{\Delta}$Means with the same letter within a column are not significantly different at the 0.05 level.

#d_{gw}: geometric mean particle diameter (by weight) of sample.

+S_{gw}: geometric log normal standard deviation (by weight) of sample.

*S = standard, T = thin hammer.

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Erratum

Bjork, A. 1991. **A three-dimensional arithmetic model to calculate grain separation and losses for a rotary combine.** Canadian Agricultural Engineering 33:245-253.

Table I, page 250, had an error in the column headings; the table, with correction, is printed below.

Table I. Measured and computed data for the individual experiments

Run #	Rotor speed (rpm)	Feed rate, crop ($kg \cdot s^{-1}$)	s of regression* ($kg \cdot m^{-2} \cdot s^{-1}$)	Grain separation** computed ($kg \cdot s^{-1}$)	Grain separation** measured ($kg \cdot s^{-1}$)	Grain separation loss adjusted computed ($kg \cdot s^{-1}$)	Grain separation loss measured ($kg \cdot s^{-1}$)
10	700	6	0.180	3.08	2.65	0.056	0.052
29	700	6	0.059	2.59	2.64	0.042	0.046
34	700	6	0.199	2.48	2.48	0.053	0.052
5	700	8	0.168	3.69	3.26	0.258	0.589
30	700	8	0.089	2.93	3.33	0.067	0.078
14	700	10	0.307	3.78	3.97	0.405	0.330
23	700	10	0.209	3.88	3.97	0.536	<0.506
7	800	6	0.169	3.62	2.52	0.059	0.062
28	800	6	0.151	2.80	2.58	0.028	0.036
31	800	6	0.114	2.67	2.51	0.028	0.032
1	800	8	0.125	3.57	3.70	0.222	0.223
27	800	8	0.115	3.52	3.45	0.150	0.155
13	800	10	0.144	4.44	4.10	0.305	0.301
24	800	10	0.328	4.10	4.15	0.397	0.248
11	900	6	0.076	3.65	2.52	0.029	0.020
25	900	6	0.013	2.18	2.65	0.022	0.017
15	900	8	0.048	3.65	3.36	0.116	0.106
16	900	8	0.174	3.54	3.40	0.056	0.059
12	900	10	0.120	5.59	4.20	0.251	0.243
18	900	10	0.093	4.55	4.11	0.260	0.258
2	1000	6	0.059	2.71	2.70	0.022	0.021
17	1000	6	0.024	2.78	2.65	0.025	0.024
33	1000	6	0.057	3.17	2.84	0.021	0.019
9	1000	8	0.036	3.51	3.41	0.062	0.059
26	1000	8	0.039	3.80	3.31	0.060	0.052
32	1000	8	0.081	3.33	3.47	0.044	0.035
4	1000	10	n/a	n/a	n/a	n/a	n/a
19	1000	10	0.215	4.39	4.41	0.120	0.110
6	1100	6	0.071	3.08	2.66	0.012	0.016
21	1100	6	0.132	3.37	2.67	0.014	0.014
3	1100	8	0.189	3.13	3.50	0.068	0.091
20	1100	8	0.194	3.60	3.46	0.071	0.070
8	1100	10	0.054	4.70	4.16	0.125	0.125
22	1100	10	0.019	4.81	4.36	0.133	0.158

* Standard deviation for the non-linear regression of the average point grain separation of each segment, in direction parallel to the rotor axis.
** Grain separated through the concaves and separating grate.