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Project Summary

Significance of Size Reduction in Solid Waste Management: Volume 3 - Effects of Machine Parameters on Shredder Performance

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Hammermill shredders for size reduction of refuse were examined at three sites to determine the influence of key machine parameters on their performance. Internal machine configuration and single- versus multiple-stage size reduction were studied. Key parameters related to performance include the number and volume of hammers, open volume fraction, hammer tip speed, grate opening, open volume, and closed volume. The machine parameters were related to throughput, mill holdup, specific energy requirements, power draw, and product size using test data and curve-fitting analysis. Studies of both actual and hypothetical scenarios of single- and multiple-stage size reduction indicated that internal machine configuration and degree of size reduction can significantly affect energy requirements for refuse size reduction.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This study identifies the fundamental parameters that influence refuse size reduction and determines their effects on the performance of refuse shredding equipment. The work developed from earlier efforts to define fundamental comminution parameters and to define energy requirements for size reduction as a function of the size distribution of the shredded product.

In addition to investigating the relationship between energy requirement and product size, the report examines the influence of key machine parameters on hammermill performance. Internal configuration of the shredder and the factors that determine the propriety of single- and multiple-stage size reduction were studied. Refuse shredders at three sites were field tested to provide new data and to verify earlier research. The results of this work can be applied to the design of energy-efficient refuse shredding equipment and systems and to the selection of operating parameters for minimal energy use.

This study is one of several research projects conducted by the Municipal Environmental Research Laboratory (MERL) to investigate the size reduction of municipal solid waste (MSW). Other reports available or in preparation are:

Significance of Size Reduction in Solid Waste Management, Volume I, EPA-600/2-77-131 (PB 272-096);

Significance of Size Reduction in Solid Waste Management, Volume II, EPA-600/2-80-115 (PB 81-107-096);

Processing Equipment for Resource Recovery Systems, Volume III - Field Test Evaluation of Shredders, EPA-600/2-80-007c (PB 81-151-557);

Determination of Explosion Venting Requirements for Municipal Solid Waste Shredders (to be published in January 1983);

Engineering Design Manual for Solid Waste Size Reduction Equipment (to be published in February 1983).

Testing Program

Earlier research indicated that machine parameters such as grate spacing, number of hammers, etc., could potentially have a significant influence on the efficiency and performance of refuse size reduction equipment. This study identifies possible techniques that could be used to optimize both single- and multiple-stage shredding. The purpose of the research was to verify some of the findings presented in earlier studies and then determine the influence of various machine parameters on net energy requirements and particle size. The influence of machine parameters was determined by field testing of shredders located at refuse processing plants in Appleton, Wisconsin; Odessa, Texas; and Richmond, California.

Before the present study, published data were not available to correlate the performance characteristics of refuse shredders with the internal design of the machine. Consequently, even if the designer knew the particle size needed and the power required to produce it, he lacked knowledge of the analytical relationships that would enable him to calculate the proper internal configuration. The designer either depended on previous results from identical or similar shredders, or he designed a machine for which operation and performance could be varied. Thus, an analytical method was needed to design the internal configuration of a shredder. The availability of such a method would eliminate trial-and-error solutions and would potentially contribute to improved shredder design.

As part of the present research, data from current and past field tests have been combined and evaluated in terms of characteristic machine parameters. Consequently, throughput (mass of material shredded), mill holdup (the amount of material in the shredder at any instant), power draw, specific energy (net energy requirement per mass of throughput), and product size were identified as parameters that depend on the design of the shredder cavity and the internal hardware. Where possible, the approach has been to identify trends and methods for general analysis so that performance may be predicted for other operating conditions. The machine parameters evaluated consist of those typically encountered in the industry -- for example, hammer tip speed, grate opening, and number of hammers, as well as newly defined volumetric terms, such as total hammer volume, closed volume, open volume, and open volume fraction.

One of the previous findings was that the number of hammers appeared to affect energy requirements for size reduction. Specifically, the Newell* shredder in Odessa, Texas, required less specific energy for size reduction compared with other horizontal hammermills when the basis of comparison was the production of an equivalent product size. The difference in the energy requirement noted at that time was attributed to the relatively few hammers used in the Newell shredder (i.e., 14 versus the 24 to 48 hammers used in the other horizontal hammermills tested in the earlier study).

To identify the relationship between energy requirement and number of hammers, the study included field tests that varied the number of hammers in two different shredders. The test program established the dependence of specific energy (kWh/Mg) on the number of hammers through: 1) measurements of energy requirement and product size for different hammer complements (i.e., number of hammers), and 2) measurements of mill holdup as a function of material throughput.

Results

Total specific energy values for a matrix of single- and mutiple-stage design parameters were calculated using each of the procedures described as follows.

I. Specific energy was related as a linear function of product size. Product size was related as a linear function of throughput. These linear-derived relationships were used to describe specific energy and particle size graphically as a function of throughput.

II. Specific energy was related as a function of degree of size reduction and characteristic product size for the Richmond test data.

III. Specific energy was related as a function of degree of size reduction and grate spacing for the Richmond test data.

IV. Specific energy was related as a function of degree of size reduction and grate spacing for a large array of data collected from six hammermills.

Procedure I data show no significant difference in the specific energy requirements for single- versus multiple-stage size reduction. But data from Procedures II, III, and IV indicate that significant energy savings may be possible if grate size and mill sequence are optimized. Procedure IV is considered to be the most accurate method for general analysis. Analyses using this procedure indicate that large degrees of size reduction may require either single-stage reduction with a 5.1-cm grate spacing or two-stage reduction using a flail mill and a shredder with a 10.2-cm grate spacing for the most energy-efficient system. Additional test data are required to improve the accuracy of Procedure IV.

Analyses of the Appleton West and Odessa data indicate that no apparent relationship exists between the number of hammers and specific energy. But relationships were identified between the number of hammers and characteristic product size (screen size corresponding to 63.2 percent cumulative passing), freewheeling power (power necessary to maintain constant rotation of shredder rotor under no-load conditions), and net power (difference between gross power and freewheeling power).

Relationships between particle size and number of hammers could only be determined for the Appleton West tests. Product particle size decreased with increases in throughput. As the number of hammers increased, the product size decreased for throughputs above 20 Mg/hr.

Freewheeling power increased with the number of hammers. For the Odessa shredder, changing the number of hammers from 10 to 14 increased freewheeling power by more than 15 percent. Increasing the number of hammers from 24 to 40 at the Appleton West shredder produced no observable increase in freewheeling power

*Mention of trade names of commercial products does not constitute endorsement or recommendation for use.

requirements. But a change from 40 to 64 hammers increased the freewheeling power requirement by approximately 8 percent. Though additional freewheeling power requirement will not significantly affect the gross power requirements, energy savings may be realized by using the minimum number of hammers so that the operation and performance of the shredder is not impaired.

The net power requirement for the Odessa and Appleton West Mills increased with throughput for all hammer complements and decreased when more hammers were added. An increase in the number of hammers from 24 to 64 on the Appleton West Mill decreased net power by as much as 30 percent. The corresponding increase in freewheeling power requirement is relatively insignificant.

Discussion

The size reduction process may be affected by changing one or more of the shredder parameters considered (i.e., hammer tip speed, grate opening, number of hammers, total hammer volume, closed volume, open volume, and open volume fraction). The relationships developed in this study may be used to assess the potential consequences of making these changes. If the relationships were developed for a particular shredder, the consequences of varying the number of hammers, grate opening, or open volume fraction may be estimated for operating conditions near those originally used in the assessment. But the range over which the relationships for a particular shredder remain accurate must be determined through testing.

The derived relationships and equations may be used to help optimize shredder operations once an operating setpoint has been determined. And provided that a throughput or product size constraint has been established, a group of selected relationships may be used to establish whether or not the machine parameters are appropriate for obtaining maximum performance (i.e., low energy consumption).

Available test data were used to plot specific energy as a function of degree of size reductio[redacted]spacing. This relationship ap[redacted]e value as the basis of a method for predicting specific energy requirements for single- and multiple-stage size reduction.

A study of the specific energy requirements of various single- and multiple-stage processes concluded that the most energy efficient systems for size reduction are: (a) single stage size reduction using a 10.2-cm grate spacing, and (b) a flail mill primary shredder supplemented by a secondary shredder with optimized grate spacing. The process is for producing characteristic product sizes ranging from 0.85 to 2.0 cm.

For shredder throughputs in excess of 20 Mg/hr of MSW, characteristic product size increased significantly as the number of hammers decreased on the shredders tested. For a constant characteristic product size, throughput and net power requirement for size reduction tend to increase with a decrease in the number of hammers.

No significant changes in specific energy requirements were observed for a decrease in the number of hammers. Consequently, the use of as few as 10 hammers (as opposed to as many as 64) appears to be possible without adversely affecting shredder operation or performance. Decreasing the number of hammers may have significant maintenance and cost benefits.

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Carlton C. Wiles *is the EPA Project Officer (see below).*

The complete report, entitled "Significance of Size Reduction in Solid Waste Management: Volume 3. Effects of Machine Parameters on Shredder Performance," (Order No. PB 83-154 344; Cost: $11.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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