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SLUDGE DEWATERING BY IMPULSE DRYING

Michael Zawadzki, Talat Mahmood, Sujit Banerjee
Institute of Paper Science and Technology
500 10th Street, NW
Atlanta, GA 30318

ABSTRACT

An innovative and energy efficient sludge dewatering technology has been developed. The technology, impulse drying, involves briefly contacting the sludge under pressure with a heated surface. A unique feature of impulse drying is that the majority of moisture removal occurs as liquid water.

A pilot- and laboratory-scale demonstration was performed on low ash primary paper mill sludge. The pilot-scale impulse dryer was able to increase the sludge solids level 23.2% greater than belt pressing alone. The pilot scale equipment was not optimized, and further gains are expected. Laboratory-scale demonstrations suggest that impulse drying is effective on a wide variety of sludge types: primary (high and low ash), secondary, and mixed sludges.

Impulse drying efficiency depends upon the presence of sufficient moisture in the sludge. Preliminary results indicate that the process is effective for sludges with initial solids content in the range of 15 to 50%. Since, a sludge solids content of 30% is typical of the performance of an inexpensive belt press, these experiments demonstrate the potential of retrofitting existing belt presses with an add-on impulse dryer. A high percentage of liquid water removal is achieved by the impulse drying process, which gives the technology an economic advantage relative to thermal drying. The liquid water removal has major cost reduction potential for either sludge burning or landfilling.

INTRODUCTION

Since the 1980s, impulse drying has been under extensive development in the field of paper drying (Lavery 1987). Essentially, the impulse drying process involves pressing in a nip between heated and unheated rolls. Paper impulse drying involves pressing a moist paper sheet with a felt against a heated roll (200 to 350°C). Nip dwells of less than one second are generally used. Impulse drying induces an intense dewatering process that gives a higher dryness level than (wet) pressing, and it is more energy efficient than thermal drying. Unfortunately, for paper impulse drying, the useful range of operating conditions is limited by sheet delamination and product quality concerns (Crouse, Woo, and Sprague 1989; Orloff 1992). Sludge dewatering is an ideal application for the impulse drying technology because sludge delamination is not a concern. This paper describes recent work being done at the Institute of Paper Science and Technology (IPST) on the application of impulse drying to the field of sludge dewatering.

The water removal mechanism of impulse drying is different from that involved in either thermal drying or pressing. A combination of related phenomena likely contributes to dewatering.

Initially, impulse drying involves a compression and heating period during which the unsaturated material is mechanically compressed. In wet pressing, the water removal is limited by the compressibility of the web. The higher temperatures used in impulse drying may increase material compressibility and allow more water to be pressed out. Also, at high temperature, the viscosity of water is reduced and, therefore, more easily pressed from the small pores of the sludge matrix. The intense heat transfer may result in the generation of a vapor zone near the heated surface. One of the unique mechanisms of impulse dewatering is thought to be the creation of a vapor phase within the sheet that displaces sheet moisture as liquid water (Lavery 1988).

EXPERIMENTAL

Belt pressed sludge was acquired from Hollingsworth and Vose's (H&V) Hawkesville, Georgia, paper mill. The H&V sludge was determined to have an initial solids content of 33 ± 1% and an inorganic ash content of 4.2 ± 0.1% (ashing at 525°C). The sludge is broadly characterized as a primary sludge composed of fiber, filler, and inorganic components.

At the paper mill, sludge was sampled as it emerged from the belt press. The sludge samples were taken as intact sheets and stored on melamine coated 1 foot by 4 foot boards. Immediately after sampling the sludge was sealed with PVC plastic to avoid moisture loss. The sludge samples were stored separately to avoid compression during transport and storage.

The pilot scale experiments were performed on the IPST pilot-scale paper impulse dryer (**Figure 1**). The purpose of these experiments was to access scale up from the one-dimensional laboratory study to the two-dimensional pilot impulse dryer. The pilot equipment used an inductively heated top roll, grooved lower roll, and a metal wire. The wire run was 26 feet and had a width of 18 inches. The stainless steel wire was supplied by National Filtration (510 cfm airflow, 70 gal/min water flow rate). Both upper and lower rolls were 24 inches in diameter with a 24-inch width. Peak nip pressure was verified using a TekScan 5501 pinch roll sensor. The pinch roll sensor was calibrated over a range of known pressures using the laboratory-scale electrohydraulic press. Static nip measurements were made on the pilot impulse dryer to provide a measure of peak pressure, nip width, and pressure uniformity.

Comparison experiments using the same batch of sludge were performed in the laboratory on an electrohydraulic Material and Testing Systems (MTS) press. The MTS press system used flat stainless steel platens. The MTS press system was configured to simulate both the thermal and mechanical pressure profiles of the pilot-scale equipment. A haversine pressure profile was used during the study.

RESULTS and DISCUSSION

H&V sludge was impulse dewatered in a laboratory study, and results are presented in **Figure 2**. This figure reveals that increasing peak nip pressure and upper platen temperature both give greater dewatering. The lower line in **Figure 2** represents dewatering at room temperature. For the laboratory case, room temperature pressing gives little additional dewatering of previously belt-pressed sludge.

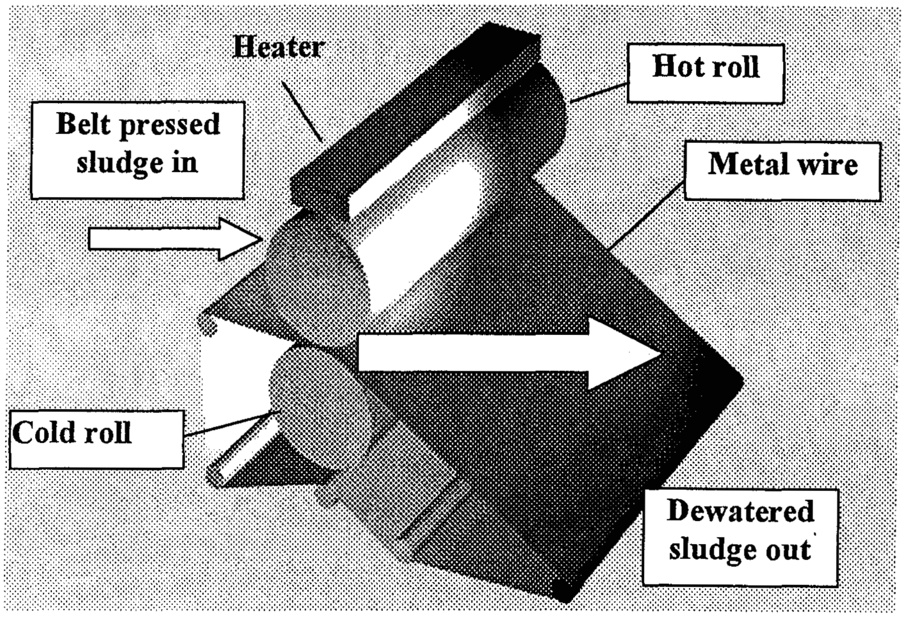


Figure 1: Schematic of the sludge impulse dewatering pilot scale equipment.

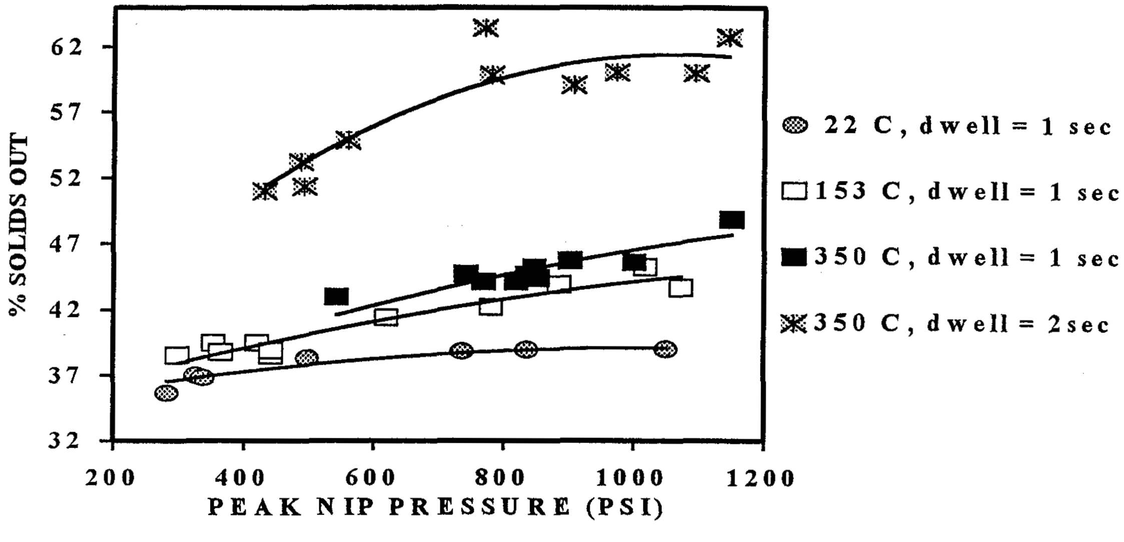


Figure 2: Impulse drying H&V primary sludge in a laboratory demonstration.

Impulse drying at 200°C (**Figure 2**, data not shown) gave 5.8% greater final sludge solids than room temperature pressing (dwell = 1 sec, P≅700 psi). By using mass balances, the amount of liquid water removal from the sludge was calculated. For the 200°C case 82±6 % of the moisture was removed as liquid water. This estimate of liquid water removal is expected to underestimate the actual amount of liquid water removal because some liquid water is lost on the platen surfaces.

At 350°C, 6.7% greater solids were achieved relative to room temperature pressing (dwell = 1 sec, P≅700 psi), and 57 ± 6% of the moisture was removed as liquid water. The upper line in **Figure 2** represents dewatering with a two-second nip dwell. In this case, the final sludge solids content achieved was 60% (P=780 psi) with 45 ± 7% liquid water removal.

The results of the pilot-scale investigation are shown in **Figure 3**. The general trend of water removal is similar to that of the laboratory case. The nip dwell for the pilot-scale data presented in **Figure 3** was one second. For the pilot-scale equipment, a one-second dwell corresponds to a linear wire speed of 10 feet per minute.

At a peak nip pressure of 707 psi room temperature pressing was able to achieve a 44.3% final solids content. By increasing the upper roll temperature to 200°C a final solids content of 51.7% can be achieved. The greatest percentage solids, 56.2%, are achieved by using a roll pressure of 820 psi. Clearly, the pilot study has demonstrated that the solids content of 33% belt pressed sludge can be increased 23.2% by the impulse drying technology.

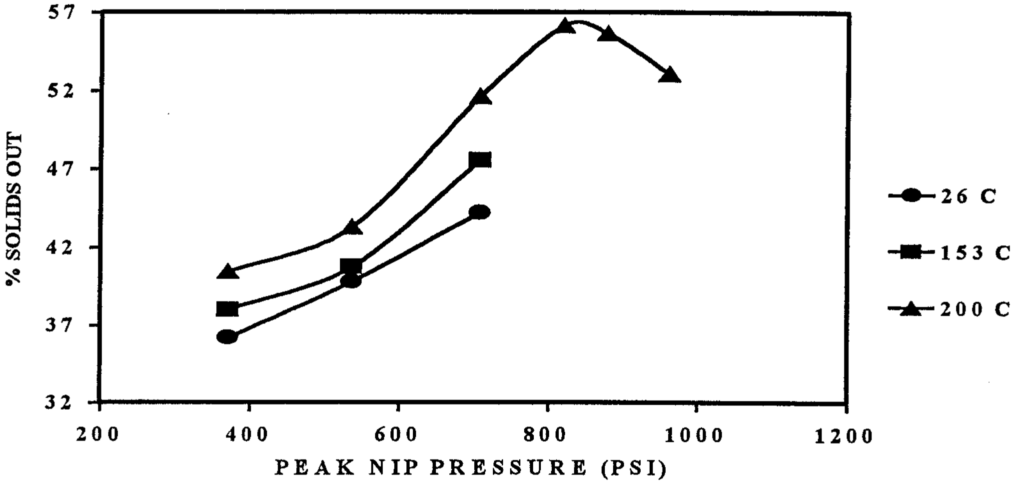


Figure 3: Impulse drying H&V primary sludge in a pilot-scale demonstration.

Figure 4 illustrates the influence of sludge initial solids on final solids after either pressing (25°C) or impulse drying (350°C). The results were acquired in a laboratory study with a nip pressure of 800 ± 200 psi and a nip dwell of one second. Data in the white region of the figure represent dewatering conditions under which final sludge solids are greater than the initial values. Pressing alone achieves little additional dewatering over the range of initial solids studied. Impulse drying was more effective than pressing alone. Impulse drying is effective over a wide range of initial solids contents with efficiency being lost only at high dryness levels. Liquid water removal for the impulse drying case was found to be approximately 80% (**Figure 4**).

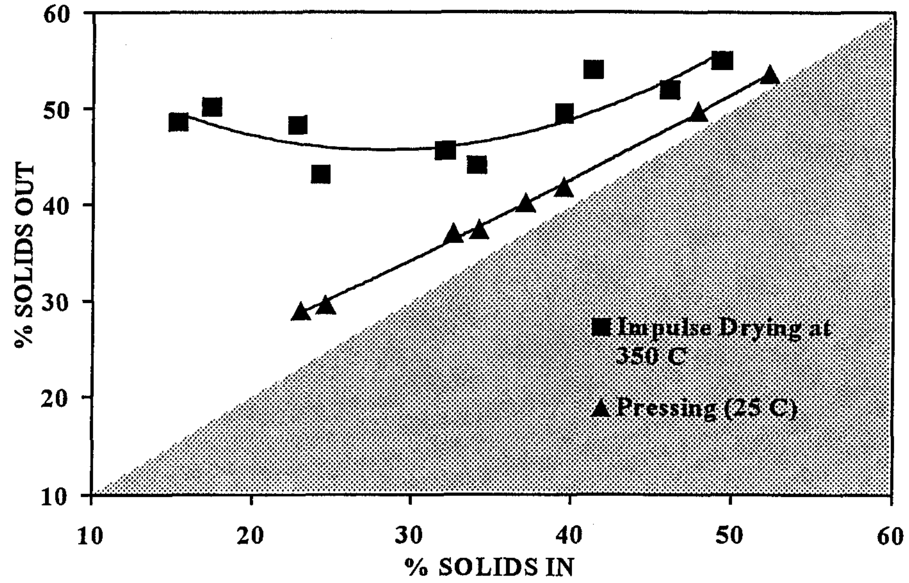
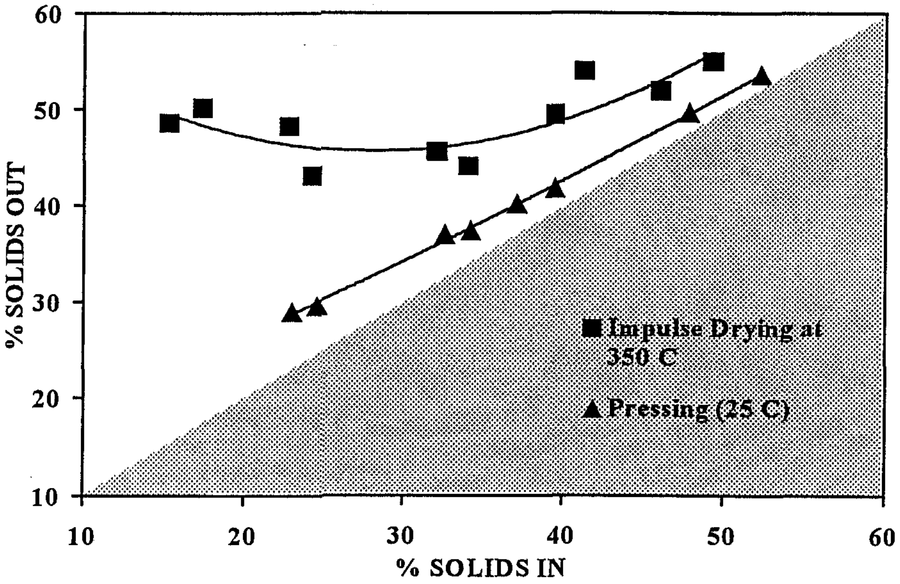


Figure 4: Sludge initial solids contents versus final solids for impulse drying and wet pressing.

Impulse drying offers the advantage of increasing the solids content from previously belt-pressed sludge. Both the laboratory and pilot studies display similar dewatering trends, but greater dewatering is observed in the pilot configuration. With increasing roll temperatures, similar increases in sludge solids were observed for both MTS and pilot studies. The laboratory study appears to simulate the results of the pilot study if the influence of pressing alone is considered.

From the pilot trial, a further advantage of the impulse drying technique was noted. Attempting to dewater previously belt-pressed sludge at temperatures below 150°C resulted in sticking of the sludge to the wire and blinding the wire. It was found that under impulse dewatering conditions (>200°C) sticking of the sludge to the roll or wire did not occur. It is hypothesized that steam generated by the impulse drying process prevents sludge from sticking to the wire. Similarly, sticking has been observed in the laboratory experiments. Therefore, there is likely a practical limit to the level of pressure alone that can be used to increase the sludge solids content. Impulse drying can be used to extend the range of practical pressures and increase sludge solids.

From the laboratory impulse drying study (200°C, dwell = 1 sec), 82 ± 6% of the sludge moisture was removed as liquid water. Increasing the roll temperature to 350°C resulted in liquid water removal of 57 ± 6%. Therefore, high liquid water removal is observed over a range of practical roll temperatures. The high liquid water removal suggests that the impulse drying process can have an economic advantage relative to sludge thermal drying. Impulse drying is energetically favorable because liquid water removal does not involve energy introduction to overcome the enthalpy of vaporization of water. The liquid water removal has major cost reduction potential for either sludge burning or landfilling.



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Experimental results suggest that the technology is useful for a wide range of sludge types: primary (high and low ash), secondary, and mixed (Banerjee et al., 1997; Banerjee, Phelan, and Foulkes, 1996). Impulse drying has been successfully applied to municipal waste activated sludge (City of Houston, TX). The belt-pressed sludge was supplied at 16% solids, and impulse drying (350°C, dwell = 0.7 sec) gave an approximately 10% increase in the solids content. Mixed primary paper mill and secondary sludge (~50:50) benefited from impulse drying. A nip dwell of 0.5 seconds and a roll temperature of 200°C were able to give a 15% increase in the solids level. Finally, high ash primary papermill sludge was investigated. Preliminary pilot and laboratory results reveal that the dewatering behavior is similar to H&V sludge, and again, the pilot-scale configuration is more effective than the laboratory.

ACKNOWLEDGMENT

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