Some Physical Characteristics of Sugar Crystals Affecting Dust Formation

SOULY A. FARAG, CHARLES L. SCHMALZ AND LLOYD W. NORMAN[1]

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Summary

The compressive and impact strength of sugar crystals were studied after a method for measuring the dust had been developed. The amount of sugar dust in a sugar sample was obtained as follows:

The sugar sample was added to a solution of sucrose saturated isopropyl alcohol and lightly agitated. This caused the suspension of the finely divided sugar particles which we have labeled as dust. Careful decanting of three to five portions of sucrose saturated isopropanol off of the sample allowed quantitative removal of the sugar dust. The combined supernatant was then filtered through a tared membrane filter. Then by drying the filter to a constant weight, the percent dust in the sample could be calculated. Two bench instruments were devised to measure the compressive and impact strengths. Those instruments enabled us to obtain objective measurements of greater precision and validity than the subjective techniques previously used.

Measurements in our laboratory have shown that sugar handling loading and shipment may increase dust levels three to five times the level in the original product from the granulator. Also the study indicated a tendency for some sugars to form dust more readily than others.

Subsequent tests showed:

1. The compressive strength is inversely proportional to the square root of the surface area. On the other hand impact strength is independent of the average crystal surface area.
2. Heating produced no significant difference in the compressive strength meanwhile it lowered the impact strength significantly.
3. Lower relative humidity improved both compressive and impact strengths and consequently lowered the dusting characteristics.

Introduction

Sugar dust is not only a nuisance both to the customer and the producer, but it also represents a financial loss and a poten-

[1] Research Chemist, Research Chemist and General Chemist-Operating Research Manager, respectively, Utah-Idaho Sugar Company, Moses Lake, Washington 98837.

tial fire hazard. Sugar dust affects the quality and therefore the acceptability of the product by certain customers.

Objectives

1. To study some physical characteristics of sugar crystals which might affect dust formation.
2. To assist the plant in utilizing this information and to improve conditions in order to minimize dust formation.

Dust formation:

Powers (1960) showed that the major cause of dust formation was rapid drying of the thin film of syrup left on sugar crystals after spinning which deposits fine sugar particles on the crystal faces (2)[2]. Other workers have explained on a theoretical basis that unfavorable phenomena, such as caking and dust formation may be caused by conditions which exist during the drying process. These are caused by the supersaturated film on the crystal (1). This was demonstrated in our laboratory by washing a wet sugar sample several times with alcohol to remove this supersaturated layer. The sample was then dried in a laboratory granulator. Clean crystals resulted and negligible amount of dust was detected (0.02%).

A further study of dust formation by tumbling was as follows:

A wet sugar sample was taken from the spinner, then dried in a bench granulator at 120° C. The amount of dust was determined as .054% The sample was then treated for four hours in a conditioning bin model using dry air. Percent dust was determined as .060. To show the effect of physical movement, the sample was then tumbled in a plastic bottle for 15, 60 and 120 minutes. The results are shown in Figure 1.

Dust measurement:

Finely divided particles of sugar that can be suspended in air may be called dust. However, it is difficult to measure the quantity of this dust or even specifically define what is dust and what is not. For our purposes dust was defined as the finely divided particles of sugar which can be suspended in isopropyl alcohol saturated with sugar; which are recoverable by filtering with a 5 micron membrane filter.

The following method was developed:

Equipment and reagents:

1. A filter flask equipped with a membrane filtering apparatus, millipore No. XX10-047-00.
2. Membrane filters 47mm diameter. Gelman VM-1; 5 micron pore size.
3. 200 mesh stainless steel screen.

[2] Numbers in parentheses refer to literature cited.

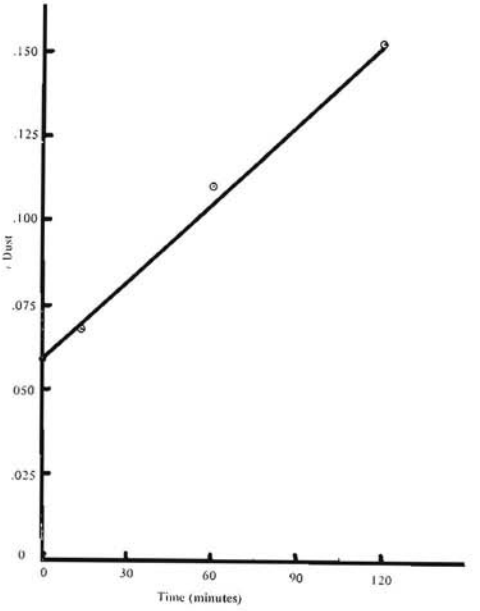

Figure 1.—Effect of tumbling on dust formation.

4. Sugar saturated isopropyl alcohol (IPA).

Procedure:

1. Add a weighed quantity (5 grams) of sugar sample to a convenient volume (100 ml) of isopropyl alcohol saturated with sugar.
2. Stir gently for a few moments and then allow sugar to settle. It will be noted that finely divided sugar or dust will be suspended in the alcohol.
3. Decant the supernatant solution making sure that individual crystals are excluded. To assure this, the suspension may be poured through a 200 mesh screen.
4. Repeat stirring and decanting with fresh saturated IPA until the supernatant liquid becomes perfectly clear.
5. Filter the combined supernatant portions through a tared 5 micron membrane filter, dry in 70° C oven to constant weight. This required no more than 10 minutes. Cool in a desiccator and weigh.
6. Calculate the weight of the particles obtained on the filter as percent on the original sample as follows:

$$\frac{\text{weight of dust on filter} \times 100}{\text{weight of sample}} = \text{percent dust in sample}$$

This method when closely followed yields reproducible results (precision of ± 5%).

Compressive strength:

The compressive strength is a measure of the crystals resistance to breakage. The greater the compressive strength the less will be the tendency to form dust. In order to measure the compressive strength a method of measuring compressive strength of individual crystals was developed.

Equipment:

1. Stereo microscope 10X.
2. 25 lbs strain gauge cell.
3. Light source.
4. High power microscope, B&L dynoptic or equivalent.
5. Photomicrograph equipment.
6. Polaroid film type 47.
7. Measuring magnifier – Van Waters & Rogers #36925-004.

Procedure:

The instrument used was a load cell connected to a recorder, the recorder needle indicating the static load applied (Figure 2). The procedure which we have adopted is as follows:

1. Select approximately 100 crystals of uniform size and shape by means of a low power microscope.
2. Measure the average surface area on a sufficient number of crystals to obtain representative information.
3. Place the crystals one at a time between the bearing blocks of the load cell and apply a gradually increasing force. A light beam is focused laterally upon the crystal being examined and the transparency of the crystal is carefully watched. As sufficient force is applied, the crystal fractures and transparency change occurs. The force at this point as measured by the load cell is taken as the compressive strength of the crystal.
4. Calculate the compressive strength in grams/mm^2.

$$\frac{\text{force at point of fracture (grams)}}{\text{surface area (mm}^2\text{)}} = \text{compressive strength}$$

Impact strength:

In addition to compressive strength the brittleness of crystals or resistance to impact should also have some bearing on dust tendency.

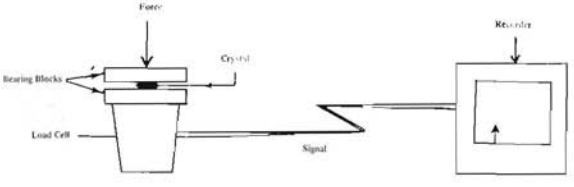

Figure 2.—Compressive strength apparatus.

Both compressive and impact strength of different sugars may vary with a number of factors such as temperature, relative humidity and shape or size factors.

The impact strength was measured on samples of screened sugar which had been well washed with IPA and dried in a 70° C vacuum oven. An apparatus was constructed for measurement of impact strength. A diagram of this apparatus is shown in Figure 3.

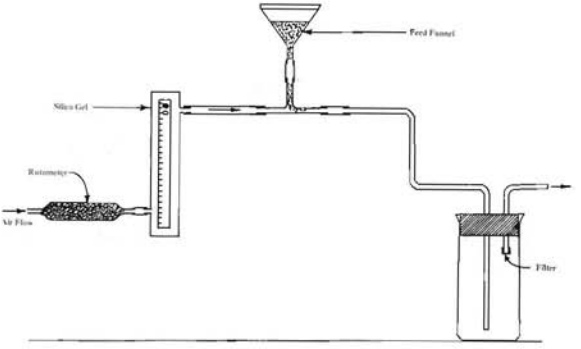

Figure 3.—Impact strength apparatus.

Procedure:

1. Place a convenient amount of the sugar sample (25 grams) in the feed funnel of the apparatus.
2. Aspirate the sample from the funnel with dry air at a constant velocity.
3. Pass the moving sugar through suitable glass tubing with right angle bends to increase the number of points of impact, and discharge vertically to the bottom of the receiving breaker which is the point of greatest impact. The air used to blow the sugar is dried with silica gel and moved at a constant rate shown by a rotameter. The beaker edges should be sealed with parafilm and the feeding funnel covered with a plastic lid to prevent dust leakage. The beaker has a filtered outlet to allow escape of the air. The air velocity used was 580 cm/sec. The glass tubing used was of 90 cm total length with three right angle bends. The distance from the glass tubing end to the bottom of the receiving beaker was 2 cm.
4. When the entire sample has been passed through the apparatus, wash both apparatus and collected sugar with saturated IPA and measure total quantity of dust formed by the method previously described.
5. Take the reciprocal of the percentage of dust as a measure of impact strength in arbitrary units.

$$\frac{1}{\%\ \text{dust formed}} = \text{impact strength}$$

Table 1 shows the compressive and impact strengths of carefully sized screened sugar from different processing plants. The results correlated directly with each other. The crystals from plant A have low compressive and impact strengths. It was postulated that several factors may affect the compressive and impact strengths, and therefore the dusting characteristics. Among these factors may be the methods of crystallization, drying and storage conditions of the final sugar. We have measured the effect of crytal size, heating and relative humidity upon both compressive and impact strengths of sugar crystals.

Table 1.—The compressive and impact strength in sugar from different plants.

Plant	Compressive strength	Std. dev.	Impact strength	Std. dev.
A	1326	32	11.0	.78
B	1552	36	17.7	1.08
C	1354	43	11.6	.82

Compressive strength is given in g/mm² and impact strength is in arbitrary units as previously shown.

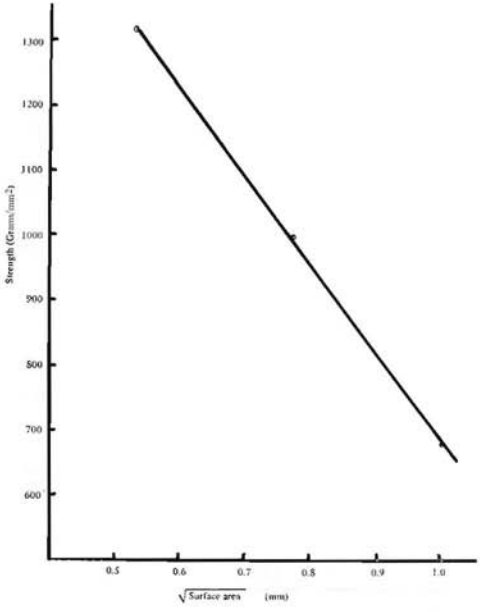

Figure 4.—Effect of crystal size on compressive strength.

1. *Average crystal size*

A sugar sample from plant A was screened through number 18, 25, 30 and 40 screens. The different portions were then

well washed with IPA and dried at 70° C under vacuum. Photomicrographs were used to determine the average surface area for each portion. Our results showed that the compressive strength is inversely proportional to the square root of the surface area (Figure 4), while the impact strength is approximately the same regardless of crystal size (Figure 5).

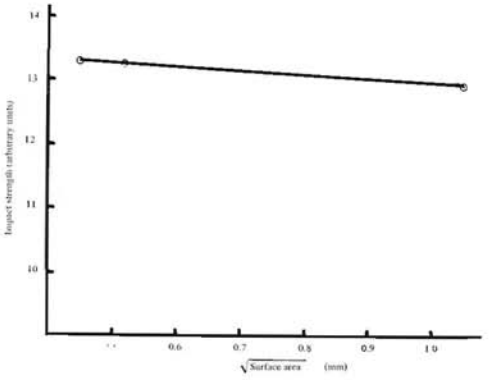

Figure 5.—Effect of crystal size on impact strength.

2. *Heating*

Sugar samples from different plants were screened through #18 and #25 mesh screens, washed with IPA and dried for two hours at 70°C under vacuum. The samples were cooled and the compressive and impact strengths determined. After heating for 22 hours more at 70° C, the samples were rechecked for their compressive and impact strengths.

The results showed a relatively small difference in the compressive strength due to heating at 70° C. (1326 g/mm^2 for the original sample versus 1477 g/mm^2 after heating for 22 hours.)

However the impact strength was significantly lowered by heating (Table 2). This may be due to formation of cracks within the crystals.

Table 2.—Effect of heating on impact strength (Arbitrary units).

Sample	Unheated	Heated (22 hrs at 70°C)
1	17.7	12.7
2	13.3	9.6
3	11.6	7.8

3. *Relative Humidity*

Samples were placed in vessels for 76 hours at different relative humidities. It seems that drying over a dessicant hardens the crystal. There was a noticeable increase in both compressive and impact strength at 0% relative humidity (Figure 6 and 7).

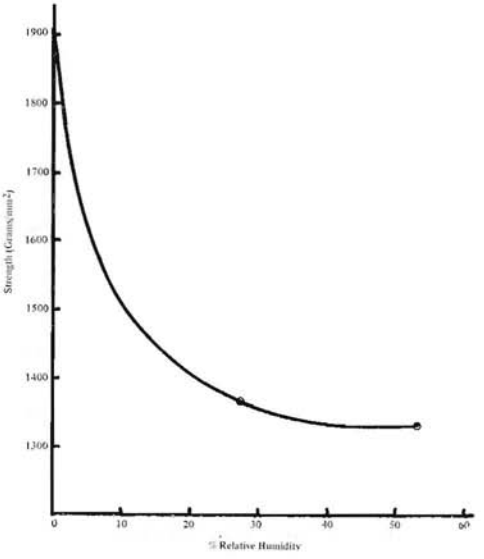

Figure 6.—Effect of R.H. on compressive strength.

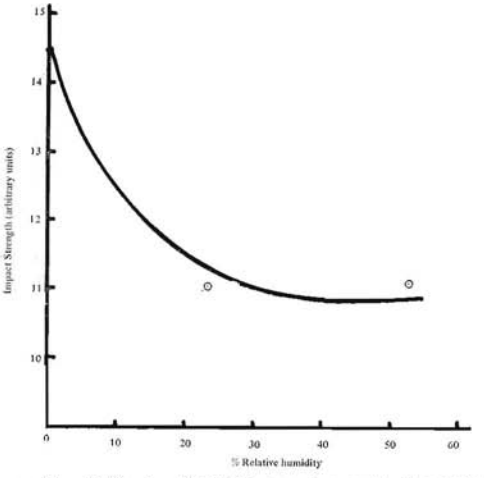

Figure 7.—Effect of R.H. on impact strenght.

Further evidence of the effect of moisture in the crystals is shown by Figure 8. Perfectly dry crystals were exposed to the atmosphere for 30, 60, and 90 minutes. The compressive strength decreased with time as moisture was picked up from the atmosphere.

Another example of the effect of moisture in the crystals was shown by cooling a sample under two different conditions. One portion was held over a desiccant and the other exposed

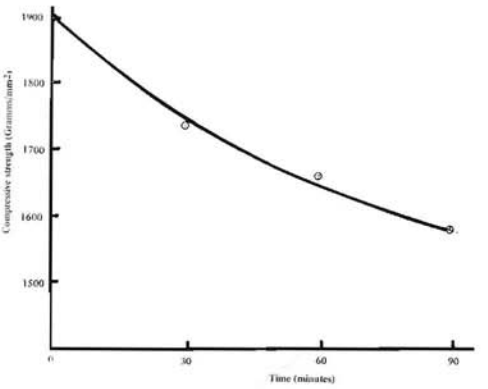

Figure 8.—Effect of Moisture absorption on compressive strength.

to the atmosphere. In the second case the sample gained moisture from the air and showed a lower impact strength, 9.6 arbitrary units versus 13.9 for the sample in the dessicator.

Conclusions

Methods have been developed to measure dust percent, compressive strength and impact strength of sugar crystals.

Measurements by these methods show:

1. Different sugars from different production areas varied in their dusting characteristics.
2. The crystal size has very little influence on the impact strength but a marked effect on the compressive strength.
3. Heating has more effect on the impact strength than on the compressive strength.
4. Relative dryness of the crystals has a marked influence on both compressive and impact strength.

Literature Cited

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