An Electronic Recording Grain Research Laboratory Mixer[1]

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ABSTRACT

An electronic attachment to convert a 200-g. mixer to a recording mixer is described. A strain-gage transducer detects the reaction of the motor casing to the mixing torque. The recording system can be calibrated for full-scale torques ranging from 2,000 to 30,000 cm.-g and provides a record of the mixing torque within ± 2%. A typical result is shown to demonstrate the apparatus. The mechanical efficiency of the mixer mechanism is determined so that the torque and energy used to mix the dough can be accurately determined.

The recording mixer has long been associated with cereal quality measurements since it was introduced by Hogarth—a Scottish miller—in 1889 (1). Since that time a number of instruments have evolved such as the Valorograph in Hungary, the Farinograph in Germany, and the Mixograph in the U.S. These use a mechanical dynamometer to record the torque to mix doughs. A simplification of the dynamometer mechanism was the use of a watt meter to record the power input to the electric motor which is proportional to the mixing torque. Hankoczy described such an arrangement in 1927 (2), and others have been reported (3). The Grain Research Laboratory is standardized on a specially developed unit (4).

New baking processes requiring mechanical dough development have, in recent years, brought increased emphasis to the measurement of the energy-absorbing characteristics of doughs as the process relies on applying an optimum level of work to the dough (5,6). Recent work has shown the value of accurate

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measurement of the intensity (7) and rate of energy input (8) to the dough and the mechanical efficiency of the mixer mechanism (9).

The use of a strain-gage transducer to record torque has several advantages, in particular instances, when compared to the power meter method (10). This technique has been used to convert a Mixograph (11), Farinographs (12,13), Hobart mixers (14,15), an Amylograph (16), and a Brabender Prep Center (17). This work demonstrated that precise repeatable results can be obtained, and energy absorption of the dough can be recorded directly (18,19,20). These methods have been applied to laboratory flour samples ranging in weight from 1 to 300 g.

The GRL (Grain Research Laboratory) 200-g. mixer (GRL-200) was previously converted to record electronically using a transmission-type electronic dynamometer (15). This adaptation, however, was expensive. Because the GRL-200 has wide application, and has since been improved mechanically, a simpler means of adding an electronic transducer was developed and is described here.

MATERIALS AND METHODS

The mixer used was a GRL-200 (maximum capacity 200 g. of flour) that was described in 1955 (21). The gears and bearings in the mixing head were modified to reduce friction and increase the mechanical efficiency. The input shaft to the mixing head was driven by a variable speed 0.25 hp. motor (Type NSH-55 with type W-63 control, Minarik Electric Co., California) via a notched belt and pulleys to provide mixing speeds up to 140 r.p.m. at the outer pins.

The motor was removed from the base and the ends of its housing machined to fit ball bearings. The motor was then mounted in a cradle attached to the mixer base which supported the bearings so that the motor housing was free to rotate (Fig. 1A). A beam made of hardened tool steel 2 cm. wide, 0.3 cm. thick, and 11 cm. long was attached at one end to the base adjacent to the motor (Fig. 1B). A horizontal lever (G) was attached to the end of the motor housing and connected to the free end of the beam by a link (F) with universal bearings at each end. Thus, the motor housing was prevented from rotating, and its reaction torque imposed on the beam. The link was connected to the lever at a radius of 10 cm. from the motor centerline, and the lever extended so that calibration weights could be applied at a radius of 20 cm. (Fig. 1B). The link was connected to the free end of the beam 6 cm. from its base clamp. When the motor was driving the mixer, the reaction of the motor casing forced the end of the beam down towards the base. To prevent damage under overload conditions, a screw was installed at the free end of the beam and adjusted so that it contacted the base at a selected torque to limit deflection of the beam.

Four strain gages were bonded to the beam close to the clamped end to make the beam into a force transducer (22). These simple arrangements added a dynamometer to the standard mixer. The strain gages were connected to an amplifier (C, Fig. 1A) and strip-chart recorder (D) with a full-scale pen response time of 8 sec. so that torque could be recorded against time (10) on a rectilinear chart 250 cm. wide. The dynamometer was calibrated by applying weights to the lever (Fig. 1B) and adjusting the amplifier so that the chart could be read in convenient units, e.g. 0 to 10,000 centimeter grams (cm.-g.). Calibrations were performed with the motor running so that the no-load friction in the mixing head gears was tared from the measurements by the amplifier zero adjustment.

A 15-tooth sprocket (A, Fig. 2) was mounted on the input shaft to the mixing head with an electromagnetic pulse generator (B) (Model 3025; Electro Products

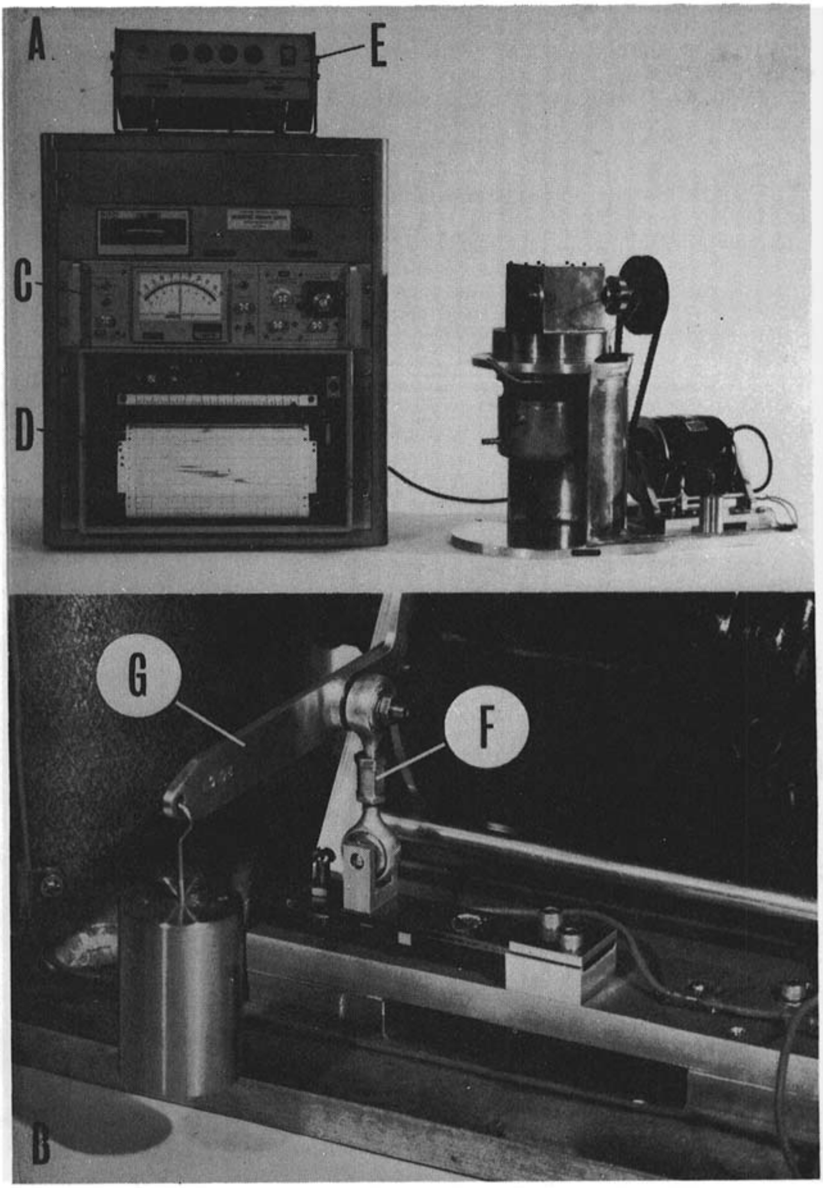

Fig. 1. A) The converted mixer; B) the transducer installation; C) strain gage amplifier; D) strip-chart recorder; E) digital tachometer; F) link; G) lever attached to motor casing.

Laboratories Inc., Chicago). For each rotation of the shaft 15 pulses were produced and applied to a solid state digital tachometer (E, Fig. 1A) (Model 2705; Electronic Research Co., Kansas) to directly indicate the rotational speed of the mixing pins.

INSTRUMENT PERFORMANCE

The relationship between mixing speed and speed control dial setting was determined and found to be linear within ±1% (Fig. 3). A mixing speed could be selected at the dial, and the exact speed set by only minor dial adjustments. Under no-load conditions the mixing pin speed was found to vary with time by a maximum of ±0.6 r.p.m. over the operating range (Table I). When mixing a standard sample (200 g. hard wheat flour + 130 cc. water), the maximum variation during a test ranged from ±1.0 to ±3.4 r.p.m. depending on the speed selected (Table I). The greatest change occurred when mixing at the highest test speed (130 r.p.m.). However, because the digital tachometer could be read to within 0.1 r.p.m., it was easy to readjust the mixing speed and keep it constant throughout a test. Since mixing torque is proportional to mixing speed, this adjustment is critical for samples where accurate results are needed.

It was found possible to calibrate the dynamometer so that full-scale pen

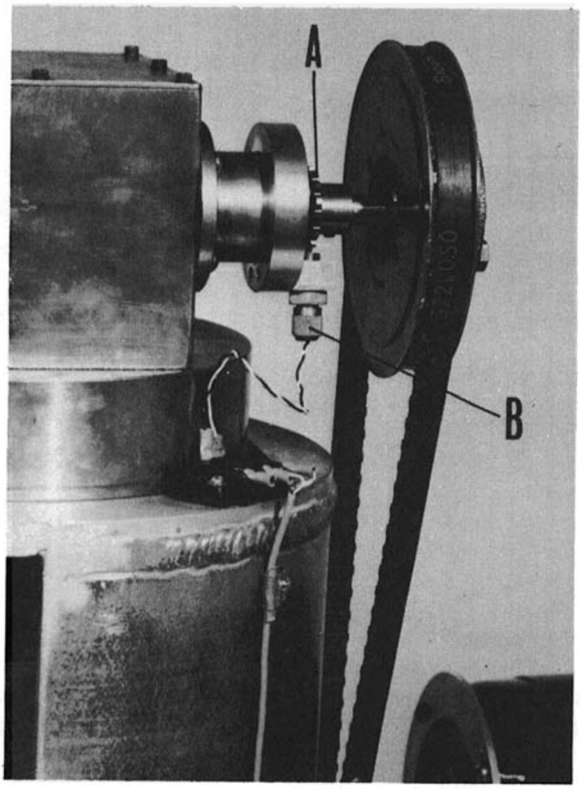

Fig. 2. Mixing speed detector. A) 15-tooth sprocket; B) pulse generator.

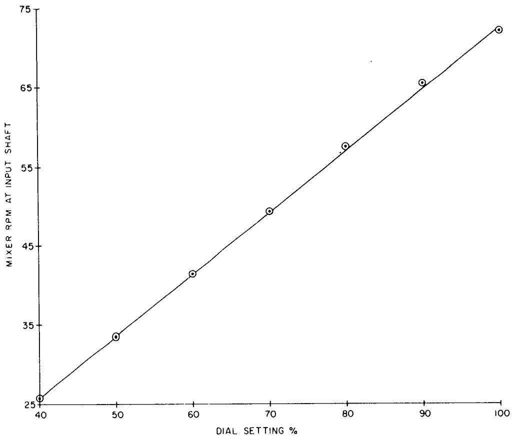

Fig. 3. Mixing speed vs. motor speed control dial setting.

TABLE I. MIXING SPEED CONTROL

Nominal Outer Pin Speed r.p.m.	Speed Changes No-Load r.p.m.	Speed Changes during Mixing[1] r.p.m.	Maximum Torque[1] cm.-g.
56	±0.6	±1.3	6,400
94	±0.4	±1.0	8,200
130	±0.4	±3.4	10,200

[1]200 g. hard wheat flour + 130 cc. water.

TABLE II. LINEARITY AND HYSTERISIS OF RELATIONSHIP BETWEEN TORQUE AND CHART READING SHOWN AS MAXIMUM DEVIATION FROM A STRAIGHT LINE. MEASURED WITH MIXER RUNNING

Full-Scale Torque cm.-g.	Maximum Deviation %
2,000	±0.5
4,000	±2.5
10,000	±2.0
20,000	±0.5
30,000	±0.5

deflection was produced for torques ranging from 2,000 to 30,000 cm.-g. Application of calibration weights in increments (10), with the motor running, showed that the relationship between pen deflection and torque was linear within a maximum error of ±2.5% (Table II). The errors increased as the dynamometer sensitivity was increased because the friction in the bearings supporting the motor became greater relative to the applied torque.

To operate the recording mixer, the speed was selected and the dynamometer

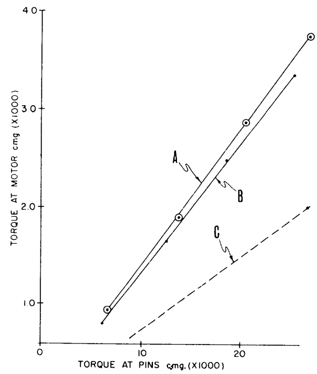

Fig. 4. Illustration of the effect of mixing speed on the efficiency of the mixer mechanism. A) 130 r.p.m.; B) 70 r.p.m.; C) theoretical friction-free slope determined from the mechanical advantage relationship between motor and mixing pins (13.33:1).

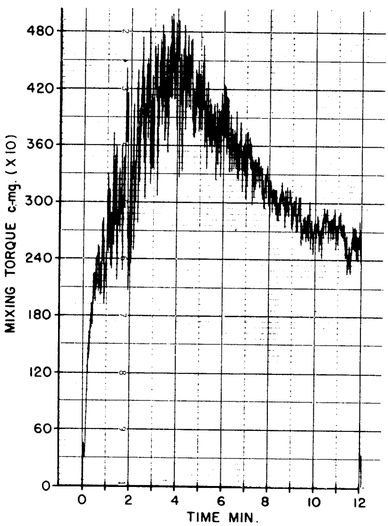

Fig. 5. Typical record obtained in mixing hard wheat flour at 130 r.p.m.

calibrated with the mixer running at this speed. Thus, zero on the recorder scale represented the torque required to drive the mixing mechanism under no load at the selected speed, thus eliminating this error from the measurement. The efficiency of the mechanism, however, varied with mixing speed and the torque transmitted through the gears and bearings. This was evaluated by measuring the torque applied to the mechanism by the motor at selected torques applied to the mixing pins using a previously described technique (9). This technique was improved by using wire rope and larger spools to apply torque to the mixing pins eliminating the correction factor previously required to allow for rope stretch.

Figure 4 shows the relationship between torque at the motor and torque at the mixer pins for various loads and at two pin speeds (130 and 70 r.p.m.). The broken line C is the theoretical friction-free slope of the mechanical advantage relationship between the motor and the mixing pins of 13.33 to 1. Mechanical efficiency was calculated as follows:

$$\text{Mechanical efficiency} = \frac{\text{Torque at pins}}{\text{Torque at motor} \times 13.33}$$

Efficiency of the mixer drive mechanism ranged from 54 to 57% at mixing speeds ranging respectively from 130 to 70 r.p.m. The appropriate mechanical efficiency value may be used to modify the dynamometer measurements of torque input to the mixer mechanism and thus determine the torque actually used to mix the dough.

It should be noted that the difference between the mechanical efficiency value of 54% for 130 r.p.m. and the value of 42% reported previously for the GRL mixer (9) may be attributed to two causes: a) the motor efficiency (approximately 90%), which is part of the total mechanical efficiency measured previously, failing to enter into the dynamometer technique; and b) improved mechanical efficiency due to modifications of mixer drive.

A typical development curve for hard wheat flour (Fig. 5) demonstrates the clear records obtained on rectilinear charts and the degree of resolution attainable.

DISCUSSION

The modification described increases the usefulness of the GRL-200 mixer for laboratory work. The commercial cost of the conversion is about $300 plus a recorder and amplifier (about $1,200). The principles used in the conversion are applicable to other mixers of any size.

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