The GRL-1000 Laboratory Dough Mixer[1,2]

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ABSTRACT

A laboratory pin mixer capable of mixing doughs from 300 to 1,000 g. flour is described. The basic mixing action is modeled on that of the smaller GRL-200 pin mixer. The scaled-up Model 1000 mixer is driven by a variable speed motor and provides for operation at any one of eight mixer pin speeds ranging from 37 to 160 r.p.m. It is thus suitable for baking methods calling for slow or high-speed mixing conditions. A signal representing the torque during mixing is obtained from the motor armature current and may be fed to a recorder to give a mixing curve. A redesigned gear and bearing mechanism in the mixing head has increased the mechanical efficiency very significantly over that of the original GRL-200 mixer.

A laboratory dough mixer capable of mixing dough for breadmaking from 300 g. up to 1,000 g. flour is described. The GRL (Grain Research Laboratory) - 1000 mixer was developed by scaling up the original GRL pin mixer (1) which is now referred to as the "GRL-200" (200 g. flour nominal capacity).

The scaling up of the GRL mixer was attempted because a definite need existed in our laboratory for a mixer capable of mixing doughs from amounts of flour in the range of 300 to 1,000 g. The mixing action of the GRL-200 has, over the past 15 years, proved to be most satisfactory for making pup loaves. Amounts of flour from 75 to 250 g. can be mixed at either slow (68 r.p.m.) or fast speed (130 r.p.m.), thus covering conditions required for a variety of baking processes ranging from straight-dough methods, with slow-speed mixing, to the remix method (2) and no-bulk-fermentation-time mechanical development procedures such as the Chorleywood Bread Process.

The success of the original mixer was attributed to the pin arrangement and pin action. Two straight pins rotate about a center curved pin which rotates in the opposite direction at a slower speed. The spur gear holding the two straight pins moves around a ring gear, thus causing the whole pin ensemble to rotate around the center axis of the bowl. Dough is mixed between the pins as they pass one another, and at the same time the curved pin provides a downward wiping action. This not only prevents the dough from climbing but moves it towards the bottom of the pins and thereby maintains a mixing action that is not overly dependent on dough mass.

In scaling up or scaling down a dough mixer, factors are introduced that unavoidably produce changes in the mixing action. In the case of the GRL pin mixer, the shearing action of the pins cannot be reproduced exactly on scaling up. Factors such as changes in pin diameter, pin clearances, pin speed and shearing rate, or bowl surface effect may all interact differently with different flours. Such factors were closely examined during the development of the GRL-1000 mixer.

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MATERIALS AND METHODS

The GRL-1000 – General Description

A general front view of the GRL-1000 mixer is shown in Fig. 1. As with the small mixer, the mixing bowl is water-jacketed to allow for closer control of dough temperatures. Features not incorporated in the smaller model include provision for mixing at any one of eight different mixing speeds ranging from 37 to 160 r.p.m., provision for recording mixing torque, and a bowl-lift mechanism.

Mixer Housing

The mixer housing is made of aluminum and covered with stainless-steel sheet. Overall dimensions are 89 cm. wide, 58 cm. deep, and 77 cm. tall. The front panel is removable, giving access to the controls, and the top cover is removable for access to the pulley and belt drive (Fig. 2).

Bowl and Bowl-Lift Mechanism

Construction of the mixing bowl is similar to that of the McDuffy bowl in that both inner and outer shells were cast from aluminum. Inside diameter of the mixing shell is 22.5 cm. and outside diameter of the water jacket shell is 28 cm. Overall height of bowl is 22.5 cm. The weight of water in the jacket, together with the fairly heavy castings and the dough, would have made the bowl inconvenient to lift up and down manually. The bowl-lift mechanism (Fig. 3) was devised to raise or lower the bowl.

Fig. 1. The GRL-1000 laboratory dough mixer with mixing bowl in "down" position.

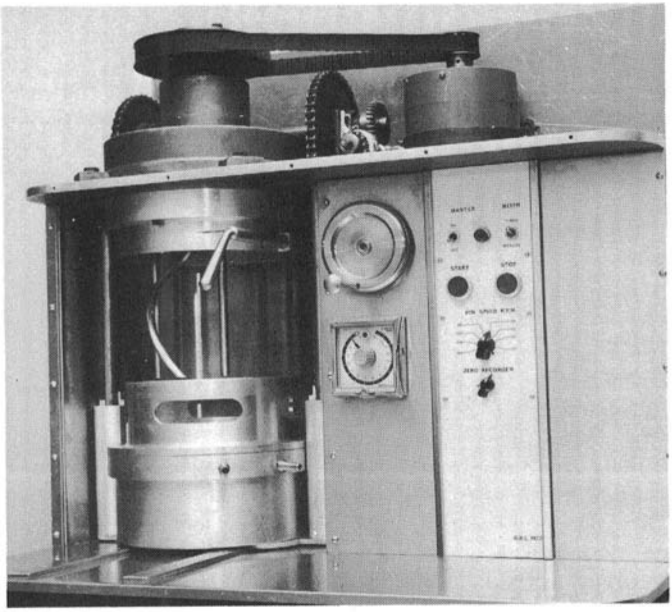

Fig. 2. GRL-1000 mixer with top cover removed, showing pulley and belt drive and part of bowl-lift mechanism.

The height-control wheel mounted on the front panel turns a worm gear which in turn drives two large chain sprockets. Two chains attached to the carriage for lifting the bowl engage and pass over the sprockets and are counterweighted. The worm drive prevents backdriving of the wheel so that the bowl will hold at any position. As with the GRL-200, a split ring attached to the mixer head is tightened around the top ring of the bowl to permit precise centering of the bowl and to prevent the bowl from rotating.

When the bowl is in the "down" position, it may be pulled back and forth along two rails attached to the base of the mixer (see Fig. 1). Dough may thus be removed or ingredients added without having to lift the bowl by hand.

The Mixer Head

As pointed out in a recent paper (3), the original GRL-200 mixer has a low mechanical efficiency. That is, the energy transmitted to the dough by the mixing pins is considerably less than the total energy consumed by the mixer motor during mixing. Ways of increasing mechanical efficiency were considered in the design of the GRL-1000. Of prime importance were: excluding the original worm gear drive; reducing bearing friction by using ball or roller bearings on all rotating parts, including retaining surfaces; using wide spacing between bearings – thereby reducing the effect of thrust from leverage afforded by the length of the mixer pins; adopting a steel-on-fiber sequencing of gears; and avoiding gearing up in the initial drive from the motor and throughout the gear train by, wherever possible, having a smaller gear or pulley driving a larger gear or pulley.

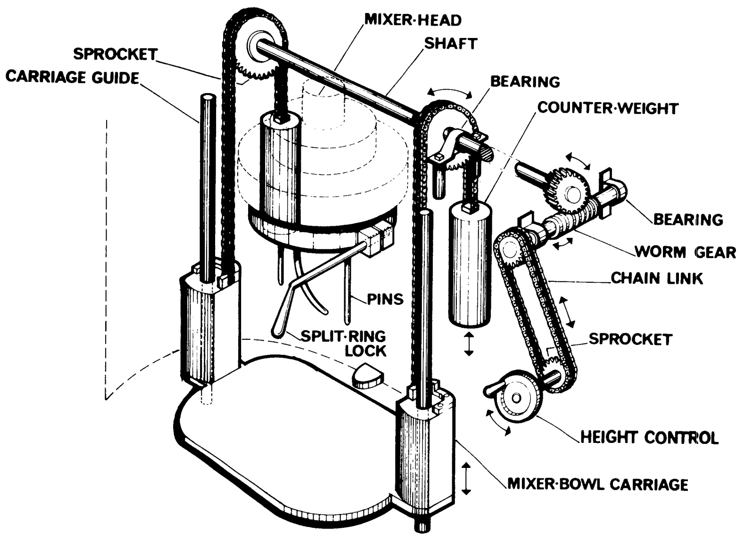

Fig. 3. Perspective drawing of bowl-lift mechanism.

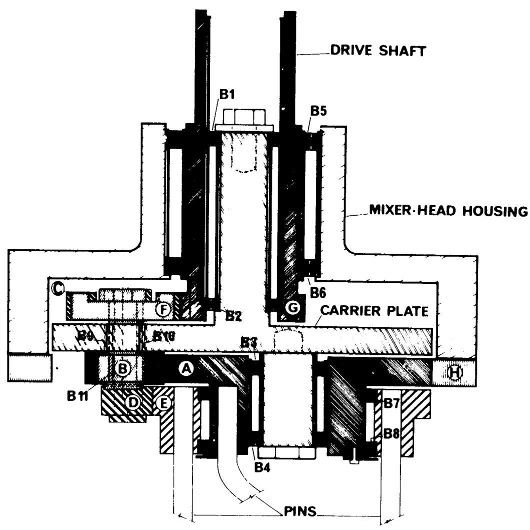

Fig. 4. Cross-sectional drawing of mixer head showing the bearing, gear retention, and suspension system. (See text for explanation of lettered parts.)

Figure 4 shows the bearing, gear retention, and suspension systems in a cross-sectional view of the mixer head. Parts labeled B1 through B11 are the bearings. Other components are labeled by a single letter and are shown in further detail in Fig. 5 which illustrates the drive train. Essentially, the two large spur gears carrying the mixer pins are driven separately in opposite directions about a

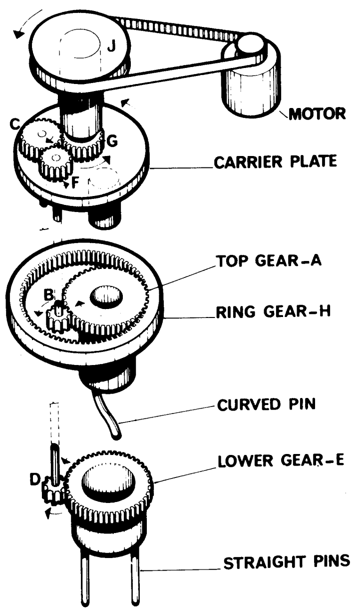

Fig. 5. Exploded drawing of the gear train shown in Fig. 4.

common axis. As seen in Fig. 6, which is a view of the mixer pins from below, the gear axis is displaced from the carrier plate axis which corresponds to the center of the mixer bowl. With the exception of the relationship between gear E and gear F (ratio 40:33) the speed of any driven gear is no greater than the speed of the driver gear. The speed relationship between the straight pins and the curved pin is not identical with that of the GRL-200. For every revolution of the straight pins, the number of times a straight pin passes the curved pin is exactly twice with the GRL-1000 mixer, whereas this relationship in the GRL-200 model equals 2.352. Mechanical considerations of gear availability, power ratings, and suitability of bearings required that this compromise be made in scaling up the GRL-200. This means that at a pin speed of 130 r.p.m., for example, there are 260 potential shear points per min. with the larger mixer as compared to 305 potential shear points per min. with the small mixer. To obtain 305 shear points per min.with the large mixer, a straight pin speed of 150 r.p.m. is required.

Mixer Motor and Speed Control

A Browning M75 SCR Speed Control (with factory modifications for 1% speed control) was used to operate at 0.75-h.p.-d.c. motor. A rotary switch in the front panel selects one of eight potentiometers, each of which can be preset for a given motor speed. With a regulated voltage of 118 v. applied to the control, speed variation over a range of loads, from that required to run the mixer empty up to the rated torque of the motor, was within ±1% when measured with a tachometer having a time base of 3 sec.

The regulation of the SCR Control was examined to determine its response to line voltage variation for application where voltage regulation was not available. With a fixed average load applied, the voltage from the regulated supply was varied

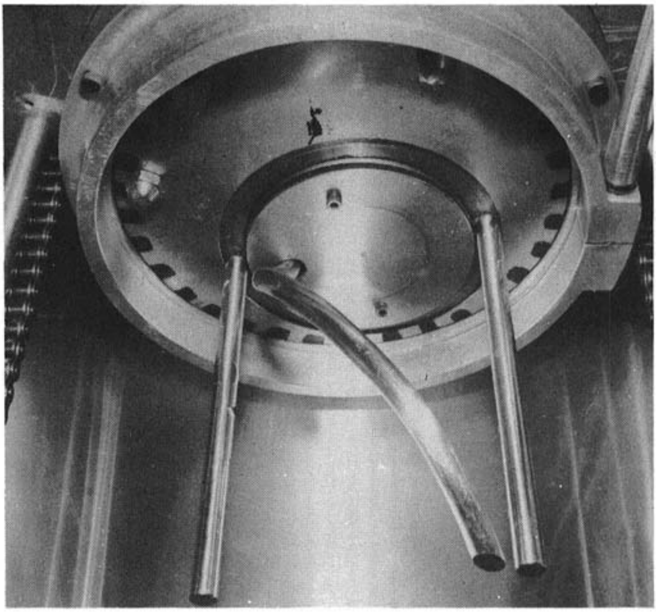

Fig. 6. Mixer pins viewed from below the mixer head.

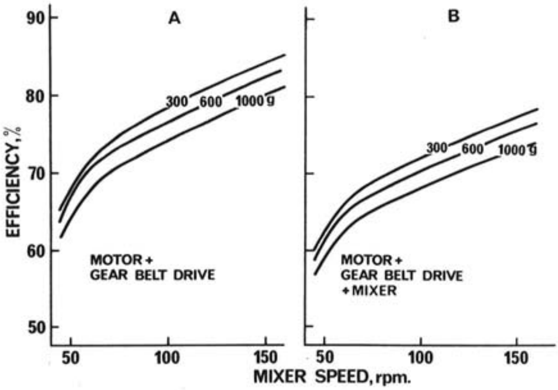

Fig. 7. Efficiency plotted against speed (outside mixing pin equivalent) for A: motor + gear belt drive, and B: motor + gear belt drive + mixer. The numbers 300, 600, and 1,000 g. denote flour weight and refer to three different dough-load situations or their equivalent.

to give 110, 118, and 124 v. There was no change in speed between 118 and 124 v., but a drop to 110 v. consistently produced a speed increase of about 1.5%. For most practical purposes, line variations of ±5% should not produce significant speed variations with this unit.

The armature current to the motor is proportional to the load or torque applied to the motor. It was therefore possible to obtain a mixing curve representing torque by recording armature current.

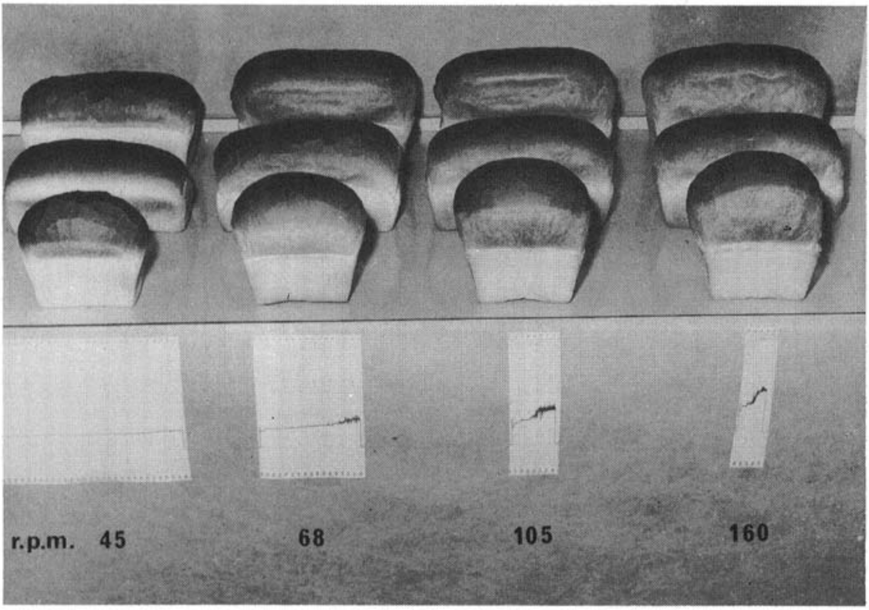

Fig. 8. Loaves of three sizes (from back to front row, respectively, 300, 200, and 100 g. flour equivalent basis) scaled and baked from 600 g. flour doughs (GRL-Chorleywood Method) mixed at (from left to right) 45, 68, 105, and 160 r.p.m. Mixing curves are shown below each set of loaves.

RESULTS AND DISCUSSION

Mechanical Efficiency

The rated torque of the SCR motor over its speed range is 31.1 kg. cm. The ratio of the gear-belt drive of 3.43:1 puts the maximum torque at the input of the mixer drive at 106 kg. cm. While torque capability of this motor is constant over a wide speed range, the efficiency decreases with decreasing speed; that is, more electrical energy is required to produce a given amount of work as speed is reduced.

The efficiency of the SCR motor and gear belt drive was determined for loads and speeds similar to those used in the mixing of dough. The 48-tooth pulley (J in Fig. 5) normally attached to the mixer head was removed and fastened to an electric clutch mounted on a mandrel. The prony brake principle, as described in a previous paper (3), was used to determine net work to the clutch, and the GRL energy-input meter (4) was used to measure the electrical energy consumed by the SCR control and motor. Figure 7A shows efficiency plotted against speed (outside mixing pin equivalent) at three different loads (representing average torque levels that occur with 300-, 600-, and 1,000-g. flour mixes) for the motor and gear belt drive. Efficiency decreased with decreasing mixing speed and with increasing load.

To determine the overall efficiency of the GRL-1000 mixer (i.e. motor, gear belt drive, and mixer) the spool-and-line technique described previously (3) was used. One 20-cm. aluminum spool was attached to the outside mixing pins, and another of the same diameter was attached to the clutch. Steel cable 1.5 mm. diameter was used as the line. Figure 7B shows the relationship between overall efficiency and mixer speed. The curves in this figure were almost identical to those in Fig. 7A, except that they were displaced downwards. The efficiency of the mixer itself was therefore constant over the range of loads and speeds examined and the variation of efficiency with loads and speed was due entirely to the SCR motor and control.

It should be noted that the "loads" of 300, 600, and 1,000 g. refer to flour weight. In terms of torque, the actual load value is proportional to speed. Whereas a dough made from 600 g. flour may produce average torque levels at the pins of about 50 kg. cm. at a speed of 150 r.p.m., if a speed of 50 r.p.m. is used the torque level will be about 25 kg. cm.

The curves therefore represent a practical basis for calculating net energy values during dough mixing at various speeds. Compared with the GRL-200, which has a mechanical efficiency of around 40% at 130 r.p.m., the GRL-1000 has a much higher mechanical efficiency. For example, at 130 r.p.m. the efficiency varied from 71.5% for 1,000 g. flour dough-load-equivalent to 75.8% for 300 g. flour dough-load-equivalent.

This work on mechanical efficiency was necessary so that net energy values for dough mixing might be determined.

Baking Studies

Although the main object of this paper is to describe the construction of the GRL-1000, the following baking results are included as an illustration of the type of work that may be carried out with this mixer. Figure 8 shows loaves of three sizes (300, 200, and 100 g. flour equivalent basis) scaled and baked from 600-g. flour doughs. These sizes cover the range from commercial "1 lb." to laboratory pup loaves. The flour used was the same in each case – a straight-grade laboratory flour – milled from an average sample of No. 1 Canada Western Red Spring Wheat, 14% protein. The GRL Chorleywood baking method was used and the only variation introduced between the four sets of loaves was mixing speed. Mixing curves are shown below each set of loaves. The far right-hand set was baked from dough mixed at 160 r.p.m. to peak consistency (5.0 min.) as indicated by the mixing curve. The dough appeared fully developed and bread was of satisfactory high volume, external appearance, and internal crumb characteristics. The pup loaf was identical in all respects to loaves produced from this flour by the same method with the GRL-200 mixer at 130 r.p.m. The other three doughs were mixed at 105, 68, and 45 r.p.m. to the same net energy level as used for the 160 r.p.m. dough. Maximum loaf volume and adequate dough development were also achieved at a mixing speed of 105 r.p.m. As mixing speed was reduced mixing time became longer and mixing curve peak became less distinct until at 45 r.p.m. (far left) no development occurred and the mixing curve was almost a straight line after 28 min. mixing. Doughs appeared grossly undermixed and bread was low in volume. Loaf volume for the 68 r.p.m. loaves was intermediate between the volumes obtained at 45 and 105 r.p.m. This is a further illustration of the significance of "critical" minimum mixing intensity which was discussed previously (5). For this flour and this mixer under the specific conditions used the correct (minimum) level of energy must be imparted at a mixing speed of around 100 r.p.m. or higher in order to achieve maximum potential loaf volume.

The GRL-1000 mixer has already found wide application in our own laboratory and subsequent publications will describe some of the baking studies for which the mixer has been used.

Acknowledgment

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