UNIT 8 MILLING OF WHEAT - GRINDING

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8.0 OBJECTIVES

The objectives of this unit are to enable you to understand the importance of the process of wheat milling into various products. The unit gives a brief account of machines used for grinding, break system and reduction system. After going through this unit, you should be able to:

- learn different aspects of wheat grinding
- know the various types of rolls used for grinding
- study about the different break systems
- know the different reduction systems
- explain the roll surface requirement

8.1 INTRODUCTION

As you are aware, the milling wheat is as ancient as the history of civilization of man. Wheat, as a source of food, used by the man from food gathering stage of human development, is primarily belongs to a group of wild grasses (Graminea) which are of genus *Triticum*. The seeds of these group of grasses were found to be more palatable and akin to cooking, when they were milled, into bits and in some cases a portion of seed coat was removed.

The object of flour milling is to open the grain, release the endosperm and grind in gradually process, so that the flour produced is least contaminated with either germ or bran.

In this unit we will consider the various stages in the process of milling, of both hard and soft wheats into maida, as well as the by products such as resultant atta, germ and bran.

Basically, wheats can broadly be divided as belonging to either hard wheat or soft wheat, depending on the morphological structure. The milling behaviour and the functional properties of milled products such as *maida*, semolina also depends on the hardness of wheat.
8.2 GRINDING ROLLS – GROOVES, POLISHED, MATT

As pointed out earlier, the roller mills employed to mill wheat consist of pairs of rolls, of various configuration. For this reason, rolls having grooves / flutes/ striations and the one that are smooth (without grooves), but their surfaces being matt / buff are used depending on the type of grinding required during the process.

8.2.1 Roll sizes

The standard diameter and length of the rolls used in flour milling industry is 250mm and the 1000mm respectively (standard). The rolls with higher lengths of 1250mm and 1500mm, are also available (rare case).

You have know that roller are being used in the modern roller mills, to produce maida, sooji, atta and bran by milling of wheat.

The rolls are made as hollow cylinders of grey cast iron, made by centrifugal casting, while casting, rolls are deeply chilled on the outside to give surface of suitable hardness. The hardness used for break rolls and reduction rolls are 480-520 and 400-420 brinell number, respectively. The thickness of chilled hardened surface is around 15mm. The grinding and refluting the surface keep this depth of hardened surface decreasing.

The rolls used in roller mills are either fluted / grooved rolls or smooth rolls, used normally in break, and reduction systems, respectively.

8.2.2 Grooved rolls

All the rolls of break system are grooved. Grooving is saw-tooth like striations done on the roll surface and inclined with respect to the axis of rolls. These striations have different profile, depending on the nature of material handled.

With increase in the time usage of fluted rolls, flutes tend to become worn out and dull. Continued use of such worn out fluted rolls, will alter the characteristics of ground material, heating-up of rolls and products, as well as increase in power consumption. It is, therefore, necessary to keep the flutes in good condition by getting the fluted rolls ground and refluted.

The aim of grooves is to cut open the cleaned and conditioned wheat in first break, and scrape the adhering endosperm from bran pieces, in the subsequent break operations. The grooves will progressively become finer from beginning of break system to end of the same.

1st Break: 250-325 flutes on entire surface of 250mm roll or 3.2-4.1 flutes per cm.

2nd Break: 400-450 flutes on entire surface of 250mm roll or 5.1-5.7 flutes per cm.

3rd Break: 500-550 flutes on entire surface of 250mm roll or 6.4-7.0 flutes per cm.

4th Break: 675-750 flutes on entire surface of 250mm roll or 8.6-9.6 flutes per cm.

5th Break: 800-850 flutes on entire surface of 250mm roll or 10.2-10.8 flutes per cm.
8.2.3 Roll speeds and differentials

Rolls do not run at same speed, as this would not cut open (shear), scrape or grind. Instead it would merely flatten or crush the material coming in between the rolls. For this, the top and bottom rolls are made to run at different speeds, by using gears or toothed-belt drive to transmit the motion between the rolls.

Normally, the top, fast rolls are run at speeds of 480-550 rpm for break rolls and 380-420 rpm for reduction rolls.

The differential speed for break rolls are 1:2.5 and that for reduction roll is 1:1.25. Higher differential of break roll will result in shearing and scraping of the incoming stock. Such high differential, if used in reduction rolls, will result in excessive heating of rolls and the ground material and shearing of bran particles, which is not desirable.

Spiral

As can be seen from figure: 1, the grooves are inclined and the inclination is referred to spiral, which is normally expressed as percentage. Both the top and bottom rolls will have either left hand and right hand spiral. On other hand, if there are

![Spiral Rolls Diagram](image-url)
opposite hand spirals, then they will mesh like gears, which will not work. Normally, the spiral varies from 4% on first break roll and gradually increases till 10% on the last break roll. The spiral together using the differential speed of top and bottom rolls, provides the necessary shearing and scraping action of break rolls. You may also note that with a larger spiral, the alpha angle increases which results in decrease in displacement ‘S’, but the number of crossing points increases and results in more cutting of product. This is desirable to handle fine stock in the later break rolls.

**Flute angles**

In the figure, the front (cutting) edge and back edges are shown. The inclinations these surfaces make using an hypothetical perpendicular drawn at the edge are referred to as back angle and front angle respectively. The back angle influences the depth of flute.

**Smooth rolls**

The rolls without any grooves / flutes are generally used in reduction system. However, if the surface is too smooth / shiny it will not grind effectively the stocks coming to reduction passages. Hence, roll surface with matt (frosted) finish is used to improve the efficiency of reducing the particle size.
8.3 BREAK SYSTEM

The break system is beginning of the actual milling process. The aim of breaks system are as follows:

a) **On the earlier breaks:** To shear open the wheat and scrape away the endosperm from bran skin in large particles and the bran is left as large flat flakes.

b) **On the latter breaks:** To scrape the endosperm off the wheat skin as cleanly, as possible, with least and no undue cutting up of the bran skin.

The bran powder can never be separated from flour and hence it is essential that the wheat skin is kept as large and whole as possible.

This is achieved by shearing open and scraping the wheat on first break and residual bran skin.

The object of break system is to release maximum amount of coarser material such as semolina and middlings and minimum amount of flour. Semolina of different granulations are handled on purification system to separate out clean endosperm particles, which are finally ground down to flour in reduction system.

The moisture content of wheat, break release, condition of flutes of rolls of break system are the factors that influence the extraction and quality of semolina and flour.

Wheat is scraped progressively on subsequent 3rd or 4th break passages. That means break operation are carried out on either 4-break or 5-break passage systems and is used for milling of wheat.

Higher the number of break passages, lesser would be the possibilities of cutting bran skin. Hence, a 5-break system is used when more of clean low ash flour is required to be produced. Also, a 5-break system is used, for milling soft wheat, which has thicker bran than hard wheat and scraping of endosperm from bran is difficult. When the extraction of large proportion of low ash flour is not critical, a 4-break system is used.

An example of setting the roll gaps are given below.

<table>
<thead>
<tr>
<th>Passage</th>
<th>Gap between top and bottom rolls mm</th>
<th>Release %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-Break</td>
<td>5-Break</td>
</tr>
<tr>
<td>B1</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>B2</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>B3</td>
<td>0.1</td>
<td>0.25</td>
</tr>
<tr>
<td>B4</td>
<td>Just touching</td>
<td>0.10 less to clean bran</td>
</tr>
<tr>
<td>B5</td>
<td>Just touching to have clean bran</td>
<td></td>
</tr>
</tbody>
</table>

The figures are for medium hard wheat with 15.0-16.0% moisture.

Release test is done to set the break rolls for desired working levels. It represents percentage of material that can pass through a sieve with 1000m opening, under standard conditions.
From the above table you will notice that in a 5-break system, the severity of grinding in each step of break roll operation is lower than that in a 4-break system. This will help in preserving the bran skin at the end of break system, as large as possible. That means, the bran is not unduly fragmented or ground into finer particle size.

**Action of break rolls**

The illustration given below explains the shearing and scraping action of break rolls.

![Diagram of Action of break rolls](image)

*Fig. 3: Action of break rolls*

A single wheat is shown entering the nip of rolls or grinding zone. Note that the top roll moving 2.5 times (480 rpm) faster than the bottom roll (192 rpm). At any instant of times the bottom roll can be assumed to be static and the top roll is moving. Under this circumstance, you may see that the grain entering is held on the flutes of slow roll and that of fast roll shear and scrape the grain. The number of flutes, spiral and flute angles influence, the type of ground material after the roll action.
Scheme of break system

The general scheme of break system is shown below in the form of flow diagram. The basic operations in flour milling is grinding followed by sieving to separate particles of different granulation ranges, while flour is taken out as finished product.

Wheat is cut open in first break. In doing so, lot of materials of different granulation ranges are also produced. The coarsest material is the bran skin with adhering endosperm, which is sent to next break passage, namely second break. This process continues till the last break, when coarse bran and fine bran, free of any adhering endosperm is separated out. During each of the sieving operation, the finest fraction namely, flour is produced. The fraction between the coarse fraction, namely bran skin and finest fraction, namely flour, are referred to as intermediate products, which are sent further in the process.

Towards the end of break system, bran finishers (BF) are employed to dust out finer endosperm particles adhering to bran skin, before handling on the next break passage. The role and use of bran finishers is discussed in next unit.

After each of the successive operations by the fluted break rolls of opening the wheat grain and scraping the adhering endosperm particles from the bran skin, the ground material is graded in a plansifter into several fractions according to defined granulation ranges. A model of this is illustrated below:

![Diagram of break system](image)

### Fig. 4: Scheme of break system

The plansifter section will have a stack of sieves-coarsest sieve at the top which gradually becomes finer towards the bottom. Using this arrangement ground material after each of successive beak rolls, is separated into break stock (coarse and fine) semolina (coarse and fine), middling (coarse and fine), dunst and flour. Incidentally, the proportion of bran in the separated fractions is highest in the coarsest stock (break stock), and keeps becoming lesser and it is least in the flour.

The bran content in the other intermediate products will be in between these two extremes.

The object of each of beak passages is to produce as much of coarse material as possible and at the same time, appropriate scraping of endosperm from the bran skin going to next passage.
The semolina and middling thus produced in break system is a mixture of pure endosperm particles, endosperm particles to which some bran piece is adhering (composite stock) and free bran particles. These stocks are sent to purification system to separate them into constituent materials for further appropriate process. The dunst produced is sent to reduction system for grinding the same into flour. However, the flour produced in each of break passages is taken out of process and packed as finished product.

### 8.4 REDUCTION SYSTEM

The clean semolina, middlings and dunst produced in break and purification systems, are eventually sent to reduction system to reduce their size to that of flour, using a series of smooth roll passages. The reduction system consists of series of smooth rolls and sifting passages.

The object of reduction system is to:

a) Reduce the endosperm particles and sieve out flour as a finished product.

b) Separate the branny stock, which eventually go to bran at end of reduction system.

c) Produce middlings/dunst (coarse flour) to be handled in the subsequent reduction passages.

![Fig. 5: Reduction System](image)

The brany stock is handled separately so that it does not get mixed up with clean middlings and dunst, which are ground down to particle size of flour, in the subsequent reduction passages.

The large pieces of endosperm in the form of semolina, middling and dunst are ground down and shattered, whereas bran particles are flattened and elongated because of their tough and leathery nature, on the reduction rolls. This helps in separating the branny stock and germ particles from endosperm particles in the plansifter. This is done to keep the incoming stocks to most of reduction passages free of bran and the flour produced thereby is bright and of low ash content.

**Grinding action of reduction rolls**

Each pair of smooth reduction rolls having matt finish surface, run at speed differential of 1:1.25.
Fig. 6: Grinding action of reduction rolls

It can be seen from the above illustration, the endosperm particle entering the nip of roll, is subjected to both compression force due to reduction in the gap at the nip of roll and shearing force due friction action in opposite direction.

**Scheme of reduction system**

Clean and purified semolina and middling are sent to reduction to reduce the particle size as that of flour.

Semolina (1000m - 300m) are sent to first reduction passage, (the semolina passage-C1), where as middling is sent to second and third reduction passages (middling passages). These three are referred to as head reduction passages and handle 60-70% of the mill load and produce nearly 50% of the total flour produced.

The fourth passage is called the ‘first collecting passage’, as the branny stock tailed out from head reduction passages are collected and sent to this passage. This is illustrated below: (Fig: 7)

Similarly, seventh and last passage in the above illustrations, are referred to as second and third collecting passages. With this scheme of operation, dirty and branny material is kept away from the remaining passages and handled separately. Finally, branny material goes out of the process as fine brans, of different grades.

Fifth, sixth and eight passages handle clean middlings, devoid of flaked and flatted branny materials.

**Operation of reduction system**

Appropriate operation of reduction system is essential to produce the desired amount and quality of flour.

For the optimum working, the amount, the range of granulation and the quality of incoming stock to the respective passages is required to be similar.

Apart from this, feeding of stock should be of even thickness throughout the length of roll and is critical in the production of maximum amount of flour.
8.5 ROLL SURFACE

As per convention, the roll surface refers to the total length of rolls, in millimeter required to mill a known quantity of wheat in 24 hrs, in different stages namely on break rolls and reduction rolls.

For example, a flour mill needs 20,000mm of pair of roll surface to process 140 tonnes wheat in 24 hrs. This means, we need 10 roller mills of 1,000mm long rolls. You know, from the earlier units, that a roller mill consists of 2 pairs of 1,000mm rolls i.e. 2,000 mm per roller mill. For a mill, mentioned above, we need 10 roller mills of 1,000mm rolls. Similarly, to process 160 tonnes wheat in 24 hr., normally we need 12 roller mills i.e. 24,000mm of roll surface.
The above figures can be expressed as total specific roll surface, which means millimeter of roll surface required to process one deci-tonne of wheat in 24 hrs. The specific roll surface of 140 and 160 tonnes of wheat per day works out to be 14.28mm and 15.0mm, respectively.

It should be noted here that this is the average roll surface used in Indian roller flour mills. This figure depends on the following factors, apart from the skill of the operator.

- Type of wheat-hard or soft,
- Moisture of cleaned and conditioned wheat being fed to first break,
- The design and construction of roller mill
- Flow sheet of the mill
- Usage of bran finishers in break system and detachers (flake disrupters) in reduction system
- The expected extraction rates of maida, sooji, atta and bran.

The examples of 140 and 160 T/day mills given above are for the Indian medium hard wheats, with an average moisture content of 15.5 to 16.0 percent in wheat being milled on roller mills of fairly good design and construction. Two or three bran finishers are used towards end of break system and two or three detachers are used in the beginning of reduction system.

The range of extraction rates of different milled products are as follows:

<table>
<thead>
<tr>
<th>Product</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maida</td>
<td>49-55%</td>
</tr>
<tr>
<td>Sooji</td>
<td>8-10%</td>
</tr>
<tr>
<td>Resultant atta</td>
<td>15-18%</td>
</tr>
<tr>
<td>Bran</td>
<td>22-23%</td>
</tr>
</tbody>
</table>

Sooji and atta being coarse products, they need to be ground down to finer particle size, if more of maida and less of sooji are required to be produced. Under this situation, the capacity of the mill comes down, increasing the specific roll surface requirement.

The ratio of rolls used for break and reduction system varies from 45:55 to 50:50. This ratio again depends on type of wheat-whether it is hard or soft, extraction pattern of finished products etc.

Check Your Progress

Note:  
a) Use the spaces given below for your answers  
b) Check your answer with those given at the end of the unit

1. Which are the different types of rolls used in the milling of wheat? What are the differences in their working?

2. Write notes on the following:
   a) Flute profile
b) Roll differential of break and reduction rolls

3. Wheat is break release and how it is determined?

4. Explain the scheme of reduction system, designed to keep the bran particles away from the stocks going to all the reduction passages.

5. Explain the term specific roll surface. How much is it in the present Indian roller flour mills?

8.6 LET US SUM UP

There has been tremendous development over the couple of decades in the technology of milling of wheat very efficiently into milled products – *maida*, *sooji*, *resultant atta* and bran. The morphological structure of wheat, with a longitudinal crease, into which the bran layers are folded, makes milling of wheat, a complex process.

The milling of wheat is done on rolls—both fluted and smooth, where in the cleaned and conditioned wheat is first opened and endosperm in the large bran pieces is scraped on the fluted rolls of break system. The endosperm particles thus obtained are purified. A portion of purified stock is packed as *sooji*, while remaining material reduced to desired particle size in reduction system to obtain *maida*. The endosperm portion, which cannot be further rendered free of bran is ground to desired particle size and extracted as resultant *atta*. The bran fractions free from endosperm called coarse (flake) bran, and fine (rough) bran are obtained at the end of break and reduction systems, respectively.

For the break passages, appropriately fluted rolls are used, while for reduction passages smooth ones are used. By appropriately fluting, we mean that number of flutes / inch, spiral, front and back angles, and land being suitable to treat the incoming stocks to respective passages.

Normally, smooth rolls (without any flutes), are used in reduction system. The term
'smooth' is a misnomer, as a slightly rough (matt) surface is required to effectively grind pure endosperm particles into maida.

In the break system, we produce coarse, medium and fine semolina; coarse and find middlings are produced. These are purified to get clean endosperm particle, free of bran, on purification. These purified material as well as dunst (coarse maida) produced in break system are sent to reduction system to produce maida, and fine bran.

8.7 KEY WORDS

Milling of wheat : Here, it refers to roller flour milling of wheat to produced maida, sooji, resultant atta and bran.

Grinding rolls : They are chilled cast iron rolls manufactured by centrifugal casting of hot / molten metal – to have desired range of hardness upto certain depth.

Roll grooves : Saw-tooth like striations, have a definite profile, cut at an inclination to the axis of roll, over its entire surface.

Groove profile : It refers to details of grooves such as number per inch or centimeter; spiral %; front and back angle; and the land (mm).

Roll disposition : This refers to relative position of front and back angles of top and bottom rolls, when they move towards each other. It can be sharp to sharp or dull to dull or sharp to dull or dull to sharp.

Roll differential : Refers to the ratio of speed of bottom and top rolls. For break rolls it is 1:2.5 and 1:1.25 for reduction rolls.

Spiral of flute : It is the inclination of the flutes to the axis of roll, which is expressed generally as percentage.

Land : The uncut surface on the roll, while fluting. It is expressed in millimeters.

Break system : It is initial part of milling process, where the grain is opened and the endosperm is gradually and gently scraped in three or four stages from the large bran particles, with the help of appropriate flute of break rolls.

Reduction system : Endosperm particles of various sizes and purify, produced and processed by break and reduction systems, respectively, are ground down in reduction system to produce maida.

Roll surface : It is a system of expressing the total length rolls available for break and reduction systems.
8.8 ANSWERS TO CHECK YOUR PROGRESS

EXERCISE

1. Fluted grooved rolls and smooth rolls. Fluted rolls are used in break system to open and scrape the bran pieces to obtain endosperm particles. These endosperm particles are reduced to the size of maida, by smooth rolls, having matt finish surface, of reduction system.

All the rolls of break system are grooved. Grooving is saw-tooth like striations done on the roll surface and inclined with respect to the axis of rolls. These striations have different profile, depending on the nature of material handled.

The clean semolina, middlings and dust produced in break and purification systems, are eventually sent to reduction system to reduce their size to that of flour, using a series of smooth roll passages. The reduction system consists of series of smooth rolls and sifting passages.

The object of reduction system is to

a) Reduce the endosperm particles and sieve out flour as a finished product.

b) Separate the branny stock, which eventually go to bran at end of reduction system.

c) Produce middlings/dunst (coarse flour) to be handled in the subsequent reduction passages.

2. a) Flute profile refer to number of flutes per centimeter or inch, spiral, flute angles and land. The grooves are inclined and the inclination is referred to spiral, which is normally expressed as percentage. Both the top and bottom rolls will have either left hand and right hand spiral. The angles made by the surface with an hypothetical perpendicular drawn at the edge are referred to as back angle and front angle respectively. The back angle influences the depth of flute.

b) It is the ratio of speeds expressed in as RPM of top (fast) roll and bottom (slow) roll they are 1:2.5 and 1:1.25 for the break rolls and reduction rolls, respectively.

3. Break release is a method to assess and fix the degree of working of break rolls. Break release test is done to set the break rolls for desired working levels. It represents percentage of material that can pass through a sieve with 1000m opening, under standard conditions.

4. Clean and purified semolina and middling are sent to reduction to reduce the particle size as that of flour.

Semolina (1000m - 300m) are sent to first reduction passage, (the semolina passage-C1), where as middling is sent to second and third reduction passages (middling passages). These three are referred to as head reduction passages and handle 60-70% of the mill load and produce nearly 50% of the total flour produced.

The fourth passage is called the “first collecting passage”, as the branny stock tailed out from head reduction passages are collected and sent to this passage.

5. The roll surface refers to the total length of rolls, in millimeter required to mill a known quantity of wheat in 24 hrs, in different stages namely on break rolls and reduction rolls.

Roll surface depends on the following factors, apart from the skill of the operator.
• Type of wheat-hard or soft,
• Moisture of cleaned and conditioned wheat being fed to first break,
• The design and construction of roller mill
• Flow sheet of the mill
• Usage of bran finishers in break system and detachers (flake disrupters) in reduction system
• The expected extraction rates of maida, sooji, atta and bran.
• About 14 to 18 mm/100kg/24hr. is the roll surface used in Indian conditions.

8.9 SOME USEFUL REFERENCES


