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Investigation of the Optimum Disc Design Parameters Affecting the Pellet Resistance Index Value in Pelletized Feeds

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Abstract
In the study, the pellet press production stage, which is one of the steps in the feed process, has been examined in detail, and the design of the pellet press disc that provide mechanical compression, especially for the optimization of Pellet Durability Index (PDI) quality (Effective hole diameter and the type of holes in the disc, and also effective material selection).

Keywords: Pellet press disc, PDI, disc and type of disc holes

1. Introduction

The study will examine the effects of pelleting grain products prepared in balanced rations in feed factories under hygienic conditions. Factors that increase Pellet Durability Index (PDI) (Pellet Durability Index) quality in pellet presses will be tested. This will examine the Pellet Durability Index (PDI) quality, which is directly proportional to the starch gelatinization that occurs in compound feed under mechanical pressure, and its optimization and effects on machinery and equipment. This will also examine the effectiveness of pellet press discs of varying diameters that provide the mechanical pressure used in feed factories. This will address the topic of improving Pellet Durability Index (PDI) quality, reducing dust, energy costs, maintenance frequency and costs, reducing the amount of returned products, and improving yield and quality.

Ron Turner discussed pellet press mill design and the important parameters in the design of pellet press discs and rollers at conferences at Kansas State University in 2007 and 2008. He particularly focused on designs to prevent dust and breakage, which directly affect the quality of pelletized feed during compression. C.R. Stark (2018) conducted a study examining the stages of the pellet press process and the factors affecting Pellet Durability Index (PDI) values and conducted studies on improvements and positive developments.

Corzo, A., Mejia, L., and Loar II, R. E. (2011) investigated the effect of pellet quality on various broiler production parameters. Briggs, J.L., Maier, D.E., Wakins, B.A., and Behnke, K. C. (1999) investigated the effects of materials and processing parameters on pellet quality. Salloom A. Al-juboori (2016) also discussed the factors affecting Pellet Durability Index (PDI) quality. Keith C. Behnke (2009) and Keysuke M, Andreia M, Fabiano D, Alex M. (2015) focused on the factors affecting pellet quality in their studies. Dennis Forte (2006) discussed the stages of the feed process and explained the factors affecting pellet quality in his study. David Fairfield (2009) discussed discs and rollers and studied compression ratio, while Ramsh Subramonian and Sotero M. Lasap III (2016) described the Holmen test

method for determining Pellet Durability Index (PDI) quality. Keysuke Muramatsu (2017) discussed the purpose of the pelleting process in his study. He reported that broilers fed pelleted diets had increased feed intake, better feed conversion ratios, and greater weight gain.
In the Bühler Feed Technology Seminar (October 2018) and the Bühler Seminar (2019), he addressed the important points of disc design and focused on disc hole placement. He explained the effect of disc maintenance and frequency on disc life. In his seminar, Bühler (2014) focused on the factors affecting Pellet Durability Index (PDI) at various stages of the feed process. He discussed the importance of the nip angle. He formulated the aperture ratio of discs and focused on this. Ron Turner (2008) and (2009) examined the openness ratio in relation to pellet diameter. David Fairfield (2009) discussed the maintenance required for the discs in his study. Eugenio Bortone (2009) conducted a study on open-ended rollers.

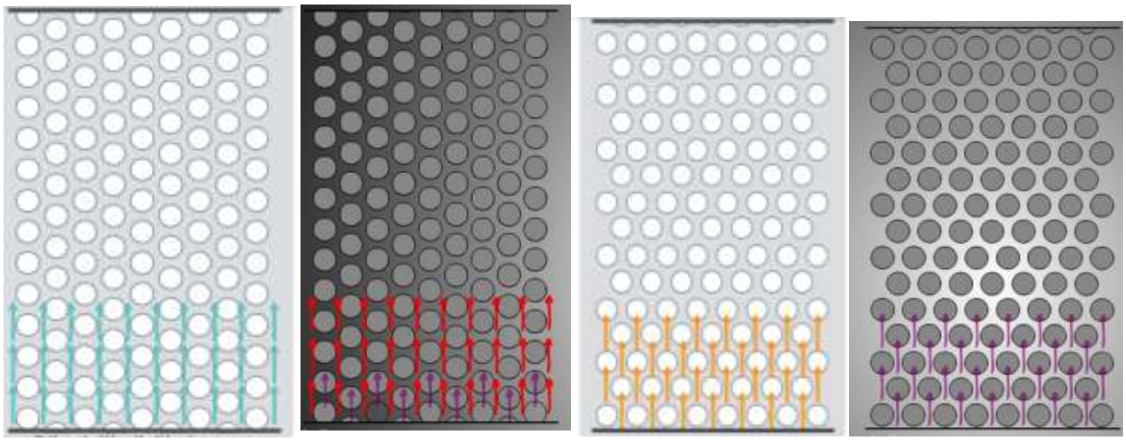
2. Materials and Methods

This study examines the pellet press production stage in detail, focusing on the design of the pellet press discs that provide mechanical compression to optimize Pellet Durability Index (PDI) (pellet durability index) quality. The Holmen method was used to examine Pellet Durability Index (PDI) quality. The design of the discs and rollers during the pelleting process is also described. The following steps were implemented to achieve the objectives set for the study.
The effects of the following items on Pellet Durability Index (PDI) quality were examined.
The designs in the manufacturing phase are as follows:

1. Disc hole design, type, and placement
2. Effective disc length
3. Disc aperture ratio
4. Disc material selection

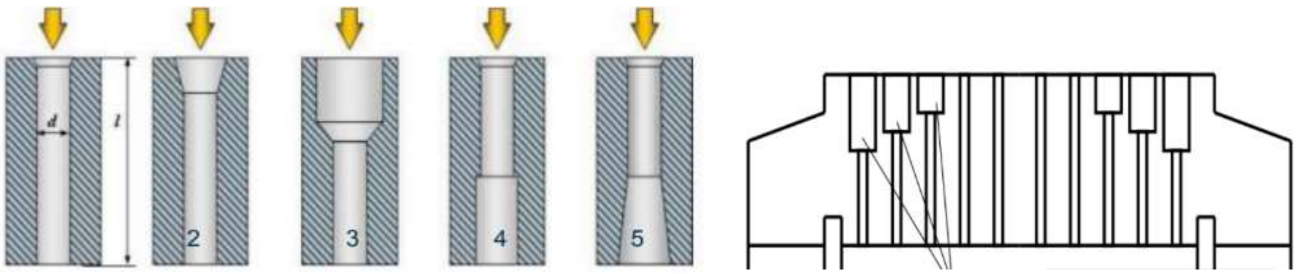
2.1. Hole design, type, and placement in the disc

For the hole design in the disc, the particle sizes of the raw materials used in the ration, the feed ration, and the estimated effective size were determined. All data, from the main process datasets (conditioner temperature to mixer mixing time), were collected and analyzed. The hole diameter was determined to ensure Pellet Durability Index (PDI) quality would not be compromised.
The hole arrangement was based on the determined hole diameter, creating a parallel flow pattern.
The dies and rollers were designed to optimize hole placement for pellet quality and high yield. Therefore, the parallel hole pattern (Buhler Miag) between the die and rollers ensured a homogeneous distribution of pressure and force and evenly distributed the feed across the surface. This was determined to reduce energy costs by ensuring even wear on the die.
The capacity increase was achieved by reducing the number of holes on the outer edges, which could potentially prevent pelleting, and by relocating these holes to the center thanks to the parallel design.



(A) (B)

Figure 2.1: Hole placement in discs, (A) straight standard hole placement, and (B) parallel hole placement. (Bühler Türkiye Customer Services – Feed Technologies Seminar October 2018)



(A) (B)

Figure 2.2: (A) Hole cross-sectional shapes in discs, (B) Hole placement. (Bühler seminar (2019))

Where, Hole Types ;

Hole number 1, Standard Hole Type: This is the profile shape for optimal effective length and the lowest cost. It is called the standard type.

Hole number 2, Conical Entry Hole Type: Used in pelletizing processes requiring greater compaction. It is used in hole diameters greater than 6-7 mm.

Hole number 3, Stepped Hole Type: Used in high-oil pelletizing processes.

Hole number 4, Cylindrical Relief Outlet Hole Type: Used to increase disc strength.

Hole number 5, Conical Relief Outlet Hole Type: Used to increase disc strength.

2.2. EFFECTIVE LENGTH IN DISC

Effective length is the length at which the feed moves through the holes in the disc, where it takes its physical form, and takes its shape under pressure. Effective length is the point where pelleting takes place, where the feed is compressed, the starch within it gelatinizes and breaks down, and the feed particles are compressed under pressure. Therefore, it is one of the most crucial factors for pelleting quality. After the pelleting process, Pellet Durability Index (PDI) quality is assessed. To achieve 96-98% Pellet Durability Index (PDI) quality, effective length is designed based on the ration. When designing effective length, all factors, from particle size to conditioning temperature to the ration, must be considered.

Figure 2.3: Pellet press disc effective size and shape, internal structure of the matrix

When Figure 2.3 is examined, the countersunk part is located on the inside of the disc; the first and second stages allow the pellet to easily exit the disc from the outside, thus increasing the disc's thickness, thus affecting strength. These discs (made in stages) are more durable due to their increased thickness, resulting in less bursting. However, users have reported that they cause dust in the final product. Currently, our trial discs do not have stages.

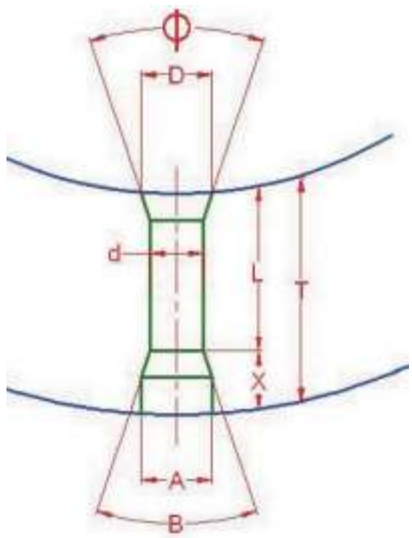


Figure 2.4: Matrix hole terminology (Hatice Basmacıoğlu (2004)),(Edward perez (2019)),(,Richard H. Leaver (2019))

Where dimensions were ;
d: Matrix hole diameter
L: Matrix effective length (thickness)
D: Hole entrance diameter
T: Total thickness
X: Hole exit depth
A: Hole exit diameter
Ø: Hole entrance angle
B: Hole exit angle
The hole entrance angle here is 30 degrees. This allows the product to enter easily.

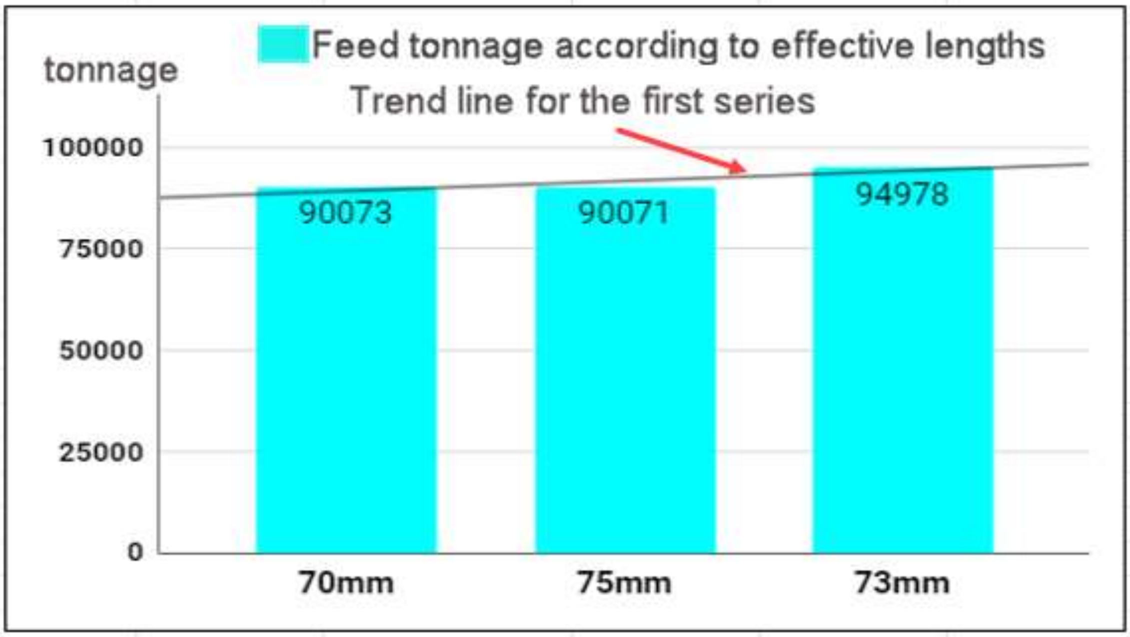


Figure 2.5. Feed tonnage drawn in pellet press discs according to effective length,

As seen in Figure 2.1, the disc with an effective length of 73mm has reached a higher capacity than the others.

Similarly, it has been determined that the hole cross-section also affects dusting, as the effective size of the holes on the discs increases the compression pressure, leading to starch gelatinization in the ration.

Consequently, there is a relationship between the effective size and the hole diameter. This is expressed as L/d. This is called the compression ratio. Hole diameter varies between 1.6 mm and 8-9 mm for different feeds and biomass. It varies depending on the raw materials to be pelleted.

L/d = Compression Ratio (9.1)

L: Hole size (mm)

d: Hole diameter (mm)

In the ring pellet press trial conducted at our facilities, the optimum value for fattening feed was L/d = 73/4.5 = 16.22, depending on the ration, using 800-piece discs.

When calculating the effective length (thickness) of pellet press discs, the L/d ratio is generally kept between 12 and 16. This value allows the disc to operate at different rations. In flat die pellet presses, this L/d ratio is maintained between 4 and 7.5.

2.3. Material selection for disc

When selecting materials for discs, experiments were conducted considering hole design and effective length, and wear rates were monitored based on tonnage.

Chrome stainless steel has been shown to provide better resistance to corrosion, pitting, scoring, and die hole widening. Stainless steel pellet molds are generally used for pelletizing highly abrasive or corrosive materials. Because the feed is characterized by moisture and heat, stainless steel (Cr)-containing materials should be preferred.

X46Cr13 was selected as the disc material, and the hole design and effective length were designed as described above. X46Cr13 alloy steel is more resistant to corrosion due to its high chromium content. However, it is more expensive than other steels. This alloy steel is most commonly used in the feed industry. Nickel has an impact on durability. Manganese increases wear resistance. Oxidation does not occur.

Ron Turner (2008) stated in his study that it should have a hardness of 57-61 HRc. In our experiments, we made it 50-55 HRc.

3. Results

- In fattening feed, a 73 mm diameter pellet disc achieved 85% feed efficiency at 290 A and pellet quality exceeding 95 Pellet Durability Index (PDI) at 62ºC in September. In dairy feed, the highest feed and temperature values were achieved in November, with 78% feed efficiency at 290 A and pellet quality exceeding 96 Pellet Durability Index (PDI) at 58ºC.
- The pellet quality (PDI) of feeds produced by the 73 mm disc and the 75 mm disc generally averaged 95% or more in fattening and dairy feed. However, in the first pellet press machine equipped with the 70 mm disc, the average value (excluding specialty feeds) dropped to 91 Pellet Durability Index (PDI) in dairy feed between September and December. This value was even lower for specialty feeds. Because both rations and environmental conditions (temperature, humidity, etc.) vary between summer and winter, PDIs are negative in summer conditions.
- The 73 mm disc; Compared to the 75 mm disc, it yielded better and faster results in terms of both feeding capacity, steam feedability, and pellet quality (less dusting). Between these two discs, the 73 mm disc should be preferred. It would be more appropriate to conduct trials and evaluate them during warmer seasons, and to take the necessary precautions.
- Based on our past experience, the diameter of used 70 mm discs, after being countersunk, drops to 63-64 mm. Pellet quality from feed produced with discs of this very low effective thickness is very poor, and dusting is excessive. After the 73 mm disc wore out (December 21st), it dropped to 69.90 mm and was re-countersunk. No dusting was observed.
- It has been determined that disc life can be extended by design modifications, and discs can be reused multiple times by grinding. This will reduce disc costs.
- The compression ratio of discs is an important factor. It is among the factors affecting Pellet Durability Index (PDI) quality. This value must be maintained within a specific range. This compression ratio is determined during disc design and significantly impacts pellet quality. In our trials, the openness ratio was calculated as 36%, and the disc design was made accordingly, and it was successful.
- It has been observed that the effective length, which determines the compression ratio of discs, affects pellet dusting in a pellet, depending on the PDI.

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