Improved fuzzy logic controller for cane juice extraction

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Abstract. In current days Fuzzy logic plays auspicious role to provide so many choices for many applications which are system control. Fuzzy logic having no. of practical methodologies in soft computing. Sugar making industries are one of the applications using fuzzy logic controller. sugarcane juice extraction is an industry which is highly seasonable. If the supply of sugar cane is irregular then that reduces the efficiency of extractor from cane to mass producing sugar. So, it is necessary to improve the efficiency of extractor, which gives juice from cane billets. For that we must keep up the Donnelly height (or) level of cane is closed to 90cm. Where a methodology introduced to improve the three inputs controller with fuzzy is used to keep up the cane volume (or) level of Donnelly channel. For that cane level must and should always at 90cm. To limited that level (or) height of cane in chute (or) channel was developed by using of tool box in fuzzy logic designer, MATLAB software.

1. Introduction
The sugar having the most importance in our day-to-day life. In world most of the countries are manufacturing sugar. In which, India is in the second position to largest manufacturing of sugar from sugarcane [1]. Sugar manufacturing from sugarcane is very difficult to give with good quality in less price. And it is having lots of processes to manufacturing sugar like juice extraction process, crystallization process, etc. [2]. Where the Fuzzy logic place’s greatest role to decrease that difficulty to manufacturing of sugar. Making process of sugar is described in below. The trucks collect cane billets from different places and reached to yards of factory. In factory the yards are fed by trucks with cane billets and the billets are transformed in cane carrier. the cleaning of cane billets is done passing through the cane carrier. After that the billets are transformed to cane knives and shredder knives which are rotated thoroughly, to get little bit of cane pieces (in 1-2 cm) by cutting billets with knives. While the cane rails (or) billets are converted into small cane pieces by using of five to six mills in a series. In this process we get two materials one is fiber residual and cane juice; the extraction of cane juice schematic diagram is shown in figure 1. In which the fiber residual is used as fuel, it is going to the boiler station. The converted cane juice is having lots of impurities. These impurities are converted into the thickish paste contains of mud. And the mud is settled down in the clarifier vessel. Then the mud and juice are separated, the mud is used like fertilizers. And juice is boiled to get a syrup like thick liquid. This syrup having the 65% of sugar. After that the syrup is converted as sugar crystals by using of crystallization process [3] [4]. This paper gives the improved fuzzy controller by using of three inputs with fuzzy toolbox in MATLAB.
2. Terminology in sugar mill with important parameters

For juice production process of cane rails is arranged with two rolls to crushing cane, we required different parameters like roll length \((L_r)\) with 183cm and roll width \((B_c)\) with 43.5cm, the angle at optimum level \((\alpha)\) with 61 degrees and roll fastest movement (or) speed is measured in (meter/second). The roll mean volume (or) desire diameter is

\[
D = D_o - D_g, \quad (1)
\]

where \(D_g\) means Depth of Groove and \(D_o\) means roll diameter at outside. Cane having escribed volume \((m^3/s)\) which is given by [5].

\[
V_e = L_r \times B_c \times S \cos \alpha, \quad (2)
\]

where \(S\) is the speed of roll surface which is \(S = (\omega \times D) / 2\).

\[
\cos \alpha = (D + W - B_c) / D, \quad (3)
\]

And \(\cos \alpha\) is the contact angle between centre of two rolls. Which is given by

\[
\cos \alpha = (D + W - B_c) / D, \quad (4)
\]

The mass flow rate or crushing rate \((\text{Kg/s})\) is given by \(Q_c = V_e \times q_c\).

\[
\text{Speed of carrier (Cm/s)} = (\text{Feed rate}) \times 1 / (1\text{cm from Mass of cane in carrier}), \quad (7)
\]

\[
\text{The motional Speed of Motor} = (1.91 \times S_{rake}) \text{rev/min}, \quad (8)
\]

in which the \(S_{rake}\) is the speed of rake carrier(cm/s). And all these parameters came by using of such mill parameters like contact angle [6] and roll mean diameter, work opening [7]. Values for various parameters in mill are \(L_r = 183\text{cm}, D = 75.5\text{cm}, W = 11.45\text{cm}, B_c = 43.5\text{cm}, \alpha = 61^o, S = 16.6\text{cm/s}\)

3. Extraction process of cane juice

First the sugar cane passed through the two knives (cane and shredder knives respectively) which are rotated thoroughly to crushing the cane and gives the cane fiber. This cane fiber passed and throw out to the Donnelly chute, which is having the height of 180cm. where the cane fiber passed through the rake carrier and filled in Donnelly chute. The rake carrier having the length is 800cm and width is 150cm and carries the weight up to 500kg. The rake carrier carries the cane fiber varies from 500kg to 1000kg. for rake carrier we need two sensors to sense height and weight, that is shown in figure 3. For height, the light sensor is used and for weight, load cell is used. Depending upon these two parameters (height or level of chute and cane weight of rake - carrier), the motor speed of rake - carrier is senses by one sensor to rotate speedily or slowly for maintaining the level of cane at 90cm [9]. We have different circuit designs for height of the chute and load cell, roll speed to conditioning the signals [8]. For cane juice extraction we need three inputs. Three inputs are the cane weight prepared by variations in rake - carrier, cane level in Donnelly channel and the circling speed of the roll those are 500kg to 1000kg, 17.2rpm to 115.5rpm and 180cm respectively. The fuzzy logic controller algorithm is created by using of these three inputs, the fuzzy controller schematic is shown in figure 2. Fuzzy toolbox in MATLAB is used for creating three inputs controller with fuzzy logic. By using of algorithm, six cases are considered. For six cases three different roll speeds are 12cm/s, 14.3cm/s and 16.6cm/s respectively, flow rate \((Q_c)\) of each roll speed is 19.3kg/s, 22.8kg/s and 26.6kg/s [11]. Every input and output having the different variables with different ranges, using these variables membership functions are created by Fuzzy Inference System (FIS) in MATLAB used by fuzzy toolbox. The Fuzzy Inference System (FIS) is shown in figure 4.

4. Fuzzy controller algorithm with three inputs terminology

The Fuzzy Controller having four components are 1. fuzzifier, 2. rule base, 3. inference engine and 4. defuzzifier [10]. Fuzzy Inference System (FIS) is designed by membership functions, which can be created by three inputs of variables are considered and output is getting by the membership function. Membership function is nothing but triangular membership function is designed, the input and output parameters of triangular membership function are 50% overlapped with their nearby function of membership. [5]. With using of membership function fuzzy rules are created. In one controller we
have so many rules which are called as rule matrix of fuzzy controller these rule matrices are considered by roll speed 12.0cm/s is shown in table 1, roll speed 14.3 cm/s shown in table 2 and another roll speed is 16.6cm/s at which the rule matrix is tabled in table 3.

5. Experiments and Analysis
Total six experiments are done. In each experiment the fuzzy inference system (FIS) is created by different parameters. The FIS is created by giving different cane levels 0cm, 30cm, 45cm, 60cm, 90cm, 120cm, 150cm, 180cm as first input followed by the cane feed rate is added by 42%, 31%, 20%, 9%, 0% respectively. If in case the level of cane is placed at 90cm, feed rate always same as flow rate. In case the cane is reached to level at 120cm, 135cm, 150cm, 180cm then feed rate subtracted by 9%, 20%, 31%, 42% respectively. In each experiment six cases are considered. In every six cases the percentage of time period and time period are calculated for 210 seconds. And each six cases the lower level of cane and higher level of cane are noted, also the lowest level of motor speed and carrier speed and highest level of motor speed and carrier speed also noted. All these noted results are shown in figure 20 to 25. In this paper analyses the things like low range of input variables and high range of output variables and high range of input variables and low range of output variables are applied to the fuzzy inference system then we noticed that differentiation between all these experiments output results.

5.1. Experiment - 1
The Fuzzy Inference System (FIS) designed by three inputs and outputs. Each input and output are fuzzified into 9, 13, 3, 9 triangular linguistic variables respectively. Each parameter explained clearly in below figure 5. With using of these three inputs and one output the fuzzy controller with fuzzy rules is created. The one simulation result with height or level taken as 90cm and weight considered as 750kg, roll speed is 15 cm/s then the output speed is 46.2 rpm of experiment 1 is shown in figure 7.
Input 1 - HEIGHT having the nine variables are EL, VL, ML, L, JR, H, MH, VH, EH.
Input 2 - WEIGHT having 13 variables are SL, UL, EL, VL, ML, L, JR, H, MH, VH, EH, UH, SH.
Input 3 – ROLL SPEED having three variables are RL, RM, RR and
Output – SPEED having nine variables EL, VL, L, JR, H, VH, EH, UH, SH.

5.2. Experiment - 2
The Fuzzy Inference System (FIS) designed by three inputs and outputs. Every input and output are fuzzified into 9, 13, 3, 11 triangular linguistic variables respectively. Each one explained clearly in figure kept with authors. The one simulation result with height or level taken at 90cm and weight is 750kg, roll speed by 15 cm/s then the output speed is 50 rpm of experiment 2 is shown in figure 8.
Input 1 - HEIGHT having nine variables are EL, VL, ML, L, JR, H, MH, VH, EH.
Input 2 - WEIGHT having 13 variables are SL, UL, EL, VL, ML, L, JR, H, MH, VH, EH, UH, SH.
Input 3 – ROLL SPEED having three variables are RL, RM, RR and
Output – SPEED having eleven variables EL, VL, ML, L, JR, H, VH, VL, EH, UH, SH.

5.3. Experiment - 3
The Fuzzy Inference System (FIS) designed by three inputs and outputs. Every input and output are fuzzified into 5, 9, 3, 7 triangular linguistic variables respectively. Every variable explained clearly in figure kept with the authors. The one simulation result with height or level from 90cm and weighted by 750kg, roll speed is rolled at 15 cm/s then the output speed is 50 rpm of this experiment is shown in figure 9.
Input 1 - HEIGHT having five variables are VL, L, JR, H, VH.
Input 2 - WEIGHT having 9 variables are UL, EL, VL, L, JR, H, VH, EH, UH.
Input 3 – ROLL SPEED having three variables are RL, RM, RR and
Output – SPEED having seven variables VL, L, JR, H, VH, EH, UH.
5.4. Experiment - 4
The Fuzzy Inference System (FIS) designed by three inputs and outputs. Every input and output are fuzzified into 5, 9, 3, 9 triangular linguistic variables respectively. Each variable explained in figure 6. The one simulation result with height of 90cm and weight of 750kg, roll speed as 15 cm/s then the output speed is 46.2 rpm of this experiment is shown in figure 10.
Input 1 - HEIGHT having five variables are VL, L, JR, H, VH.
Input 2 - WEIGHT having 9 variables are UL, EL, VL, L, JR, H, VH, EH, UH.
Input 3 – ROLL SPEED having three variables are RL, RM, RR and
Output – SPEED having nine variables EL, VL, L, JR, H, VH, EH, UH, SH.

5.5. Experiment - 5
The Fuzzy Inference System (FIS) designed by three inputs and outputs. Every input and output are fuzzified into 5, 9, 3, 8 triangular linguistic variables respectively. Each variable explained clearly in figures, kept with the authors. The one simulation result with height or level placed at 90cm and weight is taken at 750kg, roll speed is rollover by 15 cm/s then the output speed is 50 rpm is shown in below figure 11 of this experiment.
Input 1 - HEIGHT having five variables are VL, L, JR, H, VH.
Input 2 - WEIGHT having 9 variables are UL, EL, VL, L, JR, H, VH, EH, UH.
Input 3 – ROLL SPEED having three variables are RL, RM, RR and
Output – SPEED having eight variables VL, L, JR, H, VH, EH, UH, SH.

5.6. Experiment - 6
The Fuzzy Inference System (FIS) designed by three inputs and outputs. Every input and output are fuzzified into 5, 9, 3, 9 triangular linguistic variables respectively. Each one explained clearly with the figures being with the authors. Using of three inputs and one output the one simulation result with height or level taken at 90cm and weight placed at 750kg, roll speed covered by 15 cm/s then the output speed is 46.2 rpm is shown in below figure 12.
Input 1 - HEIGHT having five variables are VL, L, JR, H, VH.
Input 2 - WEIGHT having 9 variables are UL, EL, VL, L, JR, H, VH, EH, UH.
Input 3 – ROLL SPEED having three variables are RL, RM, RR and
Output – SPEED having nine variables EL, VL, L, JR, H, VH, EH, UH, SH. Where the output is considered by the variable federate algorithm [11].

6. Results and discussion
After completing six experiments we get some results. In experiment one considering six cases in each case got time period like 139, 186, 130, 158, 119, 155 for consideration of 210 seconds which are having the percentages are 66.2%, 88.6%, 61.9%, 79.5%, 56.6%, 73.7% respectively shown in below table 4. And in experiment two, the time period for each six cases is 125, 125, 114, 78, 44, 93 and their percentage of time period are 59.5%, 59.5%, 54.3%, 37.1%, 20.9%, 44.3% and these are classified in table 5. for experiment three we got values for time period are 134, 117, 168, 124, 106, 97 for these time periods the percentage with considering of 210 seconds is 63.8%, 55.7%, 80%, 59%, 50.5%, 46.2% described in table 6. As same as third experiment the fourth experiment have small difference in variables of output but it got the time period for some cases better than the all the experiments. Those values of time period are 145, 210, 122, 170, 102, 180 and their percentages are 69.1%, 100%, 58.1%, 80.9%, 48.6%, 85.7% clearly mentioned in table 7. and the fifth experiment having time period values are 197, 175, 163, 160, 130, 138 by getting one case is better than all the experiments for these values the percentage of time period are 93.8%, 83%, 77.6%, 76.2%, 61.9%, 65.7%, values are shown in table 8. Finally, the sixth experiment considered as variable feed rate algorithm. For this algorithm we get some time period values for all six cases are 125, 101, 99, 63, 82, 85 and the percentage values are 59.5%, 48.1% 47.1%, 30%, 39%, 40.5% of time period respectively, which are tabulated and mentioned in table 9.
7. Conclusion
Using Fuzzy Controller, the cane level is maintained between 85cm to 95cm. So the level of Donnelly chute is maintained to get improved efficiency of cane juice extraction. Considering all the six experiments, the experiment four get better results all of other experiments by using less input variables for height and weight and output having 9 variables only. The time required to reaching cane level in experiment four are 145, 210, 122, 170, 102, 180 when considering the level of cane in middle of 85 to 95 cm. In this experiment case II, case IV and case VI are get best results of time are 210, 170, 180. case II got 100% of time period so, the roll speed of motor is fast then we get best accuracy. And remaining case IV and case VI are gotten percentage of time are 80.9%, 85.7%. In experiment 3 and experiment 5 also we get one case in each are get best time period because of fast rolling of roll speed. The time of those two cases is 168 in case III and 197 in case I respectively. the percentage of case III in experiment 3 is 80% and case I in experiment 5 is 93.8%. Comparison between all six cases of six experiments are shown in figure 13.

Figure 1. Schematic diagram for extraction process of cane juice from sugarcane.

Figure 2. Schematic diagram for Fuzzy Controller.

Figure 3. Figure for maintaining the cane level using three inputs Fuzzy Controller

Figure 4. The figure for Fuzzy Inference System (FIS) objects explaining the blocks of input and output
Figure 5. With Input and Output, created Membership Functions of Experiment – 1

Figure 6. With Input and Output, created Membership Functions of Experiment – 4

Figure 7. Fuzzy Rule of Experiment- 1

Figure 8. Fuzzy Rule of Experiment- 2

Figure 9. Fuzzy Rule of Experiment- 3

Figure 10. Fuzzy Rule of Experiment- 4
Table 1. Rule Matrix for Experiment at Roll Speed RL when roll speed is "RL=12cm"

| HEIGHT | EL   | VL   | ML   | L    | JR   | H    | MH   | VH   | EH   |
|--------|------|------|------|------|------|------|------|------|------|
| SL     | VH   | H    | H    | JR   | JR   | JR   | L    | L    | VL   |
| UL     | VH   | H    | JR   | JR   | JR   | L    | L    | VL   | VL   |
| EL     | H    | H    | JR   | JR   | JR   | L    | L    | VL   | VL   |
| VL     | H    | JR   | JR   | L    | L    | L    | VL   | VL   | EL   |
| ML     | H    | JR   | L    | L    | L    | L    | VL   | VL   | EL   |
| L      | H    | JR   | L    | L    | L    | VL   | VL   | EL   | EL   |
| JR     | H    | L    | L    | L    | VL   | VL   | EL   | EL   | EL   |
| H      | JR   | L    | L    | L    | VL   | VL   | EL   | EL   | EL   |
| MH     | L    | L    | L    | VL   | VL   | VL   | EL   | EL   | EL   |
| VH     | L    | L    | L    | VL   | VL   | VL   | EL   | EL   | EL   |
| EH     | L    | L    | VL   | VL   | VL   | VL   | EL   | EL   | EL   |
| UH     | L    | L    | VL   | VL   | VL   | VL   | EL   | EL   | EL   |
| SH     | L    | L    | VL   | VL   | EL   | EL   | EL   | EL   | EL   |

Table 2. Rule Matrix for Experiment at Roll Speed RM when roll speed is "RM=14.3cm"

| HEIGHT | EL   | VL   | ML   | L    | JR   | H    | MH   | VH   | EH   |
|--------|------|------|------|------|------|------|------|------|------|
| SL     | EH   | EH   | VH   | H    | H    | JR   | JR   | L    | L    |
| UL     | EH   | VH   | VH   | H    | JR   | JR   | L    | L    | L    |
| EL     | VH   | VH   | H    | JR   | JR   | JR   | L    | L    | L    |
| VL     | VH   | H    | JR   | JR   | L    | L    | VL   | L    | L    |
| ML     | VH   | H    | JR   | JR   | JR   | L    | L    | VL   | L    |
| L      | H    | JR   | JR   | JR   | L    | L    | VL   | VL   | L    |
| JR     | H    | JR   | JR   | L    | L    | VL   | VL   | EL   | EL   |
| H      | JR   | JR   | JR   | L    | L    | VL   | VL   | EL   | EL   |
| MH     | JR   | JR   | L    | L    | VL   | VL   | EL   | EL   | EL   |
| VH     | JR   | L    | L    | VL   | VL   | EL   | EL   | EL   | EL   |
### Table 3. Rule Matrix for Experiment at Roll Speed RR

|       | EL | VL | ML | L  | JR | VH | MH | EH | UH | L  | VL |
|-------|----|----|----|----|----|----|----|----|----|----|----|
| SL    | SH | UH | EH | VH | L  | JR | H  | JR | JR | JR | EL |
| UL    | EH | EH | VH | H  | H  | JR | JR | L  | L  | L  | L  |
| EL    | EH | VH | VH | H  | JR | JR | L  | L  | VL |
| VL    | VH | VH | H  | JR | JR | L  | L  | VL |
| ML    | VH | VH | H  | JR | JR | L  | L  | VL |
| L     | VH | H  | H  | JR | JR | L  | L  | VL |
| VL    | EL | EH | JR | JR | L  | L  | VL |
| MH    | H  | H  | JR | JR | L  | L  | VL |
| VH    | H  | H  | JR | JR | L  | L  | VL |
| EH    | JR | JR | L  | L  | VL |
| UH    | JR | JR | L  | L  | VL |
| SH    | JR | JR | L  | L  | VL |

Table 4. Comparison of All Experiments for Case - 1

| S. No | parameter                              | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 | Experiment 6 | OLD-experiment |
|-------|----------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|----------------|
| 1.    | Time period for cane level within 210 seconds | 186          | 125          | 117          | 210          | 175          | 101          | 199            |
| 2.    | Percentage of cane level in b/w 85 - 95 cm | 88.6%        | 59.5%        | 55.7%        | 100%         | 83%          | 48.1%        | 94.7%          |
| 3.    | Lower level of cane in chute(cm)        | 80.0         | 79.6         | 86.9         | 86.1         | 85.7         | 77.1         | 84.2           |
| 4.    | Higher level of cane in chute(cm)       | 94.2         | 92.8         | 102.5        | 94.5         | 101.1        | 101.9        | 95.9           |
| 5.    | Faster speed of carrier motor(rpm)      | 71.9         | 73.6         | 65.3         | 65.3         | 73.5         | 81.4         | 71.5           |
| 6.    | Slower speed of carrier motor(rpm)      | 29.6         | 36.2         | 33.4         | 35.6         | 31.1         | 29.6         | 31.2           |
| 7.    | Faster speed of cane carrier(cm/s)      | 37.7         | 38.6         | 34.3         | 34.3         | 38.6         | 42.6         | 37.4           |
| 8.    | Slower speed of cane carrier(cm/s)      | 15.5         | 19.0         | 17.5         | 18.7         | 16.3         | 15.5         | 16.3           |

Table 5. Comparison of All Experiments for Case - 2

| S. No | parameter                              | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 | Experiment 6 | OLD-experiment |
|-------|----------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|----------------|
| 1.    | Time period for cane level within 210 seconds | 130          | 114          | 168          | 122          | 163          | 99           | 156            |
| No. | Parameter                                                                 | Experiment-1 | Experiment-2 | Experiment-3 | Experiment-4 | Experiment-5 | Experiment-6 | OLD-experiment |
|-----|---------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|----------------|
| 1.  | Time period for cane level within 210 seconds                             | 130          | 114          | 168          | 122          | 163          | 99           | 156            |
| 2.  | Percentage of cane level in b/w 85 - 95 cm                                | 61.9%        | 54.3%        | 80%          | 58.1%        | 77.6%        | 47.1%        | 74.7%          |
| 3.  | Lower level of cane in chute(cm)                                         | 39.6         | 36.4         | 40.7         | 39.6         | 26.8         | 38.9         | 39.3           |
| 4.  | Higher level of cane in chute(cm)                                        | 108.3        | 94.2         | 99.3         | 100.7        | 97.5         | 96.9         | 97.2           |
| 5.  | Faster speed of carrier motor(rpm)                                       | 71.9         | 70.1         | 72.0         | 71.2         | 73.4         | 71.2         | 71.4           |
| 6.  | Slower speed of carrier motor(rpm)                                       | 33.4         | 29.9         | 33.5         | 33.7         | 33.7         | 33.8         | 33.3           |
| 7.  | Faster speed of cane carrier(cm/s)                                       | 37.7         | 36.8         | 37.8         | 37.4         | 38.5         | 37.3         | 37.4           |
| 8.  | Slower speed of cane carrier(cm/s)                                       | 17.5         | 15.7         | 17.6         | 17.7         | 17.7         | 17.7         | 17.4           |

Table 6. Comparison of All Experiments for Case -3
### Table 7. Comparison of All Experiments for Case -4

| S. No | Parameter                        | Experiment-1 | Experiment-2 | Experiment-3 | Experiment-4 | Experiment-5 | Experiment-6 | OLD-experiment |
|-------|----------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|----------------|
| 1.    | Percentage of cane level in b/w 85 - 95 cm | 79.5%        | 37.1%        | 59.0%        | 80.9%        | 76.2%        | 30%          | 78.9%          |
| 2.    | Time period for cane level within 210 seconds | 158          | 78           | 124          | 170          | 160          | 63           | 165            |
| 3.    | Lower level of cane in chute(cm)    | 40.0         | 36.4         | 42.5         | 40.0         | 27.8         | 39.6         | 39.6           |
| 4.    | Higher level of cane in chute(cm)   | 94.1         | 91.0         | 99.2         | 94.4         | 100.6        | 101.3        | 96.0           |
| 5.    | Faster speed of carrier motor(rpm)  | 73           | 73.8         | 74.3         | 73.0         | 73.5         | 73.0         | 73.0           |
| 6.    | Slower speed of carrier motor(rpm)  | 29.6         | 36.8         | 33.4         | 35.6         | 31.1         | 29.6         | 31.2           |
| 7.    | Faster speed of cane carrier(cm/s)  | 38.3         | 38.7         | 39.0         | 38.3         | 38.6         | 38.2         | 38.2           |
| 8.    | Slower speed of cane carrier(cm/s)  | 15.5         | 19.3         | 17.5         | 18.7         | 16.3         | 15.5         | 16.3           |

### Table 8. Comparison of All Experiments for Case -5

| S. No | Parameter                        | Experiment-1 | Experiment-2 | Experiment-3 | Experiment-4 | Experiment-5 | Experiment-6 | OLD-experiment |
|-------|----------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|----------------|
| 1.    | Percentage of cane level in b/w 85 - 95 cm | 56.6%        | 20.9%        | 50.5%        | 48.6%        | 61.9%        | 39.0%        | 61.2%          |
| 2.    | Time period for cane level within 210 seconds | 119          | 44           | 106          | 102          | 130          | 82           | 128            |
| 3.    | Lower level of cane in chute(cm)   | 86.2         | 80.5         | 84.6         | 82.6         | 84.3         | 75.9         | 86.2           |
| 4.    | Higher level of cane in chute(cm)  | 146.1        | 141.8        | 153.2        | 146.1        | 149.3        | 146.1        | 156.8          |
| 5.    | Faster speed of carrier motor(rpm) | 71.9         | 70.1         | 69.3         | 69.4         | 72.3         | 82.0         | 74.5           |
| 6.    | Slower speed of carrier motor(rpm) | 29.6         | 27.0         | 32.8         | 29.6         | 29.9         | 28.9         | 32.0           |
| 7.    | Faster speed of cane carrier(cm/s) | 37.7         | 36.8         | 36.4         | 36.4         | 37.9         | 42.9         | 39.0           |
| 8.    | Slower speed of cane carrier(cm/s) | 15.5         | 14.2         | 17.2         | 15.5         | 15.7         | 15.1         | 16.8           |
Table 9. Comparison of All Experiments for Case -6

| S. No | parameter                             | Experiment-1 | Experiment-2 | Experiment-3 | Experiment-4 | Experiment-5 | Experiment-6 | OLD-experiment |
|-------|---------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|----------------|
| 1.    | Time period for cane level within 210 seconds | 155          | 93           | 97           | 180          | 138          | 85           | 173            |
| 2.    | Percentage of cane level in b/w 85 - 95 cm | 73.8%        | 44.3%        | 46.2%        | 85.7%        | 65.7%        | 40.5%        | 82.6%          |
| 3.    | Lower level of cane in chute(cm)       | 81.1         | 80.6         | 87.2         | 85.9         | 86.1         | 77.1         | 84.8           |
| 4.    | Higher level of cane in chute(cm)      | 143.6        | 139.3        | 150.7        | 143.6        | 146.8        | 143.6        | 143.2          |
| 5.    | Faster speed of carrier motor(rpm)     | 71.9         | 73.4         | 64.8         | 65.2         | 73.4         | 81.4         | 71.3           |
| 6.    | Slower speed of carrier motor(rpm)     | 29.6         | 27.0         | 33.4         | 29.6         | 31.1         | 29.6         | 29.5           |
| 7.    | Faster speed of cane carrier(cm/s)     | 37.7         | 38.5         | 34.0         | 34.2         | 38.5         | 42.6         | 37.3           |
| 8.    | Slower speed of cane carrier(cm/s)     | 15.5         | 14.2         | 17.5         | 15.5         | 16.3         | 15.5         | 15.4           |

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