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# Investigations on Sugarcane De-Trashing Mechanisms

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***Abstract*— *Mechanisation of harvesting is crucial for ensuring cost effectiveness of sugarcane cultivation. De-trashing is the removal of leaves and top from harvested cane stalk. The operating parameters of a high speed rotating brush type de-trashing mechanism were investigated so as to aid the development of a combine harvester.***

Keywords—**Sugarcane de-trashing, Rotating brush, De-trashing efficiency, cane velocity**

## I. Introduction

Sugarcane is the second most important industrial crop in India grown in 4.4 million hectares with an average productivity of about 68 tonnes per hectare (Anon.2013). To mitigate the labour scarcity and ensure timely operations mechanization is a must. Mechanisation will also improve the overall energy use efficiency of sugarcane based farming (Duttamajumder *et al*. 2011). About 45-48% of the total cost of cultivation is accountable to harvesting operation in manual harvesting. Mechanisation of harvesting operations is imperative in increasing the cost effectiveness of sugarcane production system.

De-trashing the harvested canes is a time consuming manual operation. De-trashing is the removal of tops and leaves (trash matter) from the stalk by techniques other than burning. Mechanised de-trashing can be achieved mainly by two methods *viz.* cleaning the leaf with compressed air or the centrifugal cleaning method. A variety of mechanisms have been investigated by different researchers for the removal of tops and leaves.

Even though Ramp (1965) conducted extensive experimentation of stripping leaves from cane at harvesting using rotating cylinders with different types of stripping fingers, the developed system had many drawbacks. Clayton and Whittemore (1970) reported on different polygon shaped rolls developed at Louisiana State University. Clayton and Roberts (1971) observed that stripping fingers worked satisfactorily only for straight cane and they did not remove green trash. Srivastava (1990) reported that the leaf cleaner is the key part of the centrifugal-type small scale sugarcane harvester, and the cleaning element is the core component of the cleaner. Caillouet (2001) described a cleaning mechanism consisting of a powered rotatable cleaning shaft supporting elongated flexible members. Li*et al*. (2002) reported that brush type de-trashing system was suited for small sugarcane harvesters. Meng *et al.* (2003) reported that in brush type cleaning system, the leaves are striped away from the stalk by the high speed rotating cleaning elements by pushing, rubbing and striking. Wang et al. (2006) found that the main factors affecting de-trashing efficiency are speed of de-trashing plate, speed of input and output roller, distance between input roller and de-trashing plate and the distance between output roller and de-trashing plate. Yang et al. (2009) also investigated the factors influencing de-trashing and their interaction on the work quality.

Conclusive results on the optimum arrangement of components and the feeding method could not be found and hence a study was taken up to investigate different alternatives for the development of a cost effective, energy efficient brush type de-trashing system for harvested sugarcane stalks.

## II. Material and Methodology

The investigation was carried out with a high speed rotating brush type system in which the cleaning elements push, rub and strike the sugarcane stalk thereby separating the leaves from the stalk. The different orientations of the cleaning systems tested are shown in Fig. 1.

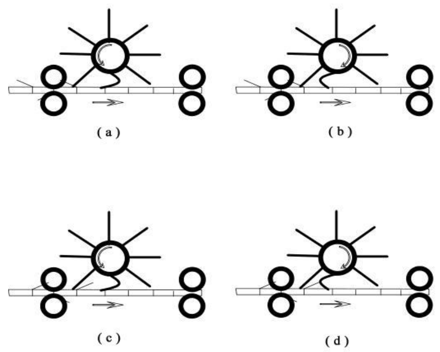


Fig. 1 Different systems of de-trashing

a. Cane bottom feeds first, brush rotates in the same direction
b. Cane bottom feeds first, brush rotates in the opposite direction
c. Cane top feeds first, brush rotates in the same direction
d. Cane top feeds first, brush rotates in the opposite direction

The available commercial model of sugarcane de-topper cum leaf stripper with brush type cleaning element powered by a 6 hp Greaves diesel engine was used. The machine had counter rotating input rollers, de-trasher brush rollers and output rollers. This machine was converted to a test rig by incorporating facilities for varying spiral angle of the brushes, de-trasher roller speeds and the input roller speeds. Fig. 2 and 3 shows the different de-trasher rollers and the experimental set up respectively

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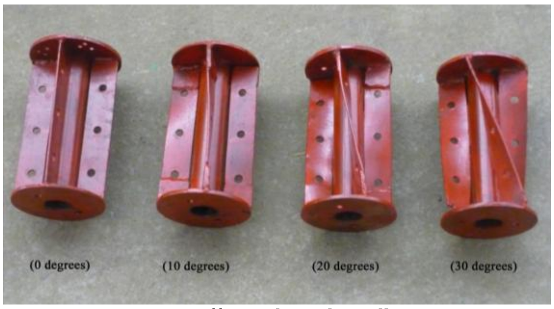


Fig. 2 Different de-trasher rollers

Fig, 3 Test rig for de-trashing studies

The variables selected for the investigation were input roller speed, de-trasher roller speed and spiral angle of the brushes. The different levels of the input roller speed selected for the study were 250, 325 and 400 rpm. The de-trasher roller speeds investigated were 800, 1000, 1250 and 1500 rpm. The spiral angle of de-trasher brushes studied were 0, 10, 20 and 30 degrees.

The performance of the sugarcane de-trashing unit was evaluated in terms of de-trashing efficiency and the velocity of cane movement.

i. De-trashing efficiency

The de-trashing efficiency was calculated using the following formula:

$$\text{Detrashing Efficiency}(\%) = \frac{(\text{Mass of detopped cane} - \text{Mass of detrashed cane}) \times 100}{(\text{Mass of detopped cane} - \text{Mass of cleaned cane})} \quad (1)$$

To determine the cane velocity in the de-trasher unit, video-graphic method was used. The video of the movement of the cane from the output roller was captured using a digital camera (Panasonic- Lumix- DMC-FS3) having a capacity to record 36 frames per second. Time required for the cane to travel in the system was obtained from the video. The length of the cane and its diameter at top, middle and base were also measured. Then the velocity of cane was calculated.

## III. Results and Tables

Table 1. shows the variation in de-trashing efficiency of the different systems.

TABLE 1. DE-TRASHING EFFICIENCY OF THE DIFFERENT SYSTEMS

| Sl. No. | De-trashing systems | De-trashing efficiency (%) |
|---|---|---|
| D1 | Cane bottom feed first, brush rotates in the same direction | 95.32 |
| D2 | Cane bottom feed first, brush rotates in the opposite direction | 85.65 |
| D3 | Cane top feed first, brush rotates in the same direction | 84.35 |
| D4 | Cane top feed first, brush rotates in the opposite direction | 95.45 |

D1 and D4 showed a high de-trashing efficiency. In both these systems the brushes were working opposite to the direction of the leaves formation.

The performance of sugarcane de-trashing unit was evaluated for the efficiency of de-trashing and the cane velocity. The variables and the levels selected is shown in Table 2

TABLE 2. VARIABLES AND THE LEVELS OF DE-TRASHER STUDIES

| Variables | Levels | | | |
|---|---|---|---|---|
| Spiral angle of de-trasher brushes ( degree ) | $A_1$ (0) | $A_2$ (10) | $A_3$ (20) | $A_4$ (30) |
| De-trasher roller speed (ms$^{-1}$) | $N_1$ (8.8) | $N_2$ (11.0) | $N_3$ (13.75) | $N_4$ (16.5) |
| Input roller speed (ms$^{-1}$) | $S_1$ (1.3) | $S_2$ (1.7) | $S_3$ (2.1) | |

**De-trashing efficiency**

The de-trashing efficiency of different combinations of the spiral angle of de-trasher brushes (A), the de-trasher roller speed (N), and the input roller speed (S) are shown in Table 3.

The de-trashing efficiency data were analysed as per three-way analysis of variance and the significance of each factor and their combinations were studied using Fisher's least significant difference (*LSD*) procedure in completely randomised lock design by AgRes Software statistical package. The results of the statistical analysis are shown in Table. 4.

TABLE 3. DE-TRASHING EFFICIENCY AT DIFFERENT COMBINATION OF VARIABLE LEVELS

| De-trasher roller speed (ms$^{-1}$) | Input roller speed (ms$^{-1}$) | Spiral angle of de-trasher brushes | | | |
|---|---|---|---|---|---|
| | | 0 degree | 10 degree | 20 degree | 30 degree |
| | | η (%) | η (%) | η (%) | η (%) |
| 8.8 | 1.3 | 87.60 | 80.78 | 86.15 | 80.46 |
| | 1.7 | 89.32 | 82.27 | 89.41 | 77.94 |
| | 2.1 | 87.41 | 74.70 | 90.68 | 85.75 |
| 11.0 | 1.3 | 85.70 | 90.60 | 91.47 | 85.58 |
| | 1.7 | 88.25 | 91.38 | 92.40 | 88.20 |
| | 2.1 | 86.15 | 88.75 | 90.67 | 85.14 |
| 13.75 | 1.3 | 92.08 | 90.30 | 85.72 | 90.00 |
| | 1.7 | 96.39 | 91.11 | 92.22 | 91.33 |
| | 2.1 | 86.65 | 86.25 | 91.88 | 92.13 |
| 16.5 | 1.3 | 85.67 | 93.00 | 92.78 | 93.71 |
| | 1.7 | 96.27 | 94.00 | 93.17 | 92.27 |
| | 2.1 | 93.75 | 89.80 | 95.79 | 90.17 |

TABLE 4. ANALYSIS OF VARIANCE SUMMARY FOR THE EFFECTS OF DIFFERENT COMBINATIONS ON DE-TRASHING EFFICIENCY

| Source | SS | DF | MS | F | P-value |
|---|---|---|---|---|---|
| A | 276.701 | 3 | 92.234 | 3.9954 | 0.010 ** |
| N | 1305.011 | 3 | 435.004 | 18.8437 | 0.000 ** |
| S | 131.917 | 2 | 65.959 | 2.8572 | 0.062 NS |
| AN | 576.171 | 9 | 64.019 | 2.7732 | 0.006 ** |
| NS | 45.850 | 6 | 7.642 | 0.3310 | 0.919 NS |
| AS | 261.887 | 6 | 43.648 | 1.8908 | 0.090 NS |
| ANS | 353.377 | 18 | 19.632 | 0.8504 | 0.638 NS |
| Residual | 2216.139 | 96 | 23.085 | 1.0000 | |
| Total | 5167.0534 | 143 | 36.134 | 1.5652 | |

**Significant at ($p < 0.01$) level; NS Non significant C.V. (Treatment): 5.40%

Analysis of variance of the de-trashing efficiency values with respect to the tested de-trashing combinations at 0.01 level showed that the factors, the spiral angle of de-trasher brushes (A) andthe de-trasher roller speed (N) were highly significant at their one-way and two-way interactions. The factor input roller speed (S) was non-significant for the de-trashing efficiency.

Based on these results it can be concluded that the de-trashing efficiency for the four spiral angles and the four experimental de-trasher speeds were not the same. It can also be concluded that the de-trashing efficiency at a spiral angle depends on the de-trasher roller speed.

The ranked orders of the main effects and their interactions showed that, the spiral angle of de-trasher brushes $A_1$ (0 degree) and $A_3$ (20 degree) were on par. The de-trasher roller speed $N_3$ (13.75 $ms^{-1}$) and $N_4$ (16.5 $ms^{-1}$) were the best, while combinations of $A_1N_3S_2$ were found to be having the highest mean value of de-trashing efficiency.

The variance of the de-trashing efficiency with respect to the spiral angle of the de-trasher brushes (A) and the de-trasher roller speed (S) were plotted in Fig. 4. It is clear from this graph that the de-trashing efficiency increased with the increase in the de-trasher roller peripheral speed. The best spiral angle of the brushes was 0 degree. The de-trashing efficiency at the de-trasher brush roller speed of 13.75 $ms^{-1}$ and 16.5 $ms^{-1}$ at 0 degree spiral angle were similar and showed the maximum de-trashing efficiency.

Sensitivity of the de-trashing efficiency and the de-trasher roller speed for the different input roller speeds at the best spiral angle (0 degree) of the de-trasher brushes are depicted Fig. 5. It is clear from the graph that the input roller speed of 1.7$ms^{-1}$ performed the best, compared to other input roller speeds. The de-trashing efficiency at 1.3 $ms^{-1}$ and 1.7 $ms^{-1}$ for the input roller speeds were similar up to the de-trasher roller speeds of 13.75 $ms^{-1}$ and after 13.75 $ms^{-1}$ the input roller speeds of 1.7 $ms^{-1}$ and 2.1 $ms^{-1}$ showed the similar trends.

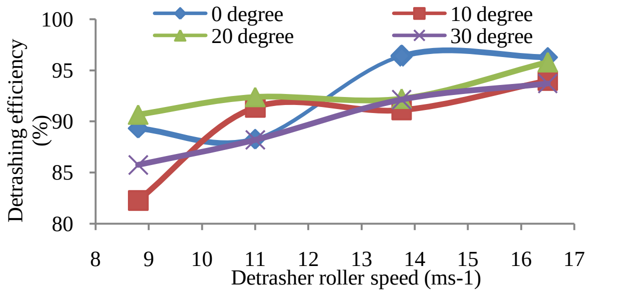


Fig. 4. Variation of de-trashing efficiency with respect to spiral angle of de-trasher brushes and de-trasher brush roller speed

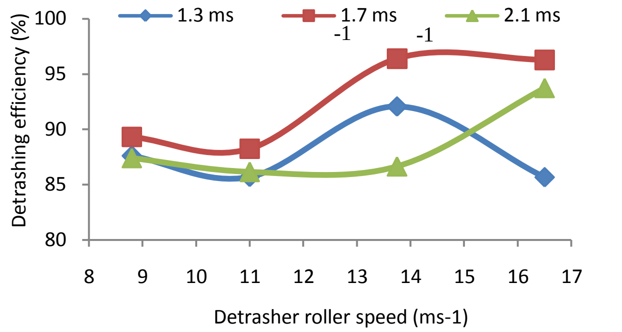


Fig. 5 Sensitivity of de-trashing efficiency and de-trasher roller speed for the different input roller speeds at 0 degree spiral angle

**Cane velocity in the de-trasher unit**

The cane velocity in the de-trasher unit at different combinations of the spiral angle of the de-trasher brushes (A), the de-trasher roller speed (N), and the input roller speed (S) are reported in Table. 5.

The cane velocity in the de-trasher data were analysed as per three-way analysis of variance and the significance of each factor and their combinations were studied using Fisher's least significant difference (*LSD*) procedure in completely randomised block design by AgRes Software statistical package. The results are shown in Table. 6

TABLE 5. CANE VELOCITY IN THE DE-TRASHER UNIT AT DIFFERENT COMBINATION OF VARIABLES

| De-trasher roller speed ($ms^{-1}$) | Input roller speed ($ms^{-1}$) | Spiral angle of de-trasher brushes | | | |
|---|---|---|---|---|---|
| | | 0 degree | 10 degree | 20 degree | 30 degree |
| | | Velocity ($ms^{-1}$) | Velocity ($ms^{-1}$) | Velocity ($ms^{-1}$) | Velocity ($ms^{-1}$) |
| 8.8 | 1.3 | 1.51 | 1.72 | 1.18 | 0.94 |
| | 1.7 | 1.78 | 1.63 | 1.23 | 0.94 |
| | 2.1 | 2.03 | 1.55 | 1.30 | 0.98 |
| 11.0 | 1.3 | 1.45 | 1.34 | 0.91 | 0.72 |
| | 1.7 | 1.83 | 1.55 | 0.91 | 0.69 |
| | 2.1 | 1.96 | 1.61 | 1.09 | 0.80 |
| 13.75 | 1.3 | 1.37 | 1.06 | 0.91 | 0.68 |
| | 1.7 | 1.67 | 1.07 | 1.12 | 0.81 |
| | 2.1 | 1.77 | 1.22 | 1.16 | 0.82 |
| 16.5 | 1.3 | 1.34 | 0.99 | 1.06 | 0.75 |
| | 1.7 | 1.54 | 1.07 | 0.95 | 0.67 |
| | 2.1 | 1.68 | 1.17 | 1.09 | 0.74 |

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TABLE 6. ANALYSIS OF VARIANCE SUMMARY FOR THE EFFECTS OF DIFFERENT COMBINATIONS ON CANE VELOCITY IN THE DE-TRASHER

| Source | SS | DF | MS | F | P-value |
|---|---|---|---|---|---|
| **A** | 14.713 | 3 | 4.904 | 303.877 | 0.000 ** |
| **N** | 1.999 | 3 | 0.667 | 41.297 | 0.000 ** |
| **S** | 0.868 | 2 | 0.434 | 26.892 | 0.000 ** |
| **AN** | 1.101 | 9 | 0.122 | 7.579 | 0.000 ** |
| **NS** | 0.119 | 6 | 0.019 | 1.228 | 0.299 NS |
| **AS** | 0.581 | 6 | 0.097 | 6.001 | 0.000 ** |
| **ANS** | 0.256 | 18 | 0.014 | 0.882 | 0.600 NS |
| **Residual** | 1.549 | 96 | 0.016 | 1.000 | |
| **Total** | 21.187 | 143 | 0.148 | 9.180 | |

**Significant at ($p < 0.01$) level; NS Non significant; C.V. (Treatment): 10.45%

Analysis of variance values of cane velocity in the de-trasher with respect to the tested de-trashing combinations at 0.01 level showed that the factors, the spiral angle of the de-trasher brushes (A), the de-trasher roller speed (N), and the input roller speed (S) were highly significant. The AN, AS 2-way interactions were also highly significant.

Based on these results, it is concluded that the cane velocity in the de-trasherfor the four spiral angles, four experimental de-trasher roller speeds and three input roller speeds was highly significant. It can also be concluded that the cane velocity in the de-trasher at a spiral angle depends on the de-trasher roller speed as well as on the input roller speed.

The ranked orders of the main effects and their interactions showed that, the spiral angle of the de-trasher brushes $A_1$ (0 degree), the de-trasher roller speed $N_1$ (8.8 $ms^{-1}$) and the input roller speed $S_3$ (2.1 $ms^{-1}$) were the best. These results occur in the de-trashing system of cane top feed first and brush rotates in the opposite direction. Hence, the best de-trasher roller speedin the case of cane bottom feed first and brush rotates in the same direction system will be vice-versa. Therefore in the second system the de-trasher roller speed $N_4$ (16.5 $ms^{-1}$) will be the best.

Comparison of cane velocity on the spiral angle (A) and the input roller speed (S) at different de-trasher speeds were studied. Fig. 6 shows the cane velocity performance of various de-trasher roller speeds in all the input roller speed against the spiral angles. It is clear from the plot that the velocity of the cane will decrease as the spiral angle increase from 0 degree to 30 degree in all the de-trasher roller speeds. In all the cases the cane velocity increased with increase of the input roller speed.

Sensitivity of the cane velocity on the spiral angle of the de-trasher brushes at different de-trasher roller speed and the input roller speed were studied. Fig. 7 shows the cane velocity performance against the spiral angles at various de-trasher brush roller speeds and in various input roller speeds.The variation of cane velocity with respect to the de-trasher roller speed in all the cases showed a decrease of cane velocity with increase of the de-trasher roller speed. The reduction of the cane velocity with an increase of de-trasher speed is because, the de-trasher is rotating opposite to the cane feed direction. It is clear from figure 6 and 7 that the velocity of the cane will decrease as the spiral angle increased from 0 degree to 30 degree irrespective of the input roller speed *viz-viz* the de-trasher roller speed. The maximum cane velocity was shown at 0 degree in all the combinations of the de-trasher roller speeds and the input roller speeds.

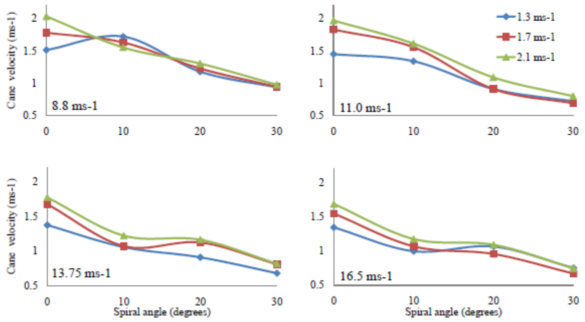


FIG.6 SENSITIVITY OF CANE VELOCITY ON DIFFERENT SPIRAL ANGLES AT VARIOUS INPUT ROLLER SPEED AND DE-TRASHER ROLLER SPEED

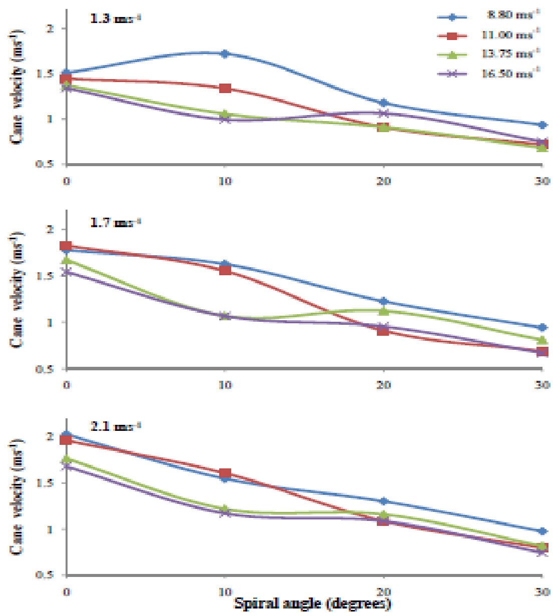


FIG. 7 SENSITIVITY OF CANE VELOCITY ON DIFFERENT SPIRAL ANGLES AT VARIOUS DE-TRASHER ROLLER SPEEDS AND INPUT ROLLER SPEEDS

## Modelling of cane velocity

Creation of a mathematical model for the cane velocity would aid in prototype design of the de-trashing unit of the sugarcane combine harvester. In the de-trashing efficiency, the input roller speed is non-significant variable as detailed above. Hence, the input roller speed is to be determined based on the required cane velocity. Analysis of variance values of cane velocity in the de-trasher with respect to the tested de-trashing combinations at 0.01 level showed that all the factors were highly significant. An attempt was made to model the cane velocity based on all the significant variables and its combinations.

Multiple regression analysis was carried out to find out the relationship among the independent variables (A, N, S) and its interactions for combined effect on the dependent variable (cane velocity). A multiple regression equation of the following model was used for the regression analysis.

$$Y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{i=1}^{n} b_i x_i \sum_{i=1}^{n} x_{(i+1)} + \sum_{i=1}^{n} a_i x_i^2 \quad (2)$$

A regression equation that mathematically represents the cane velocity was thus developed and is presented below. (R2 = 0.92)

$$v = 2.263797 - 0.01999A \pm 0.17424N + 0.477332S \pm 0.00091AN - 0.01386AS \pm 0.00146\,NS + 0.00012A^2 + 0.004882\,N^2 - 0.00394\,S^2 \quad (3)$$

The independent variable N is provided with'±'sign since the value was positive when the de-trashing brush rotated in the same direction of the cane and negative in opposite feed direction. The equation is modified by deleting the variables which were having the higher 'p' values, since the introduction of such variables having less predictive power will reduce the models total predictive power. Hence, the independent variables having the 'p' value > 0.05 were discarded and a new regression equation was developed involving the independent variables, which were having more predictive power. Thus the modified equation for the velocity (v) by considering only the significant variables N, S and AS is given below:

$$v = 1.3047 \pm 0.03935N + 0.4881\,S - 0.01669AS \quad (4)$$

## IV. Conclusion

Sugarcane de-trashing mechanisms were investigated on developed sugarcane de-trashing test rig. It was evaluated in terms of de-trashing efficiency and the cane velocity in the de-trasher unit. The variables selected for the investigation are the input roller speed, the de-trasher roller speed and the spiral angle of the de-trasher brushes.Out of four different orientations of the brush type cleaning systems, cane bottom feed with brush rotating in the same direction and cane top feed with brush rotating in the opposite direction systems showed higher de-trashing efficiency.The de-trashing efficiency is increasing with the de-trasher roller speed and the optimum arrived is 13.75ms$^{-1}$ with a spiral angle of zero degree. The cane velocity in the de-trasher unit is directly proportional to the input roller speed and the de-trasher roller speed and inversely proportional to the spiral angle. The cane velocity decreased as the spiral angle increased from 0 degree to 30 degree irrespective of the input roller speed and the de-trasher roller speed. The maximum cane velocity was found at 0 degree in all the combinations of the de-trasher roller speeds and the input roller speeds.

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