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MATHEMATICAL SIMULATION MODEL OF SEED DISTRIBUTION UNIFORMITY ON FLUTED ROLLERS

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Abstract: *The paper presents a mathematical based simulation in MathCAD used for calculus of seed distribution uniformity of fluted rollers used for seeding small seeds like trifolieae crops. The mathematical model uses the equations of instantaneous particle flow for calculating distribution uniformity, for the aim of comparing theoretical uniformity and uniformity obtained after stand experiment. The simulation can be used for comparing performance of different types of fluted rollers.*
Key words: *seeds, distribution, uniformity, simulation, mathematical model, fluted rollers.*

1. INTRODUCTION

Agriculture plays a crucial role in the life of an economy. It is the backbone of every economic system. Agriculture provides food and raw material for a continuous growing industry and human population.

A very important role in agriculture is attributed to seeding process. In the context of seeding process, metering devices have a significant influence over distribution uniformity.

Distribution uniformity quantifies as an appreciation degree of the distribution process. For plants to sprout and grow normally, regardless of sowing method, seeding must be made in a uniform manner, with equally spaced seeds.

Seed metering devices like fluted rollers are the most common used for seeding small seeds like trifolieae crops. A large part of the harvest it's being attributed to the use of high performance fluted rollers, hence their use for more than 300 years.

Progress in areas such as computers and software's, allows nowadays to simulate seed distribution uniformity before actual fabrication of rollers. Currently used methods evaluate seed distribution uniformity after seeds are sowed, thereby this method saves time and resources, by the aid of software simulation.

Distribution uniformity depends on many factors, but most of them are related to geometrical parameters.

There is a need to perform a computer simulation, based on instantaneous flow equations, for calculating distribution uniformity, in order to compare theoretical uniformity with experimental uniformity obtained after practical subjection. The differences between the values obtained can also be used in assessing the efficiency of stands used for experimental research.

2. METHODS

To determine the distribution uniformity of fluted rollers metering devices, U_d, instantaneous flow equation is used, described in the specific literature [1] [2], of the form:

$$U_d = \left[1 - \sqrt{\frac{\sum_{i=1}^{k}(Q_i - Q_m)^2}{k} \cdot \frac{1}{Q_m}} \right] \cdot 100 \text{ [\%]} \qquad (1)$$

where Q_i is instantaneous flow of a i probe; Q_m is mean of all probes;

To further develop mathematical equations that allows calculation of instantaneous flows, one fluted roller is considered, plotted in figure 1:

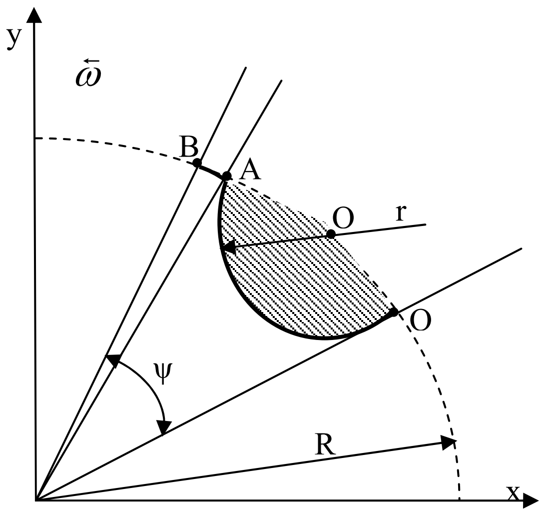

Fig. 1. Graphic representation of one flute.

To simplify the proposed method, the evolvent of the flute is obtained by running the roller on a horizontal surface:

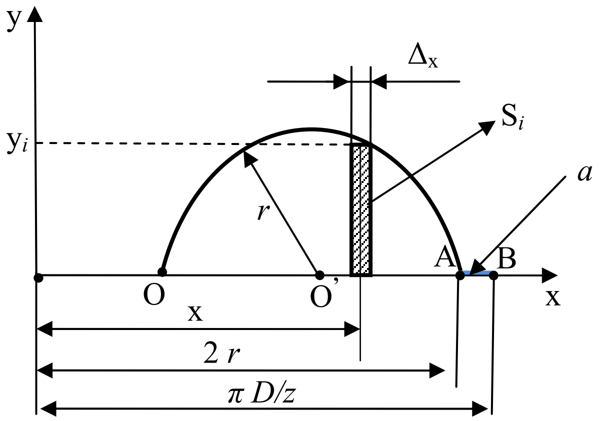

Fig. 2. Schematic representation of the flute evolvent.

Taking in account that the rotation angle ψ value, corresponding to a flute, is $\psi = \frac{2\pi}{z} < 15^0$, the approximation of the string length OA of the arch $\widehat{OA}$ is made.

OAB curve is described by a circle arch of equation:

$$(x-r)^2 + y^2 = r^2, \tag{2}$$

and AB line of equation

$$y = a, \tag{3}$$

where a is the distance between two flutes.

Under these conditions, equation of the OAB is obtained:

$$\begin{cases} y = \sqrt{2rx - x^2} & for\, x \in [0,\, 2r] \\ y = a & for\, x \in [2r, \pi D / z] \end{cases}, \tag{4}$$

To calculate the surface area enclosed by the OAB curve, it's equation is integrated:

$$S = \int_0^{2r} \sqrt{2rx - x^2} \cdot dx + \int_{2r}^{\frac{\pi D}{2}} a \cdot dx, \tag{5}$$

Since calculating uniformity of distribution requires knowledge of instantaneous flows, recourse is made to numerical methods for solving this problem. Thus, the surface S is decomposed into k_e elementary surfaces of S_i rectangular shape:

$$S_i = \Delta x \cdot y_i, \tag{6}$$

In these conditions, instantaneous flows are obtained:

$$Q_{i=} \frac{S_i \cdot lc}{\Delta t}, \tag{7}$$

where lc is the length of the flute; Δ_t - is the time interval, correspondent to the rotation angle ψ / k_e.

By replacing equation (6) and (7) into equation (1), results:

$$U_d = \left[1 - \sqrt{\sum_{i=1}^{k} (k \cdot S_i - S)^2} \cdot \frac{1}{k \cdot S} \right] \cdot 100\ [\%], \tag{8}$$

Introduction and processing of the equations needed for calculating instantaneous flows in MathCAD software, is made. The simulation shows that uniformity of distribution (calculated with equation 8) for a full rotation, is influenced by the geometry of the flutes, the distance between the mobile flap and roller, and AB line, corresponding to the distance between two adjacent flutes.

3. APPLICATION AND RESULTS

For practical demonstration, the simulation is made to determine the uniformity of distribution. A imaginary fluted roller is conceived.

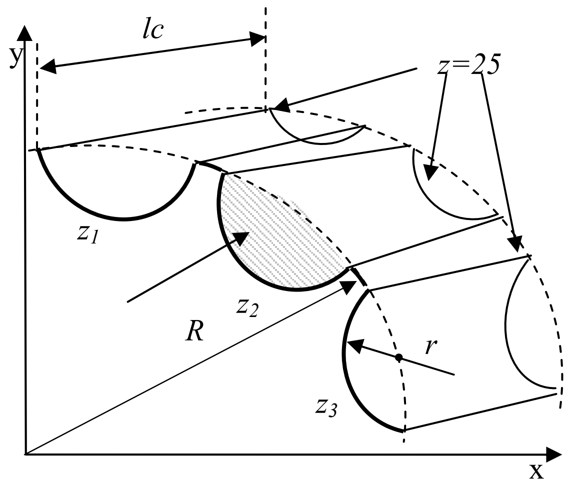

Fig. 3. Conceived roller for numerical application.

The cinematic characteristics and geometrical parameters of the roller, inputted into the software, are presented in table 1:

Table 1

The input data required for running the application to determine the theoretical uniform distribution

Entry data	Value	Units
Flutes - *z*	25	-
Radius of roller - *R*	3	*cm*
Radius of flute- *r*	0.4	*cm*
Length - *lc*	0.3	*cm*
a distance	0.3	*cm*
Rotational speed of roller	5; 10; 15	*rpm*

After processing the inputted data, theoretical distribution uniformity is obtained. The value delivered by MathCAD software for the fluted roller experimented is 94.166%, at each rotational speed of the roller.

In figure 3, 4, 5, the variation chart of the flow and time is presented, corresponding to: ψ rotational angle, and three different roller speeds: 5, 10, 15 rpm's.

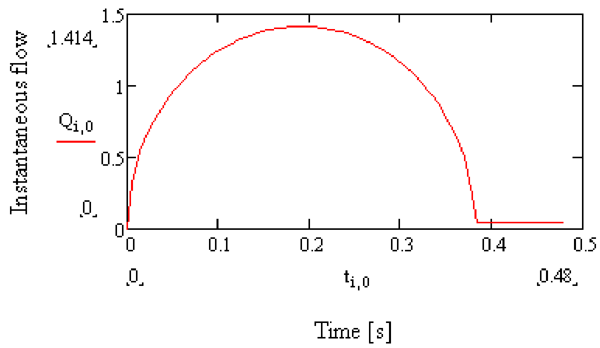

Fig. 4. Variation chart of flow at 5 rpm.

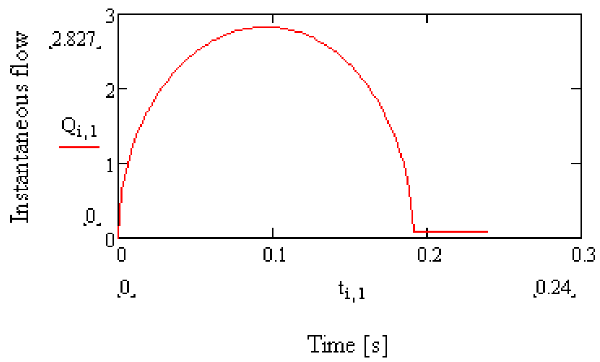

Fig. 5. Variation chart of flow at 10 rpm.

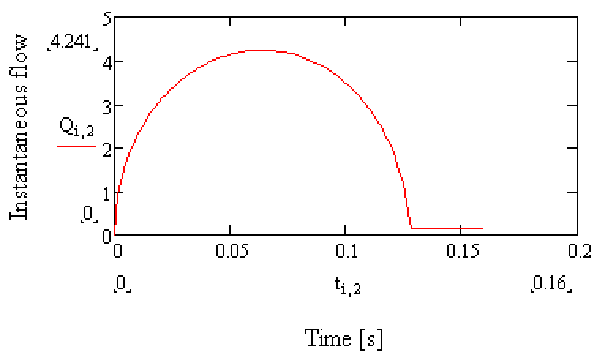

Fig. 6. Variation chart of flow at 15 rpm.

4. CONCLUSIONS

After analyzing the above charts, the conclusions indicate that distribution uniformity can be improved by reducing the space between the flutes. Inclined fluted rollers can influence in a positive manner the uniformity of distribution, by inclining the flute at a certain degree, so seeds will be metered in a continuous uniform flow.

Although, by increasing rotational speed, the flow rates increase, distribution uniformity remains, theoretically, the same.

The objective of this paper to simulate the uniformity of distribution with the aid of mathematical equations based on instantaneous flow, was achieved. The simulation can be used for determining theoretical uniformity of fluted rollers, based by geometrical parameters introduced into the software.

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Modelare matematică pentru simularea uniformității teoretice de distribuție a semințelor la aparatele de distribuție canelate

Rezumat : Lucrarea prezintă o simulare matematică implementată în softul Mathcad, utilizată pentru calculul uniformității de distribuție a semințelor la aparatele de distribuție canelate, folosite pentru semănatul semințelor mici cum ar fi culturile trifoliene. Modelul matematic utilizează ecuațiile debitelor instantanee pentru calculul uniformității de distribuție, cu scopul de a compara uniformitatea obținută teoretic cu cea experimentală. Simularea poate fi folosită şi la compararea diferitelor aparate de distribuție canelate din punct de vedere al performanței.

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