http://dx.doi.org/10.15576/GLL/2014.4.7

GLL

Geomatics, Landmanagement and Landscape No. 4 • 2014, 7–12

CALCULATION OF TRANSIT TIMES WHEN TURNING WORKING MACHINES AT THE EDGES OF RECTANGULAR PLOTS

Wojciech Anigacz

Summary

The article presents the derivation of formulas for calculating the length of the sector and transit times of working machines at the edges of a rectangular plot. Working width of machines and the width and length of the patch were taken into account. This article is the first in a series devoted to the influence of the path length and the transit times on the edges of plots upon the decrease of net profit in agricultural farms.

Keywords

agricultural economy • agricultural engineering

1. Introduction

The present article is the first in a series devoted to the influence of the sector length and the transit times on the edges of plots upon the decrease of net profit in agricultural farms. Below we present the derivation of formulas for calculating the length of the sector and transit times of working machines at the edges of a rectangular plot. The appropriate shape of land plots is an important consideration for the proper land organisation of any agricultural farm. The more regular shape of the plots, the more constancy and predictability can be introduced to the crop rotation fields, which is very important due to the requirements of mechanised agriculture. We shall define "patch" as a specific part of the plot, which is used in a homogenous way. Each patch shall include only one type of farmland, for instance arable land. Small size and irregularity of patches are the two factors, which have a very negative impact on the net profit generated by agricultural farms, decreasing that profit dramatically. The "decrease of net profit" is here defined as losses resulting from the faulty shape of the patches, compared to patches of the same total area, but with a shape of a rectangle with optimum ratio of its sides. Often, however, the conditions of the terrain do not allow the correct shaping of the patches. In those cases, the future patch is shaped so that – in the given terrain conditions – the decrease of net profit is as small as possible.

When determining the optimum (desired) shape of the patches, we should be guided by the following determining factors:

1. Harvest losses at the edges of the patches:
   - losses on the edges,
   - losses on the headland.
2. Time losses at the edges of the patches:
   - losses on the edges,
   - losses on the headland.
3. Time losses from the transportation within the field.

All the methods – known to date – for calculating the shape of crop rotation plots and demand for mechanical work are of very limited relevance, as they only address rectangular plots and similar. Therefore their practical application is narrow [Anigacz 1973, Urban 1984]. In Holland, research was conducted aimed at developing a method feasible for evaluating fields of any given shape. The method elaborated and presented by Sprik and Kester [1972] makes it possible to calculate, with a high degree of probability, the decrease of net profit on a given patch due to the shape of the latter. Losses in time and in harvest should be calculated for particular tillage tasks, and particular crops – which is very time consuming. The aforementioned method should find broad application in the design practices, used in agricultural land planning.

The purpose of this article is to present the derivation of formulas for calculating the length of the sector and transit times of working machines at the edges of a rectangular plot. Sprik and Kester [1972] did not present the ways by which they arrived at their algorithm. Due to the labour-intensity of the issue in the context of a wide variety of tillage tasks and applications, the range of the present discussion was limited to those tasks, which are necessary for potato growing.

2. Calculation of the total required time of passage at the edges of a rectangular patch, with circular work within the crop rotation plot, with an unlimited belt width for turning manoeuvres

In circular work at a crop rotation plot, tillage tasks are performed in a circular manner, in belts of a certain width. The circular work within a crop rotation plot consists in two turns of 90° each, therefore 180° in total, while the length of the path travelled is πr, plus a certain length across. The length of the path travelled across the plot depends on the width and the situation of the given crop rotation field – see Figure 1.

If the width of the crop rotation field is S, then the longest passage across (B) will amount to [hm]:

$$B = S - 2r - w \tag{1}$$

where:

S – width of the crop rotation field [hm],
r – radius of the rotation of the machine's centre [hm],
w – effective working width [hm].

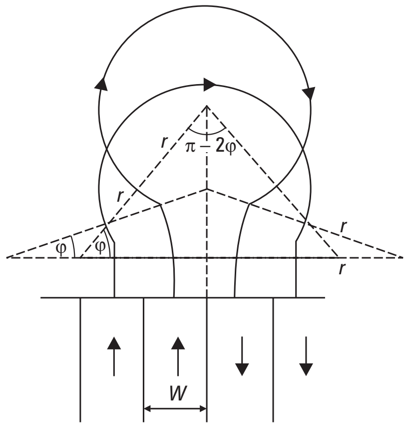

Fig. 1. Turning in the middle part, in the case of tilling crop rotation fields

As follows from formula (1) for the tilling of the mid-part of the crop rotation field with the width of less than $2r$, a passage across is not necessary, and the smallest length of the passage will equal w. Average length of the passage for the $S – 2r$ part will amount to in [hm]:

$$B_{Sr} = \frac{S - 2r - w + w}{2} = \frac{1}{2}S - r \tag{2}$$

The number of turns n for this part will equal:

$$n = \frac{S - 2r}{2w} \tag{3}$$

where:

$2w$ – one single turn.

Total length of the passage equals in [hm]:

$$D = \left(\frac{S - 2r}{2w}\right) \cdot \left(\frac{1}{2}S - r\right) = \frac{(S - 2r)^2}{4w} \tag{4}$$

Formula (1) is applicable only when the passage across is performed in parallel to the edge of the crop rotation field. Turning in the mid-part of $2r$, however, must be performed as shown in Figure 1 above.

The length of the passage for these turns is calculated as:

$$D = 4\varphi + (\pi - 2\varphi) + 2\varphi = \pi + 4\varphi \tag{5}$$

$$D = (\pi + 4\varphi)r \tag{6}$$

where:

D – length of the passage [hm],

φ – expressed in radians.

With the turn of 180°, and not in the middle part, that length equals πr, therefore the additional length of the path amounts to $4\varphi r$.

If the distance between the centres of two consecutive working passages equals nw then:

$$\cos\varphi = \frac{\frac{1}{2}wn + r}{2r} \tag{7}$$

$$\varphi = \arccos\varphi = \frac{\frac{1}{2}wn + r}{2r} \tag{8}$$

$$4\varphi r = 4r \arccos\varphi = \frac{\frac{1}{2}wn + r}{2r} \tag{9}$$

The length of the passage across from the last belt to the centre of the field will amount to in [hm]:

$$\frac{1}{2}S - \frac{1}{2}w - r \tag{10}$$

The length to the middle of the next crop rotation field equals in [hm]:

$$\frac{1}{2}S - \frac{1}{2}w - 2r \tag{11}$$

taking into account the r which is the sector travelled from the first working passage.

Table 1. Collation of the length of sector (turning path)

Transit	$\frac{w}{2r}$	0.2	0.4	0.6	0.8
---------->	1	$-r$	$-r$	$-r$	$-r$
---------->	2	$3.71r$	$3.18r$	$2.15r$	$1.13r$
---------->	3	$3.18r$	$1.35r$	$0.15r$	$0.17r$
---------->	4	$2.58r$	$0.10r$		
---------->	5	$1.80r$			
---------->	6	0			
Total		$10.27r$	$2.63r$	$1.30r$	$0.30r$
$n - 1 = \frac{2r}{w} - 1$		4		2/3	1/4
$(n - 1)\ 2.5r$		$10.00r$	$3.75r$	$4.67r$	$0.63r$
Deviation		$-0.27r$	$+0.12r$	$+0.39r$	$+0.35r$

Where:

$\frac{2r}{w} - 1$ – number of working passages in belt $2r$, in which turning should be performed

Due to the complicated form of formula (4), which is not suited for quick calculations, another one was developed empirically based on a large number of cases: formula (12) which has a simple structure and which can be used in an electronic calculator. The values obtained from the calculations using formula (12) are not too different from the values derived using formula (4), therefore in order to simplify further discussion we shall apply the formula:

$$\left(\frac{2r}{w} - 1\right) \cdot 2.5r \tag{12}$$

Total travel time in the turning belt amounts to:

$$\left(\frac{2r}{w} - 1\right) \cdot 2.5r = \frac{5r^2 - 2.5rw}{w} \tag{13}$$

As passages in the middle part consist of circular arcs only, the coefficient of 1.5 has been arbitrarily assumed, in order to reflect the decrease in the passage speed

$$\frac{(S-2r)^2}{4w} \cdot t_r + \frac{\left(10r^2 - 5rw\right)}{4w} 1.5t_r \tag{14}$$

where:

t_r – time of passage during turning [min · hm^{-1}].

Because $2r/w$ is not always expressed as an integer, the length of additional travel 0.50 L to crop rotation field should be accounted for (L – length of crop rotation field) to the turning belt, which shall equal 0.25.

Total travel time to the crop rotation field and to the turning belt will amount to:

$$\frac{(S-2r)^2}{4w} \cdot t_r + \frac{10r - 5rw}{4w} \cdot 1.5t_r + 0.25Lt_m \tag{15}$$

where:

L – length of the crop rotation field,

t_m – time of the working passage [min · hm^{-1}].

$$\frac{\left(S^2 - 4Sr + 19r^2 - 7.5rw\right)t_r + wLt_m}{4w} \tag{16}$$

Time of passage per hm of the turning belt will equal in minutes:

$$\frac{\left(S^2 - 4Sr + 19r^2 - 7.5rw\right)t_r + wLt_m}{4w} \cdot \frac{1}{S} \tag{17}$$

3. Conclusions

We have calculated the sector, which needs to be travelled in the turning belt, according to initial assumptions, as well as the time necessary to travel that path. Another stage will be to look for the minimum of the resultant function versus the sector, seeing that for given machines and conditions, the speed of passage is a constant.

References

Anigacz W. 1973. Wpływ czasów przejazdów na krawędziach parcel na depresję dochodu czystego gospodarstw rolnych. Akademia Rolnicza we Wrocławiu, Katedra Planowania i Urządzeń Terenów Wiejskich, Master's thesis, Wrocław.

Spirk J.B., Kester J.A. 1972. Kantverliezen op rechthoekige en onregelmatig gevormde akkerbouwpercelen. Instituut voor Cultuurtechniek en Waterhuishouding. Vol. 144, Wageningen, Netherlands.

Urban M. 1984. Zarys ekonomiki i organizacji gospodarstw rolnych. PWN, Wrocław.

Dr hab. inż. Wojciech Anigacz
Politechnika Opolska
Wydział Budownictwa
Katedra Geotechniki i Geodezji
45-061 Opole, ul. Katowicka 48
e-mail: w.anigacz@po.opole.pl