International Journal of Mechanical Engineering and Technology (IJMET)
Volume 10, Issue 03, March 2019, pp. 594-602. Article ID: IJMET_10_03_061
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=10&IType=3
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

DETERMINATION OF THE SIZE OF THE SPACER FORCES ACTING ON THE FEED ROLLERS, TAKING INTO ACCOUNT THE ELASTIC CHARACTERISTICS OF RAW COTTON

Fazil Ali Veliev
Doctor of Technical Sciences, Professor
Department of Technological Machines and Equipment
of the Branch Azerbaijan State Economic University (UNEC),
Istiglyaliyat str., 6, Baku, Azerbaijan, Az 1001

Mahammadali Nuraddin Nuriyev
Doctor of Technical Sciences, Professor
Department of Standardization and Certification
Azerbaijan State Economic University (UNEC),
Istiglaliyyat str., 6, Baku, Azerbaijan, AZ 1001

ABSTRACT

The result of theoretical research is the established spreading efforts during deformation of a cotton layer by the cleaner's blades and the analyzed shapes of the deformed layer of cotton. We estimated the elastic characteristics of raw cotton and calculated spreading efforts. To determine the numerical values for the pressure forces at which a blade acts on the flow of raw cotton, for a coefficient k of the generalized properties of a material, the magnitude ν *for raw cotton was adopted in a range of 0.25-0.3.*

Experiments have shown that a layer of raw cotton with a thickness from 170 to 380 mm and a width of 700 mm was loaded with the force of 30-100 N concentrated along the line. Based on our calculations, it was established that 38.89 % of the raw cotton cleaning time accounts for the operation of a single blade of the roller.

The result of our experimental and theoretical research is the data that make it possible to organize effective operation of cleaning machines in the cotton cleaning industry.

Keywords: large impurities cleaner, cotton mill, maturity of raw cotton, flow of raw cotton.

Cite this Article Fazil Ali Veliev, Mahammadali Nuraddin Nuriyev, Determination of the Size of the Spacer Forces Acting on the Feed Rollers, Taking into Account the Elastic Characteristics of Raw Cotton, International Journal of Mechanical Engineering and Technology, 10(3), 2019, pp. 594-602.
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=10&IType=3

1. INTRODUCTION

We consider a problem on determining the magnitude of spreading forces acting on feeding rollers, which are one of the most important factors in the process energy intensity, strength conditions for blade rollers and, most significantly, the preservation of the material being processed[1].

In contrast to solutions proposed earlier [2] that consider the deformation of a layer by conditional round-shaped rollers, and raw cotton as a one-dimensionally deformable material, which is matched in elasticity theory by a material with the Poisson coefficient ν= 0, in the proposed scheme, at the same condition for a flow continuity, it is proposed to describe a raw cotton deformation with blade rollers using the methods of contact problems from the theory of elasticity.

2. MAIN PART

Given this, it is necessary to conduct a geometrical analysis into the deformation of a layer of raw cotton by roller blades. Assume that a cotton layer of thickness *S* is being deformed by a feeding roller that contains n blades(Fig.1), arranged evenly along its circumference, with the central angle between its adjacent blades being equal to: $\varphi_n = \frac{2\pi}{n}$ Diameters of rollers are denoted by *D*, and the inter-center distance between them – by *A* [3]. The figures of the natural series of numbers denote the serial numbers of blades – in the direction opposite to the sequence of their contact with the product – 1, 2, 3,..., *n*.

The number of blades, which are simultaneously in the space of flow width *S*, and may have an impact on a layer of raw cotton, is a variable and can accept two values: *r*min:

$$r_{\min} = \left[\frac{n \cdot \arccos\frac{A-s}{D}}{\pi} \right] \qquad (1)$$

where, according to [4,5], square brackets mark a no nelementary function, equal to the greatest integer, not exceeding the figure in brackets, and *r* max:

$$r_{\max} = r_{\min} + 1. \qquad (2)$$

For any intermediate position of blade I, the deformation of a layer in the direction perpendicular to its axis will be equal to:

$$W_1 = \frac{D}{2}\sin\varphi_1 - \frac{A-S}{2} = D\cos\frac{\varphi_1+\varphi_0}{2}\sin\frac{\varphi_1-\varphi_9}{2} \qquad (3)$$

Denote $\varphi_1 - \varphi_0 = a$ and simplify (4):

$$W_1 = D\cos\left(\varphi_0 + \frac{\alpha}{2}\right)\sin\frac{\alpha}{2}\omega \qquad (4)$$

For the *i*-th blade $(1 \le i \le r_{\max})$max , in a general case, we obtain:

$$W_i = D\cos\left[\varphi_0 + \frac{\pi}{n}(i-1) + \frac{\alpha}{2}\right]\sin\left[\frac{\pi}{n}(i-1) + \frac{\alpha}{2}\right] \qquad (5)$$

in this case, we shall add a condition for non-negativity to this expression:

$$W_1 \geq 0 \tag{6}$$

We shall define basic equations for a layer deformation. Assuming the smallness of the contact area compared to the total surface of bodies in contact, which corresponds to the problem considered here, the elasticity theory produces for a semi-space an expression to determine displacements *w* of body surface at distance ρ from the point of application of the concentrated force *P* (Boussinesq formula) [6,7]:

$$W = \frac{1-\nu^2}{\pi E} \cdot k \frac{P}{p} \tag{7}$$

where *E* and ν are the elastic modulus and a Poisson's ratio of the deformed material, respectively; *k* is a coefficient of generalized properties.

In order not to reduce solving the problem to the analysis of complex integral equations, one applies a certain mean displacement *Wcr* of the contact site assuming varying pressure *q*(*F*), which is matched by the assigned mean magnitude *q*. This mean integral displacement:

$$W_{cr} = \frac{\int_F W\, d\, F}{F}$$

whose solution for a rectangular site takes the form:

$$W_{cr} = 4kq\left[b\, l_n \frac{\sqrt{b^2+l^2}+l}{b} + l l_n \frac{\sqrt{b^2+l^2}+b}{l} + \frac{b^3+l^3-\left(b^2+l^2\right)^{\frac{3}{2}}}{3bl}\right] \tag{8}$$

and allows us to argue with reasonable accuracy about the magnitude of mean pressure *q*. Comparison of *q* with the mean magnitude of pressure, obtained at *w* = const, reveals that their values are not significantly different from each other.

We shall define basic equations for a layer deformation. Assuming the smallness of the contact area compared to the total surface of bodies in contact, which corresponds to the problem considered here, the elasticity theory produces for a semi-space an expression to determine displacements *w* of body surface at distance ρ from the point of application of the concentrated force *P* (Boussinesq formula) [8]:

$$W = \frac{1-\nu^2}{\pi E} \cdot k \frac{P}{p}, \tag{9}$$

where *E* and ν are the elastic modulus and a Poisson's ratio of the deformed material, respectively; *k* is a coefficient of generalized properties.

Consider the problem in a general form. Let the semi-infinite medium, linearly elastic, isotropic, be exposed to the action of several blades, of length *l* and width *b* (Fig.1). Denote the deformation of the layer under the blades as W_1, W_2,..., W_j,..., and the corresponding reactions of elastic medium as P_1, P_2,..., P_j.

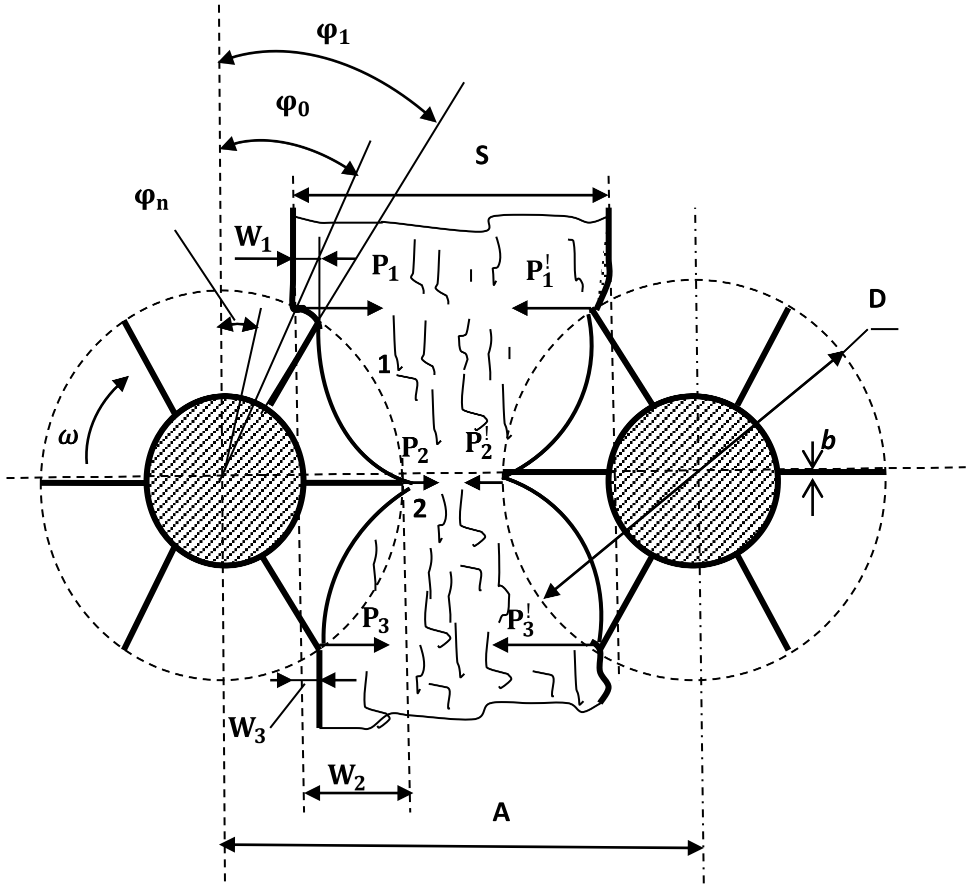

Figure 1. Schematic of interaction between a feeding roller blades and a layer of raw cotton (symmetrical)

In the presence of n forces and the same number of displacements, corresponding to them, we derive the following system of equations based on the principle of independence of displacements on the order of force application

$$\begin{aligned}
W_1 &= W_{11}(P_1) + W_{12}(P_2) + \cdots + W_{1i}(P_i) + \cdots + W_{1n}(P_n), \\
W_2 &= W_{21}(P_1) + W_{22}(P_2) + \cdots + W_{2i}(P_i) + \cdots + W_{2n}(P_n), \\
&\text{-------------------------------} \\
W_j &= W_{j1}(P_1) + W_{j2}(P_2) + \cdots + W_{ji}(P_i) + \cdots + W_{jn}(P_n), \\
&\text{-------------------------------} \\
W_n &= W_{n1}(P_1) + W_{n2}(P_2) + \cdots + W_{ni}(P_i) + \cdots + W_{nn}(P_n),
\end{aligned} \tag{10}$$

where W_{ji} is the displacement of point j under the action of force P_i, applied at the i-th point.

Considering, in accordance with [9,10], that displacements depend linearly on forces, and denoting the matrices-columns of displacements and forces through

$$\|W_j\| = \begin{Vmatrix} W_1 \\ W_2 \\ \cdots \\ W_i \\ W_n \end{Vmatrix} \|P_i\| = \begin{Vmatrix} P_1 \\ P_2 \\ \cdots \\ P_i \\ \cdots \\ P_n \end{Vmatrix}, \tag{11}$$

and the square matrix of rank n of coefficients of influence δ_{ij} through

$$\|\delta_{ij}\| = \begin{Vmatrix} \delta_{11}\delta_{12}\ldots.\delta_{1i}\ldots\delta_{1n} \\ \delta_{21}\delta_{22}\ldots\delta_{2i}\ldots\delta_{2n} \\ \ldots\ \ldots\ \ldots \\ \delta_{j1}\delta_{j2}\ldots\delta_{ji}\ldots\delta_{jn} \\ \ldots\ \ldots\ \ldots \\ \delta_{n1}\delta_{n2}\ldots\delta_{ni}\ldots\delta_{nn} \end{Vmatrix}; \tag{12}$$

linear equations (10-1) can be represented in a matrix form

$$\|W_j\| = \|\delta_{ij}\| \cdot \|nP_i\|. \tag{13}$$

Hence

$$\|P_i\| = \|\delta_{ij}\|^{-1} \cdot \|W\|_j\,. \tag{14}$$

Here δ_{ij} is the displacement at point j under the action of a single force applied at point i; coefficient of influence; $\|\delta_{ij}\|^{-1}$ is the matrix inverse to $\|\delta_{ij}\|$.

The principle of independence of displacements means that

$$\delta_{11} = \delta_{22};\ldots\ldots;\delta_{ij} = \delta_{ji}\ldots. \tag{15}$$

Coefficients of influence of the matrix diagonal can take the form

$$\delta_{11} = \delta_{22} = \ldots\delta_{ii} = \frac{W_{av}}{P} = \frac{W_{av}}{4qbl}. \tag{16}$$

Denoting the magnitude t through t_{ij}, that is, by giving it the value corresponding to the distance between the i-th and j-th blades, we shall similarly obtain the rest of the coefficients' values at $i \neq j$ with respect to (Fig. 2).

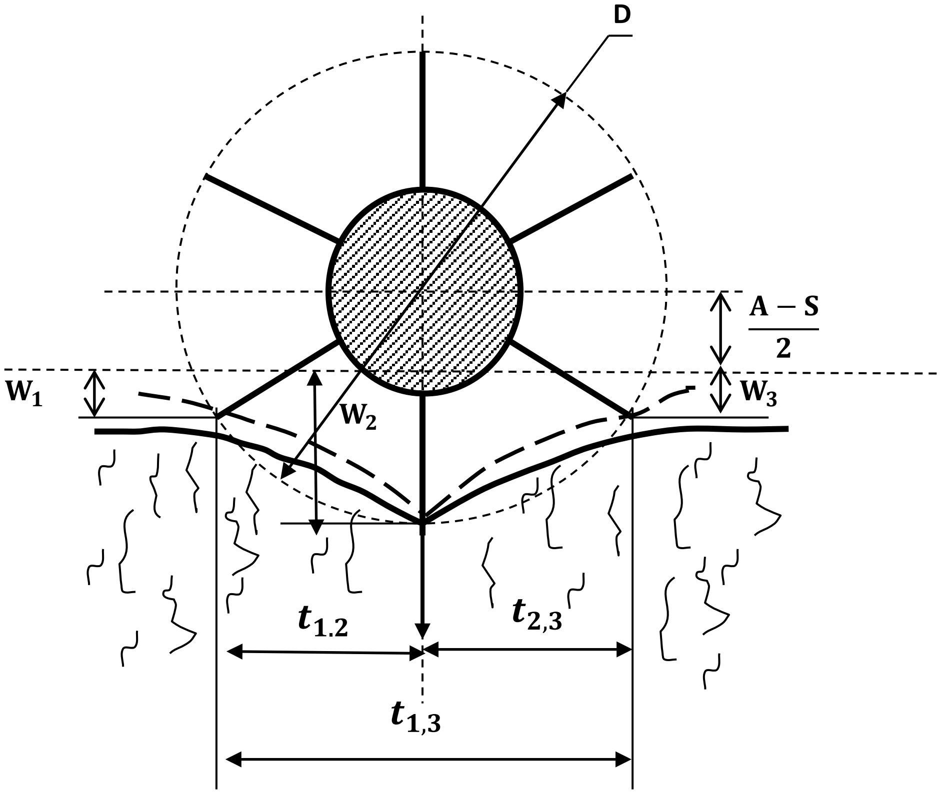

Figure 2. Estimation scheme for determining the spreading efforts at deformation of a layer of cotton by two blades of a roller

$$\delta_{ij} = \delta ji \frac{Wt}{P} = \frac{Wt}{4qbl} \qquad (17)$$

The shape of the surface of the deformed layer of raw cotton can be determined by summing the displacements of the point, the distance between which and the *i*-th blade t_i.

$$W = \sum_{i=1}^{i=n} Wt_i. \qquad (18)$$

For a small total number of blades that simultaneously deform a cotton layer ($n \leq 3$), matrix inversion (12) is not difficult and the calculation of forces based on the assigned displacements can be performed using determinants from the Cramer formula.

Denoting the determinant

$$\det\left\|\delta_{ij}\right\| = \Delta_0 = \begin{vmatrix} \delta_{11}\delta_{12}\cdots\delta_{1i}\cdots\delta_{1n} \\ \delta_{21}\delta_{22}\cdots\delta_{2i}\cdots\delta_{2n} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ \delta_{j1}\delta_{j2}\cdots\delta_{ji}\cdots\delta_{jn} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ \delta_{n1}\delta_{n2}\cdots\delta_{ni}\cdots\delta_{nn} \end{vmatrix}, \qquad (19)$$

that has a non-zero value, since the rank of matrix (12)is equal to *n*, and the attached determinants through

$$\Delta_i = \begin{vmatrix} \delta_{11};\delta_1(i-1);...W_{1i};...\delta_{1n} \\ \delta_{21};\delta_2(i-1);...W_{2i};...\delta_{2n} \\ ------------ \\ \delta_{j1};\delta_j(i-1);...W_{ji};...\delta_{jn} \\ ------------ \\ \delta_{n1};\delta_n(i-1);...W_{ni};...\delta_{nn} \end{vmatrix}, \qquad (20\text{-}11)$$

where elements of the *i*-th column are replaced with elements of the matrix-column of displacements (11), we derive the expressions for calculating efforts P_i:

$$P_1 = \frac{\Delta_1}{\Delta_0} \geq 0; P_2 = \frac{\Delta_2}{\Delta_0} \geq 0; .....P_i = \frac{\Delta_i}{\Delta_0} \geq 0. \qquad (21)$$

The non-negativity of magnitude P_i implies the condition that the blade touches the surface of a layer of raw cotton, and if this condition is not met, it is required to recalculate the system from which a blade with $P_i<0$ should be deleted.

Paper [12] gives the estimation values for q and E for $E(\varepsilon)$ γ_{x0}=92 kq/m^3; m=11.54; n'=0.3 ν=0.25 and ν=0 (for the conditions of cotton deformation in a squeezed volume).

For the feed device with characteristics shown in Table 1, at n=6, and when 2l=1,840 mm and 2b=4 mm, we obtain $\delta_{11} = \delta_{12} = 0.0096$. for the accepted designs of feed rollers. For two blades, t_{12}=t_{21}=70 mm, and, accordingly, $\delta_{11} = \delta_{ii} = 0{,}00515k$. With three blades ($r_{\max}$), we obtain $\delta_{12} = \delta_{21} = \delta_{23} = \delta_{32} = 0{,}00552k$, $\delta_{13} = \delta_{31} = 0{,}00412k$.

According to (8-16), for $r_{\min}$=2 and W_1=W_2=45.6

$$P_1 = P_2 = 3091{,}5\frac{1}{k}(N) \qquad (22)$$

The total force is the magnitude $P_\Sigma = 6183\frac{1}{k}(n)$. In the case $r_{\max}$=3 and W_1=W_3=20 mm, W_2=45 mm (Fig. 2)

$$P_1 = P_3 = -\frac{13{,}88}{0{,}3368n10^{-2}k} < 0.$$

This indicates that blades I and 3 layers of raw cotton are not in contact and the scheme is reduced to the single-blade one. In this case,

$$P_2 = P_{\Sigma 3} = \frac{W_2}{\delta_{22}} = 5729{,}2\frac{1}{k}. \qquad (23)$$

Table 1. gives values for k, P_{Σ_2} and P_{Σ_3} at the different relative deformation of a layer at $\gamma_0 = 92$ kg/m^3. The values derived for $\nu = 0{,}25$ at ε=0.2 –0.7 are in good agreement with the experimental results obtained in studies.

Table 1. Estimation values for spreading efforts at different relative deformation of a layer

Magnitudes	ε							
	0.2		0.3		0.5		0.7	
	$\nu = 0$	$\nu = 0{,}25$	$\nu = 0$	$\nu = 0{,}25$	$\nu = 0$	$\nu = 0{,}25$	$\nu = 0$	$\nu = 0{,}25$
k, $\frac{sm}{N}$	0.340	0.762	0.215	0.457	0.0453	0.128	0.0059	0.0158
P_{Σ_2} N	172.4	83.2	302.4	136.6	1,312.1	496.8	12,086	3,826.0
P_{Σ_3} N	156.7	74.2	288.9	125.5	1,212.2	467.2	11,212	3,514.3

Table 1 shows that experimental data are in good agreement with the results of theoretical studies.

The benefits of present research when compared with analogues demonstrate that theoretical calculations account for the most important technological characteristics of raw cotton. Specifically, the magnitude of effective open surface of cotton structural particles calculated per cotton unit mass.

It is clear that it is linked to a structure coefficient – E and ν, coefficient of the generalized properties of a material k, and a loosening degree of mass; it correlates to the capability of cotton to isolate weedy impurities.

3. SUMMARY

1. We have established a mechanics of the process of interaction between a feeding roller blades and the transported layer of raw cotton. We examined systems of uniform feed of cotton machines taking into account the development of criteria for the uniformity of a product feed based on mass

and geometrical parameters. We have solved a problem on the deformation of a layer by blade rollers; and determined analytically the deformations of a raw cotton layer for any intermediate position of the blade, and, therefore, a maximum of the total spreading force in the system.

2. The mechanism of interaction between a feed roller blades and the transported layer of raw cotton has been revealed. It was theoretically proven that the non-negativity of the magnitude P indicates the condition when a blade comes into contact the surface layer of raw cotton.

3. Application of the matrix method for calculating the spreading efforts and the shape of a deformed layer, based on a system of elastic characteristics of raw cotton, makes it possible to develop new designs of a roller blade, which reduce spreading efforts and deformation along the length of the rollers' blade. That could reduce consumption of energy by the cleaner's mechanism engine by 30 %. Based on a given model, we made an attempt at revealing the conditions for throwing a material on the blade and fixing it by a brush drum taking into consideration the deformations of portions of raw cotton. Our calculation has established that the deformation of the layer under the blades is 33.6 mm

REFERENCES

[1] Kadyrov B. G., Tursunov H. K., Aripdkanov M. Issledovanie dvizheniya hlopka-syrca v ochistitelyah ot krupnogo sora // Hlopkovaya promyshlennost'. 1982. Issue 1. pp. 15–16.

[2] Tyutin P. N., Lugachev L. E. O vydelenii sornyh primesey cherez yacheyki setchatyh poverhnostey // Mekhanicheskaya tekhnologiya voloknistyh materialov. 1977. Issue 19. pp. 51–58.

[3] Baydyuk P. V. Primenenie valkovyh ustroystv pri pressovanii voloknistyh materialov // CINTI. 1964. Issue 4. pp. 2–8.

[4] Sultanov A. Issledovanie po izyskaniyu optimal'nyh sposobov ochistki hlopka-syrca ot melkogo sora. Tashkent: TITLP, 1980. 169 p.

[5] Miroshnichenko G. I., Burnashev R. Z., Lugachev A. E. Sposob pitaniya mashiny po obrabotke hlopka-syrca. Avtorskoe svidetel'stvo No. 524870. declareted: 15.08.1976, Bul. No. 30.

[6] Hafizov I. K., Rasulov A. Issledovanie razryhlitel'nogo effekta razdelitelya dolek tonkovoloknistogo hlopka-syrca na letuchki // Hlopkovaya promyshlennost'. 1979. Issue 3. pp. 9-12.

[7] Miroshnichenko G. I., Burnashev R. Z. Vybor parametrov ustroystv dlya izmeneniya napravleniya dvizheniya semyan // Hlopkovaya promyshlennost'. 1973. Issue 3. pp. 20-24.

[8] Prochnost', ustoychivost', kolebaniya. Spravochnik v trekh tomah. Vol. 1 / M. I. Birgera, Ya. G. Panovko (Eds.). Moscow: Mashinostroenie, 1968. 464 p.

[9] Bronshteyn I. P., Semendyaev K. A. Spravochnik po matematike. Moscow: Nauka, 1981. 720 p.

[10] [Prochnost', ustoychivost', kolebaniya. Spravochnik v trekh tomah. Vol. 3 / M. I. Birgera, Ya. G. Panovko (Eds.). Moscow: Mashinostroenie, 1968. 568 p.

[11] Pervichnaya obrabotka hlopka / Dzhabarov G. D., Baltabaev S. D. et. al. Moscow: Legkaya industriya, 1978. 430 p.

[12] Sailov R. A., Veliev F. A., Kerimov Q. K. Determination of the heat distribution in the raw cotton packed in the coil // EUREKA:Physics and Engineering. 2017. Issue 3. pp. 3–11. doi: https://doi.org/10.21303/2461-4262.2017.00359