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DETERMINATION OF TECHNICAL AND OPERATING PARAMETERS OF AN AIRCRAFT FOR SPECIAL PURPOSE

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Abstract: *Despite of unfavorable economical conditions in agriculture as a single customer of aero-agriculture works, it seems to be necessary to think of the development and manufacture of a new special single-purpose aircraft. There are terms during the plant biological process when according to the weather conditions such special aircrafts are irreplaceable. The paper deals with the specification of suitable size of agricultural aircraft determined particularly by the effective weight of chemicals. Based on the mathematical model, the working productivity in the relationship to the application dose of chemicals is computed for the medium model of agricultural aircraft. Moreover, the suitable size category of agricultural aircraft is determined for the required application dose.*
Key words: *useful weight of chemicals, application dose, productivity, work speed*

1. INTRODUCTION

Technical requirements on the aircraft determined for the aero-agricultural works are very contradictory according to the operating demands (***,2009). On one hand, a very short taking-off from unmetalled working runway and fast flypast above the working area with low flying height during application of solid or liquid chemicals is required. On the other hand, the maximal working catch is demanded together with minimal loss of time during turning at the end of working field. Moreover, the after several flyovers above the working field, the fast moving back to runway with short landing is necessary. All these operations must be carried out with the maximal possible cargo of working substance. According the set of requirements defining the working fly of a plane for agricultural works, the design and construction of such plane represent considerable compromise. Efficiency of the plane can be evaluated by operating parameter of working productivity P related to the working area per unit time [hectare per hour] (Danihel, 1984, Švrček, 2000).

2. CALCULATION OF PLANE PRODUCTIVITY

Generally, the productivity of single size categories of planes can be calculated applying Baltin´s equation (Danihel, 1984)

$$P = \frac{10000}{\left(\frac{t_R Q}{Q_F} + \frac{1}{v_2 B} + \frac{t_W}{L_P B} + \frac{a Q}{v_1 Q_F} + \frac{a Q}{v_3 Q_F} + \frac{C}{v_1 A} \right)} \tag{1}$$

in which the denominator represents the sum of durations of particular phases of working flight related to the unit area: $t_R Q/Q_F$ is the time of chemicals loading, time of rolling, time of taking-off to 15 m or landing from 15m, $1/(v_F B)$ is the time of chemicals application, $t_W/(L_P Q_F)$ is the time of working turn, $aQ/(v_1 Q_F)$ is the flight time from working airport to the working field $aQ/(v_3 Q_F)$ is the flight time from the field back to airport and $C/(v_1 A)$ is the flight time between fields by their consolidation. In term of equation (1), it is advisable to relate all variables with the function of $f = f(Q, Q_F)$, i. e. the function of the application dose Q and the useful weight of chemicals Q_F.

To find tje function, the statistical data of available aero-agricultural aircrafts were used to define the input parameters (*** ,1988,*** 2001). From the technical and operating parameters of planes, it is possible to specify the determining relationships needed for construction design of the plane (Švrček, 2002):

- dependence of the working catch width of application equipment on the useful weight of chemicals ()

$$B = 20.56 + 6.75\times10^{-3} Q_F + 7.36\times10^{-7} Q_F^{\,2} \tag{2}$$

- dependence of the maximum take-off weight on the useful weight of chemicals

$$M_{max} = 13.598 \times Q_F^{\,0.767} \tag{3}$$

- dependence of the total treated area on the useful weight of chemicals maximum take-off weight

$$S = 20 - 1.509\times10^{-3} M_{max} + 1.143\times10^{-6} M_{max}^2 \tag{4}$$

- dependence of the working speed on the maximum take-off weight and the total treated area

$$v_2 = 0.599 \left(\frac{M_{max}}{S} \right)^{0.938} \tag{5}$$

- dependence of the speed during the flight from working airport to the working field on the working speed

$$v_1 = v_2 + 2.77 \tag{6}$$

- dependence of the speed during the flight from working field to the airport on the working speed

$$v_3 = v_2 + 4.16 \tag{7}$$

- dependence of the working turn on the working speed

$$t_W = -5.00 + 1.58\, v_2 \tag{8}$$

- dependence the total time of chemicals loading, rolling, taking-off and landing

$$t_R = 22 + 0.02 Q_F + \frac{266.64 + 3.52 Q_F}{v_1} \tag{9}$$

Additionally, parameters specifying the agricultural conditions must be given for the application of the equation (1), namely

- average size of the field A,
- average length of the field L_p,
- average distance between working airport and a field a,
- average distance between fields C.

As an average management unit in agriculture, the independent legal subject is considered with the managed land area from 1000 to 1200 hectares (*** 2001). The working airport is mostly placed to the center of managed area, thus the average flying distance and radius can be defined for given conditions. Based on defined input parameters, the dependence of productivity P for the plane with average technical and operating parameters on the application dose Q and useful weight of chemicals Q_F can be calculated (Fig. 1).

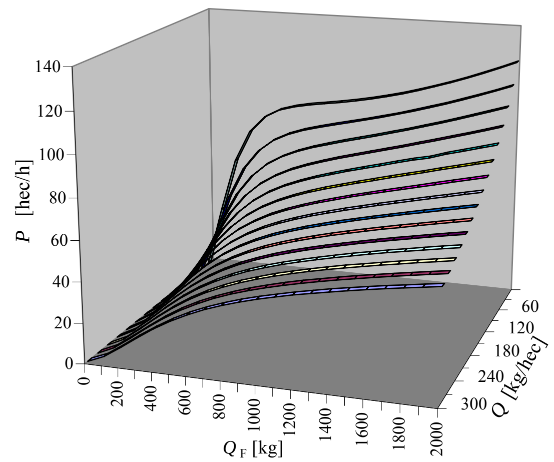

Fig. 1. Dependence of productivity P for the plane with average technical and operating parameters on the application dose Q and the useful weight of chemicals Q_F

3. DETERMINATION THE OPTIMAL USEFUL WEIGHT OF CHEMICALS

As it follows from the Fig. 1, computed values of productivity for single application doses of chemicals after the rapid initial increase to the local maximum rise only slightly. This point can be recognized as the point expressing the optimal useful weight of chemicals for given application dose. The curve passing through these points defines the optimal useful weight of chemicals and the optimal size of the aircraft (Fig. 2). As well as, it is possible to derive the relationship between useful weight of chemicals and the application dose (Fig. 3) in the form

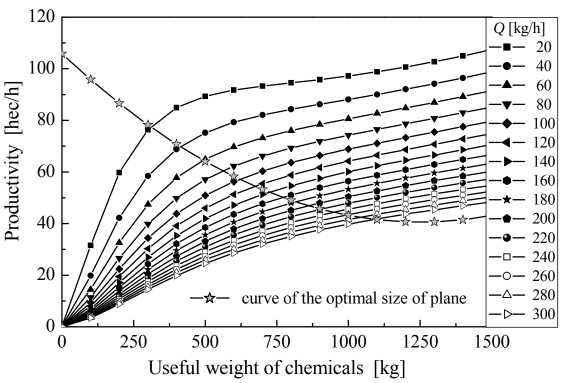

Fig. 2. Optimal plane size in the dependence on the useful weight of chemicals and the plane productivity

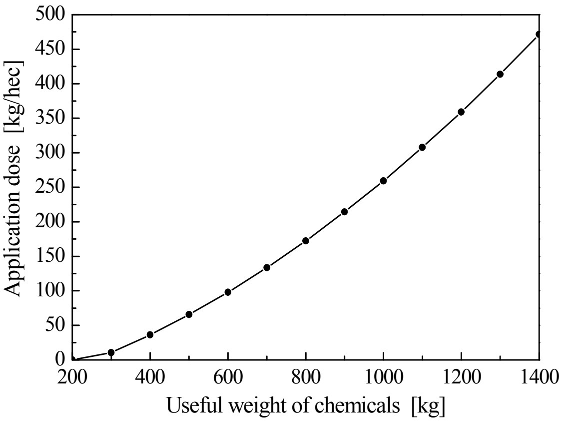

Fig. 3. Relationship between useful weight of chemicals and the application dose

$$Q = -48.85 + 0.149 Q_F + 1.585 \times 10^{-4} Q_F^{\,2} \qquad (10)$$

Using the inverse approach (Bartsch, 1983), the inverse function for the determination of the useful weight of chemicals $Q_F = Q_F(Q)$, can be expressed in the form

$$Q_F = 247.07 + 3.51 Q - 2.656 \times 10^{-3} Q^2 \qquad (11)$$

4. SPECIFICATION OF THE OPTIMAL SIZE OF PLANE FOR THE SLOVAK MARKET

Considering the statistical data of the company AGROLET (***, 1998), the following average parameters for the determination of the optimal plane size can be specified: the average application dose for solid chemicals $Q_S = 141.3$ kg/hectare and for liquid chemicals $Q_L = 82.2$ kg/hectare. Related values of the useful weight of solid chemicals $Q_{FS} = 717.5$ kg and liquid chemicals $Q_{FL} = 563.3$ kg can be calculated from the equation (11).

As it is not effective to consider design of two planes different for application of solid and liquid chemicals, the weighted average the useful weights can be used with

$$h_1 = \frac{V_S}{V} = \frac{3788}{6727} = 0.56 \text{ and } h_2 = \frac{V_L}{V} = \frac{2920}{6727} = 0.44$$

where V_S/V and V_L/V are the ratios of volumes of aviation works by application of solid and liquid chemicals, respectively to the overall volume of aviation works (Fecenko & Ložek, 2000, Švrček, 2000). Finally, the useful weight of chemicals for the market in the Slovak Republic will be

$$Q_F = h_1.Q_{FS} + h_2.Q_{FL} = 0.56 \times 717.5 + 0.44 \times 563.3 = 650 \text{ kg}$$

5. CONCLUSIONS

In the paper, the specification of suitable size of agricultural aircraft is determined particularly from the point of view of effective weight of chemicals. Based on the mathematical model, the working productivity in the relationship to the application dose of chemicals is computed for the medium model of agricultural aircraft. Moreover, the suitable size category of agricultural aircraft is determined for the required application dose.

Finally, as an example of application of introduced mathematical model, the useful weight of solid and liquid chemicals for the market in the Slovak Republic is computed and determined to be 650 kg.

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