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Energy-efficient environmentally friendly electric device for the destruction of weeds by heating them

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Abstract. Weeds damage cultivated agricultural plants. There are many ways to control weeds. These include biological, chemical, mechanical and electrical methods. With an increase in sown areas, the types of weeds increase. On the one hand, weeds perform some useful functions, such as transporting moisture and trace elements from the soil, increasing the diversity of flora. However, with a very large number of weeds, the yield can be reduced by up to 50%. The use of pesticides to kill weeds leads to environmental pollution and deterioration of human health. Certain types of chemicals cause cancer disease. In recent years, smart technologies have appeared for the local application of pesticides in weed control. At the same time, there is a decrease in pesticides up to 90%. Intelligent technologies allow effective control of weeds. Burning weeds directly in the fields leads to a decrease in soil humus and, subsequently, to a decrease in land productivity. We have developed a method and a device for the destruction of collected weeds directly on the field using energy-efficient electric contact heating. This technology and electrical circuit can be connected to both centralized power supply and autonomous power (diesel or solar power plants). In order to save energy resources, an electronic model for the use of a solar beam concentrator is also proposed.

1. Introduction

To date, there are more than 140 harmful parasitic plants in the world that cause great damage to forests and agricultural plants. This, of course, seriously harms the good development of the plant, reduces its productivity and product quality. As a result, the level of desertification will increase or we will not get the planned harvest. To prevent such a negative situation, it is necessary to fight pests (weeds). Below are some ways to control weeds.

Various mechanical methods for removing weeds (by cutting, burial or uprooting) are considered depending on the growth stage and type of weed [1].

A method of combating the growth of weeds on railway tracks with the spraying of weeds with herbicides is also considered [2]. Some researchers studied the use of sulfuric acid about a century ago [3]. However, there is an important obstacle to the implementation of this method, namely twenty-four hours of good weather after a rainy day for application was too difficult to implement under normal conditions. When using sulfuric acid, it only takes an hour or so to spray in dry weather. In the conditions of Central Asia, dry weather is not a problem. The problem is the use of chemicals. In order to control weeds in the onion field, experimental studies were carried out [4] with a 3-fold repetition of 7 variants of 2 types of herbicides.

Chemicals pollute the environment, harm warm-blooded animals and are especially dangerous for humans.

The researchers created a device using a Fresnel lens to focus sunlight [5]. This creates a high temperature band (>300°C) to control weed emergence (Johnson et al. 1990). The general view of this device is shown in Fig.1.

Figure 1. A device using a Fresnel lens to focus sunlight [5].

Systems used for electrical processing of plants are of two main types - spark and contact. The first method uses high-voltage, short pulses to control weeds, thin out plants, and speed up maturation. The latter method uses an electrode connected to a high voltage source (eg 15 kV, 54 kW) and when it touches the plants, a discharge current flows during the contact time. This method is used for trimming and drying the foliage of root crops, as well as for weed control and thinning row crops. In this case, plant tissues are damaged by the flow of discharge current and the shock wave of the discharge in pulsed systems and by the rapid heating effect of electric currents in continuous contact devices [6].

2. Materials and methods

Heat transfer in solids systems is important to a huge number of industries, but is poorly understood even in the simplest case, heat conduction through a solid phase. This is partly due to the voltage and contact inhomogeneities inherent in these systems. Thermal conductivity in a stacked layer of cylinders is studied experimentally and by calculation. This simple system can also provide insight into phenomena such as the formation of hot spots in a reactor and spontaneous combustion of bulk reactive materials [7,8]. Electrocontact heating is the best method for thermal and mechanical processing of normal-shaped parts (shafts, axles, belts) [9,10]. Used (Fig. 2). The heated material (1) is connected to an electrical circuit and heated due to the current passing through it [9-14].

To reduce the technical moisture content of seeds, the method of electrocontact heating was used. On fig. 2 shows a schematic diagram of electrocontact heating. The main element of electrocontact heating is a heating transformer. The calculations mainly take into account the parameters of the heating transformer with electrical contact.

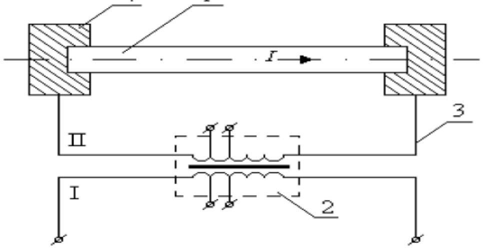

Figure 2. Schematic diagram of electrocontact heating: 1 - detail; 2 - heating transformer; 3 - transmission tires; 4 - clamps (contacts).

In electrocontact heating, the required temperature and dimensions of the heated material are taken as initial data. Estimated, total and useful power of the transformer for electrocontact heating of the material, operating current and voltage in the secondary winding of the transformer.

The useful power of the material heating transformer with electrical contact (P_{useful}) is found according to the following formula [10,11]:

$$P_{useful} = \frac{m \cdot c(t_2 - t_1)}{\tau_h}, \text{kW}$$

here m - is the mass of the heated material, kg;
b –material width, m;
l – material length, m;
j – the density of the heated material is assumed to be 7.8 10^3 kg/m3 for steel;
c — specific heat capacity of the heated material, 0,48·10^3 kJ/kg ^{0}C;
t_1, t_2 — start and end temperature;
τ_h — heating time, hour;

$$\tau_h = \frac{\Delta M}{\Delta \rho} c \cdot (t_2 - t_1), \text{ s.}$$

ΔM — specific weight of material 1 m long, kg/m;
$\Delta \rho$ — average energy intensity corresponding to a unit length of a part heated per unit time, W/m. According to the results of the experiment $\Delta \rho = 160...250$ W/m.

2. Transformer Apparent Power:

$$S = \frac{k_z \cdot P_{useful}}{\eta \cdot \cos\varphi}, \text{kVA}$$

here, k_z - safety factor, taken in the range of 1.1 ... 1.3;
η — Efficiency, depending on the ratio, is taken from the table - 2;
$\cos\varphi$ – power factor, depending on the ratio $\frac{l}{S}$, adopted from the literature.

The rest of the calculation points with specific numerical values are given in the Results and Discussion section.

3. Results and discussion

Determination of the power of an electrocontact heating transformer for reducing the moisture content of weeds and their destruction.

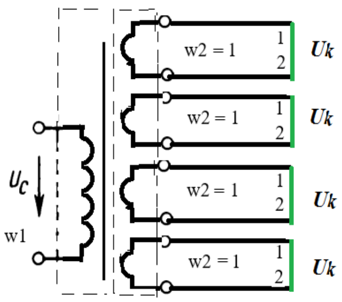

Figure 3. The conditional arrangement of the windings of the step-down transformer: w1 - primary winding ; w2 - secondary winding of the transformer with the number of turns 1 in each winding; 1 and 2 - beginning and end of the secondary winding.

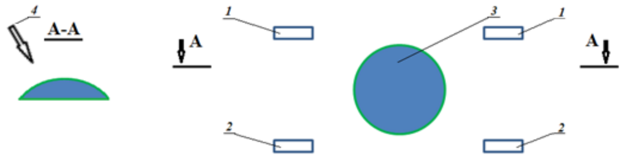

Figure 4. The conditional location of the contact electrodes and the convex part of the stack (3) of weeds: 1,2 - contact elements connected to the beginning (1) and end (2) of the secondary winding, 4 - the sun's rays directed through the concentrator (using a Fresnel lens to focus sunlight).

Based on the calculations, the main parameters of the transformer are apparent power, secondary voltage, operating voltage, operating current and rated power. Figures 3 and 4 show diagrams for representing the physical phenomena of the devices under study.

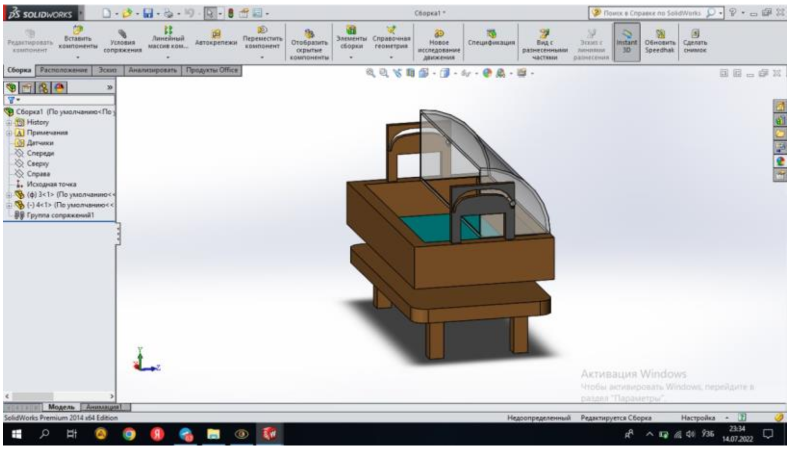

Figure 5. General view of the electronic model (electrical connections are not shown).

Based on the above expressions, we calculate the parameters of the electrocontact heating transformer.

Useful power of the transformer (P_{useful}):

$$P_{useful} = \frac{m \cdot c(t_2 - t_1)}{\tau_h} = \frac{0.42 \cdot 0.48 \cdot 10^3 (160 - 20)}{0.16} = 646 \text{ W}$$

here, m — mass of material to be heated, kg;

$$m = a \cdot b \cdot l \cdot j = 0.001 \cdot 0.4 \cdot 0.4 \cdot 7.8 \cdot 10^3 = 3.12 \text{ kg}$$

a – material thickness, 0.001 m;

b – material width, 0.4 m;

l – material length, 0.4 m;

Heating time:

$$\tau_h = \frac{\Delta M}{\Delta \rho} \cdot c \cdot (t_2 - t_1) = \frac{0.23}{200 \cdot 10^3} \cdot 0.48 \cdot 10^3 (160 - 20) = 0.08, \text{ hour}$$

Transformer Apparent Power:

$$S = \frac{k_z \cdot P_{useful}}{\eta_{tr} \cdot cos\varphi} = \frac{1.2 \cdot 646}{0.94 \cdot 0.95} = 868 \text{ VA}$$

Heating transformers often operate in intermittent mode, therefore, the duration of operation at full power is determined taking into account OD (On duration) (in relative units), in the process of reducing the moisture content of the seed, the electrocontact heating transformer operates in continuous mode. Considering this, you should:

$$S_{calculated} = S = 868 \text{ VA}$$

The voltage in the secondary winding of the transformer, that is, the voltage supplied to the part, is as follows:

$$U = \sqrt{\frac{P_{useful} \cdot R_t}{\eta_{tr}}} = \sqrt{\frac{646 \cdot 236.25 \cdot 10^{-6}}{0.9}} = 0.411 \text{ V}$$

here, η_{tr} – average temperature difference Transformer efficiency, taken within 0.9 ... 0.95;

R_t – resistance of the part at an average heating temperature.

$$R_t = k_n \cdot \rho_t \frac{l}{\frac{\pi \cdot d^2}{4}} = k_n \cdot \rho_t \frac{l}{a \cdot b} = 1.25 \cdot 0.189 \cdot 10^{-6} = 236.25 \cdot 10^{-6} \text{ ,Ohm}$$

$$k_n = 1 + \frac{1}{4} + \frac{3}{64 \cdot a^*}$$

a^* — dimensionless indicator (corresponding to all dimensions) is determined by the following formula:

$$a^* = \frac{l}{4 \cdot Z_n} = \frac{0.9}{4 \cdot 0.001} = 100 \text{,}$$

Specific resistance ρ_{20} at a temperature of 20 ^{0}C it is accepted $0.135 \cdot 10^{-6}$ Ohm·m.

$\theta = \dfrac{t_1 - t_2}{2}$ – average temperature difference.

Due to the fact that the heated material here is in the form of a sheet, it is accepted $Z_n = a$.

Z_n – depth of penetration of current into the metal, m:

$$Z_n = 503 \sqrt{\frac{\rho_t}{\mu \cdot f}} = 0.001$$

μ – magnetic permeability, can be accepted $\mu = 100$,

ρ_t – specific resistance of steel to the average temperature difference during heating

$$\rho_t = \rho_{20}\left(1 + 0.0055 \cdot \Theta + 9 \cdot 10^{-6} \cdot \Theta\right) = 0.135 \cdot 10^{-6}\left(1 + 0.0055 \cdot 70 + 9 \cdot 10^{-6} \cdot 70\right) =$$
$$= 0.189 \cdot 10^{-6} \text{ Ohm} \cdot \text{m}$$

Specific resistance ρ_{20} at a temperature of 20 ^{0}C it is accepted $0.135 \cdot 10^{-6}$ Ohm·m.

$\theta = \dfrac{t_1 - t_2}{2}$ – average temperature difference.

Due to the fact that the heated material here is in the form of a sheet, it is accepted $Z_n = a$.

The operating current is found as follows:

$$I = \frac{\frac{P_{useful}}{3}}{U} = \frac{646}{3 \cdot 0.411} = 524 \text{ A}$$

The operating voltage of the transformer during operation is the sum of the voltage in the part (U) and losses in the secondary winding (ΔU). $U_{no\text{-}load\,mov.} = U + \Delta U$

The value ΔU can be taken as follows $\Delta U = 0.1U$, then $U_{no\text{-}load\,mov.} = 1.1 \cdot U = 1.1 \cdot 0.411 = 0.452$ V

The light concentrator has many uses around the world. In work [4] concentrator of light in the form of a transparent device when focusing light (Fresnel Reflector) was used weed. In the following figure, we simulated an installation containing a Fresnel Reflector, and it can be adjusted in mutually perpendicular planes. Thanks to the use of a concentrator, the weed control device will work in an energy-saving mode. In this case, the efficiency of the device will increase to 1. Approximately half of the efficiency corresponds to electrocontact heating, and the second half is achieved by using a concentrator (Fig.5). The figures below show the design options for the device for the destruction of the collected weeds. Electrical circuits and elements of the electronic model are built according to samples [13,15].

4. Conclusions

We have developed a method and a device for the destruction of collected weeds directly on the field using energy-efficient electric contact heating. This technology and electrical circuit can be connected to both centralized power supply and autonomous power (diesel or solar power plants). In order to save energy resources, an electronic model for the use of a solar beam concentrator is also proposed. The power of the electrocontact heating transformer is calculated depending on the set temperature and the size of the heated sheet in the process of reducing the moisture content of grasses and weeds.

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