Mathematical modeling of soldering iron heating process in automated terminal soldering installations

S. M. Abdurakhmonov[1*], *Sh.* Sayitov[1], and *S. I.* Xaliev[1,2]

[1]Fergana Polytechnic Institute, Tashkent, Uzbekistan
[2]National Research University TIIAME, Tashkent, Uzbekistan

Abstract. The article describes a mathematical model of temperature changes in the soldering iron of an automated installation used in the terminal of the glass heating system created for automotive glass manufacturers. The effect of changing the shape of the welding machine on the temperature distribution has been studied. The results of the mathematical model were compared with the experimental data

1 Introduction

In the modern auto industry, all brands of cars are equipped with electric heating systems on the rear window to protect cars from freezing the rear windows on cold days. A conductive grid is formed with a silver mixture by vacuum deposition or painting on the surface to do this. The technology of forming a "conductive grid" on the glass surface has been fully developed and is widely used. However, work is still underway to improve the technology for installing terminals (terminals) on glass, designed to connect electricity to this heating conductor. The technologies use semi-automatic, manual modes, but their result completely depends on the human factor [1-4].

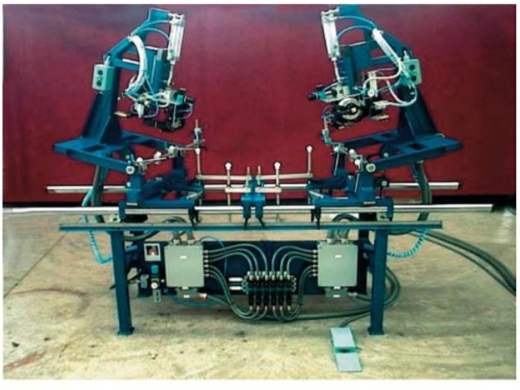

Fig. 1. Device for semi-automatic soldering terminal TAI-SWS [3].

*Corresponding author: sulton59_15@inbox.ru

Our research aims to improve the result by reducing the human factor in the process of soldering the terminal of the glass heating system. This study relates to the automotive glass industry; therefore, it is relevant.

2 Methods

The main technological parameters that must be taken into account when soldering the terminal are the following:

- installation of glass on the welding table according to the specified coordinates;
- support the temperature of a soldering iron in the set range;
- correctly install the terminal in the soldering area;
- holding the necessary pressure on the terminal during soldering;
- the creation of a system for the automatic supply of the terminal to soldering areas;
- control and time management of the terminal soldering process.

During our research, it was found that it is advisable to study each of the listed technological processes separately, automate some stages, and implement some manually. At the same time, they took into account not only the increase in the productivity of the process but also estimated the cost of the developed installations [5-7].

A schematic representation of the proposed device for soldering the terminal to the glass heating system is as follows:

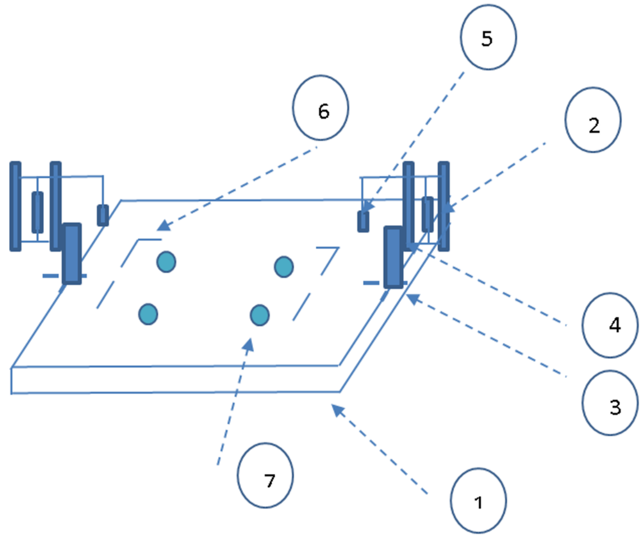

Fig. 2. Schematic view of the setup: 1 is table, 2 is pneumatic cylinders, 3 is mechanism for adjusting the soldering unit in height, 4 is mechanism for adjusting the soldering unit in plane, 5 is assembly for holding the soldering iron with a bellows, 6 is devices for orienting the glass in the plane, 7 is pneumatic fixation of the glass in the horizontal position.

This paper describes the mathematical models of the soldering iron heating process and the measured experimental data.

To perform special work using a soldering iron, there is an urgent need to create a specially shaped soldering iron tip. This time, this tip is shape is close to the shape of a truncated cone figurative prism, which has a division at a certain level in the form of a reduced shape of the same sample, therefore, similar to the main one.

The purpose of the task is to determine and calculate the temperature of a given special tip at its various points, coordinates, and levels. It is possible to perform this task, to divide this formation into components, as a result of which it turns out that it consists of many truncated prisms, the area which is determined through (1).

$$S = ab \tag{1}$$

To carry out calculations with finding the volume of data of truncated prisms, it is necessary (2), which will be quite suitable for the general pattern, because to describe the prism or rather its edges, it is enough to use formula (3), which can also be represented as canonical, complete (4) or parametric (5) presented in the analytical study.

$$V = \frac{1}{3}h\left(S_1 + S_2 + \sqrt{S_1 S_2}\right) \tag{2}$$

$$y = kx \tag{3}$$

$$Ax + By + Cz + D = 0 \tag{4}$$

$$\frac{x - x_0}{m} = \frac{y - y_0}{n} = \frac{z - z_0}{p} => \begin{cases} x = x_0 + tm \\ y = y_0 + tn \\ z = z_0 + tp \end{cases} \tag{5}$$

Following from (3) and (4), we can derive (5), that is, the prism equation in space:

$$\begin{cases} Ax + By + Cz + D = 0 \\ Ax + By + Cz = -D \\ \frac{Ax}{-D} + \frac{By}{-D} + \frac{Cz}{-D} = 1 \\ \frac{x}{\left(-\frac{D}{A}\right)} + \frac{y}{\left(-\frac{D}{B}\right)} + \frac{z}{\left(-\frac{D}{C}\right)} = 1 \end{cases} \tag{6}$$

Thus, from the outgoing regularity, a sequence of decreasing areas is obtained, which is described through (6) for each of the members of the indicated sequence and through a series of conclusions in the same (6) and (7), the resulting answer of formula (8) is obtained.

$$S_{n-1} = S_1 + (n-1)d = S_1 + \frac{(n-1)(S_2 - S_1)}{n} \tag{7}$$

$$S_{n-1} = S_1 + \frac{(n-1)(S_2 - S_1)}{n} = S_1 + \frac{nS_2 - nS_1 - S_2 + S_1}{n} \tag{8}$$

$$\mathrm{S}_{\mathrm{n}-1} = \mathrm{S}_2 - \frac{\mathrm{S}_2 + \mathrm{S}_1}{\mathrm{n}} \tag{9}$$

Changing the areas for the prism was necessary to use them in the volume formulas for each small fractional prism (10) and for the entire prism (11). And although it is possible to calculate for an infinitely greater number of values due to the possibility of dividing the prism's volume into an infinitely greater number, in this case, the calculation is carried out for 7000 units.

$$V_0 = \frac{1}{3}h\left(S_1 + \sum_{n=1}^{n}\frac{S_2 - S_1}{n}\right) \tag{10}$$

$$V_n = \frac{1}{3}h\left(S_1 + \sum_{n=1}^{n}\frac{S_{n+1} - S_n}{n}\right) \tag{11}$$

Once the moment with volume has been solved, one can proceed to calculate energies, which is determined in (12) due to the transfer through the heating element, where there is voltage and current, along with heating time. After the above calculations, you can only proceed to the conclusion of the temperature.

$$Q = UIt \tag{12}$$

The moment of temperature transition due to the insulating material, that is, its total thermal conductivity is about 95-96%, which is also considered in regularity (13).

$$Q_1 = \varphi Q \tag{13}$$

Finally, the energy is revealed through (14) with the dependence and through the temperature, where the temperature derivation (15) can also be derived.

$$Q_1 = cm\Delta t = UIt; \qquad p = \frac{2}{3}\frac{N}{V}E_\kappa => \frac{pV}{N} = \frac{2}{3}E_\kappa => \frac{pV}{N} = kT \tag{14}$$

$$\Delta t = \frac{Q_1}{cm} = \frac{UIt}{cm} \qquad 15)$$

Speaking about (15) it is important to point out that the temperature does not exceed the specified temperature obtained from the thermal equilibrium equation.

After indicating the full regularity in temperature, you can notice the moment with the mass; it was for this that the calculation was used from the equation for calculating the volume, which, due to the density of the material, in this case, nichrome, gives a formula for the mass through (16), which already in the total set gives a regularity for temperature (17). Thus, this design's mathematical model of temperature change is as follows (16)-(17):

$$\rho = \frac{m}{V} => m = \rho V \tag{16}$$

$$\Delta t = \frac{UIt}{cm} = \frac{UIt}{c\rho\frac{1}{3}h\left(S_1 + S_2 + \sqrt{S_1 S_2}\right)} = \frac{UIt}{c\rho\frac{1}{3}h\left(a_1 b_1 + a_2 b_2 + \sqrt{a_1 b_1 a_2 b_2}\right)} \tag{17}$$

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It is important to note that this pattern calculates the temperature for the core itself, for the average temperature of the entire prism, creating in a general sense diagrams for the whole part and for the divided part, while meaning one divided part.

The existing differences between the experimental and calculated data can only inquire into the differences between the shape taken into account and the actual volume.

To determine the temperature on the same surface, it is enough to calculate the ratio of the top to the core, which is the similarity coefficient. And depending on this, the equation is solved if there are 5 divisions in each truncated prism (18).

$$ax+(a+1)x+(a+2)x+(a+3)x+(a+4)x=Q' \tag{18}$$

Thus, the following regularity (19) follows, from which it is easy to calculate the unknown (20), and it is enough to multiply by the first output value, namely by one; that is, this unknown is the very answer.

$$S_n(a)x=x\sum_{n=1}^{n}(a+n)=Q' \tag{19}$$

$$x=\frac{Q'}{\sum_{n=1}^{n}(a+n)}=Q'' \tag{20}$$

These patterns for the surface create the following graphs (Fig. 3, 4). In these graphs, the temperature increase occurs due to the approach to the heating center.

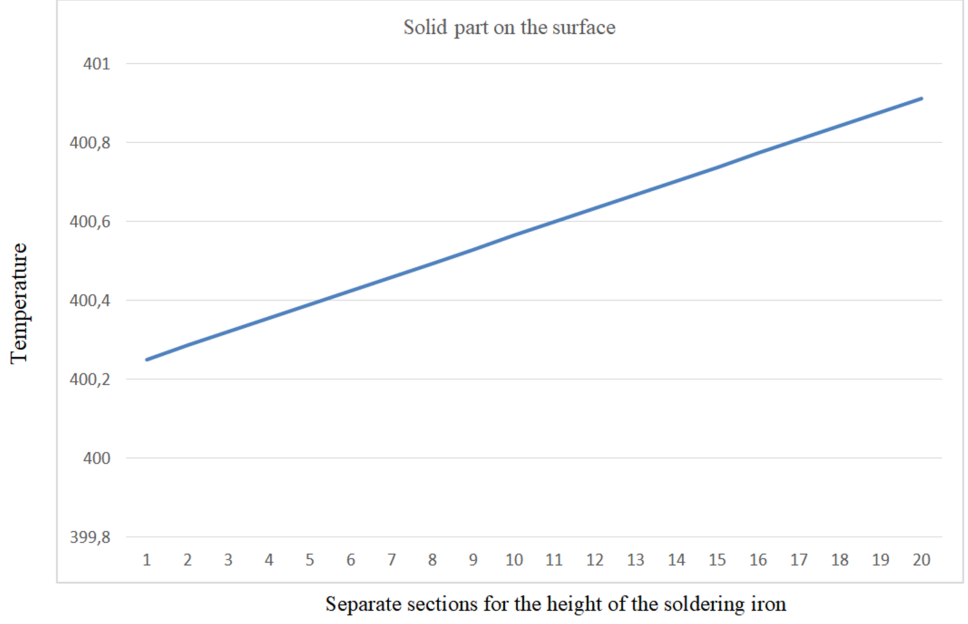

Fig. 3. Temperature on surface of truncated prism on each part in integral part of entire soldering iron tip

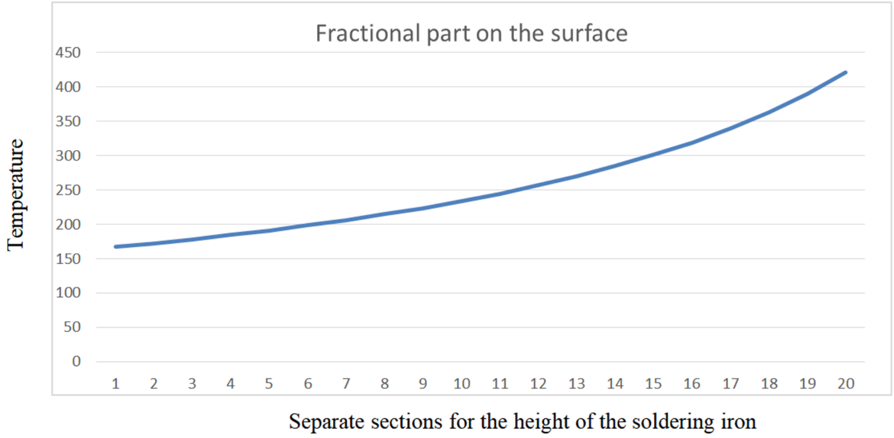

Fig. 4. Temperature on surface of truncated prism on each part in fractional part of entire soldering iron tip.

As a result, a general pattern was obtained for calculating the temperature of a soldering iron tip of a special shape and the resulting necessary conclusions without any strong assumptions.

The graphs generated by the computer program fully correspond to the experimental ones obtained as a result of the experiment. However, there is a distinctiveness that is characteristic of all calculations in the face of the presence of some small error. Experimental data are also presented, and all results are recorded (Fig. 5) [8-10].

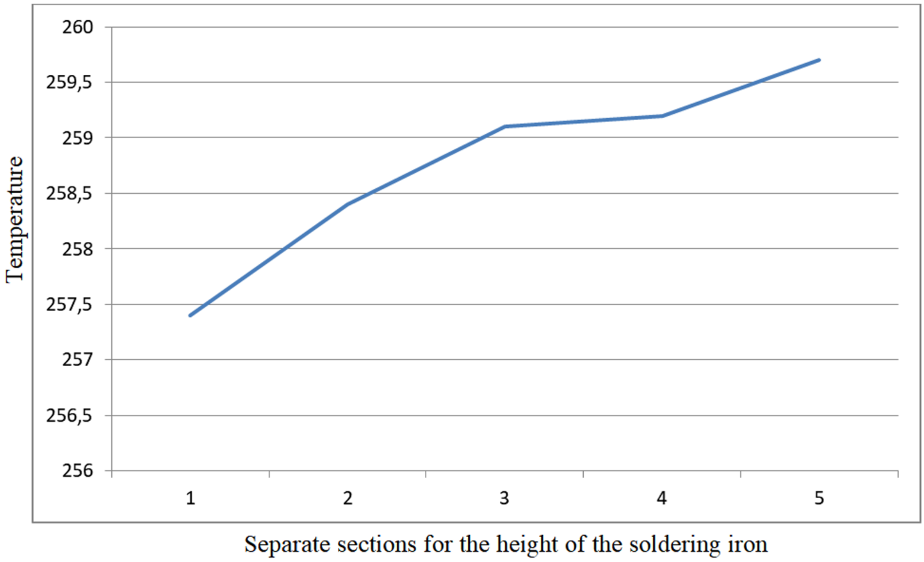

Fig. 5. Experimental data

3 Conclusions

The efficiency of dividing the soldering iron itself from the usual "prism cone" of representation was that the temperature at the edges became much higher, as shown by the experiment and by a computer program. According to the latest estimates, when changing the shape of the soldering iron in the format of setting the terminal, the overall efficiency was 15 - 20%.

References

1. Shavkat S. Automated Device for Welding the Window of the Car Window Heating System. Texas Journal of Engineering and Technology, Vol. 14, 59-63. (2022).
2. Abdurakhmonov S. M., Sayitov Sh. S., Oshchepkova E. A., Rakhmonov D. Kh., and Khuriboeva M Sh. A new design for soldering the terminal of the car rear window heating system. Actual science. International scientific journal. No. 9(26), pp. 22-28. (2019).
3. Zbinden L. R. Glass Engineering: Design Solutions for Automotive Applications. SAE International. (2014).
4. Nielsen J. H., Belis J., Louter C., Overend M., and Schneider J. Glass engineering!. Glass Structures and Engineering, Vol. 4(3), pp.277-278. (2019).
5. Abdurakhmonov S. M., Sayitov Sh. S., Yuldasheva E. N. Automated soldering device for terminal heating systems in auto glass. Scientific-technical journal (STJ FerPI, 2021, Vol. 25(6), pp. 256-259. (2021).
6. Abdurakhmonov S. M., Sayitov Sh. S., Mukhammadzhonov H. Work of authorship: Development of a device for tacking tin to the terminal or pouring tin into the terminal. Certificate of copyright. Original Sign of INTEROCO. EC-01-002680 (2020).
7. Das A., Li D., Williams D., and Greenwood D. Joining technologies for automotive battery systems manufacturing. World Electric Vehicle Journal, Vol. 9(2), p.22. (2018).
8. Otakulov O. Kh., Abdurakhmonov S. M., Sayitov Sh. International scientific and practical conference., "Actual problems of the introduction of innovative techniques and technologies at enterprises for the production of building materials, chemical industry and related industries" May 24-25 2019 (2019).
9. Kirwan K. Automotive Glazing. Encyclopedia of Automotive Engineering, pp.1-12. (2014).
10. Khorasani N. Design principles for glass used structurally. Department of Building Science, Univ. (2004).