FEATURES HARDENING SURFACES OF PARTS WITH THE USE OF THERMITE MIXTURES

Kovalevskyy S. V., Hmelevaya J. A.

Результаты исследования, представленные в статье, показывают, что точечное воздействие источника энергии на поверхность детали может обеспечить повышение качества поверхностного слоя. Моделирование тепловых процессов в упрочняемом слое позволило выявить особенности распространения тепловых потоков по поверхности детали и прогнозировать развитие термических процессов в поверхностном слое. Особенно актуальным является численное моделирование процесса, при котором установлена взаимосвязь между тепловыми характеристиками термитных смесей и достигаемыми результатами на различных материалах. Также показана возможность и целесообразность использования термитных смесей в сочетании с точечными источниками энергии, такими как низкотемпературная плазма. Суммарное воздействие такого источника и горения термитной смеси позволяет достигать эффекта упрочнения рабочей поверхности детали с более низкими, по сравнению с традиционными, затратами энергии.

Результати дослідження, що представлені в статті, показують, що точковий вплив джерела енергії на поверхню деталі може забезпечити підвищення якості поверхневого шару. Моделювання теплових процесів в зміцнювальному шарі дозволило виявити особливості поширення теплових потоків по поверхні деталі і прогнозувати розвиток термічних процесів в поверхневому шарі. Особливо актуальним є чисельне моделювання процесу, при якому встановлено взаємозв'язок між тепловими характеристиками термітних сумішей і результатами, що досягаються на різних матеріалах. Також показана можливість і доцільність використання термітних сумішей у поєднанні з точковими джерелами енергії, такими як низькотемпературна плазма. Сумарний вплив такого джерела і горіння термітної суміші дозволяє досягати ефекту зміцнення робочої поверхні деталі з більш низькими, в порівнянні з традиційними, витратами енергії.

The findings presented in the paper show that the impact point source of energy to the workpiece can improve the quality of the surface layer. Modelling of thermal processes in the reinforcement layer revealed the features of propagation of thermal fluxes at the surface detail and predict the development of thermal processes in the surface layer. Particularly relevant is the numerical simulation of the process in which the interrelation between the thermal characteristics of thermite mixtures and the results achieved on different materials. Also, the possibility and feasibility of using thermite mixtures in conjunction with point sources of energy, such as low-temperature plasma. The net effect of such a source and burning thermite mixture allows to achieve the effect of hardening the working surface of the component with the lower, in comparison with traditional energy consumption.

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FEATURES SURFACE HARDENING DETAILS WITH APPLICATION THERMITE MIXTURE

At the moment we know enough ways to hardening of parts. Among them, become traditional, surface-plastic deformation, heat and chemical heat treatment, heat treatment by high frequency, as well as new methods to improve performance, such as plasma spraying, laser and electron beam welding, cladding, thermoplastic hardening thermocyclic processing and so forth. These methods can solve the problem of hardening of the surface layer, but also have several disadvantages. These disadvantages are high energy consumption, high cost of equipment, labor and processing time, the presence of adverse environmental factors and labor process. There is therefore a need to reduce energy consumption and find alternative methods of heat treatment [9, 11, 12].

In light of the foregoing, the challenge is to develop a method of hardening, which allows to minimize costs and ensure receipt of quality competitive products. In the study, the problem of increasing the wear resistance of components, it was decided to develop a method of hardening the surface layer of parts based on the use of thermite mixtures [4, 5]. For better results, a model was developed combustion wave propagation in the likeness of cellular automata [1–3, 6, 7].

Hardening of parts through the use of thermite mixture involves the use of heat from its combustion emitted as a result of highly exothermic reactions, which subsequently provides the thermal processes in the surface layer of the parts [7, 8, 10–12].

Thermite mixture are a group of pyrotechnic mixtures, which use allows to obtain metals and alloys by the reduction of metal oxides active metal with considerable release of heat, resulting in a change in the potential energy state and recrystallization of components involved in the process.

The most common type of thermite mixture is iron-aluminum thermite (25% aluminum and 75% iron oxide (Fe_3O_4)). Given that the aluminum - one of the main dense fuel with a relatively low cost, and as iron oxide rust can be used (77% Fe_2O_3), can be guaranteed minimum commodity costs, which partially provides the performance of a task [8, 11].

Conditions to initiate the exothermic reaction using thermite mixture.

1. Thermite should be designed so that the reaction will allocate the necessary heat for melting, and overheating of the final reaction products.

2. The components of thermite mixture: aluminum powder and iron oxide fines should be thoroughly mixed.

3. To start the reaction at a thermite mixture temperature necessary to create a push (upwards), after which the combustion wave spreads to the entire mixture [11].

Thus, having an idea of the flow of a thermite reaction, it is possible to control the combustion reaction by the use of cellular automata [1–6].

For the computer simulation package MS Office (Excel) established a model of combustion wave propagation in the form of a cellular automaton. Below is a description of the creation of this model.

1. Create 2 field 10x10 cells (Figure 1).

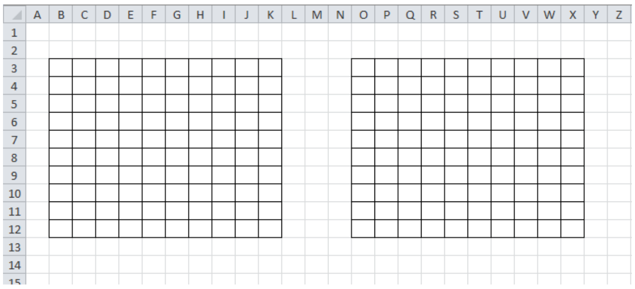

Fig. 1. Creating a cellular automaton fields

2. Null first field, by filling all the cells digit 0 (Figure 2).

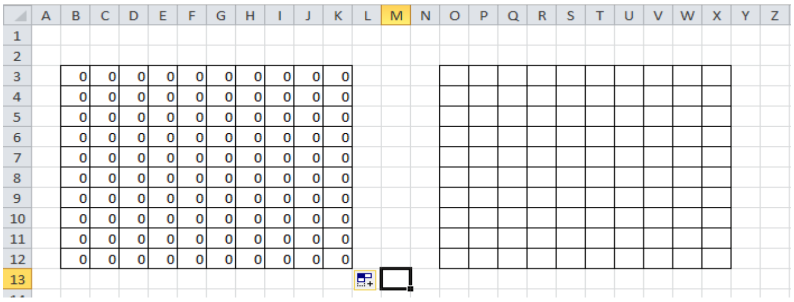

Fig. 2. Resetting the field of cellular automaton

3. Record macros to automatically reset. Copy the value of one cell field 1 and insert it into the cells of the same field (Figure 3).

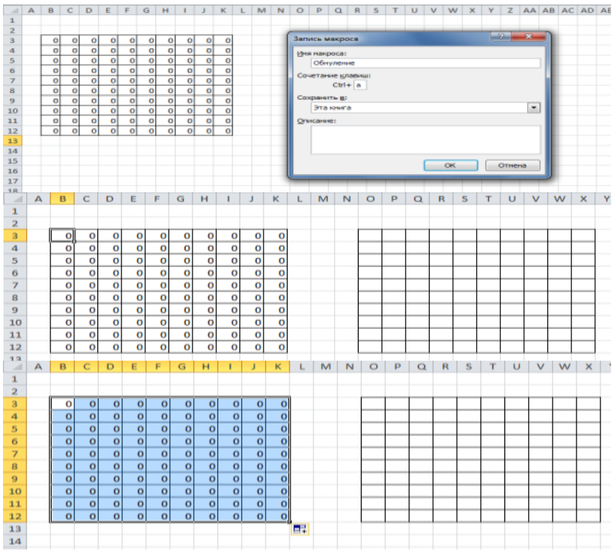

Fig. 3. Creating a macro is automatically reset

4. According to Rule neighbor cellular automata, the value of the cell depends on the values of surrounding cells, ie, neighbors. Consequently, for determining the temperature at each point it is advisable to use the formula:

$$t_i = \frac{1}{9}\sum_{i=1}^{9} i \qquad (1)$$

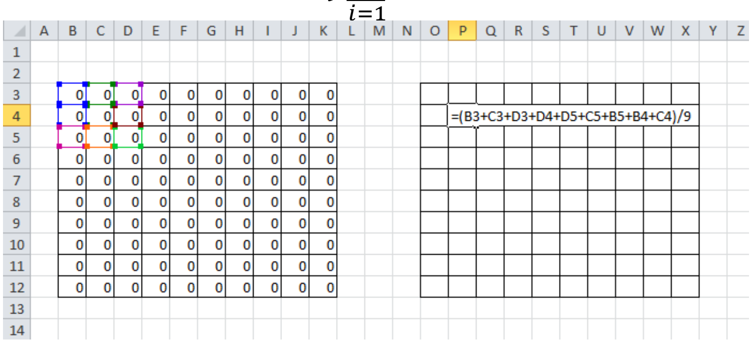

Fig. 4. Setting the cell values

5. We set the value in all cells, copy and paste the value of P4 cells.

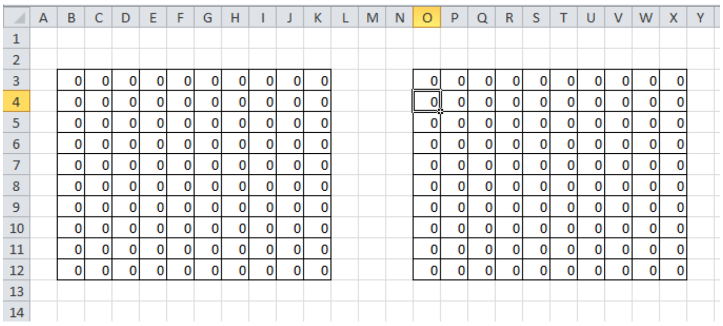

Fig. 5. Set-up of all cells

6. Since the field is a drill shaft, the values of the cells A2, A3, and A4 must be moved to the position K2, K3 and K4 respectively. Thus, by performing gluing the edges of the field. For the other extreme cells simply copy and paste the value of the above cells (Fig. 6).

7. Create a macro, meaning a step by step movement of the source. Copy the value of the field 2, insert them in the field 1 with a special insert.

8. Create two additional fields, copy the values of the field 1. This is necessary to separate consideration of all aspects of the process the thermal wave propagation, namely, the thermal conductivity properties of the material, the motion of the heat source, the heating pattern, and the total picture of the whole experiment.

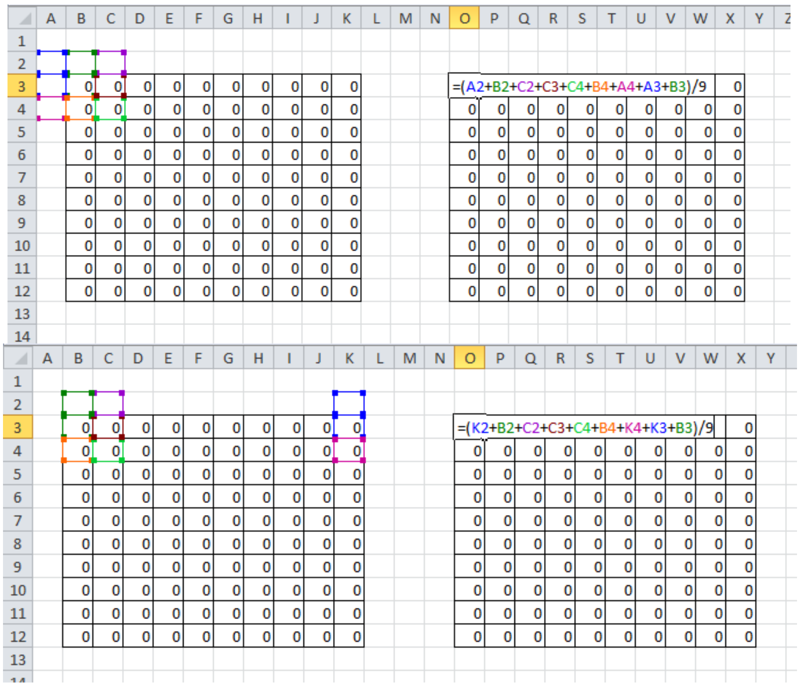

Fig. 6. Implementation of gluing the edges of the field

9. We set all the values in a field 3.
10. Write macro movement of the heat source.
11. Copy the value of a field 3 and insert in the 1 with a special insert.
12. For each field, create a chart that reflect changes related mapping fields.

The following will illustrate the principle of the proposed simulation.

One of the main objectives is to find a machine experiment optimal treatment regimes, and consequently maximizing the reaction temperature and the combustion stability of material properties. Therefore, the experiment is considering five options for passing the combustion reaction. For each option will set different speed corresponding serial number version (V = 1..5 °C/s). In turn, will change the supply point source at a constant speed (S = 1..4 mm/rev). Thus, the result will be obtained 20 graphs of heating temperature at a wave moving heat source.

1. Null 1st box by pressing Ctrl + a.
2. Point AX3 set to 1.
3. Run the macro movements of the heat source by pressing Ctrl + d. Then you can observe the changes in the fields and on the charts. Temperature distributed according to the rule of neighbors, so much change values in some cells of three fields.
4. Next, perform the steps in claim 3, wherein the removing the heat source from the previous cell, as long as the source is not will be in one of the last cells.

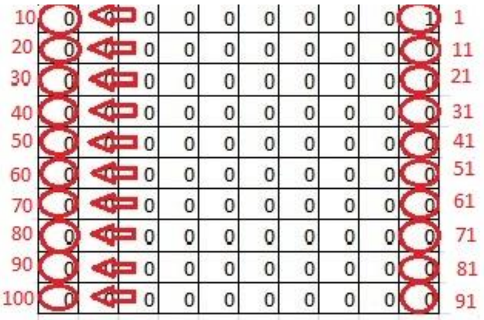

Fig. 7. The movement of the heat source at a speed V = 1 ° C/s and feed S = 1 mm/rev.

According to the results of the experiment plotted thermal conductivity of processing modes.

Analyzing the results, we can say the simultaneous flow of endothermic and exothermic reactions. Ie thermite reaction is accompanied by absorption of heat when exposed to the environment, is an endothermic process, the heat released by the combustion of thermite mixture – an exothermic process.

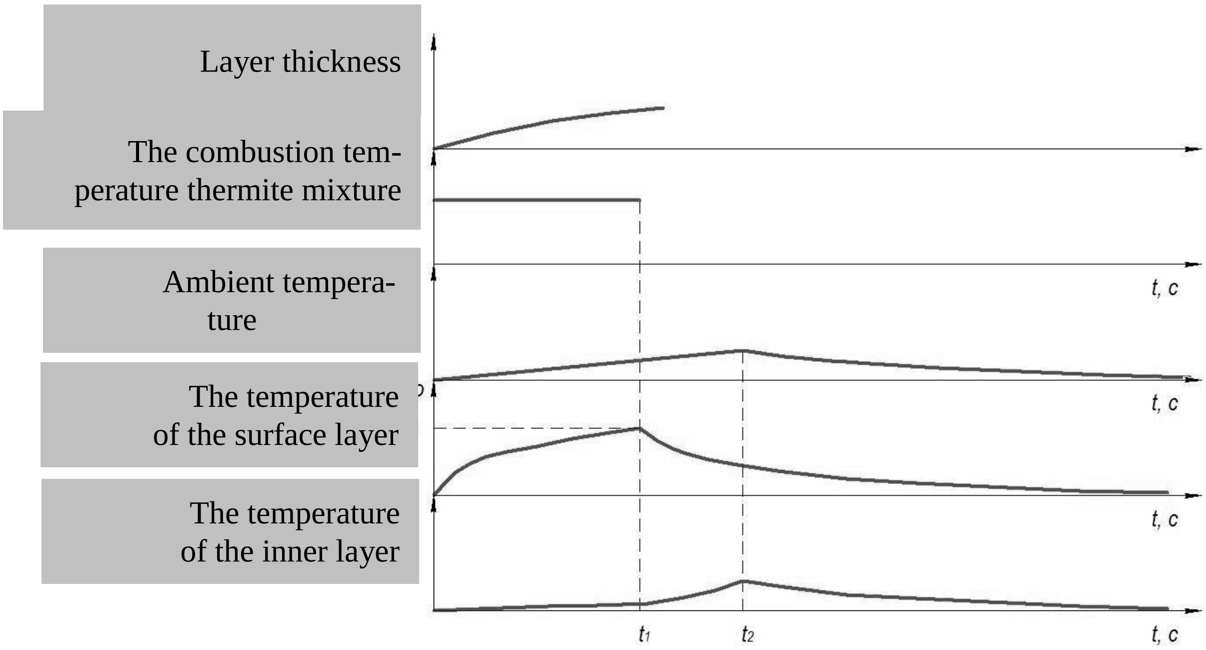

Fig. 12. Graph of temperature and thickness of the reaction time

Each graph describes the specific conditions of the reaction:
1. The higher layer, the longer the time of combustion (cm. Above).
2. A = Q according to the first law of thermodynamics, ie, the amount of heat received by the system, goes on changing its internal energy and a work against external forces.
3. Loss of heat in the environment.
4. The effective portion of the heat is converted to the temperature of the surface layer.
5. Part of the heat transferred from the inner surface layer, followed by cooling.

The heating of the surface layer is performed by the formula:

$$t^{\circ} = t_{max} \cdot e^{-\lambda_{cm} \cdot t} \quad (2)$$

where t_max – the maximum heating temperature, ° C; λ_st – thermal conductivity for steel, W/m°C; t – time of combustion with.

The cooling of the surface layer is performed by the formula:

$$t^{\circ} = t_{max} \cdot e^{(-\lambda_{cm} \cdot t)^{-1}} \quad (3)$$

Also according to the formulas 2 and 3, the temperature changes of the environment and in the inner layer part, wherein the thermal conductivity changes.

Thus, knowing the maximum combustion temperature, and the time to achieve a layer thickness can be achieved by obtaining any relevant microstructure and strength characteristics using the state diagram Fe_3C.

CONCLUSIONS

1. Spot the impact of energy sources can provide the high quality of the surface layer.

2. Simulation of thermal processes may allow to load layer is at the stage of numerical main features and characteristics of the relationship between the thermal mixture and achieve results on different materials

3. The results of the studies cited in the article suggests that the replacement of the thermite mixture to a source of high-temperature plasma or electric arc, which would have destroyed the surface (you need to match the conditions of its combustion) can afford to get the same effect without the use of thermite mixtures. However, this assumption should be balanced against the costs of such alternative methods of strengthening the special arc.

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