Mathematical and Physical Modeling Cooling Process for Solid Waste Tire Pyrolysis Products

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Main issues

• the realization of a continuous process of shredded tires waste pyrolysis, the limiting factor in which can be the cooling process;

• the burnup of the coke residue at high temperatures with open air cooling;

• the thermal conductivity of the coke residue in the temperature range up to 500 °C.
Physical modeling using IT

- the measuring chamber filled with coke residue;
- the tunnel furnace;
- the metric data system of automated collection and information processing consisting of:
  - the Advantech™ USB-4718-AE I/O module;
  - the Advantech Automation™.
The measuring chamber (scheme)
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The measuring chamber

The base
The investigated substance (the backfill) and the tunnel furnace
The metric data system of automated collection and information processing
Data analysis in Microsoft Excel™ and Mathcad™
The results of the experiment (time dependence of temperatures in the layers of backfill)
The results of the experiment (Time dependencies for logarithms of extra temperatures)
Mathematical modeling of experimental conditions

Boundary and geometric conditions:

• the coordinates of the junctions of the three thermocouples are known;
• in the plane of contact of the chamber and the base there is an ideal thermal contact;
• the enclosure surfaces of the analyzed area lying in the X0Z and Y0Z planes are adiabatic;
• the lower surface of the base is also adiabatic;
• on enclosure surfaces there is a free-convective and radiation heat exchange;
• there are no internal sources of heat.
Mathematical modeling of experimental conditions

Initial conditions:

• the backfill in the chamber is isothermal and has the set temperature in the range of 450-600 °C;
• the fireproof base is isothermal and has an ambient temperature.

The simulated process is a three-dimensional unsteady-state thermal conduction without internal heat sources.
The software implementation

- the control volume approach;
- the method of alternating directions;
- Microsoft Visual C++.
The system «measuring chamber – base» (analyzed area)
Analytical-experimental determination of thermal conductivity

The mean-square deviation of the calculated temperatures from the experimental ones at the given point:

\[ \Delta = \sqrt{\frac{1}{N_{\text{exp}}} \sum_{i=1}^{N_{\text{exp}}} (t_{\text{exp}}(i) - t_{\text{calc}}(i))^2} \]

In the framework of this approach, the problem can be referred to the class of inverse problems of thermal conductivity.

The maximum value of the mean-square deviation was \( \Delta_{\text{max}} = 257 \, ^\circ\text{C} \).
Characteristic segments of the experimental curve

The function $\lambda(t)$ is continuous on the boundary of the ranges $t = t_{bound}$:

$$\lambda^f_0 + \lambda^f_1 t_{bound} = \lambda^s_0 + \lambda^s_1 t_{bound}$$
The research results

Implementation of the steepest descent method allows to achieve reduction of the response function to the level of $\Delta_{\text{min}} = 19.45$ °C, which is 7.6 % of the maximum $\Delta_{\text{max}}$.

The minimum value is reached when:

$$\lambda_0^f = 0.062 \text{ W/m}\degree\text{C}$$
$$\lambda_1^f = 1.683 \cdot 10^{-5} \text{ W/m}\degree\text{C}^2$$
$$\lambda_0^s = 0.065 \text{ W/m}\degree\text{C}.$$
Compare of temperature curves
Conclusion

1. The analytical-experimental method for determining the thermal conductivity of fine materials at high temperatures, based on physical and mathematical modeling and based on a variety of applications of IT, has been developed and tested.

2. As a result of the developed method implementation the temperature dependences of thermal conductivity of the coke residue (a solid product of waste automobile tires pyrolysis), have been established:
   \[
   \lambda = 0.065 + 0.572 \cdot 10^{-5} \cdot t \text{ W/m/°C in the interval of 60–270 °C;}
   \]
   \[
   \lambda = 0.062 + 1.683 \cdot 10^{-5} \cdot t \text{ W/m/°C in the interval of 270–480 °C.}
   \]

3. The developed method and its supporting software are used in scientific researches, as well as in the educational process of bachelors, masters and post-graduate students.
Thank you for attention!

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