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Information energy diagrams of thermodynamic interaction at drying of printed products

Abstract

The article analyses information energy diagrams of thermodynamic interaction at drying of printing products. It shows the models of thermodynamic interaction of thermal energy with drying objects. We have built the structure of the integrated system of thermal process control at drying of printing products. We have formulated the tasks of optimization of drying technological process.

Key words: *drying, energy flow, mathematic model, thermal field, optimal control, energy diagram*

Introduction

The problem of supplying the technological process of products drying with thermal energy has not been completely solved through a wide range of objects that have different physical, chemical, constructive structure and properties. Respectively the thermal energy sources are characterized by different principles of transformation of energy flows into thermal ones, which in interaction with the object of drying change its physical structure [1, 2, 12].

Analysis of the problem. In the technological cycle of printed products manufacturing thermal energy is used for structural changes (photopolymer matrix), acceleration of chemical reactions (films developing, thermal treatment of polymer matrix), drying of materials, semi-finished and finished products (bindings, book blocks) [1]. Accordingly, it requires choosing the efficient thermo--technical equipment for generating thermal flows at a certain spatial and thermodynamic structure and a high rate of energy transformation of active energy into thermal one (processes of burning, electrical heaters, ultra and infra-lamps, lasers) [3, 4].

The interaction of the thermal energy source with the object is characterized by different type of energy transfer process, which changes its thermodynamic parameters and structural properties interacting with it [1÷7].

Classes of processes of energy active interaction [1 ÷ 8]

– conduction (thermal conductivity) is due to the transfer of thermal flows in the direct contact

$$\Pi_{T_2}\left(T_2^0 C, S_{TK}^2\right) = A_{TD}\left(S, \vec{n}, K_T\right) \times \Pi_{DE}^K\left(T_d^0 C, S_B\right)$$

where $A_{TD}()$ – is the operator of thermodynamic transformation,

S – is the contact area,
$\vec{n}$ – is the normal vector,
K_T – is the coefficient of interaction,
$\Pi_{DE}()$ – is the flow of energy source with the temperature $T_d^0 C, S_B$,
S_B – is the area of radiation,
$\Pi_{T_2}()$ – is the flow of thermal energy which is transferred into the object due to the gradient of the thermal field

$$\text{grad}\, T\left(t, S, \vec{n}\right) = \lim_{\Delta l \to 0}\left(\frac{\Delta T(S, \vec{n}, t)}{\Delta l}\right) = \frac{dT(\vec{r}, t)}{d\vec{l}}$$

where $T(t, S, \vec{n})$ – is the thermal field with the front S,
$\vec{n}$ – is the normal,
$t \in \tau_m$ – is the terminal time,
dl – is the direction vector.

– the photonic thermal radiation (IF-radiation) takes the energy due to the quantum effects of the energy transfer as well as the excitation of molecular structures by the external energy (electric field, thermodynamic exchange), $E_D(t, \vec{r}) \to E_K(t, \vec{r}) \to \lambda_j h$ and then we have: $P(T^0 C, t, \vec{r}) \to \sum_{i=1}^{m} P_i\left(S_i, (\lambda_j h, t, r)\right)$ – the capacity of photonic energy transfer,
where $E_D()$ – is the energy of the external source,
E_K – is the energy of the photonic flow with the frequency λ_i,
$S_i(\lambda_i)$ – is the range of radiation,
$P(T^0 C)$ – is the thermal capacity of radiation,
$P_i\left(S_i, (\lambda_j)\right)$ – is the spectral capacity,
and the energy of the optical radiation flow

$$E_K\left(t, r\right) = \int_{\lambda}\int_{\Omega} P\left(S_i(\lambda_i), t\right) W\left(t, \Omega, \lambda\right) d\Omega\, d\lambda$$

has a complex diagram of the capacity distribution in the angular sector Ω.

– the convectional thermal transfer of the thermodynamic energy is due to the movement and interaction of hot and cold micro-masses according to

$$E_{TD} \to \sum_{K=1}^{N_1} E_K\left(m_i, T^0, t, \vec{v}\right) \xrightarrow{K_{TD}} \sum_{l=1}^{N_2} E_l\left(m_l\right);$$

$$E_K\left(m_i, T_1^0, t, \vec{v}_1\right) \xrightarrow{K_{TD}} E_l\left(m_l, T_2^0, t, \vec{v}_2\right);$$

$$m_i\left(T_1^0 C\right) \overset{A_{TD}}{\otimes} m_l\left(T_2^0 \to T_2^0\right);$$

where E_K, E_l – is the energy of micro-masses (m_i, m_l),
A_{TD} – is the operator of thermodynamic interaction.

Respectively the convectional thermodynamic flow

$$\Pi_{TD}^{K}\left(t, \vec{n}, S\right) = \int_{t_1}^{t_2}\int_{S}\left(\sum_{i=1}^{N_1} E_K\left(m_i, T_1^0, t, \vec{v}_1\right) W\left(T, t, S\right)\right)\frac{dt}{dS}$$

is characterized by the energy, the capacity, the function of distribution through the crosscut , the direction vector – of the energy flow.

Formation of energy flows [1÷6, 9]. For the synthesis of thermodynamic flows which ensure the drying process of printing products, it is necessary to form their direction diagrams so that you can receive the optimal total diagram of the flow that provides the drying process with high quality with appropriate integration of methods and means of forming the thermal flow (Fig. 1) and its interaction with the object of drying.

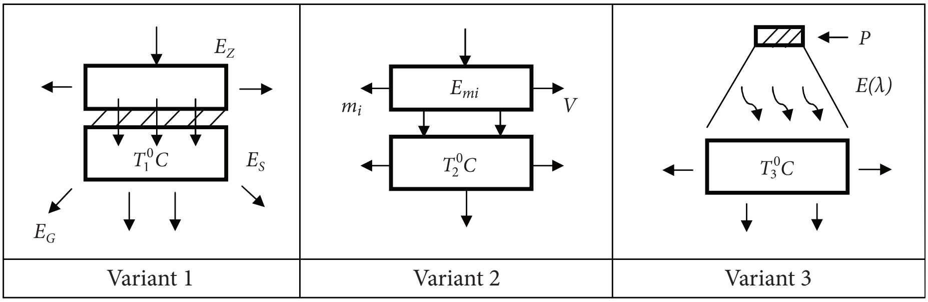

Fig. 1. Models of thermodynamic interaction

The change of the energy object $dQ(t,T) = pcdv\left(\frac{\partial T(t,z)}{\partial \tau}\right)dt$, $\frac{\partial T(t,z)}{\partial \tau} = A_T \nabla^2 T(t,z)$ and the thermal field of the object is formed due to the energy flows [12]

$$\Pi_{DE}\left(T,S\right)$$
$$\Pi_K^{\lambda}\left(S(\lambda),t,r\right)$$
$$\Pi_{TD}^{K}\left(t,\vec{n},S\right)$$

with the appropriate information energy diagram of its interaction with the object, where ρ – is the material density,

c – is the mass thermal capacity,

ρ_V – is the volumetric thermal capacity,

$T(t,z)$ – is the temperature,

$A_T = \frac{\lambda_T}{c\rho}$ – is the coefficient of thermal conductivity,

S_V^E – is the range of interaction of the energy flows,

$T_\Pi^0 C(t,x,y,z)$ – is the internal thermal field of the object.

According to the diagram we can form two tasks [2, 4÷7]:

1. The direct task: to determine the thermal field and the dynamics of the object drying at a given structure and capacity of sources of the thermodynamic flow;

2. The inverse task: to determine the structure of the complex source of the thermal energy in order to ensure the appropriate mode of the object drying process (printed products) with optimum energy effects.

So we should solve the problem of optimal control of drying the products, taking into account the characteristics of the energy spatial structure of the thermal energy sources (Fig. 2) [6÷12].

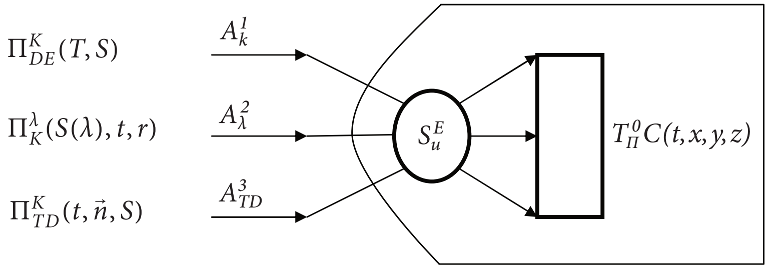

Fig. 2. Integrated control system of the thermal process of products drying

According to the problem we can form the structure of the integrated control system for the drying process of printed products (Fig. 2) [11, 12].

Symbols on the scheme:

Π^λ_K – is the flow of the optical energy;

Π^K_{DE} – is the flow of conductive energy;

Π^K_{TD} – is the flow of the convectional component of the energy;

DE_P – is the source of the primary energy.

Conclusion

We have shown on the basis of the conducted analysis that solving the problem of quality drying process of products must be based on the synthesis according to the object, the structures of the energy source with complex using of different types of transformers and systems of effective control of the drying process based on the method of structural integration.

To solve the problem of optimization of the technological process it is necessary to build a complex structure scheme of the drying object, to conduct the identification of parameters based on the thermodynamics equation of the exchange process for each type of the source, taking into account the structure and the construction of the object and the dryer. Limit modes of products drying are based on the complex experimental research and theoretical data, providing trouble-free process (burning, explosion). This provides the efficiency of the transformation process of active energy into thermal one with the given spatial-energy structure.

References

1. Shot R.I., *Thermal Processes in Printing: Textbook* / R.I. Shot, I.T. Strepko – Lviv: UAP; Phoenix, 1998. – 202 p.
2. Zarubin V.S., *Engineering Methods of Solutions of Thermal Conductivity Problems* / V.S. Zarubin – M.: Energoatomizdat, 1983. – 328 p.
3. Beliaev N.M., *Thermodynamics* / N.M. Beliaev – K.: Higher School, 1987. – 344 p.
4. Isachenko V.P., *Thermal Transfer* / V.P. Isachenko, V.A. Osipova, A.S. Sukomel – M.: Energy, 1975. – 488 p.

5. Blokh A.G., *Thermal Exchange of Radiation* / A.G. Blokh, Yu.A. Zhuravlev, L.M. Ryzhkov – M.: Energoatom, 1991. – 432 p.
6. Siegel R., *Thermal Exchange by Radiation* / R. Siegel, J. Howell – M.: World, 1975. – 934 p.
7. Grigoriants A.G., *Laser Processing of Non-Metal Materials* / A.G. Grigoriants, A.A. Sokolov, V 4 – M.: Higher School, 1988. – 191 p.
8. *Handbook on Laser Technology* – M.: Energoatomizdat. 1991 – 544 p.
9. Lykov A.V., *Theory of Drying* / A.V. Lykov. – M.: Energy, 1968. – 471 p.
10. Trembach V.V., *Light Devices* / V.V. Trembach M.: Higher School, 1990. – 463 p.
11. Sikora L.S., *Cognitive Models of Formation of Operational Management Strategies by Integrated Hierarchical Structures in Terms of Risks and Conflicts* / L.S. Sikora, B.V. Durnyak, M.S. Antonyk, R.L. Tkachuk – Lviv: UAP, 2013. – 449 p.
12. Sikora L.S., *Systematology of Decision-Making in the Management of Complex Technological Structures* / L.S. Sikora - Vol. 3 – Lviv: Kameniar, 1998. – 453 p.

Streszczenie

Informacyjno-energetyczne wykresy termodynamicznego współdziałania przy suszeniu produkcji poligraficznej

Podjęto problem zapewnienia prawidłowości technologicznego procesu suszenia produkcji poligraficznej, który dotychczas nie był w pełni rozwiązany, m.in. z powodu rozmaitości obiektów o różnej postaci fizycznej, chemicznej, strukturalnej oraz wielorakich właściwościach. Także w źródłach energii cieplnej stosowane są różne rozwiązania systemu działania. Autorzy proponują optymalizować proces technologiczny przez zbudowanie strukturalnego schematu obiektu suszenia oraz identyfikację parametrów na podstawie równania termodynamiki procesu wymiany dla źródeł danego typu i samej suszarki. Graniczne wymagania procesu suszenia oparto na kompleksowych badaniach eksperymentalnych i teoretycznych. W efekcie uzyskano bezawaryjność procesu oraz jego efektywność.