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Principles of Automation of Setting up Heat Carrier for Drying Installation of Concrete Mixing Plants

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ABSTRACT

The article reviews existing systems of automation for thermal processes of drying out some ingredients of road concrete mix. Automation of processes of thermal treatment comes down to multiple parameter, however one-level system, owing to which achieving of optimal result is almost impossible. Therefore, either analysis or the development of more advanced ways of automated control by thermal objects of coating plants that enable to reduce energy consumption, as well as refinement of mixture, have become very essential. It has been detected that a very important parameter of both technologies turns out keeping up permanency as to fraction composition and purity of inorganic materials at stock-piles of Coating Plants. It can be achieved by stock-pile of inorganic materials on an area covered with concrete or bitumen concrete, as well as by arranging of parting layers to bar from fraction mix between stock-piles. Dose accuracy for inorganic material, mineral fines and natural asphalt, therefore, deviations in nominal mix reflect the main causes of obtaining mix of inadequate quality; attaining of such parameters are to be achieved by batcher scale for inorganic materials, mineral fines, and natural asphalt on embedment gauge. It has been determined an accuracy of time for «dry» and «wet» admixing of bitumen concrete constituents of mixture in the blending tank; attaining of such parameter is to be achieved by inserting the admix signal generator into Automatic Process Control System. It has been discovered that cross-section dimensions of the storage bin in a plan, the extension of which leads to segregation of coarse grain gravel in mixture that bring down either soothness or quality of mixture; attaining of such parameter is to be achieved by applying of narrow storage bin or by extraction of mixture over the surface of broader storage bins excluding formation of broad cone mixture, triggering the main push to segregation. It has been evaluated the storage time for bitumen concrete mixture in the storage bins as due to long-time storage of mixture effects upon natural asphalt performance, whereas at a lowered temperature, it prevents from extraction; attaining of such parameter is to be achieved by bining only the required amount bitumen concrete mixture for the time of the work shift.

KEYWORDS
Concrete bitumen mixture; automation of Asphalt Concrete Mixing Plant (ACMP); thermal objects; production activity.

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Introduction

The survey of thermal process points out that elimination of loss of adequate quality factor, lowering of energy consumption while performance of technological processes gain specific meaning for decrease of working cost on released products, as well increase of production profitability (Thanaya, 2003; Thanaya et al., 2009; Brown & Needham, 2000; Garcia et al., 2013; Li et al., 1998). It is essential to introduce a new

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approach as to designing the automation systems of thermal objects of concrete mixing plants that maintain effect of stabilization of temperature in thermal generating units, including reduce of energy loss when controlling (Rutherford et al., 2014; Pouliot et al., 2003; Yao & Sun, 2012; Higuchi et al., 1978).

Drying units are intended for complete removal of surfaces, hygroscopic moisture from grit, gravel, as well as heating them up depending on type of prepared mixtures up to 180°C (Abdulkhanova et al., 2008).

Thermal conditions are commonly set up according to temperatures at the input and output of a drying drum. While maintaining it, a special care is to be given to firing, vacuum of which (10–20 pascal) should be adjustable by flue blower and smoke exhaust (Sarychev et al., 2010; 2012).

The required temperature condition at the input of a drying drum is to be achieved by thermal energy flux created as a consequence of blending exhaust gases at firing, that statute material flow having different heat content (Oruc et al., 2007; Schmidt et al., 1973; Bocci et al., 2011; Harada et al., 1983; Wang et al., 2008; Terrel & Wang, 1974). The outlet temperature regulation of mix of heat-carrying agent at drying process is primarily performed with the aid of one-loop closed automated control system wherein control action is gas flow.

Materials and Methods

Applying an automatic controller R with integral at law of control (Proportional Plus Integral – or PID control) in simple system, given at Figure 1, should ensure given value of temperature at a set mode in inlet of a dryer. However, qualitative characteristics of dynamic process within the system having slow response of control channel or essential disturbance amplitude is not satisfactory.

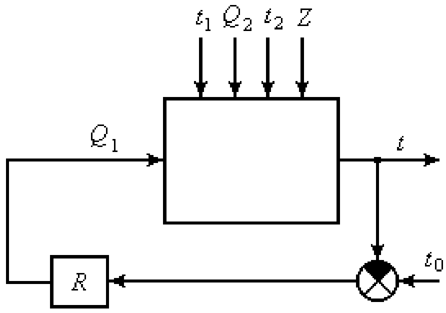

Figure 1. Closed one-loop ACS of temperature

It has been suggested to eliminate such a shortcoming in the system by means of signal generation as a proportion of gas flow and air consumption $Q_1/Q_2 = \alpha$ (Figure 2), that makes the temperature of the heat carrier t invariant to disturbance at air consumption Q_2.

However, upon the effects of other disturbance the temperature value t will not be equal to the specified value, in other words the system is marked by drawbacks of open-loop disturbance control system of any type.

The control system given at Figure 2 differs from that one at figure 1, with self-dependent temperature for a heat carrier t coming from both disturbance effects – flow Q_2 and air temperature t_2.

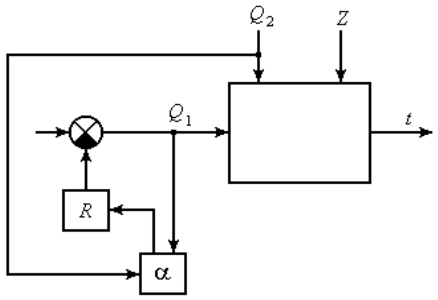

Figure 2. Open-loop ACS of temperature

At an upgraded version of control system for temperature (Figure 3) it has been applied the corrected value as flow rate ratio α depending on temperature t_2, with supply of air for blending it with heat carrier at the firing system. The corrector in this instance appears to be a compensator group of temperature t_2.

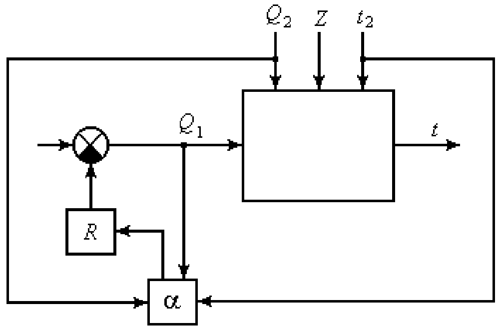

Figure 3. Open-loop ACS of temperature with disturbance-variable compensation.

The existing of two other disturbances, such as excursion in external heat loss would inevitably lead to temperature excursion.

It is possible to achieve upgrade to thermal object control by applying of integrated ACS in which basic disturbance-variable compensation is to be obtained by introducing of reversed feedback via controlled coordinate – temperature of a heat carrier. One of these possible options to an integrated ACS is given at Figure 4.

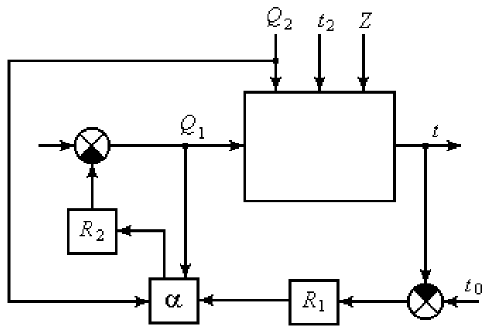

Figure 4. Cascade Control system for temperature.

Introduction of the flow rate correction of air-to-gas ratio α depending on temperature excursion in outlet of a blending chamber would turn the system into two-stage ACS that implies the major (external) controller to be a temperature regulator R_1, whereas an assisting (external) one – is the ratio control R_2 performing disturbance compensation as to air consumption Q_2.

The dynamic compensator R_K, adjust to the system consisting of computing unit that performs evaluation of correction to the regulator's target tasks R_1 as to temperature of the heat carrier considering flow rate and air temperature.

At the figure 5 there is a diagram of integrated ACS of temperature of the heat carrier that involves, as well as in system at the figure 3, correction of 2 disturbing effects.

The above said machinery of automated processes used at construction engineering sector are fairly typical. For the specified parameters of thermal process, the process variables would be temperature and moisture of the heat carrier, temperature differential and moisture gradient of the heat carrier, etc. (Mintsaev & Burdacheva, 2009; Murtazaev et al., 2015a; 2015b; Kuladzhi et al., 2015).

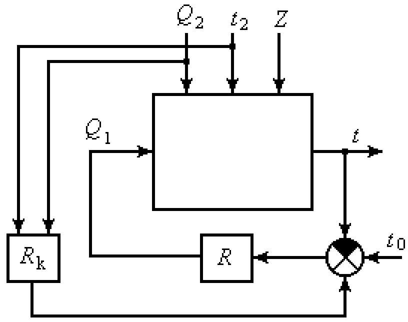

Figure 5. Integrated ACS for temperature

Results and Discussion

Within the analysis the examined above control systems of temperature reflect a tendency towards gradual complication as to automated control system due to extension of their structures and functional building with aiming to enable as many as possible variables. Correlation of variables together with intention to achieve better controlling efficiency caused initiation of range of control loop having own regulators. Thermal process automation leads to set up multi-parameter but one-level systems owing to which optimal results would hardly be achieved. There it is obvious limited viewing of approach to the principles of automation of objects with the essential response time. The criteria for controlling of such objects are primarily understood standard figures of merit by means of which type of transition process and dynamic parameters are to be evaluated. Quality performance of basic technological function of an object is to be evaluated implicitly, coming out of necessity to exact instantaneous value representation of desired process in outlet, including specification to required accurate and dynamic index. However, such approach towards thermal process objects would not often justify itself. The quality index of control process stated by theory cannot by default be applied to a process facility, since commonly the evaluation does not correspond to figures of merit.

It is necessary to develop methods of automated control of thermal objects that would efficiently provide with modes on temperature regulation, reduce energy cost and develop the quality of mix.

To produce a required temperature mode in a dryer drum of the blending bin the temperature of the heat carriage t_T – fuel combustion product (black oil fuel, gas), blended with air G_2^0 in a firing box is to be maintained according to process procedure. Atomizer efficiency increase, as well as contribution to required combustion efficiency, is gained by air amount control Q_2, temperature t_2 that flows to atomizer body or by fuel amount.

The main aim of control lies in maintaining of defined value of temperature t_T of the heat carrier in outlet of the firing box, namely in outlet to the drying drum. Static characteristic curve of firing box, namely temperature t_T air flow t_T = f(Q_2) relation should be determined by correlation and is distinguished by extreme value (Figure 6) (Khakimov, 2011; Mintsaiev et al., 2010; Suvorov & Khakimov, 2011).

$$\text{for } 0 \le Q_2 \le Q_2^{\text{н}}: \quad t_{\text{т}} = \frac{\left(1/G_2^0 + c_2 t_2\right) Q_2}{Qc};$$

$$\textit{for } Q_2 > Q_2^{\text{н}}: \quad t_{\text{т}} = \frac{Q_2^{\text{н}} + c_2 t_2 Q_2}{Q_2}.$$

Extreme characteristics would obviously vary according to either, quantity and quality fuel composition, or change in ambient temperature. The optimality for t_T would be finding the extreme value.

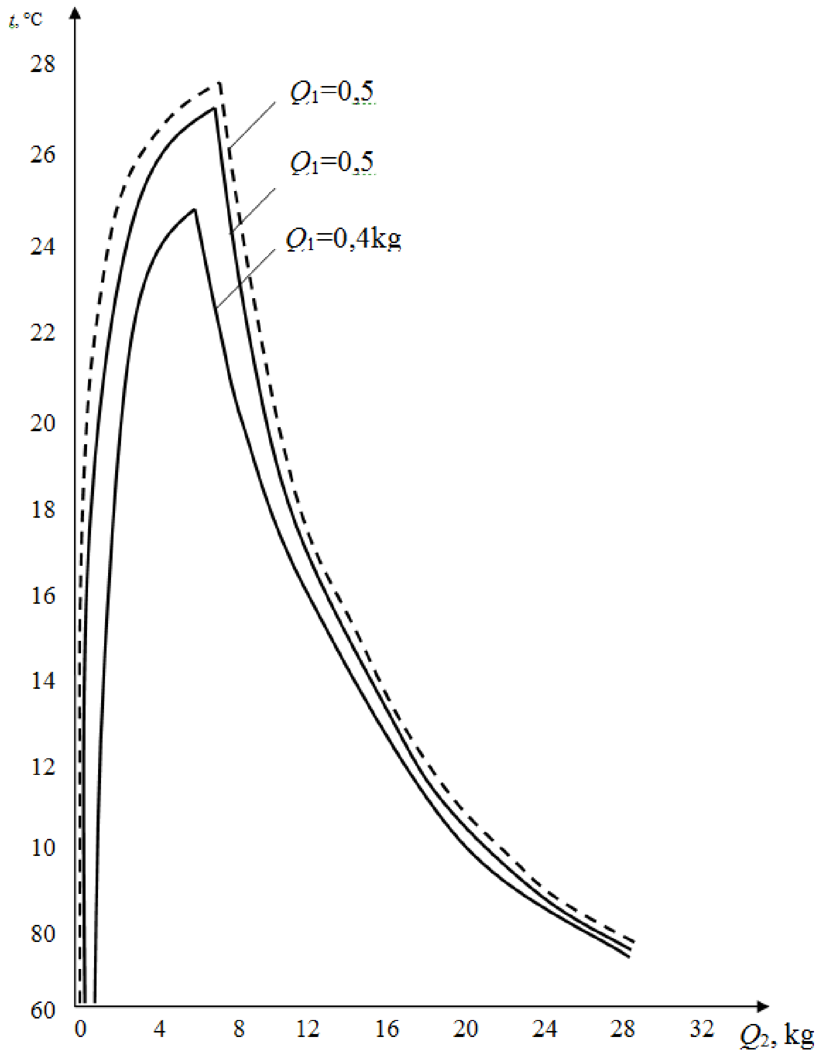

Figure 6. Static characteristics for combustion chamber

Conclusion

Consequently, there become necessary either the research or the development of more advanced methods for automated control of thermal objects of concrete mixing plants that would reduce energy cost and improve the quality of mix.

With the purpose to improve efficiency of systems controlling thermal processes at a concrete mixing plant it is necessary to deliver on target:

- Chose methods of automation and single out a criterion for optimal evaluation of quality of thermal processes based on energy consumption approach;
- Develop a design, methods of calculation and of systems of automation control;
- Determine the effects of change of tuning parameters of automated systems upon quality characteristics of thermal processes;
- Perform an experimental check on gained results.

Disclosure statement

No potential conflict of interest was reported by the authors.

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