Risk Control of Multilinked Melting Objects

M. B. Guzairov
Department of computer science and robotics
Ufa state aviation technical university
Ufa, Russia
e-mail:GuzairovMB@mail.ru

A. P. Kostyukova
Department of computer science and robotics
Ufa state aviation technical university
Ufa, Russia
e-mail: stasis_mail@mail.ru

Abstract[1]

The article deals with the way of multilinked melting objects risk control with the help of identification, monitoring and diagnostics of its condition.

1. Introduction

Russian melting industries prefer diagnostics of melting modular to automation of melting processes. Technical diagnostics is one of the major elements of industrial safety control system in Russia that is defined in safety rules for melting industry and exploitation rules for high-voltage equipment. Melting modular safety level depends on exploitation conditions and technical state. Such kind of data is collected and analyzed to be a base for decision making of industrial risk control system (fig.1).

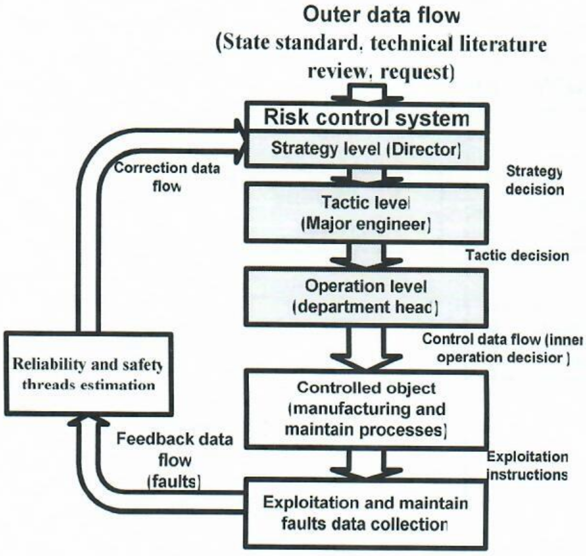


Fig. 1. Industrial risk control system

The main level of such system as represented in fig. 1 is operation level because it deals with the object itself and is responsible more than others for the safety of the industry in hole. This level is usually presented by automated on-line diagnostic system.

The main tasks that can be solved with the help of such system are but not limited to:

- the decrease of energy loss;
- the furnace period of life increase;
- the decrease of failure frequency and probability;
- the decrease of reclamation cost.

2. Melting modular on-line diagnostic system research

Melting processes time performance in induction crucible furnace is continuous and usage period of the furnace is regular [1,2]. Such object has to be diagnosed in work-mode and continuously. So the furnace is analyzed in process of time-dependent change of its condition with the help of statistic and probability estimation. This process model is described

$$Z = (T, S, F),$$

here S is a set of states, T is a time set and F is the process performance path.

As such the dynamic model of melting modular performance is presented in figure 2.

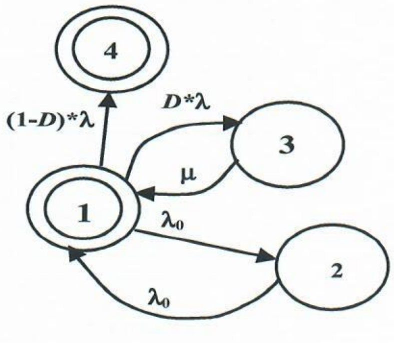


Fig. 2. Condition graph that represents the melting modular performance

---

[1] **Proceedings of the 12th international workshop on computer science and information technologies CSIT'2010, Moscow – Saint-Petersburg, Russia, 2010**

Four conditions are marked during melting modular functioning (fig. 2): 1 defines the first and posterior unfelt working conditions of melting modular, where the probability of unfelt working is $P(mT)$ (m – melt number, T – the duration of the melt); 2 defines idle time; 3 defines controlled fault, that was prognosticated by diagnostics system and prevented with D probability; 4 defines uncontrolled fault, that was not prevented with $1 - D$ probability. Melting modular work recurrence is shown with 1→2→1 cross.

This graph (fig. 2) suits to Markov's model, describing melting modular performance process [3] in terms of probability. So it is represented as the differential equations set:

$$\begin{cases} \dfrac{dP_4(t)}{dt} = (1-D)\cdot\lambda P_1(t), \\ \dfrac{dP_3(t)}{dt} = D\cdot\lambda P_1(t) - \mu P_3(t), \\ \dfrac{dP_2(t)}{dt} = \lambda_0 P_1(t) - \lambda_0 P_2(t). \end{cases} \quad (1).$$

Here (1) $P_i(t)$ is the probability of melting modular being in i-numbered (1, 2, 3, 4) state, λ is melting modular fault frequency and μ is the intensity of melting modular repair.

The normalizing condition is to be adding to this equation set:

$$\sum_{i=1}^{4} P_i(t) = 1,$$

as well as initial conditions $P_1(0)=1$ and $P_i(0)=0$, meaning that at the initial time state the system remains in unfelt working mode.

In order to compute the unknown parameters (λ – melting modular fault frequency, μ – intensity of melting modular repair, D – the probability of fault prevention and prognostication and λ_0 – the frequency of melting modular being on idle) the melting modular is represented as the multilinked system (fig. 3). It outlines the complexity of the furnace, consisting of multilinked and multidependent elements, that can't be considered without each other.

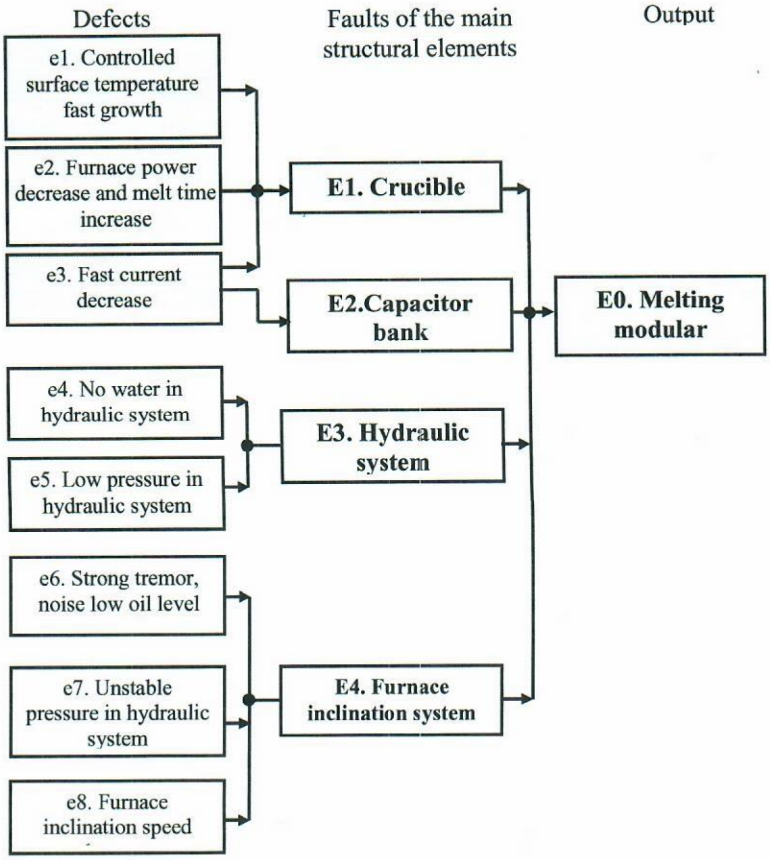


Fig 3. Faults of the main furnace structural elements

Never the less the most frequent reason of melting modular fault is lining wear because of high temperature and various physical and chemical processes acting inside of the melt. Further more lining life period is less then other's structural elements life period, so melting modular fault probability estimation is done concerning only lining fault frequency. Concerning lining life period that is about 80–100 melts and repair duration that is about 14 hours it can be estimated:

$$\lambda = \frac{1}{80} \div \frac{1}{100} = 0{,}0125 \div 0{,}01\,,$$

$$\mu = \frac{1}{14} = 0{,}0714\,.$$

At last the analysis of melting modular performance is made with the help automated facilities for control systems analysis. So the melting modular performance is presented as control system in fig. 4.

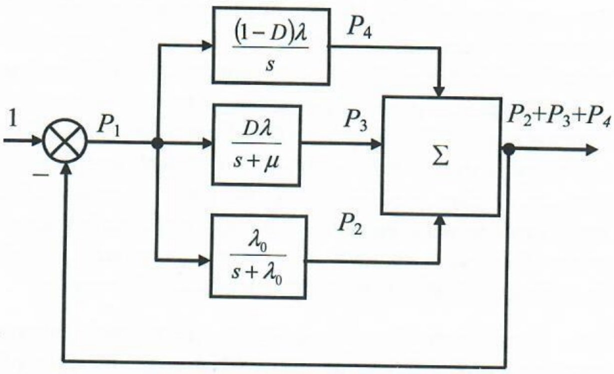
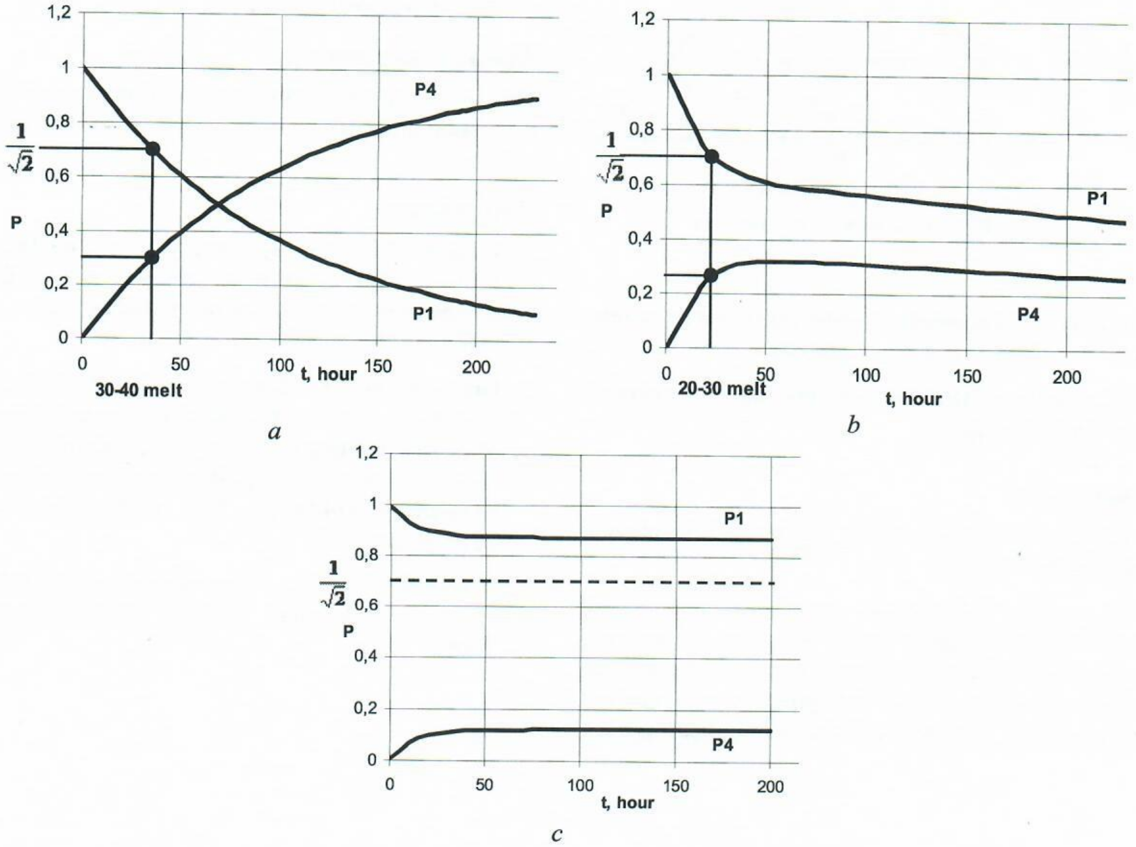


Fig 4. Equivalent structure scheme of melting modular performance

Three cases for D value were considered for this scheme (fig. 5): case a) when there is no diagnostic system ($D = 0$), case b) when there is a diagnostic system able to prevent 50% ($D = 0{,}5$) of faults and case c) when the diagnostic system is able to prevent 80% of faults ($D = 0{,}8$).



a

b

c

Fig. 5. The probabilities of unfelt work (P_1) and failure (P_4): case a) no diagnostic system ($D = 0$), case b) when diagnostic system able to prevent 50% ($D = 0{,}5$) of faults and case c) diagnostic system is able to prevent 80% of faults ($D = 0{,}8$)

As it is shown in fig. 5 the failure probability without diagnostics becomes critical during 20th or 30th melt, the probability of failure for such system doesn't stabilize but it continues to grow. The probability of failure for diagnostic system with only 50% of prevented failures is still very high and the need for modernization becomes obvious. Eighty percent diagnostic level is enough for good furnace working and as further investigation show the cost for such diagnostic system is not much higher then the cost of the system with 50% failure prevention.

The comparison between existing diagnostic systems costs and probable damage cost (that is the percent of sum of costs of furnace relining, inductor and hydraulic system change cost dependant on failure heaviness) shows that the optimal level of diagnostics is about 90% (fig. 6).

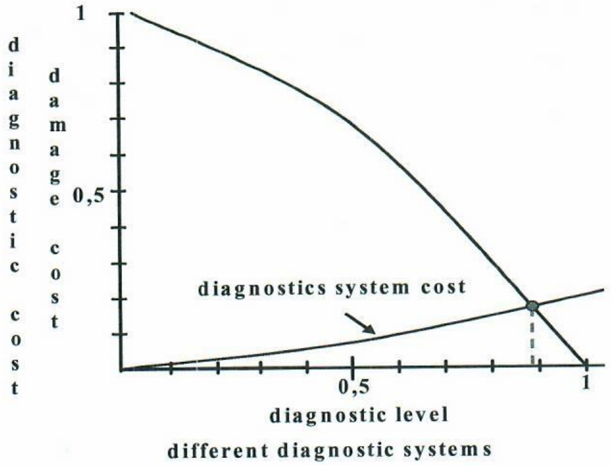


Fig. 6. Existing diagnostic systems costs and probable damage cost comparison

So the diagnostic system cost is acceptable in comparison with probable damage cost.

3. Conclusion

The main features of diagnostic system able to prevent 80–90% of failures are:

- The usage of optical way for temperature measurement because other ways of temperature measurement are based on average temperature measurement that can not provide the required measurement accuracy. The usage of optical way for temperature measurement also allows increasing system interference stability and making the monitoring device more compact.
- The measurement of absolute temperature forming the temperature portrait allows localizing risk zones.
- Sensors are placed on furnace surface that allows increasing of diagnostic system mobility so it can be placed on all furnaces during the standard repair time.
- Automated decision making about the repair necessity or failure probability.
- Prognostication of furnace structural elements condition.
- Statistical data processing.

The economical effect of such diagnostics system usage is based on:

- At least 10% energy saving.
- 10% furnace period of life prolonging.
- 40% failure probability decrease.
- 50% repair cost decrease.

Acknowledgements

This investigation is supported by President of Russian Federation grant НШ 65497.2010.9 for leading scientific schools.

References

1. Guzairov M. B., Kostyukova A. P. "Computer system for non-invasive control of complex-loaded units". In: *Information technologies of modelling and control* . 2009; 2(54):284–289.
2. Guzairov M. B., Kostyukova A. P. "Information models constructing for identification and diagnostics of electric melting elements". In: *Proc. of 4th Russian Workshop on Projecting of engineering and scientific software in MATLAB* , Vol. 1. Astrakhan, Russia, 2009, pp.589–590.
3. Phedorov Yu. N. "Costruction of ASCTP for explosive industries", Vol 2. SINTEG. Moskow, 2006.