Monitoring Thermal Conditions

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Cargo fires and explosions are often happening due to self-heating (Sanders, 2019). Self-heating occurs when an exothermic (heat-producing) chemical or biochemical reaction starts within a body of cargo. Monitoring thermal conditions in a container with cargo is important for detection of the source of overheating. It is a challenging problem due to the complexity of the three dimensional heat exchange models, which provide information about the behavior of the cargo (Raval, et al, 2011; Seitz, et al, 2016). Finding the source of overheating allows predicting dangerous thermal situations and events. This task is critical for multiple situations such as air cargo transport safety, protecting pharmaceutical product from spoiling, and preventing fire.

The list of overheating causes includes:

a. Calcium hypochlorite and other solids oxidation. The self-decomposition of such solids can evolve self-heating process This can lead to 'thermal runaway'
b. Biomass heating due to the rotting process in which produced methane concentration. 'Anaerobic' rotting can produce dangerous concentrations of methane and lead to explosion.
c. Fertilizers decomposition in the bulk with evolution of heat.
d. Lithium batteries heat release due to the natural discharge.
e. Liquid monomers polymerization that evolves heat.

Self-heating normally occurs in localized hot spots within a bulk cargo, and identifying events by temperature measurement is a challenging problem. The defined solution reveals to monitoring container temperatures at defined points and solving ill-posed problem of re-engineering temperature transfer in 3-d space with insulated boundaries conditions. The heat exchange in the package of the batteries could be approximated with composed heat rate coefficient.

The direct model of heat exchange with pointed heat source in semi-infinite body is developed in (Ramesh, 2006). The model can be extended for bounded three dimensional spaces. Such extension is given below. The location of the source can found by resolving ill-posted problem using the minimum least square criterion and finding solution of non-linear system of the equations with hypernumber method (Burgin and Dantsker, 1995, 2014, 2015).

In this work we are focused on detecting the pointed sources of overheating in homogeneous media or such that with some approximation can be assumed as homogeneous. Our model of the inverse engineering for locating the source of heating and predicting transient temperature distribution inside the container has several computational advantages:

- It is a simplified direct model for calculation of the heat propagation from a pointed source in a three dimensional space.

- The inverse model uses a hypernumber recursive analytical method, which is much faster in comparison with the utilized numerical methods.
- Thermodynamic parameters, which in most cases are not known, or the values, which cannot be estimated precisely, are calculated based on inverse re-engineering definitions.
- The hypernumber method guarantees the convergence of the process.
- Due to the relative simplicity of the algorithm the computation can be implemented using inexpensive controllers such as, for example, Atmega 2560.
- The time of calculation using embedded C would be in a range of tenth of milliseconds.
- The approach can be extended to the cases when the heat exchange is not the same in all directions.

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