FAZA O'ZGARUVCHAN MATERIALLARNING SOLISHTIRMA ISSIQLIK SIG'IMI, ISSIQLIK O'TKAZUVCHANLIGINI ANIQLASHNING ODDIY USULI, T-HISTORY USULI

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Abstract. A simple method of determining the melting point, heat of fusion, specific heat and thermal conductivity of phase-change materials (PCMs) is presented. Compared with other methods, such as conventional calorimetric methods, differential thermal analysis and differential scanning calorimetry methods, it has the following salient features: the experimental unit is simple, able to measure the heat of fusion, specific heat and thermal conductivity of several samples of PCMs simultaneously and allows one to observe the phase-change process of each PCM sample. Using the method, the thermophysical properties of various salt hydrates, paraffin and some PCMs developed by us were measured. For the PCMs whose thermophysical properties are available in the literature, our results gave fairly good agreement. The method is especially useful for the selection of lots of candidate PCMs used for the purpose of engineering and for preparing new PCMs.

Kalit so'zlar:faza o'zgaruvchan materiallar,erish issiqligi, solishtirma issiqlik sig'imi , issiqlik o'tkazuvchanligi koeffitsienti.

Kirish.

So'nggi yillarda issiqlik saqlash tizimlari ba'zi quyosh energiyasi tizimlarida, energiyani tejaydigan binolarda ko'plab energiya zichligi va izotermik xarakteristikasi tufayli muhim ahamiyat kasb etdi. Ma'lumki, issiqlik saqlash tizimi uchun mos fazani o'zgartirish materialini (FO'M) tanlash va tayyorlash eng qiyin muammo, ammo eng muhimi hisoblanadi.Chunki FO'M ning termal fizik xususiyatlarini o'lchash muhim ahamiyatga ega. Materiallarning termal tavsifi termal tahlil usullari yordamida amalga oshiriladi. Ushbu usullar ichida eng keng tarqalgan usul differensial skanerlash kalorimetriyasi (DSC) hisoblanadi. Bu FO'M ni termofizik jihatdan tahlil qilishning eng kuchli usullaridan biridir,chunki u erish/qotish entalpiyalari , erish /qotish harorati va o'rganilayotgan materiallarning o'ziga xos issiqligini ta'minlaydi. Ammo , u ba'zi cheklovlarni keltirib chiqaradi: namuna massasining termal ta'sirga ta'siri,javobning ishlatilgan isitish tezligiga bog'liqligi, takrorlash imkoniyati mavjud bo'lmasligi mumkin, geterogen namunalarni tahlil qilish va kompozit materialarda asosiy component FO'M DSC signaliga xalaqit berishi mumkin va hokazo. Shuning uchun issiqlikni aniqlash uchun FO'Mni tahlil qilish uchun boshqa usullar ishlab chiqilmoqda. FO'Mni tahlil qilishning afzal usullaridan yana biri T-history usulidir.

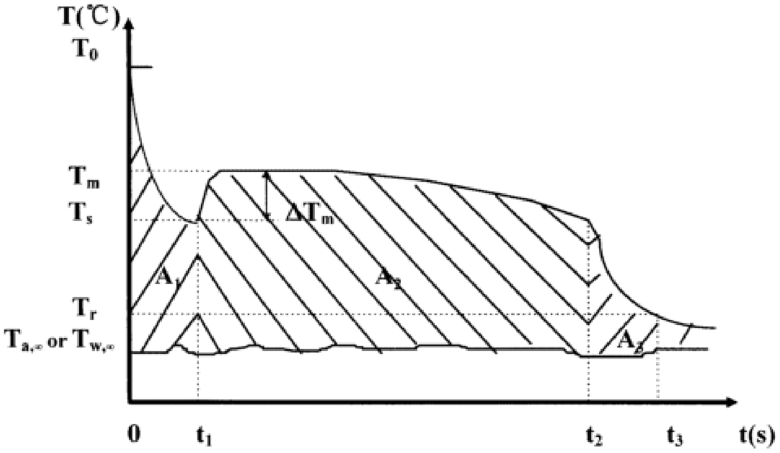
Bu usul FO'Mning haroratga nisbatan vaqt egri chizig'ini qayd etishga asoslanadi. Asosan , issiqlik sig'imi, erish va qotish entalpiyalari va fazalarning o'zgarish haroratlari T-history usulida aniqlanadi. Ushbu yangi usulning ixtirosi termal tahlil sohasida , ayniqsa FO'Mlar uchun qo'l kelmoqda.

2. O'lchov prinsiplari.

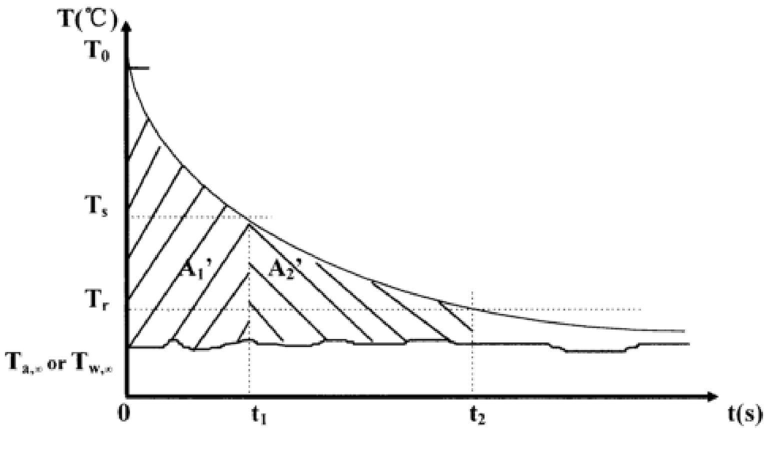
2.1 FO'Mlarning erish issiqligini, solishtirma issiqlikni va boshqalarni aniqlash.

Agar ikkita bir xil T_0 haroratdagi ($T_0<T_m$ T_m-erish va qotish harorati) faza ozgartiruvchi va solishtirma issiqlik sig'imi ma'lum bo'lgan moddalarning haroratini pasaytirib borish orqali FO'M (faza o'zgartiruvchi modda) ning suyuq va qattiq holatdagi solishtirma issiqlik sig'imini aniqlash mumkin. Bunday usullardan biri bu – T-history usuli hisoblanadi.

Erish haroratidan kichik $T_a<T_{m2}$ haroratdagi havoda yoki suyuqlik ichida joylashgan FO'M va suv haroratlari asta-sekin pasaytirib boriladi. FO'M to'la qotib bo'lgangacha haroratning vaqtga bog'liqligi 1 rasmda korsatilgan holda amalga oshiriladi.



(a)



(b)

1- rasm. Sovutish jarayonida moddalar haroratining vaqtga bog'liqligi.
(a)- FO'M, (b)-suv (juda tez sovutilganda).

FO'M uchun moddaning harorat taqsimoti 1 (a) rasmdagi kabi bo'ladi. Agar Bi<0.1 (Bi- biot soni, Bi=hR/(2k), R- quvur radiusi, h- konvektiv issiqlik berish koeffisiyenti, k- quvur materialining issiqlik uzatish koeffisiyenti) bo'lsa, quvurda harorat taqsimoti bir xil deb hisoblanadi. U holda, issiqlik balansini quyidagicha yozish mumkin:

$$(m_t c_{p,t} + m_p c_{p,l})(T_0 - T_s) = hA_c A_1 \qquad (1)$$

bu yerda, $m_t$va m_p- mos ravishda probirka va FO'M ning massalari, $c_{p,t}$va $c_{p,l}$- mos ravishda probirka va FO'M ning solishtirma issiqlik sig'imlari, T_0va T_s FO'M ning boshlang'ich va qotish haroratlari, h havoning konvektiv issiqlik berish koeffisiyenti, A_c- probirkaning issiqlik yo'qotadigan yuzasi, $A_1 = \int_{t_0}^{t_1}(T_0 - T_a)dt$

$$m_p H_m = hA_c A_2 \qquad (2)$$

bu yerda, H_m- FO'M ning sintez issiqligi, $A_2 = \int_{t_1}^{t_2}(T_m - T_a)dt$

$$(m_l c_{p,l} + m_p c_{p,s})(T_s - T_r) = hA_c A_3 \qquad (3)$$

bu yerda, $c_{p,s}$- FO'M ning qattiq holatdagi solishtirma issiqlik sig'imi, T_r- tajriba oxiridagi harorat, $A_3 = \int_{t_2}^{t_3}(T_m - T_a)dt$

Distirlangan suvda haroratning vaqtga bog'liqligi 1 (b) rasmdagi kabi bo'ladi. U holda issiqlik balansi,

$$(m_t c_{p,t} + m_w c_{p,w})(T_0 - T_s) = hA_c A_1' \qquad (4)$$

bu yerda, $m_w$va $c_{p,w}$ mos ravishda suvning massasi va solishtirma issiqlik sig'imi, $A_1' = \int_{t_0}^{t_1'}(T_0 - T_a)dt$

$$(m_t c_{p,t} + m_w c_{p,w})(T_s - T_r) = hA_c A_2' \qquad (5)$$

Haqiqattan ham tuz oksidlarining barchasida Bi<0.1 va k_s>0.2 W/(m^2K), demak (4) tenglama qanoatlantiradi.

(1) - (5) tenglamalardan quyidagilarni topish mukin,

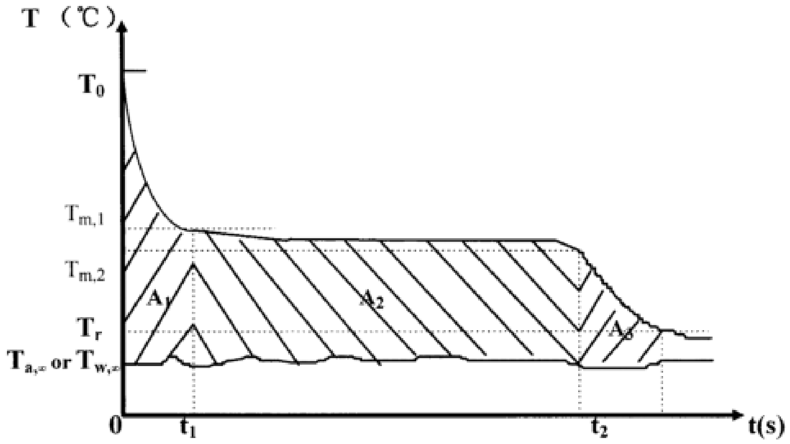
$$c_{p,s} = \frac{m_t c_{p,t} + m_w c_{p,w}}{m_p} \frac{A_3}{A_2'} - \frac{m_t}{m_p} c_{p,t} \qquad (6)$$

$$c_{p,l} = \frac{m_t c_{p,t} + m_w c_{p,w}}{m_p} \frac{A_1}{A_1'} - \frac{m_t}{m_p} c_{p,t} \qquad (7)$$

$$H_m = \frac{m_t c_{p,t} + m_w c_{p,w}}{m_p} \frac{A_2}{A_1'} (T_0 - T_s) \qquad (8)$$

Moddalar juda tez sovutimagan holatda, grafik 2-rasmdagi ko'rinishni beradi. U holda FO'M ning sintez issiqligi quyidagicha aniqlanadi.

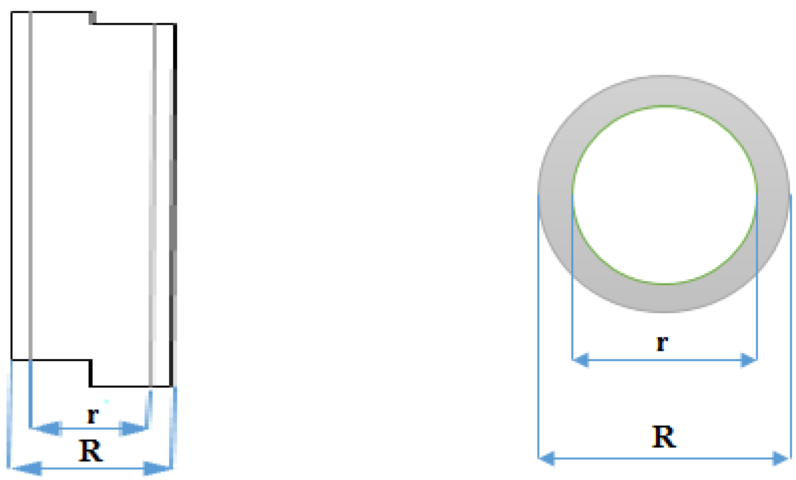
$$H_m = \frac{m_t c_{p,t} + m_w c_{p,w}}{m_p} \frac{A_2}{A_1'} (T_0 - T_s) - \frac{m_t c_{p,t}(T_{m1} - T_{m2})}{m_p} \qquad (9)$$



2-rasm.Sekin sovutilganda FO'M haroratining vaqtga bog'lanishi.

2.2FO'Mning suyuq va qattiq holatdagi issiqlik o'tkazuvchanlik koeffisiyentini aniqlash.

FO'M ning issiqlik o'tkazuvchanlik koeffisiyentinianiqlash uchun ikkita bir xil probirkaga bir xil hajmda suv va FO'M solinib, sovuq suvli vannaga solinadi. Har ikkala bir xil T_0 haroratdagi ($T_0<T_m$, FO'M ning T_m-erish va qotish harorati) faza ozgartiruvchi va solishtirma issiqlik sig'imi ma'lum bo'lgan moddalarning haroratini pasaytirib borish orqali FO'M ning issiqlik o'tkazuvchanlik koeffisiyentini aniqlanadi.



3-rasm. Probirkaning vertikal va ko'ndalang holatdagi ko'rinishi.

Agar probirka uzunligining diamaetriga nisbati 15 dan katta bo'lsa, 3-rasmdagi silindr uchun diffusion issiqlik tenglamasi

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T(r,t)}{\partial r}\right)=\frac{1}{\alpha_p}\frac{\partial T(r,t)}{\partial r} \quad (\xi<r<R,\ t>0) \qquad (10)$$

Chegaraviy shartlarni quyidagicha berilsin

$$k_s\frac{\partial T}{\partial r}=h_w(T_a-T) \quad r=R,\ t>0$$

va dastlabki holatda

$$T(\xi = R) \cong T_m \qquad t=0$$

bu yerda, T(r,t) – r radiusli va t fazadagi harorat, α_p- FO'M ning temperature tarqalishi, ξ - FO'M ning qattiq va suyuq fazalar orasidagi interfeys radiusi va h_w – sovuq suvning konvektiv issiqlik o'tkazuvchanligi.

FO'M ning ikki bosqich o'rtasidagi interfeys uchun

$$T(r=\xi)=T_m$$

$$k_s \frac{\partial T}{\partial r} = \rho_p H_m \frac{\partial \xi}{\partial t}$$

Yuqoridagi tenglamalarni yechimiga asosan quyidagicha k_s ni aniqlashimiz mumkin.

$$k_s = \frac{\left[1+\frac{c_{p,s}(T_m-T_a)}{H_m}\right]}{4\left(\frac{t_f(T_m-T_a)}{\rho_p R^2 H_m}-\frac{1}{h_m R}\right)} \qquad (11)$$

Bu yerda, k_s- qattiq holatdagi FO'M ning issiqlik o'tkazuvchanlik koeffisiyenti, ρ_p- FO'M ning zichligi, t_f- FO'M ningto'liq qotib qolish vaqti.

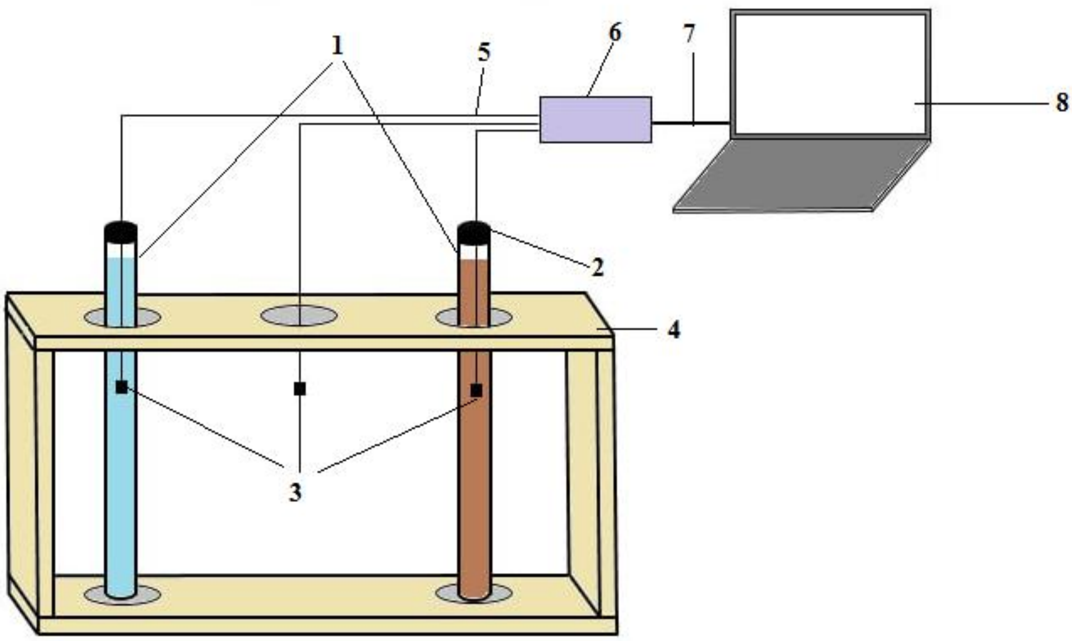
(11) ifodadagi $\frac{1}{h_m R}$ juda ham kichik bo'lganligi tufayli hisobga olmasa ham bo'ladi.

(11) ifodaga kengayishning ikkinchi tartibli hadini e'tiborga olmaslik natijasida hosil bo'ladigan xatolik Bi>0.1, 0<Ste<0.5 bo'lganda 5% dan oshmaydi (Ste-Stefan soni quyidagiga teng $Ste = \frac{c_{p,s}(T_m-T_a)}{H_m}$).

Xuddi shunday usul yordamida suyuq holatdagi issiqlik o'tkazuvchanligi k_l ni hisoblab topish mumkin.

Qurilmaning tasnifi.

Probirkalarni vertikal holatda ushlash maqsadida yog'ochdan taglik yasaladi. Qurilmaning prinsipial sxemasi 4-rasmda ko'rsatilgan. Qurilmada haroratlarni aniqlash maqsadida, ARDUINO UNO platasiga DS 18B20 harorat sensorlari ulanadi va har 0.5 minut davomada barcha nuqtalaridagi haroratlar o'lchanadi. Agar qotish vaqti juda kichik bo'lsa, bu vaqt intervallik yanada kamaytiriladi.

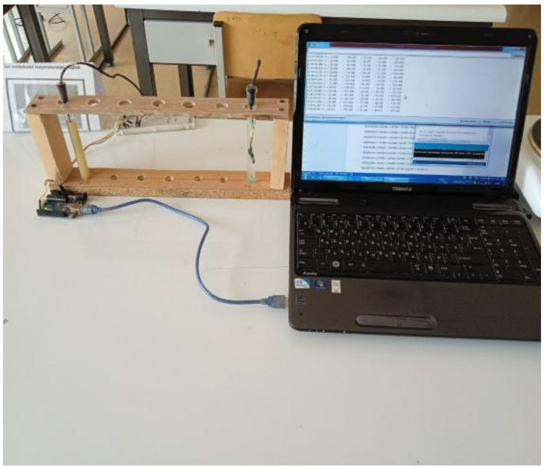


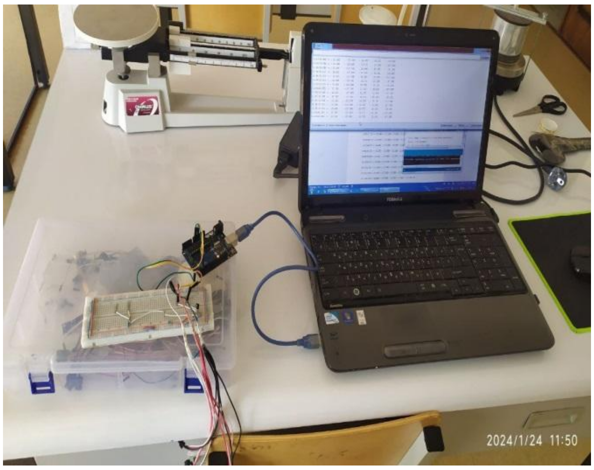
4-rasm. Qurilmaning printsipial sxemasi. 1) probirka, 2) probirka qopqog’i, 3) Ds 18B20 harorat sensori, 4) yog’och taglik, 5) sensor ulash simlari, 6) arduino platasi, 7) UZB kabel, 8) kompyuter.

3. Eksperimental tizim.

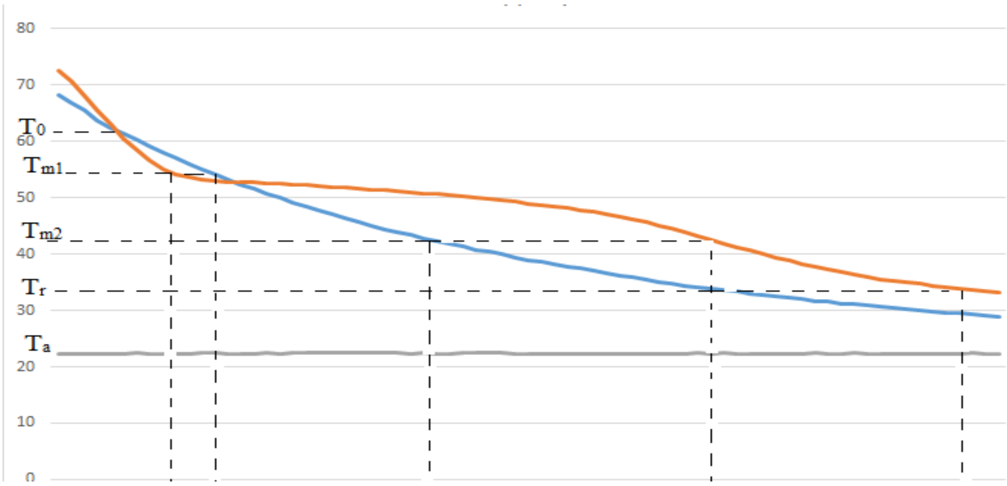
Prinsip asosida eksperimental qurilma qurilgan **(4-rasm).** Sinovda 5 ta namuna va suv olindi. Ma’lumotlarni aniqlash kopyuterga asoslangan ma’lumotlarni qayd qilish tizimi orqali amalga oshirildi. Bu turdagi eksperimental tizimning afzalligi har bir namunaning faza o'zgarishi jarayoni aniq bo'lishi hamda bir vaqtning o'zida bir nechta namunalarni o'lchash mumkin ekanligidir.

Namuna yog’och taglikka joylashtirilib xona haroratigacha sovutildi.





Haroratlarning vaqtga bog'liqlik grafigi olinib, egriliklardagi haroratlar aniqlab olindi.



Tajribadan olingan natijalar asosida parafinning suyuq $c_{p,l}$ va qattiq $c_{p,s}$ holatdagi solishtirma issiqlik sig'imi va issiqlik o'tkazuzchanlik koeffisiyenti k_s aniqlandi

$$c_{p.s} = 5288.005 \frac{J}{kg \cdot \quad C} \qquad H_m = 256.172 \frac{10^3 \cdot J}{kg} \qquad k_s = 0.168 \cdot \frac{watt}{m \cdot \quad C}$$

$$c_{p.l} = 3545.033 \frac{J}{kg \cdot \quad C}$$

Xulosa:

An'anaviy kalorimetriya usullari va DSC usullari kabi mavjud usullar bilan solishtirganda, ushbu maqolada keltirilgan usul quyidagi muhim xususiyatlarga ega: eksperimental tizim oddiy; u ko'plab namunalarni o'lchash va tajriba orqali har bir FO'M namunasining bir nechta termofizik xususiyatlarini olish imkoniyatiga ega; o'lchovning aniqligi; va har bir FO'M namunasining faza o'zgarishi jarayoni aniq kuzatilishi mumkin. Usul yordamida tuz gidratlari, parafin va ba'zi FO'Mlar (tuz gidratlari)ning termofizik xususiyatlari o'lchash mumkin. Natijalar adabiyotdagi natijalar bilan mos keladi.

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