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Performance Analysis on Inclined Solar Still with Different New Wick Materials and Wire Mesh

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ABSTRACT

Inthispapertheperformanceofaninclined typesolarstillwasexperimentally investigatedusing differentwickmaterialson differentabsorber plate configurations.Inthiswork,the newmaterials are characterised for absorption, capillary rise, porosity, waterrepellence andheat transferco-efficienttoselecta suitable materialfor the solar desalination application. Different wick materials are chosen for this analysis. Based onthisanalysis,
watercoralfleecematerial with porosity(69.67%), absorbency (2 s), capillary rise (10 mm/h) and heat transfercoefficient(34.21W/m2°C)isthemostsuitable
wicking materialforhigher productivesolarstill. Performancesofthestillwerecomparedwithdifferent
wick materials (wood pulp paper wick, wicking water coralfleecefabric andpolystyrenesponge)onthevarious absorberplateconfigurations(flat absorber,stepped absorber and stepped absorber with wire mesh).
Maximum distillate achievedinthestillwas 4.28l/dayby usingwatercoralfleecewithweirmesh–stepped absorber plate.

I. INTRODUCTION

Waterisessentialtosustainhumanlife andfor socio-economic development. Nevertheless, there is limitedaccess towater that meetsstandardlimitsof waterquality. Thequality ofwatercanbeimproved throughdesalination.Conventionaltechniques for desalination areavailable buttheyrequirealargeinput ofenergy,mostlyfromfossilfuelsthatcontribute to environmental degradation. Consequently, thereisa need to use sustainable energy sources, with solar energybeingoneofthemostpromising alternatives. Desalinationtechnology isgainingworldwide acceptanceasa proventechnologyforfresh
waterproduction.Thereviewofdesalinationhistory can be found in literature [1]. Desalination is the processof removinghigh salt content,mineralsand organisms fromawatersource.Desalination systems require energy for the separation of salt and water. Solardesalination systemsaresystemsthatutilizethe sunenergy(solarradiation) fortheseparationofwater andsalt.Classificationofsolardesalination varies depending ontechniquesandenergysupply.Themost commontypeofsolardesalination systemisthesolar still.Asolarstillisasimpledevicewhichcanbeused toconvertsaline,brackishwaterintodrinkingwater.

Solar still can be broadlydivided into passive and activetypes.Passivestillsarefurther dividedintobasin and inclined types. Extensiveresearch was made to improvetheproductivity ofthesestills.Inaninclined still,waterflowsfromthetoptothebottom ofthe absorbersurface.Tomaintain theuniformthickness of water,awick, which drawswaterthroughcapillary effect, isused.Stills withinclined absorber surfacesare reportedtohavesignificantly higherproductivitythan basintypestills[2].Thereareseveralworkspresented inliterature,toimprove theperformance ofaninclined wicktypesolarstill.Ho-MingYehetal.[3]studied the effectsofclimatic,design,andoperational parameters on the productivityof the wick-typesolar distillers. Minasianetal.[4]studiedtheperformance ofanew typeofstillformedbyconnecting asmallconventional basin-type (installedinshadowandhavinganopaque cover)withawick-type solarstill.Badranetal.[5] studiedtheperformanceofaninvertedtricklesolarstill. Radhwanetal.[6]studiedtheperformance ofstepped solarstillwithbuilt-inlatentheatthermal energy storage.Sadineni etal.[7]studiedthetheoreticaland experimental performance ofaweir-typeinclinedsolar still.Mahdietal.[8]studiedtheperformanceofawick typesolarstill,wherecharcoal clothisusedasan absorber/evaporator materialandforsalinewater transport.Sodhaetal.[9]studiedtheperformance of multiple wicksolarstill,whereblackened jutecloth formedtheliquidsurface. Janarthan etal. [10]studied theeffectoffloatingcumtiltedwicktypesolarstill withtheeffect ofwater flowing overglass cover. Anburaj et al. [11] studied the experimental performanceof a new type inclined solar still with rectangular grooves and ridges in absorber plate. Tanakaetal.[12]studiedtheimprovement ofthetilted wicksolarstillbyusingaflatplatereflector. Basedon theliteraturereviewthereisnoworkavailablerelated tothecharacters ofwickmaterials usedinaninclined solarstill.Inthiscontext, newtesting procedures are developedforanalysing theimportantwicking characters ofwickmaterials.Herefewimportant wickingcharacters suchasabsorption, capillaryrise, porosity,waterrepellence andheattransfercoefficient, aretakenintoaccounttoselectasuitablematerialfor the solardesalinationapplication[13–16].Basedonthis analysis,thebestwickmaterialischosen andusedwith wiremesh&steppedabsorberplateto enhancethe productivityoftheinclinedsolarstill.

II. CHARACTERIZATION OF WICKING MATERIALS

Efficient wickmaterial. Wickingproperties ofthe material maybedetermined bythefollowing procedures.

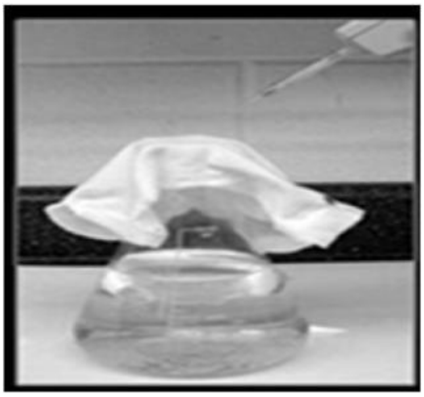

Fig.1. Testmethodforwaterabsorbency.

Fig.2. Waterrepellenttester.

2.1.Porosity

Porosityisameasure ofthevoid(i.e.,“empty”)spaces inamaterial, andisafractionofthevolume ofvoids overthetotalvolume,asapercentagebetween0and 100%.Theporosityfollowsstraightforwardlybyits properdefinition[17].

K¼Vp=Vbx 100

2.1.1.Bulkvolume(Vb)

Bulkvolumemaybedeterminedbylinearmeasurement value (dimensionofmaterials) Vb¼lxb x t

2.1.2.Porevolume(Vp)

Porevolumemaybedeterminedbythefluidsaturation method (materialimmersedinwater) Wwtr= Wsat–Wdry

Vp= Wwtr/ρwtr

2.2.Heattransferco-efficient

Theevaporationofwaterwithinthestillisdependent ontheevaporativeheattransfercoefficient,whichisa function ofheattransfercoefficient betweenthewet wickabsorber surface andtheglasscover.Theheat transfer coefficient depends upon the difference betweentheabsorbertemperature andglasscover temperature andthedifferenceinpartialpressureof water vapour between thewickabsorber andtheglass cover.Theheattransfer betweenthewetwick absorber andtheglasscovercanbegivenas,

h =q/ΔT(W/m2oC)

ΔT= Tg–Ta:

Table1

Wicking characteristicsofdifferentwickmaterials.

WickmaterialsWickingcharacters

Wickmaterials	Wickingcharacters				
	Porosity %	Absorbency (seconds)	Repellent	Capillary rise (mm/h)	Heat transfer coefficient (W/m2°C)
Cotton	28.5	1	0	120	36.0
Wool	27	150	0	110	45.8
Nylon	14.5	1	0	160	28.0
Wastecotton	28.23	10	0	90	41.04
Jutecloth	16.7	128	0	10	15.4
Coirmate	34.26	2	0	60	18.2
Charcoalcloth	16.2	2	0	180	58.4
Woodpulp paper	17	2	0	65	37.3
Polystyrene sponge	52.06	300	0	0	29.05
Waterwool fleece	69.67	2	0	10	34.21

2.3.Waterabsorbency

Waterabsorbency istherateatwhichwateristaken into,andmorphed intoanother object orphase.Water canbeabsorbedintotheatmosphere, andchangeinto anotherstate,suchasgas,oritcanbeabsorbedintoan object,likeasponge.2.3.1.Procedureforabsorbency

Measurethewaterabsorbency oftextiles bymeasuring thetimeittakesadropofwater placed onthefabric surfacetobecompletelyabsorbedintothefabric(Fig. 1).a.Sampleisplaced overthetopofabeakersothat thecentreisunsupported.b.Ameasureddropofwater is placedonthe fabric1cmfromthesurface.c.Timeis recordeduntilthewaterdropisabsorbedcompletely.

2.4.Waterrepellence Waterrepellence isthecharacter ofwick/fabricmaterialtoresisttheentirepenetrationor absorptionofwater.

2.4.1.Waterrepellenttester

Water repellenttestermeasurestheresistanceoffabrics towettingbywater. Itisusedtocheckthewater repellent ofthefabricbyspraytestintextiletesting laboratory. Itissuitable fortestingtablecloth,flooring material,fabricmanufacturerorprocessors.

Testprocedure

a.Firstofallfastenthetestspecimens securely onthe metal hoop of the water repellencetester so that it represents asmoothwrinkle freesurfaceandplaceit faceuponthetesterasshowninFig. 2.b.Adjust the metalhoopsothatthecentreofthespraycoincides withthecentre ofthemetal hoop. Laterpour 250mlof distilledwateratnormaltemperatureintothefunnel andspraythewhole quantity onthetestspecimen fora period of25–30s.c.Now detachthemetalhoop from thestand.Confirm whetherwaterhadpenetratedtothe backofthetestspecimen.With thefacesideofthetest specimen down,holdthemetalhoopbyoneedgeand taptheoppositeedgelightly onceagainstthetable.d. Thenrotateit180°Candsimilarlytaponceagainon thepoint previously heldtoremoveanyexcesswater drop.e.Thefinalstepistocomparethewetting ofthe testspecimenwithaphotographic ratingstandardand gradeitaccordingly.

2.5.Capillaryrise

Capillary riseistheriseinaliquidabovethelevelof zeropressuredue toa netupward forceproducedbythe attractionofthewatermolecules toasolidsurface,e.g. glass,fabric,andsoil.Thecapillarity ofwickmaterials maybedetermined bystandardverticalwickingtest method.Herecharcoal cloth(180mm/h)hashigh capillaryrisebutsponge haszerocapillarity.Table1 showsthewickingcharacteristics ofdifferentwick materials obtained fromtheanalysis.Among allwick materials,watercoralfleecematerial (69.67%)hashigh porosity.

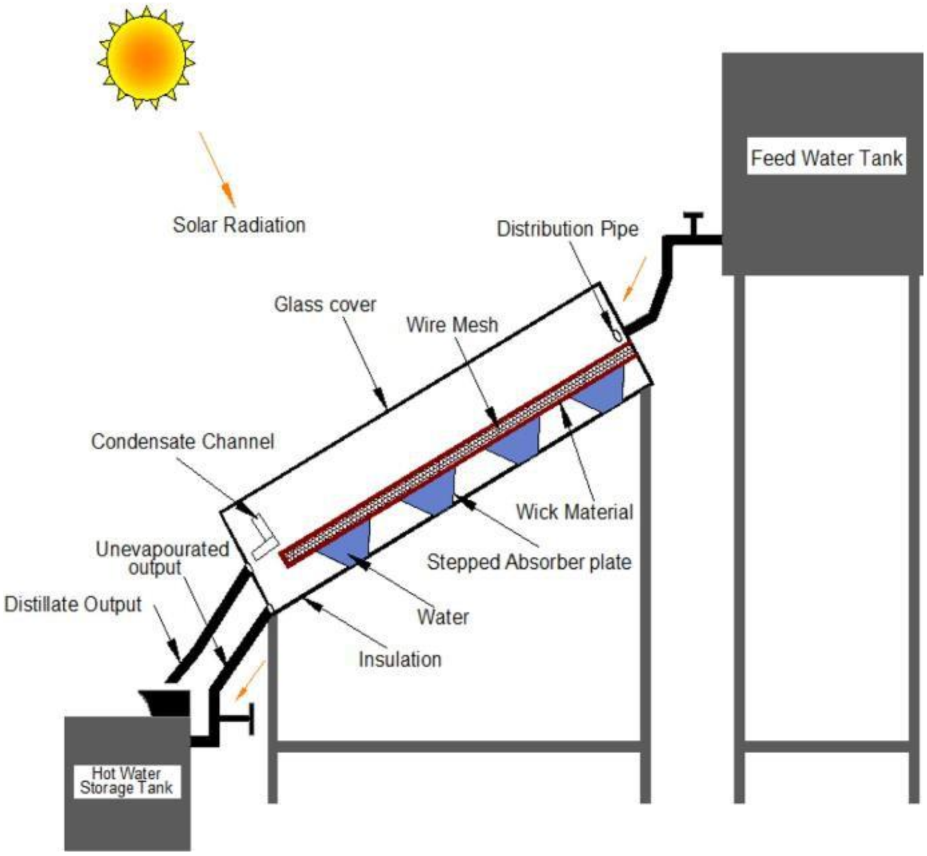

Fig.3. Schematicdrawingofinclinedtypesolarstill.

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