JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 6, ISSUE 06, 2019

Performance Analysis and Design Optimization of a Compact Plate Fin Heat Exchanger

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ABSTRACT

Thispapergivesan insight on the characteristicperformanceofa plate fined compactheatexchangers,includingall recognized types of heat exchangers and well-established cryogenic devices in industries. The structuresoftheHeat exchangersarewidelyoptimized, andtheirheattransferenhancementmechanismsare deliberately studied and comparativelydiscussed, alsotheiradvantagesandlimitationsare criticallysummarized. Afterthat, differentheattransferenhancement and optimizationtechnologiesareoptimized and comparedandtheirthermodynamicperformanceswereanalyzedon thebasis ofavailable variouscorrelationsfor heattransfer andfrictionfactordevelopedby various researchers drafted in theopenliterature.

KEYWORDS- Heat exchanger. Optimization

INTRODUCTION

Heatexchangers used incryogenicapplications needtohaverelatively veryhigh effectiveness and reliability to preservetherefrigeratingeffectproduced. And to preserve and maintain cryogenic temperatures in a large extent.Usuallytheheat exchangersusedincryogenicrefrigerators and other industrial equipment’s, liquefieshavethe effectivenessoftheorder of0.95orhigher.Iftheeffectivenessoftheheatexchangersfallsbelowthedesign value,theremaynotbeanyliquidyield and the heat exchanger will give sub-standard results(Helleret. al., 2006).Plate fin heat exchangers, based totheir compactness, lowweightandhigheffectiveness, availability,arewidelyusedinaerospaceand cryogenicapplications, they also find their uses in lots of industrial applications.Suchheatexchangers are designed so as to have closely spaced inwhichoffernarrow andleanpassagesforthefluidflowwhichleadstosignificant pressuredrop and temperature

difference there by giving the required results(Garciaet. al., 2008). Therequirement ofhighreliability, effectivenessincryogenicrefrigeratorsandindustrial liquefiers andhigh temperature andpressuredropoccurringinplate fin heat exchangers makeitnecessary totest theheatexchangerbeforeputtingintooperation inaliquefier so that the system will have reliability and long term of usage(Dostal et. al, 2006).

Plate fin heat exchanger,has fins which are corrugated in nature,bothbrazedtogetherto form aperforated block (Shah et. al.,1981). It generally exchanges heat byflowingalongthepassagesmade bythefinsbetween thepartingsheets. Where the pressure difference is created resulting in required heating and cooling effectSeparatingplatesact asthemainheat transfersurfacesandthepassages are termed asfins whichactasthesecondaryheattransfer surfacesattached withtheprimarysurface.In order to make the fins Aluminum is themostcommonlyused materialand available widely and in abundant alsostainlesssteelisemployed inhighpressureandhightemperature applications(Mehendaleet. al.,1999). Due to its durability and reliabilityVariousresearch hasbeendoneonplateandfinheatexchangersoverthe yearstounderstand theheattransferphenomenaoccurringon the systemandto determinethedimensionlessheattransfercoefficient, commonly known as correction factorandthefrictionfactor(Shah et. al., 2003).Though experimentalinvestigations predominateintheliterature,analyticalmodelingland numericalsolutionshavealsobeencarried out.Thetheoreticalsolutionsoftensuffer fromoversimplification offinchannelgeometry since the calculations for them are complicated and tiresome andsimplifyingassumptions are alsomade. Experiments onheattransferoverplatefinsurfacesarelot expensiveandare very difficult. Experimentalresultsgeneratedbyreputedinternationallaboratoriesarelimitedand haveremainedalmosttotallyproprietary. Withsuccessfulfabricationofm a n y plateandfin heatexchangers, itbecamenecessaryforustodevelopthemethodologyforthe optimumdesign; fabricationandtestingofplate fin heat exchangers.In this research thevalidityofthe existing correlations ischecked by conducting performance test on a counter flow heat exchanger.Which has a cross and counter flow arrangement?

TYPES OF COMPACTHEAT EXCHANGERS

Compact heat exchangersare classified byhavinga comparativelylargearea density. ThatArea density is theratioof heat transfersurfaceto heat exchangervolumetheoretically.Theirlargeareadensity,reflectingsmall hydraulicdiameterfor fluidflow,which resultsin ahigherefficiencyas compared to theconventionalshell and tubeheatexchangerwith respect to a significantly smallervolume. Compact heat exchangers as ithas beenarbitrarilydefined byShahashaveanarea density over700m^2/m^3orahydraulicdiameter. In the range of $D_h \leq$6mmandmaximum of400m^2/m^3. Whenoperatinginliquidor multi-phasestreams.Aconventionalshell and tubeheatexchangerspecifies as having anareadensityranging in100m^2/m^3 on onefluidsidewithplaintubes and for corrugated fins,and2–3 times greaterthan thatwithhigh fin densitylow finnedtubes. Humanlungs proves to beoneof themost efficient and reliablecompact heatexchangers, having anareadensityof about17,500m^2/m^3,which his equalto 0.19mm diametertube size.Variousmicro-scaleheatexchangers are alsounder research anddevelopment,bearingan areadensitygreaterthanabout15,000m^2/m^3 or1and implies asm$\leq D_h \leq$100m, whichareascompactasthehumanlungandsome proved to be evenmorecompact. Inspired by the lung design such designs will prove to be more efficient and reliable.

Aseasilyunderstandable,smallflowpassageshave mostlytwoeffects,a tendencytolaminarflowinthechannelsandahighsignificant pressuredrop range. Laminarflowis usuallyassociatedwithlow heattransfercoefficients and that is whytheefficiencyisimprovedby variousheat transferenhancementtechniques as mentioned,whichhavebroughtinvarietyofHeat exchangers.Some typesofHeat exchangershavebeenin working and isusedformanyyears while Othershaverecentlybeenintroducedintotheindustrial usage, and find their usage according to its suitability whilea numberoftypesare stillbeingoptimized.

Thenecessary improvementofenergyconsumption,initial capital investmentminimizationandimprovementofadaptabilityfor increasing reliability ofcomponentshas ledtorapiddevelopmentoftheHeat exchangersand its design and theirapplicationsinmanyareassuchas cryogenic industries,aerospace,automobile,gas turbinepowerplant,nuclearreaction, andsomeothers,especially inhightemperatureservices.

Since thereare manydifferenttypesofheat exchangers used worldwide fromvariousmanufactures, itis quitedifficulttosummarize and suggesttheoperating limits and efficiency.Thepurposeof the paper isto enlightenageneraloverview that isasummaryof typicaloperatingranges forPlate fin heat exchangers.In variouscases due to the different operating scenariothemaximumpressureand temperaturecannotbereachedsimultaneously.

Theareadensityofalmost all types of Plate fin heat exchangersrangesbetween120-660m^2/m^3.Hydraulicdiameterliesbetween2and10mm.for this arrangement ofthenumberofplatesis between10 and100, whichgives5–50channelsfor individualfluid flow.

One greatadvantageofthePlate fin heat exchangeristhegreatlyreducedspacerequirements and its compactness.The surface isarequiredfor a parallel flow heat exchangeris 30–50% incomparisonto ashell-and-tubeheatexchangerfor agiven amount ofheat. Thereforehelps inreducingtheoverall cost,forthesameeffectiveheattransferarea,the weightandvolumeofPlate fin heat exchangerare approximatelyonly 30%and20%, in comparisontoshell – and –tubeheatexchangers.Which have50%less volumethanafinedtubeheatexchanger,and60%less thanaindustrial liquefier forthesamethermalperformance.

Choiceofrubberizedgasketmaterialsiscriticalfortheirliableoperationof Plate fin heat exchanger. Rubber Gasketsare generallymadefromawide varietyofelasticand formablematerials already available,suchas rubberandits differentpolymerized formswhich is already available. The rubberized gasketmaterialsrestricttheuse ofPlate fin heat exchangerin highlycorrosiveindustrial applicationsandalsoIn order tominimizethemaximumoperatingtemperatureso as toavoidtheuse ofexpensive rubbergasketmaterials.

Thethermalconductivityk oftheplateplaysanimportantconsiderationfor thethermohydraulicdesignofaheat exchanger.Therefore,plate materialswithhigherthermalconductivityare generallypreferred.

Stainlesssteelis amostcommon and widely preferredmetalfor theplatesmanufacturingbecauseofits abilityto withstandhightemperature and prolonged life,itsstrength, andits corrosionresistance.

Plate Fin Heat Exchangers

Plate fin heat exchangershavebeenproducedand extensively used since1910intheautoindustry.

Plate fin heat exchangerisaformof compact heat exchanger which consistsofaperforated blockofalternatinglayersof corrugatedfinsseparatedbyparting alternatively arranged sheets enclosed attheedgesbysidebars tocreateaseriesofchambers finned and arranged respectively. Thenumberoftheplateandthe finlayer,thesize oftheplateandfin,theheightofthefinandthe typeoff inare designed and masteredforoptimumperformance.Theheatexchanger canbeconsisting of oneormorecores. Thefinandthepartingsheatsare assembledby brazingina vacuumfurnacetoformasingle rigidcore.

InaPlate Fin Heat Exchanger,thefins can be easily arranged according to design.Thisallows thePlate Fin Heat Exchanger tooperateincross-flow,counter-flow,and cross-counterflow concurrent flow pattern.Asimpelcross flowlayoutisusuallysuitable and is usedforlow ormoderateindustrial usages,which isespecially veryeffective and reliablewhenoneside contains a verylowpressuregas. For criticalindustrial usages,thecounter flowpatternarrangementoffersan veryefficient solution.Thehigherlevelsoefficiency achievedbycounter flowunits are vitaltomostlow temperatureapplications in major industries.

Heatisgenerally transferredfrom a hotfluid throughthefin interfaceto theseparatorplateandthroughthenextsetofavailable fins into theadjacentcold fluid. Heat exchangers handles both hot and cold fluids flow.

SelectionofCHEtechnologiesforsolarreceiver application

ConcentratedSolar Power mechanismwill transferheatto pressurizedairwhichwillgenerateelectricity.Thesolarreceiverwillgenerallyoperate at temperature rangingupto900°Candpressureranging upto10bar.Therearevariousdesign,materialsavailability,andfabricationissuesthatneedtobeunderstood with the concentrated solar power design.

Selectionofrelevanttechnologiesdependsontheoperatingconditionssuchas pressure, temperature of the working fluids.

Mentionedtechnologies likediffusedbondedheatexchangerswith micro-channelsas well asceramicheatexchanger,are to be considered asfutureoptionsfor ahigh-performancesolarreceiver.

CONCLUSION

Themajorimportance and broad area of considerationofthis paper istheintroduction ofthe structuresandheattransferenhancementmechanismsofvarious typesofheat exchangercommonlyusedinindustry.ThisbroadoverviewofdifferenttypesofHeat exchangerswillhelp the manufacturerstodesignand analyzefortheirspecificneeds.

Althoughaconsiderabledatabasealreadyexistsforsingle-phase heattransferinvarioustypesofHeat exchangers,Additionalexperimentalworkneeds to be carried outfor the visualizationandmeasurements oflarge pressuredrop and temperature difference,local velocityprofilesandheattransfer coefficientsto obtainmoredata,especiallyathightemperatures and pressureFor evaluating CFD results and for the determination o f thermohydrodynamicbehaviorofHeat exchangers are considered to play a vital role in this regards.

REFERENCES

1. Dostal, V., Hejzlar, P., & Driscoll, M. J. (2006). High-performance supercritical carbon dioxide cycle for next-generation nuclear reactors. *Nuclear Technology*, *154*(3), 265-282.
2. Garcia, P., Ferriere, A., Flamant, G., Costerg, P., Soler, R., &Gagnepain, B. (2008). Solar field efficiency and electricity generation estimations for a hybrid solar gas turbine project in France. *Journal of Solar Energy Engineering*, *130*(1).
3. Heller, P., Pfander, M., Denk, T., Tellez, F., Valverde, A., Fernandez, J., & Ring, A. (2006). Test and evaluation of a solar powered gas turbine system. *Solar energy*, *80*(10), 1225-1230.
4. Mehendale, S. S., Jacobi, A. M., & Shah, R. K. (2000). Fluid flow and heat transfer at micro-and meso-scales with application to heat exchanger design.175-193.
5. Shah, R. K. (1981). Thermal design theory for regenerators. *Heat exchangers: Thermal-hydraulic fundamentals and design*, 721-763.
6. Shah, R. K., &Sekulic, D. P. (2003). *Fundamentals of heat exchanger design*. John Wiley & Sons.