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Optimization in Green Sand Casting Process: A Review

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ABSTRACT

Among the industrial activities and casting process still remains as one of them ost complex and indefinite activities. Due to the complex relationship between casting defects and greens and properties, it is imperative to control many greens and characteristics that influence casting quality. Traditional method of trial-and-error based on know-how and experience has many disadvantages such as being nonsystematic, time consuming, error-prone and requirement for long durations of experimentation. There is a necessity to replace this traditional approach to produce higher quality casting products within reasonable periods of time making better use of statistics, artificial intelligence knowledge acquisition neural networks and data mining tools. This paper extensively reviews published research on greens and casting process. The effect so friser design, gating system, mouldings and, oxidation and distortion of casting all through heat treatment, machining all owance, etc., on the economical manufacture quality castings were reviewed. Determining the optimal process parameter setting will significantly improve them would yield, out put ratio of metal, shorten manufacturing period, save energy and resource, reduce pollution, and improve the competitiveness of enterprises.

KEYWORDS – Greens and casting; gating system; riser; mould yield; casting yield etc.

INTRODUCTION

The term "Greens and casting" refer stoan objects olidi fied in greens and mould. Greens and moulds are prepared with mixtures of

silicas and, bonding clay and water. Sand castings are formed in particularfactoriescalledfoundries.Over70%of all metal castings are shaped via a green sand casting process. Although there are many new advanced technologies for metal casting, green sand casting rests one of them ost widely used casting developments today due to the low cost of raw materials, a wide variety of castings with respect to size and conformation, and the possibility of recycling the molding sand.

With the fast growth of the machine building industry the casting intense are as called for steady higher productivity. The basic process stages of the mechanical molding and casting process are similar to them annuals and casting process. The technical development however was so hurried that the character of the sand casting process transformed radically. The first mechanized molding lines consisted of sand slingers and/ orjolt-squeeze devices that compact the sand intheflasks.Subsequent moldhandling was mechanicalusing cranes,hoistsandstraps.Aftercore settingthecopes anddragswerecoupled using guide pins and clampedfor closer accuracy. The moldsweremanually pushed off onarollerconveyor for castingandcooling.Themolding linescanachievea moldingrateof90to100sandmoldsperhour.In1962, Dansk IndustriSyndikatA/Sdesignedaflask-lessmoldingpracticebyusingverticallypartedandpouredmolds.

Today wecanachievea moldingrateof550sandmoldsperhour.Maximummismatch oftwomoldhalvesis0.1 mm.Coresneedtobeset withacoremaskasopposedtobyhandandmust hanginthemoldasopposed tobeingsetonparting surface.Castingsarehigh-tech productswhichareintegration ofmaterials,metallurgy, casting,heattreatment, welding,measurement,etc.,Although somenew castingtechnologies prosper,forexample,lostfoam castinganddiecasting,thegreen sandcasting technology isstillthemostimportantandpopularly usedmethodformassproduction ofsmalland medium weight casting. While foundry engineershaveaccesstoanoverwhelming amountof experimentalwork here in this paper we review different parameters effect casting process and technique suggested by various authors and concludes the best method to optimize casting process.

1. MEASURES FOR EFFICIENT ANDECONOMICAL MANUFACTURE OF QUALITY CASTINGS

Prof. John Campbell's 'Casting rules" weredevelopedoveralifetimeofworkinthefoundry and laterresearchat the UniversityofBirmingham.Much of the research work focused on the effect of melt handling at the various stages on the number of defects created and the effect on the reliability of casting subsequently made [4].

The quality of castings is affected by the technologies used in every production step such as pattern design, pattern plate utilization, feeding and gating system, sand technology, core design and its placement, melting and pouring, heat treatment, repair welding, etc.

Risers are used for prevention of shrinkage defects (Figure 2). However, they decrease the usage rate of metal and extend the cooling time of castings after solidification as well. Therefore, proper riser size needs to be designed to satisfy feeding with the smallest volume. Traditionally Caine's method, Modulus method and Naval research laboratory methods were used for riser design. In production, traditional methods and computer- aided design and computer aided engineering are combined for riser design recent

2.1. OPTIMAL RISER DESIGN

Lotsofresearchesontheoptimality ofriserdesign havebeencarriedout foritssignificance.Basedonthefiniteelementanalysisofsolidificationheattransfer,ashapeoptimization techniqueforriser designwascarriedoutbyZhangetal.[5]by using a globalconvergencemethod.

Shen etal.[6]accomplished anautomatic optimization systemforriserwithout interference of human.Thesystem could automaticallyfindoutthe defects ofcastingpart,establishriser'sminimumsize astheobjectfunction andtherequirementofprocess astheconstraintsituation through analysisofresults bycastingsimulation software,andusethenumerical optimizationalgorithmbasedontemperature gradient todetermineinitialriser parameters, andthenfurther optimizeit till the bestdesignofriserisobtained.

Lietal.[7]proposedaparticleswarmalgorithmto determineriserparameters, suchasriserdiameter, neckdiameterandheight,andtheresults showedthat theriservolumedecreasedby11.77%comparedto thatofmodulusalgorithms.Thesemethods aboveare of the optimization approaches through multi- revisionofthe risersofknownpositionand size. Shouzhuetal.[8]proposedanewfeedingdistance ruleusingcastingsimulationbaseonacorrelation between the Niyamacriterion and radiographic castingsoundness.Thepresentedrulesareshown to provide longerfeeding distances in most casting situations.

Tavakolielal.[9, 10]proposed anoptimization approach namedthefeedergrowthmethod. The methodiscomposed ofthreestages:determinationoftheriserneckconnection point,construction ofthe riserneckandtherisergrowth.Duringthegrowthstage,therisertopologyisimprovedgraduallyuntilsatisfyingsomepredefinedcriteria.Nowadays, its applicationisonlylimitedtothecaseswhereonly oneriserisrequired. Therefore,furtherextension to overcomethis limitationcanbe consideredas the outlookoffutureresearch.

Tavakolietal.[11,12] alsopresentamethodnamed evolutionarytopology optimizationwhichisinversed to the growthmethod.Mayursutariaetal.(13)presentedwork tocompute feed-paths andhotspotsbycombininglevelsetmethodbasedsharpinterfaceandfeedpathmodel.Themodelisbasedonthesolutionofenergyand levelsetequation insolidandliquidwithStefan conditiononthe interface. Inaddition,forimprovement oftheholding temperatureofriserbeforecompletesolidification, thesurfacecoatingmaterials on risers arealso significantforriserdesignthroughstrengthening the efficienciesofholding temperatureandahighly exothermicriserisalsoappliedin foundries.

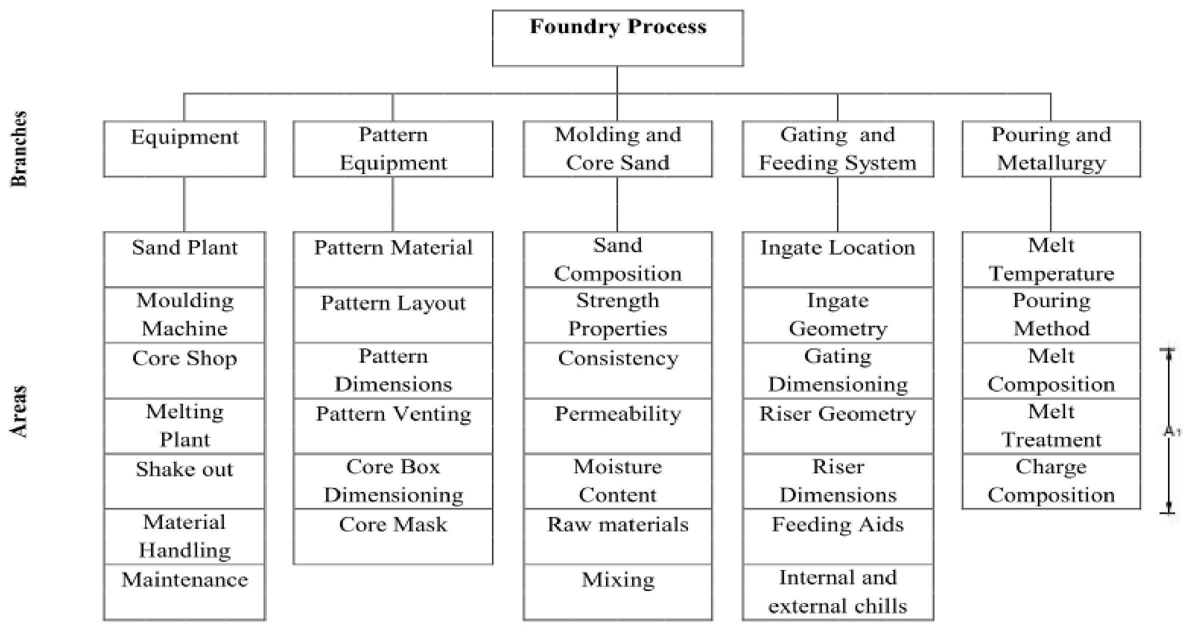

Figure 1:-shows the foundry process division into branches and areas of a modern foundry

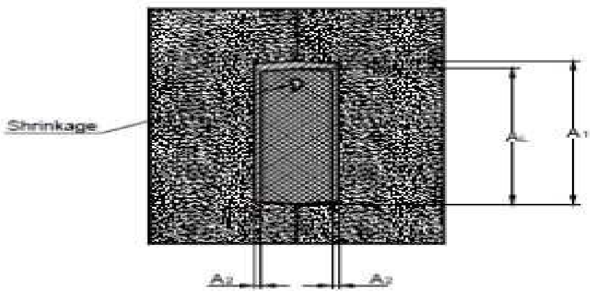

Figure2. Shrinkage defect

2.2OPTIMAL GATINGDESIGN

The gatingdesignandingateposition (Figure 3)plays an important role inthequality andcostof a metal casting. Due tothe lack of theoretical procedure tofollow,thedesign processisnormally carriedout on atrialanderrorbasis. In production, traditionalmethodsandcomputer-aideddesignandcomputeraidedengineeringareco mbinedforgating design recently. Butpotentialexistsforfurther optimizationofgatingsystem.

Mcdavidetal[14]presented,amethodology forthe optimal designof flowin foundrycastingrigging systems.Themethodology isbasedonanovel,fully analyticaldesignsensitivity formulation fortransient, turbulent, free-surface flows. Thefilling stageof the castingprocess ismodeledbysolving thetime-averagedformoftheNavier–Stokes equations viaa turbulentmixing-lengthmodel,inconjunctionwith thevolume-of-fluid (VOF)methodformodeling the free surface.

Fu-Yuan Hsuetal.[18]investigatedtheL-shaped junctionsinrunning andgatingsystemsusedin aluminumgravity casting.Usingcomputational modeling, a guideline for constructing two geometries ofL-junctionswasdeveloped. The sequentialfilling profileofliquidmetalalongL-junctionwasconfirmedbyreal-timeX-rayvideoof analuminumalloysandcasting.

Nesterova[15]presentedamathematicalmodel of kineticsoffillingthemodel during Castingby GasifiedModels basedonananalysisofthermal destructionofcellularpolystryne.

JeoanKor etal.[16] castingdesignisformulatedasa multi-objective optimizationproblemwith conflictingobjectivesandacomplexsearchspace. An optimizationmethodusingmulti-objective evolutionary algorithm(MOEA)isdevelopedto overcome such complexities.Aframeworkfor integrating theoptimizationprocedure drivenby data forthedesign evaluation isthenpresented.The proposedoptimizationframework isappliedtothe gatingsystemofasandcasting.Itisshown thatthe MOEA methods yield good results and providesmoreflexibilityindecisionmaking.

NielsSkatTiedjeand PerLarsen,[17]analyzedmelt flow infourdifferentgating systemsdesignedforthe production ofbrakedisksexperimentally andby numericalmodeling. Inthe experiments,moldswere fittedwithglassfrontsandmelt flow wasrecordedon video.Thevideorecordings werecomparedwiththe modelingofmeltflowinthe gatingsystems.

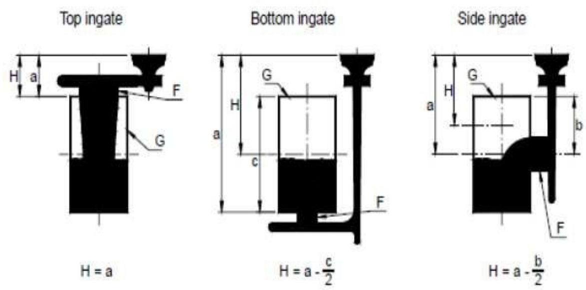

Figure3.Average Metaliostaticheight'H'inthreetypes of ingateposition

1.3.SIMULATIONOFMOULDFILLING ,SOLIDIFICATIONAND CASTINGDEFECTS

Thedefectssuchasshrinkage, crackanddeformation werethekeytopicsincastingsproduction.Oncethe shrinkage deformation andthecracksappearin castings, itwillcostmuch feesandtimeforrepair welding.Thecastingmightbediscarded ifthese problems aresevere. Thestressisoneofthemain factorsthatcausedeformationandcracksincasting sduring casting, heat treatment, machining,andservice.Deformation,tendencyto hottearing,and residual stress incasting couldbepredicted by numericalsimulationofthethermalandstressfield s incastingduring castingandheattreatment,which is helpful for optimizing the foundry technology,reducing thedefectscausedbystress-strain, ensuring theshapeandsizeofcasting,andimproving the servicelife ofcasting.Malcomblairet al [19] describes recent work to predictthe occurrence and nature of defects in castinganddeterminetheireffectonperformance. Vijayarametal.[20]presentedaworkonnumerical simulation of casting solidificationin permanent metallicmolds.

Sulaimanetal.[22,23],describesthesimulationan dexperimental results of thermal analysis insand casting process.Simulationmodelof 2-ingatemould and3-ingatemouldofsandcasting aredeveloped. They alsopresentedawork onsimulation ofmetal fillingprogressduringthe castingprocess.Karunakaretal.[24] presentedawork onprevention ofdefectsincastingusingbackpropagation neural networks.Griffithsetal. [25]proposed amethod fordetermininginclusionmovementinsteelcastin gsby positronemissionparticletracking(PEPT). Ogorodnikova[26]simulatedboththetechnology of lowpressurepermanentmoldcastingandthebendi ng test.Theshrinkagedefectsandresidualstresseswer e predictedbycomputermethods.An overview is presentedonmodeling ofalloy castingsolidificationandheattreatmentbyJianzhe ng et al. [27]Abdullin.[28]presentedawork onmodeling a complex problem on the stress-strain state of a casting in the software ProCAST. It describe themainsteps in thecalculations,theinitialdata,andthe resultsobtainedfrom calculationofthefillingofthe mold,thecrystallization ofthealloy,andthestresses inthe casting

CharlesMonroe [29] presentedawork on development on hottearindicatorbasedonthe physicsofsolidification anddeformation.This indicator isderivedusing availabledatafrom computersimulationofsolidification andsolid deformation. YingganTangetal.[30]proposedaneffective segmentation methodforthedetection oftypical internal defects incastingsderivedforanX-ray inspectionsystem.

1.4.OPTIMIZINGPROCESSPARAME TERSOF SANDMOLD

Sand mold is one ofthe key factorsthat directly affecttheproductionrateandproductquality.Meta l castingindustriesareactivelyinvolvedtoreduceth e scraprejectionandreworkduringthemanufacturin g process of the components. To achievethis, the productionconcernsmustfollowthequalitycontro l procedures correctly and perfectly without any negligence.Timelyimplementationofthemodifie d techniquesbasedonthequalitycontrolresearchisa mustto avoiddefectsinthe products.

Y.Chang et al [31] investigatedtheproperties ofgreenmoldingsandandanewmodelisdeveloped to evaluatetheflowabilityofmoldingsandcompactin thisstudy experimental resultsarepresentedtoshow howtheflowabilityof

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silicasandisaffectedbywater content,bentoniteand sea coalcontent.

CharnnarongSaikae and SermsakWiengwisetto[32]optimizetheproportion ofbentoniteandwater addedtoarecycledsandmoldforreducing iron casting wasteusingthefollowing analysis techniques: amixtureexperimental design, response surfacemethodology,andpropagationoferror.The effects of variation in bentonite and water added to a recycled sand mold on the properties of the molding sand were investigated.

Theironcastingswere measuredqualitatively usingastereomicroscopeand itssurfacehardnesswasalsomeasuredusing a Rockwellhardness testingmachine.Theresearch concluded thatthe optimalproportion was93.3 mass%ofone-timerecycledmolding sand,5mass% ofbentonite,and1.7mass%ofwaterhaving agreen compression strengthof53,090N/m2anda permeabilityof30A.F.S.

Parappagoudar etal.(33)utilizedback-propagation neuralnetwork (BP-NN)andgenetic-neuralnetwork (GA-NN) to model green sand mold system in forwardmapping (topredicttheresponsesfrom the known input parameters)aswell asreversemapping (topredictthesetof inputparameters forasetof desiredoutputs).

2.5. OPTIMIZATIONOF HEATTREATMENT

2.5.1. Reductionofburns-off

Themetalmaterialswillbeoxidized athigh temperature andoxidizingatmosphereduringheattreatment.Thematerialcorrosion willresultin addition ofde-scalingprocessanddeficiency in economicperformance. Theburninglossofmaterials duringheattreatmentisabout3%–4%oftotalcasting massat present. Decreasing theburninglossofmaterialsisanefficientmethodforimprovementof the outputratioofmetal. The oxidationofsteelduring heattreatment isclosely relatedtothefurnace temperature, timeinthefurnace, andfurnace atmosphere.[34]

2.5.2.Deformationcontrol

Thecastingvolumeandshapewillchange,andevendistort undertheactionofthermalstress andphase transformationduringheattreatment.Thefinalshape ofcastingisaffectedby thermalstrain,elasticstrain, traditional plasticstrain,phasestrain,andphase transformation-inducedplasticstrain.Itisnecessary tooptimizeheattreatmentforcontrolling the deformationofcasting,whichwillreduceoravoid the possible repairwelding and shape correction work,andalsodecreasethemachining layer thicknessandtimegreatlyaffectstheproduction cost and the casting quality in production. Large machiningallowancewillresultinextension of machiningperiodandcost[35].

2.6.Efficientcoolinginthecastingprocess

Theproductionrateinthecastingprocessisrelated tothesolidificationrate.Theproductionperiodforsandcastingislongenough,Therefore,itiscriticalto increasethecoolingrateaftersolidification and shorten the cooling period in mold To realize efficient cooling some kind of methods were proposed. Shietaldevelopedamethodbyusingafluidizationplateandforimprovement ofthecooling rateofriser aftersolidification, amethodmixedthemistcooling, andwindcooling wasdevelopedbyKanget al. [36]. Inaddition,themethodsforincreasingthecooling rateof castingstillneedtobedeveloped for improvementofproduction efficiency,forexample, rapping ofsandmold,localshakeout,andincreasing shakeouttemperature

CONCLUSIONS

Product andprocess designisthesoultorealize efficientandeconomicalmanufactureofqualitysan dcastings. Thereisgreatprogress ofgreensand castingsproduction, butitisstillfarawayfrom optimaldesign. Thereisstillhuge potentialforthe improvementofcasting design andprocess control technology.Computerscience,artificialintelligenc etechniques and statistical process control methodshavebeenutilizedforsolving various problemsin manufacturing. Similartoolscanbeusedtosolvethe problemsincastingindustry especially toreducethe defectpercentagesto reasonablelevels.

Themainareas for optimization in green sand casting process for efficient and economical quality casting are:

- Optimizingandreducingrisermass
- Optimizinggatingsystem
- Optimizingprocessparametersofsandmold
- Optimumuseofpadsandchills.
- Optimization ofmelt composition and temperature
- Efficientcoolingduringsolidification
- Reducing oxidation and controlling deformationofcastingin heattreatment
- Dimensional control and reducing machiningallowance
- Efficient sand reclamation and recycling
- Foundry mechanization
- Data acquisition system and automatic control
- Efficient Shake out.

The significance of optimization may be one or more of the followings

- Qualitycasting
- Improvingoutputratioofmetal
- Savingenergy
- Savingresources
- Increasingmanufacturerate
- Increasingenterprisebenefit
- On-timedeliveryschedule
- Reducingpollution

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