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EnergyMappingofMaterialChargingProcessforWaterBasePaintManufacturingIndustryinIndia

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Abstract: Forapaintmanufacturingplantwithvarietyofwaterbasepaintproductsitisdifficulttosetstandardsofspecificpowerconsumption(SPC)foreachprocess.InthispaperatechniquetoquantifytheSPCofmaterialchargingprocessforwaterbasepaintwiththehelpofsimpletoolsofMicrosoftExcelisdiscussed.

Keywords:-*paintmanufacturing,materialchargingprocess,specificpowerconsumption,MicrosoftExcel*

I. INTRODUCTION

Paint manufacturingisoneofthe chemicalprocessesthatinvolve extremeprecision ofmaterial composition (% w/w).Inordertopassthequalitycheckoffinishedpaintproducttheviscosityanddensityaresublimetestquantities;andthesequantities dependon3majorconstraints:Compositionmix,grindingtimeandmixingtime.Forenergymanagersinlargescale(Above250KL/day)paintmanufacturingplant(PMP)itisacumbersomejobtomanagecompositionprecisionofeachmaterialmixandoptimalpowerconsumptionformaterialtransferring.Formorethansinglecharginglineforrawmaterialswithdifferentphysicalstate,timemanagementin storage,conveyingandtransferringisnecessaryforstandardizingbatchproductiontime.Forthestudyofpaintmanufacturingsystem,anIndiabasedpaintmanufacturingfacilitywasappointed.Itistobenotedthatpaintindustryisoneofthechemicalindustries wheregeographicalandclimateconditionsaffectthequalityandconsumptionofpowersincephysicalpropertiesofmajoringredientsinvolvedinpaintcompositionaretemperatureandmoisturedependent.

II. WATERBASEPAINTPROCESS

Ageneralprocessflowalgorithmcommonlyobservedinwaterbased PMPsisshowninfigure1TwinShaftDisperser(TSD)is awell-knownelectro-mechanicalgrinderwhichisemployedinmostPMPs.GrindingtimeinTSDvariesaccordingtothedesiredviscositytobeachievedfortheemulsioninside.Thespeedofbotharmscanbecontrolledusingacdrivescoupled withPLCwhereinspecificdensity,relativegravityandgelviscosityaretakenasinputvariablesandspeedofdispenserarmsasoutput.AfterdesiredfinishinginTSDtheemulsionisdischargedintomixerwheretheanchorishauledinandoutfromvariouspredefineddepths.To ensureevengrindingateachlevelsofmixerthedepthofanchorformixingismaintained [1].

Itistobeseenthatfirst9out11processesincludechargingofmaterialatdifferenttimes.Thematerialadditiontimeofeachingredientisdependentonthebatchsizethatispredefinedbyproductionengineer.

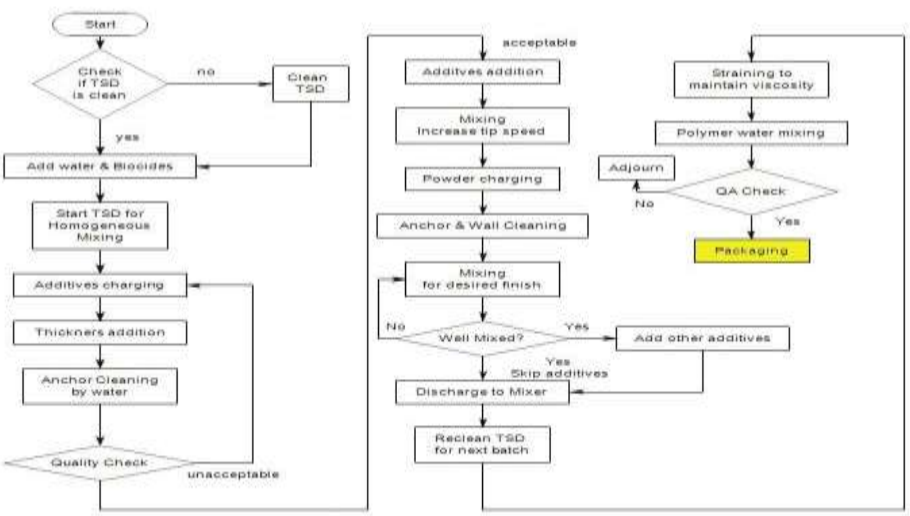

Fig.1:GeneralProcessFlowalgorithm

III. PROCESSANDPOWERMAPPING

Thereare4majorprocessgenerallyclassifiedforwaterbasepaintsareasfollows:

1) Premixingoperation
2) Rawmaterialcharging
3) Grindingoperation
4) Dischargingofbatch

Inthisarticlewerestricttoelaborateonlyrawmaterialcharging process. Raw material is often used layman termwhichotherwisecanbeclassifiedintofollowing:

- Polymorphic minerals
- Metamorphictalcs/powders
- Mineral/inorganic compounds
- Nonioniccelluloseadditives

Organic/inorganiccolourpigmentsandso on. The PMP under study hadthree stages for chargingmaterial:

1) Storagefrom Bulkcontainer toSilo
2) SilotoWeighhopperwheneverlineisavailableandbatchisplanned.
3) Weighhopper tochargehopperorminorchargehopperwheneverbatchistobecommencedafterpreconditioningofavailableTSD.

Thesestagesarevalidwhenthereisnoimmediateplanningofbatch,ifthereisanemergentneedtoproduceanybatchstage1iscarriedoutdirectlybyunloadingthematerialtruckusing requiredcapacityoftransferblowerandpneumaticconveyor.

A. BulkcontainertoSilo

Forformersituation,stage1isfollowedasshowninfigure 2.Theremaybegroupofdifferentcapacitiesofsiloaspertherequirementtostorethematerial.Generallysilodefinedforspecificmaterialisnotsharedwithotherinordertoavoidcontamination.Itisalsosafeoperationalpracticethatisfol-lowedforrutilematerial.MajorpowerconsumingelementsareAerationblower,transferblowerandscrewfeeder/pneumaticconveyor. Sincethereisnoprecisionoftargetmassrequired instoringthematerialinsilo,theseequipmentissettooperateatrateddischargeandaccordinglyratedpower.

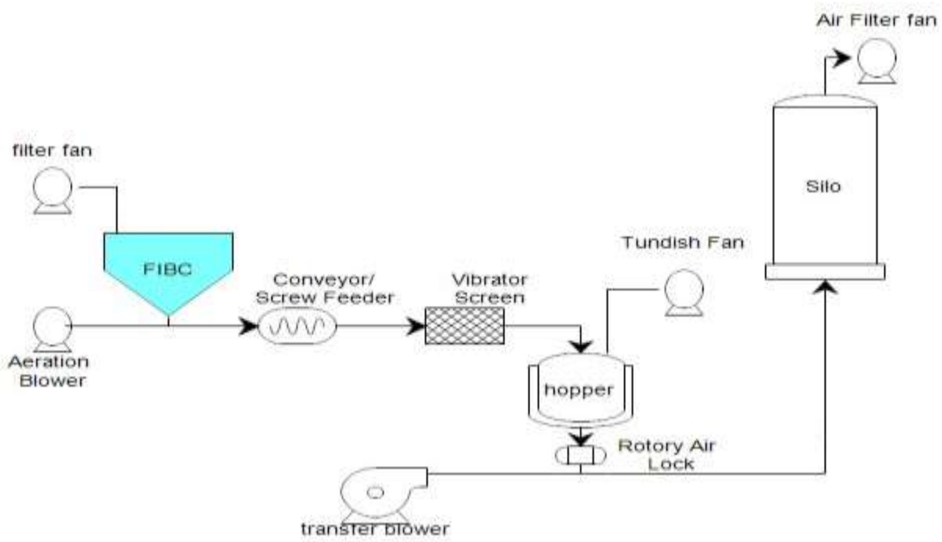

Fig.2:Storage:BulkContainertoSilo

B. SilotoWeighhopper

Forstage2 asshownin3thematerialswhichareingredientsinplannedpaintbatchareextractedinrequiredmasssoastokeepthe accurate composition (%w/w). These precisioninextractionandconveyingismaintainedbyZiegler-NocholsmethodofProportionalIntegralDerivative(PID)controlofRotofloandspeedofconveyor[2].Thistechniqueisdiscussedindetailinnextsection.AspertheavailabilityofcleanchargninglineandphysicalpositionofavailableWeighhoppertheselectionofscrewfeederanditsspeedisset.Majorpower consumingelementsareRotofloandpneumaticconveyor/screwfeederwhichareoperatedonVariableFrequencyDrive(VFD)tooptimizepower[3].

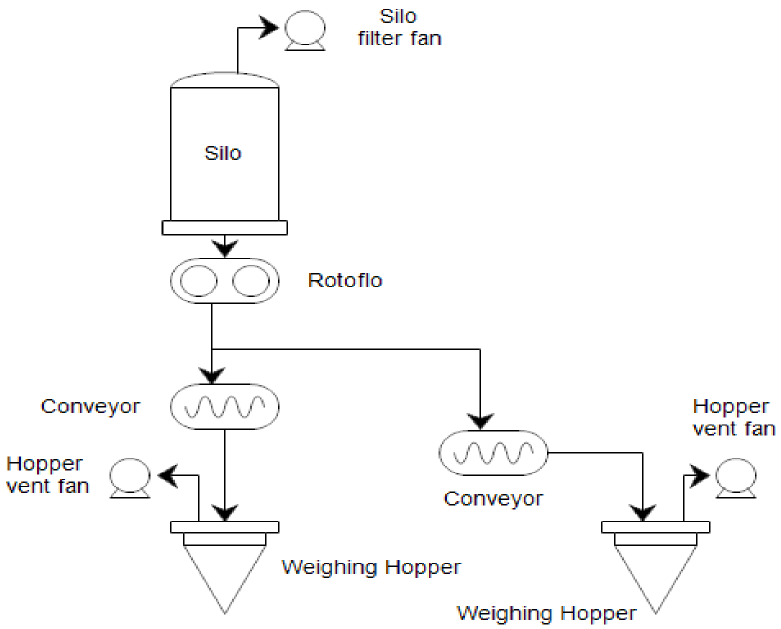

Fig.3:Stage:SilotoWeighHopper

C. *WeighhoppertoChargehopper*

Eachrecipeingredientispreweighedintheweighhopperbeneaththesilofromwhichitissuppliedpriortotransfer.Atcompletionoftransfereachingredientischeckweighed inthechargehopper.ChargingofbulkingredientstothechargehoppermaycommenceassoonasthetargetTSDisselected.BulkingredientsarethendischargedtotheTSDattheappropriatepointwithinthemixandatarateasdefinedwithintherecipeschedule.Themajorpowerconsumingelementsasshowninfigure4areaerationblowerandscrewconveyor.Atransferblowermayalsobeconnectedtoprovidenecessarymotiveforceifthearrangementisnon-gravimetric.

Theabovediscussedprocessstagesaremainlyforbulkhandlingofmaterial.Otherminor processesfor handlinglikepigmentchargingandminoringredientchargingarenotconsideredforthestudyasitspowercontributionisfoundlessthan 4%.ValvesotherthanRALusedatdifferentpositionsinthefiguresarenotdepictedforthesakeofreducingthecomplexityofdiagrams.

IV. CALCULATIONOFSPECIFICPOWERCONSUMPTION

Aswearedealingwithrawmaterialinpowderyformthecontroloftheirdischargeisdonebycontrollingthreemainpowerutilizingmachines,theyare:

1) Pneumaticconveyor
2) Rotoflo
3) RotaryAirLockvalve

Majorconstraintsthataffectthedischargeofmaterialareasfollows:

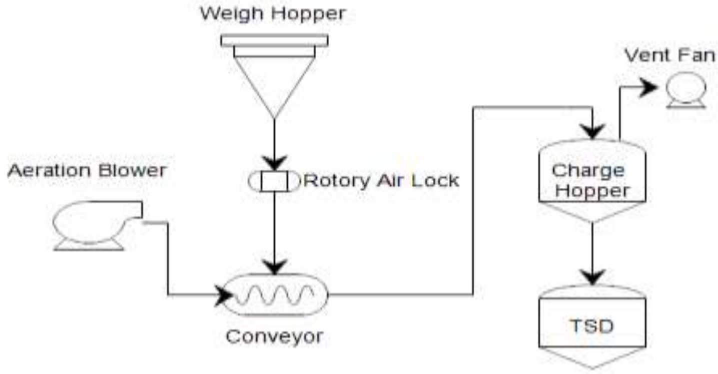

Fig.4:Stage:WeighHoppertoChargehopper

- DesignatedMaterial
- Conveyingpressureofsilo
- Rotoflofullspeedsetpoint
- Rotoflotricklespeedsetpoint
- Hopperdischargescrewfullspeedsetpoint
- Inflightallowance
- Conveyingpressureforchargehopperfilling
- Tricklefeedallowance

For process stage Silo to weigh hopper which is critical to bulk handling, the PID control to above list edmachinesisnecessary.Thecontrolmustestablishleanpneumaticconveyingwhichis considered to be high energy efficient[4].

Consider thebelowgivenexampleforcalculatingSPC of materialchargingprocess: 6rawmaterialsareingredientsinarecipeofpaintproductnamedABC[1.] Table Ibriefstheinformationofingredients Forchargingof materialX1in M1quantity, from FIBC tosilo, energycalculationisdoneasfollows:

TABLE I: Paint product material data sheet

Raw material	Density (kg/m3)	Ingredient weight (kg)	% w/w
X1	580	M1=1061	7.04
X2	290	M2= 566	3.76
X3	463	M3= 1415	9.38
X4	482	M4= 2830	18.78
X5	836	M5= 4670	30.99
X6	970	M6= 4529	30.05

Ifthesecalculationsareconsideredperhourpertonofmaterialthen,thespecificpowerconsumptionissaidtobekW/ton.Now,ifthe calculationsarerepeated foreachmaterial chargingthen,

$$P_{11} = \sum_{i=1}^{8} t_1 a_{1i} \text{kWh} \quad (1)$$

Where,a_{11}=measuredpowerofFIBCfilterfan,
a_{12}=measuredpowerofaerationblower,
a_{13}=measuredpowerofscrewfeeder,
a_{14}=measuredpowerofvibratorscreen,
a_{15}=measuredpowerofrotaryairlock,
a_{16}=measuredpoweroftundishfan,
a_{17}=measuredpoweroftransferblower,
a_{18}=measuredpowerofsiloairfilterfan

Andt1istimetakentoconveymaterialfromFIBCtosiloItistobeobservedthattimetakenbyeachmachinewillbesameaseachof itisoperatingsimultaneously.Similarly for process stageSilo to Weigh Hopper, energycalculationisdoneasfollows:

$$P_{12} = \sum_{i=1}^{8} t_2 a_{2i} \text{kWh} \quad (2)$$

where,a_{21}=measuredpowerofpneumaticconveyor,
a_{22}=measuredpowerofventfan,
a_{23}=measuredpowerofRotoflo,
t_2=Timetakenforconveyingandhopperfilling

And,forprocessstageWeighhoppertochargehopper,energycalculationisdoneasfollows:

$$P_{13} = \sum_{i=1}^{8} t_3 a_{3i} \text{kWh} \quad (3)$$

where, a_{31}=measuredpowerofrotaryairlock, a_{32}=measured powerofpneumaticconveyor, a_{33}=measuredpowerofaeration blower,
a_{34}=measuredpowerofsiloaerationblower, a_{35}=measuredpoweroftransferblower,
a_{36}=measuredpowerofventfan,
t_2=Timetakenforconveyingandhopperfilling Thusenergyconsumedincharging X1is,

$$P_1=P_{11}+P_{12}+P_{13} \quad \text{kWh} \quad (4)$$

Thus,thespecificenergyconsumptionofmaterialX1is,

$$E_1 = \frac{P_1}{M_1} \text{ kWh/kg} \quad (5)$$

Ifthesecalculationsareconsideredperhourpertonofmaterialthen,thespecificpowerconsumptionissaidtobekW/ton.Now,ifthe calculationsarerepeated foreachmaterial chargingthen,

$$S = \frac{\sum_{i=1}^{6} E_i}{\sum_{i=1}^{6} M_i} = \frac{E_{total}}{M_{total}} \text{kWh} \quad (6)$$

Hence, Sin kW/ton is the specific power consumption forABCpaintproduct.

V. BENCHMARKING

Duetoseveralpracticalissuestheenergyconsumedasperdesignedchargingsystemischallenging. Thusabenchmarkistobesetwhichisconsideredtobeatrade-offbetweendesignpowerconsumption and actualpower consumption. Inordertoestablishthebenchmark,anactivitytotestthesystematvarioussetofparametersforindividualprocessstagesandforeachrawmaterialwasconducted.Thefirstprocessstagei.e.fromFIBCtosilo,asthesystemisdesignedtooperateunderfullloadconditionstheoperationalsetbacksareminimalized.But,forsecondprocessstagei.e.fromSilotoWeighhopperwhereseveral quality constraints hamperthe production engineer to optimize energy efficiency, thebenchmarkingprocessplaysavitalrole.Calculationofstandardtransfertime t_2 and t_3 isdoneasfollows:

Let, $t_2=t_d$=Designtransfertime

Then,

$$t_d=t_b+t_t \quad \text{s} \quad (7)$$

Where, t_b=bulkchargingtime,

$$t_b = \frac{m_b}{\rho \times v_b} \text{s} \quad (8)$$

Where, m_b =Bulkmass.Thebulkmassshouldbewithin1%errorofcomparedtoingredientweight m_d.
v_b=Dischargerateofconveyor
ρ=Densityofmaterialtobecharged
And, t_t=Tricklecharging time

$$t_t = \frac{m_d - m_b}{\rho \times v_t} \quad \text{s} (9)$$

UsingaPIDcontrolthedifferencebetweeningredientbatchmassandbulkmassisfedasconstanterrorsignal,whichaccordinglysetsthespeedof conveyor andsubsequentlythedischargerateofRotoflovalve(m^3/hr).Theconveyorspeed control may be done using ac/dc drives having fastresponse.Theconveyorpressurerangemustbemaintainedinprescribedlimits.Higherconveyingpressuremayleadtopowderfluidizationwithairturbulencewhilelowerconveyingpressureleadstoslowercharging[5].Sincewithpneumaticconveying,theslipratioispracticallytakenas0.8,itshould bemultipliedwithdesigntransfertime.
Therefore,Standardtransfertime, t_{ds},

$$t_{ds}=0.8\cdot(t_b+t_t)=0.8\cdot t_{ds} \quad (10)$$

VI. ON FIELD TEST TRIALS

A sample of results of field test trials is shown in table II. The material with density 678 kg/m3 is transferred to weigh hopper from silo at different conveyor pressure and discharge rate of Rotoflo valve. The main aim is to optimize the bulk charging time so that % error between ingredient target mass and actual mass is as low as possible as a result of which there is a reduction in trickle time.

TABLE II: Test Trials for optimizing transfer time

Density kg/m^3	Target mass (kg)	Rotoflo discharge speed (rpm)	Conveyor upper set Pressure (mbar)	%Error	Design Time (sec)	Actual Time (sec)	% increase between t_d & t_a
	2765	950	353	0.7	350	1358	386
	2765	900	390	0.6	350	1305	373
678	2765	870	390	0	350	569	163
	5439	800	395	0.02	658	1621	246
	5439	820	395	-0.1	658	1033	157

Thedifferencebetweendesigntimeandactualtimeisbecauseofo ffsetinoperatingpointbetweenconveyorpressureandRotoflospeed. Formaterialwithdifferentdensitiestheoperatingpointsforoptimizingtimeispracticallycarried outbyfieldtesttrials.

VII. RESULTS

The most optimized transfer time obtained from test trails may be used as internal benchmarks for PMPs. These transfer time as further used in the calculation of benchmark SPC. The calculation is done using Microsoft Excel. Mathematical functions such as VLOOKUP and SUMIF are extensively used to filter individual material charging rate, its designated sourceand destination and the measured power associated with it. For the product X taken as example in the section IV the SPC results are shown in table III.

TABLE III: Stage wise SPC

Raw material	Stage 1 SPC (kW/ton)	Stage 2 SPC (kW/ton)	Stage 3 SPC (kW/ton)	Total SPC (kW/ton)
X1	0.47	2.34	0.97	3.78
X2	0.491	0.94	1.02	2.451
X3	0.57	1.62	1.52	3.71
X4	0.63	2.8	2.77	6.2
X5	0.624	3.81	2.65	7.08
X6	0.59	3.7	2.24	6.53

VIII. CONCLUSION

Anenergymappingtechniqueisdevelopedtocalculatethespecificpowerconsumptionofindividualmaterialthatischargedt oproduceapaintproduct.Fromthetesttrialsstudyitisconcludedthatoptimaloperatingpointofco nveyorpressureandRotoflodischarg eisnecessaryforoptimaltransfertime.Fromtheresultstableitcanbeconcludedthatmaterialwithhigherdensityandp hysicalpropertyt hepowerconsumptionduringmaterialchargingisaffected.Thistechniqueofenergymappingisaneffectivetoolforcontinuousmonitor ingofenergyconsumptionandalsoindicativeofoperationalissuesthatcauseincreaseinSPC.ThebenchmarkstandardsofSPCinthispa permaybecomparedwithinternationalstandardsforsameprocessi nvolvedandacorrectiveactiontocontinu-ouslyimprove benchmark and achieve energy efficient materialchargingsystem.

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