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The White Paper on the paint industry – engineering perspectives

The paints and allied chemical industry have core product issues of reproducibility in terms of compatibility of chemistry, the tonal consistency on a given product mix and finally the batch run times for achieving the desired productivity and economy of the product. These are generic problems in the industry world-wide and hence need to be addressed in the wake of an ever weakening macro-scenario where the fundamentals of purchasing power are skewed in nature; more than ever before across geographic domains and the uncertainty of times have caused a major slump in demand across sectors in a global perspective.

The product cost is significantly high in spite of the best efforts of the industry in modernizing and working on enhanced skill paradigms. This situation has a causal links of electrical and mechanical design of the equipment used in the paint industry as also on the quality of power and the inherent deficiency in the compressed air systems and the cooling mechanisms. These are purportedly ignored right across the industry causing serious issues in maintaining the issues highlighted at the outset.

The paper serves to attempt at studying these core issues of product and process engineering and work on arriving at proven solutions that can be implemented seamlessly to achieve the desired objectives of higher productivity at improved process yield and hence provide high end quality reproducibility at competitive costs.

A. Grinding process

1. Mechanical factors:

a) Element of vibration:

The frame vibration is a key determinant in the reciprocating motion of the grinder and needs to be dampened with rubber pads designed as shock absorbers. The granular collisions within the vessel need to be stabilized through a compressing mechanism; with the introduction of primarily an additive that releases free radicals of ionic nature to accommodate a drift in the direction countering the primary impact. The grinding process produces an electrolytic field and hence a fundamental drift that needs to be countered through additives and help establish the equilibrium within the vessel. This would help change the domain of collisions into one of micro level and cause ripples within smaller radii thereby eventually producing a colloidal of smaller particle sizes.

b) Colloidal properties: Surface tension of the solvent and the colloidal suspended particles are relative to each other and are the key determinants for quality. The properties of surface tension are influenced by the fluid pressure gradient, the temperature built-up in the system and more importantly but often ignored concentration of static charges following the release of free radicals in the fluid system during the grinding process.

b.1) FLUID PRESSURE GRADIENT: The drift mapping is vital for an understanding of the collision characteristics of the colloidal suspension since these collisions are defined by both the intensity of the impact and the frequency; the resolution is essentially into one of high impact and low frequency or into high frequency and low impact collisions. Each characteristic has a fundamentally different impact on the grinding process and on the particle dimensions; consequently the coordinates of the colloidal suspension play a critical role in defining the consistency in particle size. The major influencing factors in determining the domain boundaries of the fluid pressure gradient are the span area of the stirring process and the distributed point pressure in the fluid. Narrowing down the domain limits as explained above shall require a higher surface area and volume defined by the stirring shaft and the power generated in the stirring process. All of these are fundamental design flaws in the machinery and require corrections at the engineering level through a basic retrofit process.

b.2) SYSTEMIC ENTHALPY AND SENSIBLE HEAT IN THE FLUIDS – SOLVENT AND COLLOIDS: The electromotive power is the lead determinant in generating the systemic enthalpy and is a function of the PF of the motor as also the traction in the solvent-colloidal particles composite state. The quantum of work done in stirring and the changing dynamics of the fluid resistance with time create a system wherein the coordinates clustered around the nucleus of the impacting stirrer are influenced differently from those at the periphery and the arcs in between causing a fundamentally skewed particle dimensional inconsistency. The implications of varying temperatures in the system are in the states of the colloids with respect to attrition forces and magnitude of static charge generation.

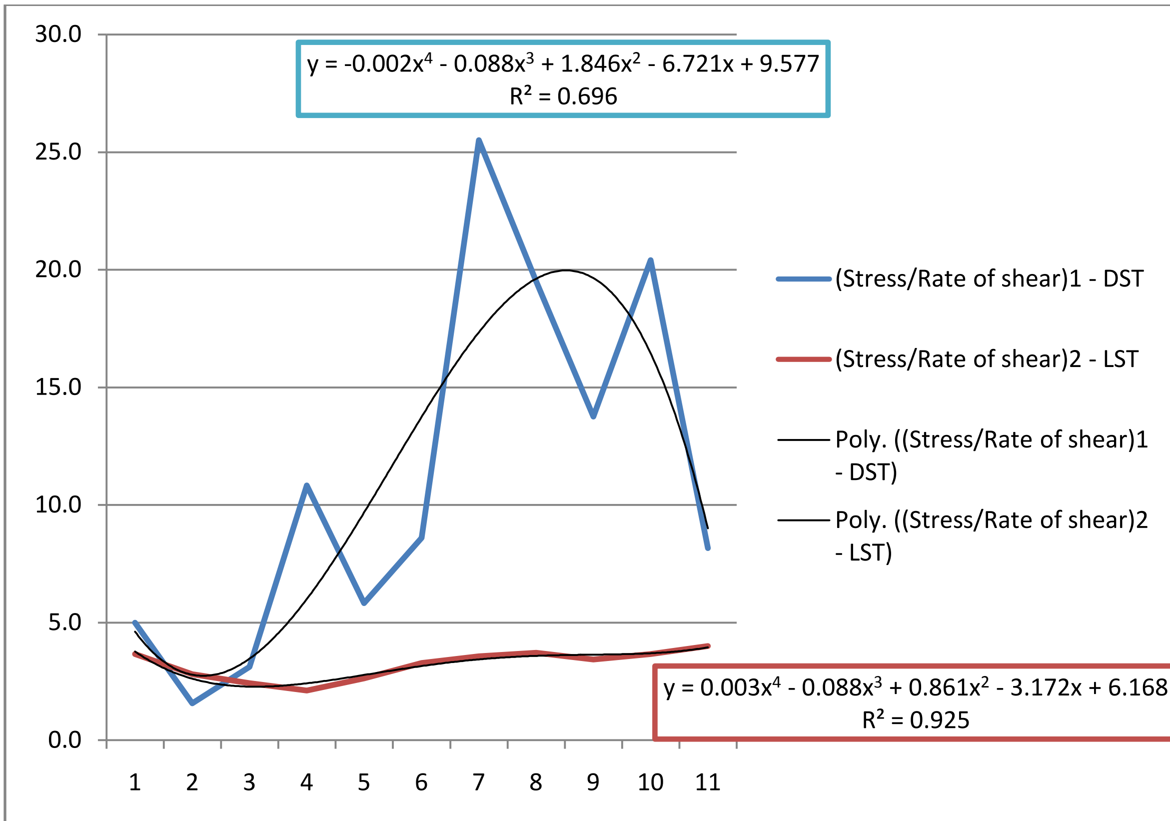
b.3) Harmonics in the system owing to non-linearity of load is another key area that leads to high CF – crest factors of essentially multiples of peak currents on the baseline current drawn in the system. This state fundamentally contributes to the distortion of the primary energy curve leading to high thermal stresses in the system and resulting in a generic increase in heat in the colloidal system; a fact that potentially distorts the equilibrium state of the shear thickening of the particles in suspension.

2. Chemical properties of the colloidal suspensions (grinding medium)

a) Shear thickening properties of the grinding medium in the paints industry are primarily non-linear and discontinuous shear thickening (DST) phenomenon in nature. Technically, following are the characteristics exhibited:

i) The stress required to shear the suspension of the grinding elements is higher than the rate of shear induced in the system causing a fundamental non-linearity of the relationship. Also, the sudden spikes in the magnitude of the stress required to be imparted for causing the shear line to proceed caused the DST phenomenon to set in. The relationship is captured in the typical DST curve for the grinding process in the paint industry as compared to a desired relationship curve between stress and rate of fluid shear.

Grinding Phenomenon - Paints industry	* Extrapolation with dummy values				
Comparative Analysis of DST V/S LST					
Stress-1	**Stress-2**	**Rate of shear-1**	**Rate of shear-2**	**(Stress/Rate of shear)1 - DST**	**(Stress/Rate of shear)2 - LST**
15	11	3	3	5.0	3.7
11	14	7	5	1.6	2.8
25	17	8	7	3.1	2.4
65	19	6	9	10.8	2.1
35	21	6	8	5.8	2.6
43	23	5	7	8.6	3.3
102	25	4	7	25.5	3.6
78	26	4	7	19.5	3.7
55	24	4	7	13.8	3.4
102	22	5	6	20.4	3.7
49	20	6	5	8.2	4.0


30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
4
5
6
7
8
9
10
11
y = -0.002x⁴ - 0.088x³ + 1.846x² - 6.721x + 9.577
R² = 0.696
y = 0.003x⁴ - 0.088x³ + 0.861x² - 3.172x + 6.168
R² = 0.925
(Stress/Rate of shear)1 - DST
(Stress/Rate of shear)2 - LST
Poly. ((Stress/Rate of shear)1 - DST)
Poly. ((Stress/Rate of shear)2 - LST)

ii) Influencing factors for the DST phenomenon:

ii.a. Static charge concentration in the colloidal suspension caused by the forces of attrition along the wall of the particle in the grinding process brings in both repulsive and attractive forces in play and randomly at that with no particular bias thereby lending strong credence to the DST phenomenon.

ii.b. The fluid pressure overwhelms the power of stirring or grinding in the mechanical realm and hence registers unbalanced flow within the colloidal system thereby further aggravating the random nature of static charge build-up and hence the levels of skew caused by the DST phenomenon.

ii.c. Heat transfer within the system is random and not structured owing to the low electromotive forces built up in the drives.

45 kW MOTOR						
PHASE	**TURBO MILL- GRINDING - fundamental energy data**					
	AMPERES	VOLTAGE	THD%	KW	KVAR	KVA
R	15.20	435.5	144.20%	5.6	2.14	10.35
Y	13.11	434.5	124.20%			
B	12.70	433.4	165.60%			
PHASE IMBALANCES	**20%**	**0%**	**33%**			

TURBO MILL- GRINDING - Power Quality Data					
PF	tan ϑ	Phase Angle	Peak i	RMS	CF (Crest Factor)
0.54	1.12	93	23.8	15.2	1.56
			23.8	13.11	1.82
			23.9	12.7	1.88
					20%

The high kVA or apparent power in the system implies that the real electromotive forces developed in the drives are low in magnitude causing the problems of imbalances in the heat distribution within the colloidal system; another facilitator for the DST phenomenon.

iii. Consequences of DST phenomenon:

iii.a. High variations in the particle size after the grinding process.

iii.b. Particle yield of color in terms of quantity and color tone are randomly varying necessitating frequent tinkering around with the additives and loss of proximity with the base color.

iii.c. Low yield shall be a generic problem; more so with multi-chromatic components and those colors exhibiting metamerism.

B. Emulsion process

1. Mechanical factors:

a) Specific gravity of the multi-component emulsion in the colloidal state varies significantly with the color composition and the supplier characteristics as determined by the manufacturing process. This variation in the specific gravity causes a domain of resolutions for the nature of the collisions – those of ***hilf*** (high impact and low frequency) or ***lihf*** low impact and high frequency) in the resultant emulsion. The bounds of the domain are wider as a function of the specific gravities of the individual components of the emulsifying mix; in effect the surface tension in the hydrodynamic medium is affected. Dynamic state viscosities are affected by these domain coordinates and hence the equilibrium of the emulsion.

b) Static charge concentration as a function of the internal enthalpy of the emulsion is an important derivative that needs close attention in analyzing the emulsions; especially in the paint industry. The fluids being the derivatives of crude oil; the hydro carbons tend to break away at different attrition points and changes in internal enthalpy of the colloidal states yielding an array of charges that are fundamentally static in nature. The setting apart phenomenon happens primarily in the amorphous regions of the compounds but progressively change in configuration with the structural changes caused by mechanical attrition and the random enhancement in thermal energies within the system.

c) Particle dilation and sedimentation are the other important derivatives that do happen as a consequence of the changing enthalpy scenario in the emulsion. The attractive forces help create dilation in the particles while the breaking apart causes the sedimentation and the sludge formation; both these phenomena are influenced sharply by the changes in charge concentration and nature as the equilibrium points of the emulsion keep shifting. These phenomena of dilation and sedimentation occur concurrently in the emulsion and significantly change the hydrodynamics of the medium. In turn, changes in the internal enthalpy of the system do happen influencing the following properties of the paints:

i) Color affinity, ii) Tonal quality as determined by the effective charge configuration on the particle cluster that influences reflection of light energies, iii) The power of precipitation within the particle cluster that determines the migration properties and adhesion with external substrates for the paint.

2. Chemical factors:

a) The shear thickening follows the DST route but the process is increasingly configured towards the linearity through the dissolver; the addition of thinners and the designed attrition.

b) The fundamental premise in this exercise is all about the changing electrolyte concentration and the neutralization process designed to set in to influence linearity in the stress V/S rate of shear relationship.

c) The following tabular and graphical representation illustrates the conditions:

i) The DST phenomenon is exhibited in the emulsion state but with the progression through the dissolver and the attrition as well as the addition of thinners, the cluster of particles configure to linearity relationship.

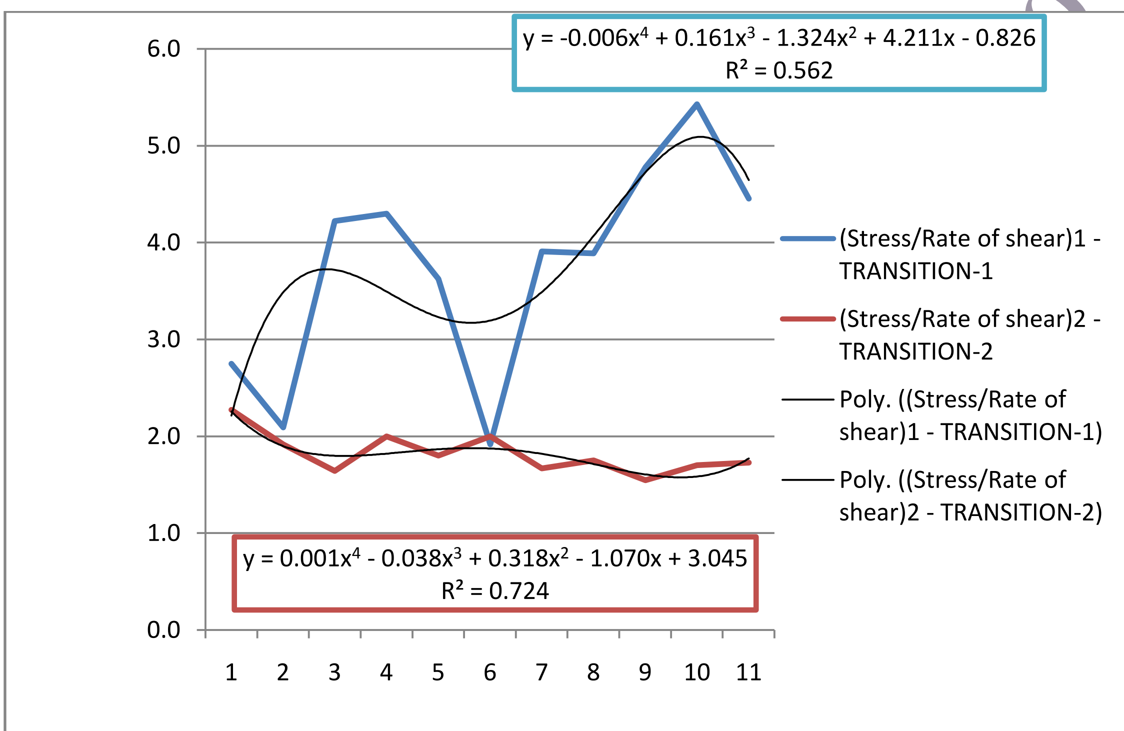
ii) The statistical inferences of the simulation are reflected by the progressive improvement in values of the R2; that of the preliminary stage being 0.562 gradually moving in to level of 0.724 implying higher predictability in the scatter and therefore establishing the linearity in the stress V/S shear rate.

iii) The progression is defined by the electromotive forces generated in the system to bring in the stirring for establishing the emulsion, the dissolution with solvents and finally the entire process of compound dilution and establishing the right particle cluster. In the absence of these electromotive forces at the desired magnitudes, the impacting curves of linearity suffer significantly as illustrated in the simulation.

d) Consequences for the decline in linearity of stress-shear rate relationship are wide ranging inclusive of color affinity losses, the tonal decline and more importantly the color depth realization

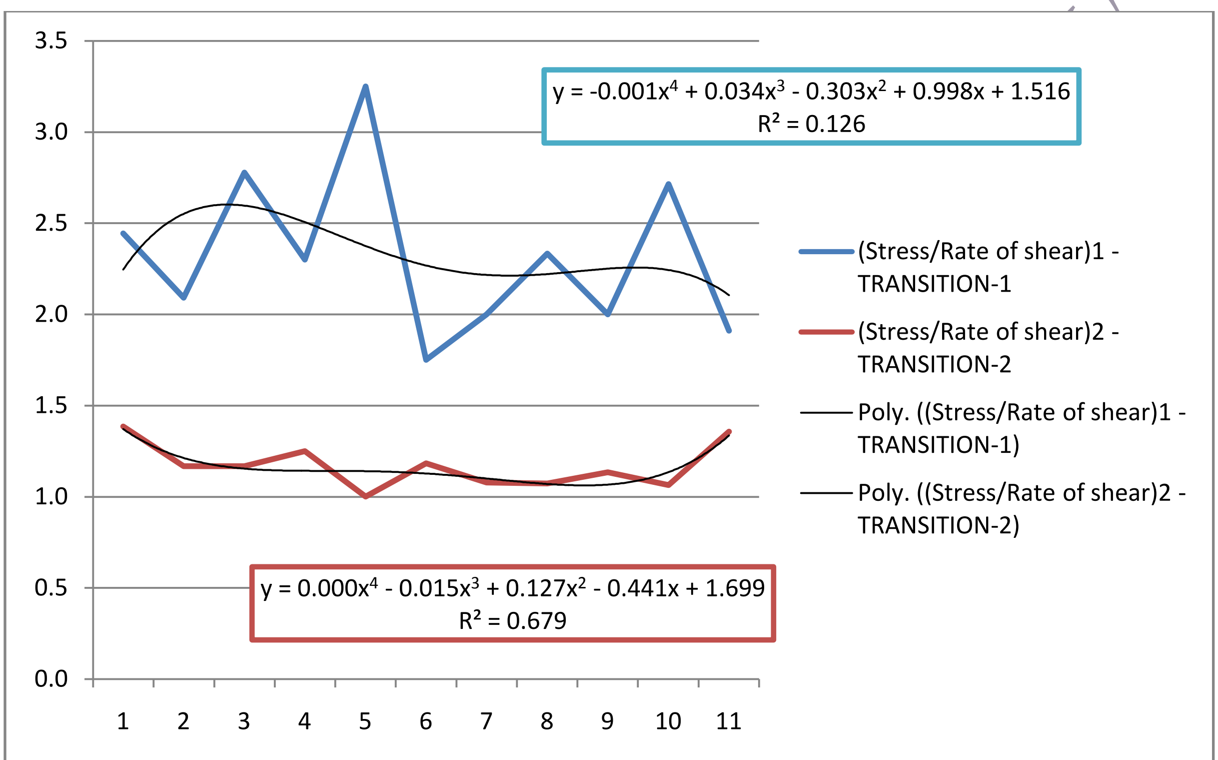
ILLUSTRATIONS FOR GRADE-A; PF RANGE OF 0.2-0.5

GRADE-A: PF- 0.2-0.5					
Emulsion-dissolver-attrition + thinner addition process dynamics	* Extrapolation with dummy values				
Comparative Analysis of stages in the DST-LST progression					
Stress-1	**Stress-2**	**Rate of shear-1**	**Rate of shear-2**	**(Stress/Rate of shear)1 - TRANSITION-1**	**(Stress/Rate of shear)2 - TRANSITION-2**
22	25	8	11	2.8	2.3
23	23	11	12	2.1	1.9
38	23	9	14	4.2	1.6
43	22	10	11	4.3	2.0
29	18	8	10	3.6	1.8
23	16	12	8	1.9	2.0
43	15	11	9	3.9	1.7
35	14	9	8	3.9	1.8
43	17	9	11	4.8	1.5
38	17	7	10	5.4	1.7
49	19	11	11	4.5	1.7


y = -0.006x⁴ + 0.161x³ - 1.324x² + 4.211x - 0.826
R² = 0.562
y = 0.001x⁴ - 0.038x³ + 0.318x² - 1.070x + 3.045
R² = 0.724
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1 2 3 4 5 6 7 8 9 10 11
(Stress/Rate of shear)1 - TRANSITION-1
(Stress/Rate of shear)2 - TRANSITION-2
Poly. ((Stress/Rate of shear)1 - TRANSITION-1)
Poly. ((Stress/Rate of shear)2 - TRANSITION-2)

ILLUSTRATIONS FOR GRADE-B: PF RANGE OF 0.5-0.7

GRADE-B: PF 0.5-0.7					
Emulsion-dissolver-attrition + thinner addition process dynamics	* Extrapolation with dummy values				
Comparative Analysis of stages in the DST-LST progression					
Stress-1	**Stress-2**	**Rate of shear-1**	**Rate of shear-2**	**(Stress/Rate of shear)1 - TRANSITION-1**	**(Stress/Rate of shear)2 - TRANSITION-2**
22	18	9	13	2.4	1.4
23	14	11	12	2.1	1.2
25	14	9	12	2.8	1.2
23	15	10	12	2.3	1.3
26	14	8	14	3.3	1.0
21	13	12	11	1.8	1.2
22	14	11	13	2.0	1.1
21	15	9	14	2.3	1.1
18	17	9	15	2.0	1.1
19	17	7	16	2.7	1.1
21	19	11	14	1.9	1.4

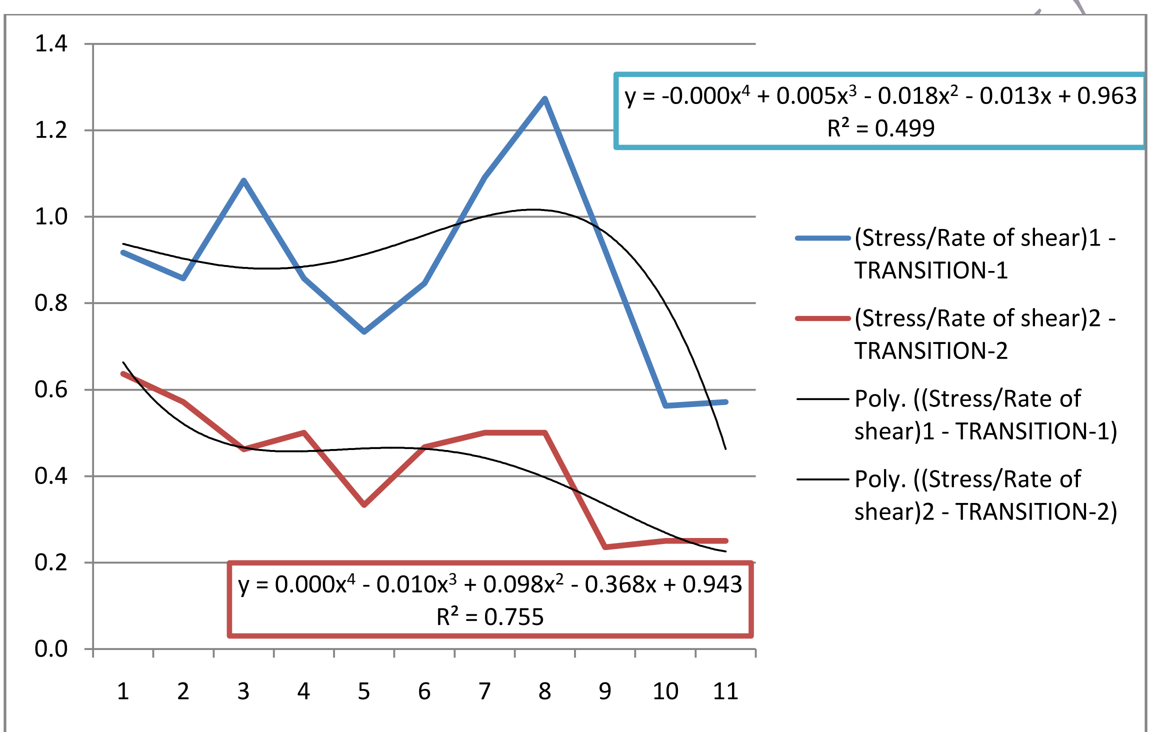

3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1
2
3
4
5
6
7
8
9
10
11
y = -0.001x⁴ + 0.034x³ - 0.303x² + 0.998x + 1.516
R² = 0.126
y = 0.000x⁴ - 0.015x³ + 0.127x² - 0.441x + 1.699
R² = 0.679
(Stress/Rate of shear)1 - TRANSITION-1
(Stress/Rate of shear)2 - TRANSITION-2
Poly. ((Stress/Rate of shear)1 - TRANSITION-1)
Poly. ((Stress/Rate of shear)2 - TRANSITION-2)

GRADE-B: PF > 0.75

Emulsion-dissolver-attrition + thinner addition process dynamics	* Extrapolation with dummy values

Comparative Analysis of stages in the DST-LST progression

Stress-1	Stress-2	Rate of shear-1	Rate of shear-2	(Stress/Rate of shear)1 - TRANSITION-1	(Stress/Rate of shear)2 - TRANSITION-2
11	7	12	11	0.9	0.6
12	8	14	14	0.9	0.6
13	6	12	13	1.1	0.5
12	6	14	12	0.9	0.5
11	5	15	15	0.7	0.3
11	7	13	15	0.8	0.5
12	7	11	14	1.1	0.5
14	8	11	16	1.3	0.5
12	4	13	17	0.9	0.2
9	4	16	16	0.6	0.3
8	4	14	16	0.6	0.3



INFERENCES:

1. With improving PF and the overall drive quality, the chemistry changes for the better.

2. The statistical inferences derived from the R2 values are indicative of the lowering entropy in the color chemistry and consequently an equilibrium points that are fundamentally on a higher threshold.

C. Analysis of facts:

a) Emulsion

PHASE	EMULSON PAINT -Diamix 6000 liters - fundamental energy data					
	AMPERES	VOLTAGE	THD%	KW	KVAR	KVA
R	247.80	418.9	5.09%	452.4	62.83	470
Y	245.60	410.2	5.75%			
B	243.80	416.2	4.79%			
PHASE IMBALANCES	**2%**	**2%**	**20%**			

EMULSION PAINT - Diamix 6000 liters - Power Quality Data					
PF	tan ϑ	Phase Angle	Peak i	RMS	CF (Crest Factor)
0.89	2.32	112	1122.0	247.8	4.53
			1145.8	245.6	4.67
			1129.3	243.8	4.63
					3%

b) Dissolver

PHASE	DISSOLVER - 3000 liters - fundamental energy data					
	AMPERES	VOLTAGE	THD%	KW	KVAR	KVA
R	41.25	430.6	2.93%	13.15	27.44	32.55
Y	46.58	429.8	2.77%			
B	44.54	428.6	3.11%			
PHASE IMBALANCES	**13%**	**0%**	**12%**			

DISSOLVER - 3000 liters - Power Quality Data					
PF	tan ϑ	Phase Angle	Peak i	RMS	CF (Crest Factor)
0.39	2.14	112	75.6	41.25	1.83
			75.7	46.58	1.63
			75.9	44.54	1.71
					13%

c) Variable speed dispersion

37 kW MOTOR						
PHASE	**VARIABLE SPEED DISPERSION - fundamental energy data**					
	AMPERES	VOLTAGE	THD%	KW	KVAR	KVA
R	31.78	435.4	3.80%	16	4.6	24.66
Y	33.44	433.9	3.50%			
B	33.57	432.6	3.15%			
PHASE IMBALANCES	**6%**	**1%**	**21%**			

VARIABLE SPEED DISPERSION - Power Quality Data					
PF	tan ϑ	Phase Angle	Peak i	RMS	CF (Crest Factor)
0.65	0.28	31	56.6	31.78	1.78
			56.8	33.44	1.70
			57.0	33.57	1.70
					5%

d) Dyomill dynamics

PHASE	DYOMILL - fundamental energy data					
	AMPERES	VOLTAGE	THD%	KW	KVAR	KVA
R	23.95	431.6	3.18%	2.55	5.7	17.47
Y	24.14	430.2	2.94%			
B	22.98	429.5	2.83%			
PHASE IMBALANCES	**5%**	**0%**	**12%**			

DYOMILL - Power Quality Data					
PF	tan ϑ	Phase Angle	Peak i	RMS	CF (Crest Factor)
0.14	2.21	112	40.5	23.95	1.69
			40.6	24.14	1.68
			40.7	22.98	1.77
					5%

e) Attrito

37 kW MOTOR						
PHASE	**ATTRITO - fundamental energy data**					
	AMPERES	VOLTAGE	THD%	KW	KVAR	KVA
R	11.34	435.4	2.06%	1.57	2.52	8.63
Y	11.78	433	2.36%			
B	11.03	432.2	2.18%			
PHASE IMBALANCES	**7%**	**1%**	**15%**			

ATTRITO - Power Quality Data					
PF	tan ϑ	Phase Angle	Peak i	RMS	CF (Crest Factor)
0.17	1.52	104	19.8	11.34	1.75
			19.9	11.78	1.69
			20.0	11.03	1.81
					7%

f)

PHASE	**KHD 1 - 087A KREIS - fundamental energy data**					
	AMPERES	VOLTAGE	THD%	KW	KVAR	KVA
R	45.52	431.3	5.20%	8.84	5.7	33.76
Y	43.95	430	5.65%			
B	43.28	429	4.98%			
PHASE IMBALANCES	**5%**	**1%**	**13%**			

KHD 1 - 087A KREIS - Power Quality Data					
PF	tan ϑ	Phase Angle	Peak i	RMS	CF (Crest Factor)
0.26	0.65	66	78.3	45.52	1.72
			78.5	43.95	1.79
			78.7	43.28	1.82
					6%

D. INFERENCES:

a) Impedance factors have already set in causing a decline in the power quality and hence that of the drives being transmitted in the process.

b) Thermal stresses in the system are significantly higher causing progressive wear in the cables, the wiring and panel components.

c) THD% is extremely high in certain applications wherein the load in non-linear and need to be addresses through the incorporation of rectifiers.

E.Solutions – energy and engineering:

Energy Saving Parameter	Engineering Logic	Technology
Traction Load in stirrer	The traction generates non-linear loads contributing to harmonic energy and these in turn cause the onset of the	The cylinder of higher volume made in stainless steel to be retrofitted to the stirrer to enable a rotational torque to overcome the friction of the emulsion
PF bank is ineffective in providing the reactive power compensation	The harmonic energy is high in the process and PFC bank with adequate resonance controls or filters cannot be effective	PFC bank with filters where harmonic filtration and correction are the primary roles while compensating with reactive load is the secondary role are the answer for sustained improvements
Damping the mechanical vibrations	Damping with rubber pads eliminates reactive loads and compensates for the mechanical vibrations	The damping pads shall be provided with the anchor bolts of the equipment and the fixtures of the motors

Solutions – chemical processing

a) Extensive use of electrolytes in the colloidal to eliminate static charge concentration.

b) Using compounds that are thermally stable and with higher internal enthalpy levels that can be ensured through opting for higher bond strength compounds and formulations.

Entropy and the incorporation of the concept in the paints manufacturing process:

The thermodynamic concept that enumerates the rate of change in enthalpy for a unit change in sensible heat is borrowed extensively in evaluating the color dynamics. The following are the derivatives as an off-shoot in introducing the thermodynamic concept in the paints manufacturing process:

i) The key variables in the emulsion are the viscosity at a given emulsion temperature and fluid pressure while the pH is the consequence of the chemical changes that are in process; in effect the state of the exchange of the free radicals in the bonding process of the color are the determinants.

ii) The boundary and the domain differences within the emulsion would give the analyst the required insights into the process progress and this shall be effectively captured by evaluating the entropy within the system.

iii) Fundamentally, a lowering of the entropy value would imply broadening of the bounds in the domain or the fundamental increase in the scatter of the data points while the vice versa is true when the entropy values are increasing implying narrower domain bounds.

iv) The mathematical expression is the logarithmic of the probability of the scatter and hence can serve as an excellent measure of the state of the process.

v) The series of entropy data shall serve to understand the process in a better perspective; the changes within the emulsion process are best captured by the entropy for viscosity and pH and when steps are taken in the electro-mechanical realm to control the fluid pressure and built-up temperatures, then the initiation of consistency is set into the process.

	Multi-domain evaluaton of the emulsion process							
	Viscosity	pH	Flash point	Hydraulic load - measure of the abrasive properties	Vibration of the stirrer assembly	kW	PF	Phase imbalances - current
	22	8.3	135	25	10	5.2	0.43	0.05
	23	7.7	142	22	12	5.5	0.38	0.03
	26	9.2	138	20	9	4.9	0.38	0.07
	21	9.1	143	32	8	4.7	0.39	0.08
	28	8.5	144	29	7	5.6	0.41	0.09
	31	7.8	139	28	11	4.8	0.43	0.1
	27	8.3	138	27	12	5.3	0.29	0.11
	29	7.7	132	29	10	5.1	0.31	0.03
	24	6.5	141	27	9	6.1	0.41	0.12
	27	6.8	143	26	8	5.9	0.45	0.09
	28	7.3	139	25	7	6.2	0.28	0.07
Target	25	7	145	29	7	7	0.75	0.03
Median	27	7.8	139	27	9	5.3	0.39	0.08
Average	26.0	7.9	139.5	26.4	9.4	5.4	0.4	0.1

Standard deviation	3.13	0.86	3.67	3.35	1.80	0.52	0.06	0.03	
Variance	9.80	0.74	13.47	11.25	3.25	0.27	0.003	0.001	
Target variance	5	0.65	10	10	2	0.25	0.001	0.0005	
Entropy	0.149	0.050	0.096	0.046	0.130	0.027	0.156	0.142	**0.099**
Standardization	-0.639	-0.929	-1.635	-0.596	-1.109	-3.291	-6.106	-1.662	**-1.996**
Score	53%	40%	20%	55%	33%	4%	0%	19%	**28%**

PHASE-1 INTERVENTION DELIVERY POINTS					
S.No.	**Element**	**Steps in the intervention**	**Impact**	**Influence weight**	**Outline of the conclusions**
1	**Power quality profile for individual drives**	Logging energy analyzer data	Clarity in **core power profile issues like THD%** (total harmonic distortion%), **reactive and apparent power and CF- crest factor-** current as also individual motor PF	0.99	Linking the electrical, mechanical, process and quality issues in a decision model
		Inspection of mechanical condition of the equipment being analyzed for power profile	Analyzing the **vibration, thermometry of key rotary and thrust elements** and **effects on the emulsion caused by the stirrer**, evaluating the compressed air leakages wherever applicable and overall quality of compressed air	0.97	Comprehensive RCA (Root Cause Analysis) with reasoning and lasting solutions outlined
		Logging breakdown history of the equipment	Historical mapping of the **probable causes for the breakdown profiles**	0.92	A model for testing the accuracy of the predictions for the causal links in the process and equipment through actual interventions and subsequent validation of the findings
		Logging process issues in the related equipment being analyzed for power profile	Analyzing the **effects of color coordinates on dwell times and process reproducibility** in the context of the **mechanical and power quality issues**	0.93	

		Creation of multi-domain evaluation matrix based on real time aggregation of power profile, mechanical condition, states of the process and empirical evaluation of breakdown data	**Statistical interpretation of data for decision-making** on the root causes of process and equipment failure on a **predictive mode - an automated foundation** shall be in place for regular usage by the shop teams	0.99	
2	**Skill development matrix creation - shop floor teams**	Influence groups in the process - outlining and explaining the concepts to the shop floor teams	Batch runs shall be predictive and reproducible to the **extent of >95% of all batches in process**	0.99	Empowered teams shall be on a proactive mode in trouble shooting to derive quicker batch times at consistent quality levels
		Understanding the quality data in the context of impact variables from power, mechanical aspects and the color chemistry	**Color reproducibility** on a given recipe shall be accurate to the **extent of 90% even for the difficult multi-chromatic shades**	0.99	
		Appreciation of the relevant statistical concepts in interpreting data and arriving at conclusions	Process **run time reduction by 15-20%**	0.99	
3	**Cross-functional engineering**	Influence groups in the power profiling - conceptualizing the fundamentals	**Near-zero breakdown or equipment failure**	0.99	Assurances in trouble shooting way before the occurrences of an actual

	teams - trouble shooting skills development	Mechanical parameters - training on the interpretation of mechanical data and the RCA of general trends on cross-functional -electro-mechanical data	**Foundation for creation of enhanced designs** for better process variables shall be laid through the conceptualization outlined herein	0.99	breakdown - predictive condition based maintenance shall be the fall out of the intervention
Summary of the delivery points on Phase-1 intervention		**1**	Mapping the plant in the electro-mechanical and process domains for potential areas of improvement		
		2	Creating the statistical controls in the comprehensive process lines on multi-domain data modeling		
		3	Creating the foundation for training the shop floor and engineering teams in shaping trouble shooting and predicting potential pitfalls in process run times and color reproducibility well in advance of the actual occurrences		

PHASE-2 INTERVENTION DELIVERY POINTS					
S.No.	**Element**	**Steps in the intervention**	**Impact (performance guarantees)**	**Influence weight**	**Outline of the conclusions**
1	**Power quality profile for individual drives**	Correction of THD% and **improving significantly the power quality**	**Energy bill savings > 15%, elimination of electrical breakdown inclusive of motor burning > 95% on historical data, reduction in mechanical breakdown by > 75% on historical data**	0.99	Sustainable improvements to be registered as outlined herein
		PF of individual drives		0.97	The decision making shall be **quantitative and objective to minimize judgmental errors**
		Reduction of **CF**		0.92	**Dissemination of knowledge and information** within the grassroots team shall inculcate a spirit of manufacturing excellence with objectivity in the results
		Minimizing **phase imbalances**		0.93	
		Corrections for mechanical vibrations through **damping mechanisms, stirrer redesigning, creation of prototypes for reduction in thermometry of critical rotary elements** and enhanced **bearing performances**		0.99	

2	**Skill development matrix creation - shop floor teams**	Execution of the **statistical decision models**	Batch runs shall be **predictive and reproducible to the extent of >95% of all batches** in process	0.99	Empowered teams shall be on a **proactive mode in trouble shooting to derive quicker batch times at consistent quality levels**
		Ease in **interpreting trends** and predicting causes through **interactions among the regular cross-functional teams**	**Color reproducibility** on a given recipe shall be accurate to the extent of 90% even for the difficult multi-chromatic shades	0.99	
		Actually implementing the **RCA findings in the shop floor** and evaluating the results for the interventions by the teams	**Process run time reduction by 15-20%**	0.99	
3	**Cross-functional engineering teams - trouble shooting skills development**	**Implementing** the **trouble shooting concepts** on the floor by **evaluating** the **real-time engineering data**	**Near-zero breakdown** or equipment failure	0.99	Assurances in trouble shooting way before the occurrences of an actual breakdown **- predictive condition based maintenance shall be the fall out of the intervention**
		Validating the trouble shooting steps day in and day out with the **changes registered in the quality of the engineering data**	A clear **decision-tree for 95% of the potential problems** in the realm of engineering on the shop floor shall be constructed for the sustainable future	0.99	
Summary of the delivery points on		**1**	Demonstrating the changes in a positive way as outlined above		

Phase-1 intervention	**2**	Creating the decision trees for trouble shooting in process and engineering with enhanced reliability of execution and consistency in outcomes
	3	Imparting the advanced skills of design and process engineering in the cross-functional groups for sustainable improvements in the future

PHASE-3 INTERVENTION DELIVERY POINTS

S.No.	Element	Steps in the intervention	Impact (performance guarantees)	Influence weight	Outline of the conclusions
1	**Engineering - electrical and mechanical intervention quality**	**Sustainable** improvements in **energy**	**Energy bill savings > 15%, elimination of electrical breakdown inclusive of motor burning > 95% on historical data, reduction in mechanical breakdown by > 75% on historical data - SUSTAINABILITY. Maintenance and repair costs reduction to the extent of 30% on historical values**	0.99	Sustainable improvements to be registered as outlined herein
		Quality of drives and monitoring for **improved equipment health**		0.97	The decision making shall be quantitative and objective to minimize judgmental errors
		Consistent power quality in the plant irrespective of the source quality		0.92	Dissemination of knowledge and information within the grassroots team shall inculcate a spirit of manufacturing excellence with objectivity in the results
		Maintenance and repair costs reduction		0.93	
		Overall productivity and efficiency improvements on a **continual mode**		0.99	

2	**Skill development matrix creation - shop floor teams**	Execution of the **statistical decision models**	Batch runs shall be predictive and reproducible to the extent of >95% of all batches in process	0.99	Empowered teams shall be on a proactive mode in trouble shooting to derive quicker batch times at consistent quality levels
		Ease in **interpreting trends and predicting causes through interactions** among the regular cross-functional teams	**Color reproducibility** on a given recipe shall be accurate to the extent of **90% even for the difficult multi-chromatic shades**	0.99	
		Actually **implementing** the **RCA findings** in the shop floor and **evaluating the results for the interventions by the teams**	**Process run time reduction by 15-20%**	0.99	
3	**Cross-functional engineering teams - trouble shooting skills development**	Implementing the **trouble shooting concepts on the floor** by evaluating the **real-time engineering data**	**Near-zero breakdown or equipment failure**	0.99	Assurances in trouble shooting way before the occurrences of an actual breakdown - predictive condition based maintenance shall be the fall out of the intervention
		Validating the trouble shooting steps day in and day out with the **changes registered in the quality of the engineering data**	A clear **decision-tree for 95% of the potential problems in the realm of engineering** on the shop floor shall be constructed for the sustainable future	0.99	
4	**Market research on**	**AMR** - advanced market research	**Sales revenue > 15% on historical highs**	0.99	**Quantitative research** driven

	advanced quantitative modes	**Macro-fundamentals mapping** and **integrating with the brand strategy of the company**	**Brand permeability and reach > 20% on historical highs**	0.98	on **analytic will give in insights to realize the stated targets**
5	**Factorization of product efficiency and innovation in the pricing strategy models**	Exploring new **purchase points at changed paradigms of pricing equilibrium and product innovation**	**Achieving pricing equilibriums for higher sales volume and margin growth > 10%**	0.99	
Summary of the delivery points on Phase-3 intervention - SUSTAINABILITY		**1**	Demonstrating the changes in a positive way as outlined above		
		2	Creating the decision trees for trouble shooting in process and engineering with enhanced reliability of execution and consistency in outcomes		
		3	Imparting the advanced skills of design and process engineering in the cross-functional groups for sustainable improvements in the future		
Branding initiatives		**4**	Creating brand value at higher margins		
		5	Overcoming the challenges in the macro-fundamentals through predictive modes and decision-making on advanced mechanisms		

SUMMARIZATION:

1. The initiatives are meant to be pioneering in the industry in as much as the attempts are for solving the generic process issues as also for the mainstream engineering issues that are in the realm of both electrical and mechanical disciplines.

2. The implications in the process are studies in detail, evaluated and monitored on a multi-domain statistical framework to finally find the corrections with lasting impact.

3. The intervention gradually migrates into a phased manner from research into analytics and data modeling for building the product strategies in the backdrop of ever weakening and uncertain purchase dynamics in a macro-scenario.. Hence the challenges of the times are addressed on a sustainable note through this intervention.

The initiatives are part of the business transformation modeling wherein the fundamentals of an energy intervention migrate into one of a sustained asset efficiency improvement program; the implications of which spill over into the realm of product differentiation and brand marketing as part of the strategic moves to make a lasting difference.