International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.9, No.09 pp 198-208, 2016

Process Improvements in Elimination of Miscut Generation in Granulation Process

S.Lakshmi Sankar[1]*, G.Mageshwaran[1], Gobinath[1], Satheeshkumar Govindan[1], Tamil Arasan[1]

[1]Dept. of Mechanical Engineering, Sathyabama University, Chennai-600119, India

Abstract : Granulation refers to the process in which large objects are cut or shredded and re-melted into granules or pellets. Granules typically have a size range between 0.2 to 4 mm depending on their subsequent use. Granulation is a process that aids downstream processes to ensure high quality and safe product but the process is not without its potential sources of rejected material or waste. The particle size distribution is the most important physical property of a granulated material. Some issues that occur during a granulation process are under granulation, over granulation and wide particle size distributions. This problem can occur as a result of too much or little liquid and binder addition, incorrect pressure application during granulation. Under granulated particles have not adhered to a sufficient level to maintain agglomeration and will result in smaller particles than desired with sub-optimal attributes. This can have a negative impact on the flowability of the granule and any subsequent compression process. Over granulation leads to particles which are larger than desired. This can impact how the material blends with subsequent excipients and can lead to problems such as picking and lamination during compression. Due to process instability, miscut generation in the granulation process increases between 8-10 incidents in a month. Due to miscut generation, the chip line is getting choked and centrifugal pump gets tripped which leads to high production loss and high scrap generation. The location of problem has been identified that the lump generation of polymers between spinneret and rotary cutter. To overcome the above, quality tools are considered from quality management system in which Pareto chart tool is to find the main part of the problem and Cause & Effect diagram is to find the granulation related issues. With the help of these tools, the process equipment design is modified, strand guide roller material change, blower drive change and exact multi groove roller was added for strands separation in the cutter and after changing the dimensions few parts are taken to achieve zero miscut generation.

Keywords: Miscut, Tripping, Root causes, Rollers, Granulation.

1. Introduction

Polymerization is a process of reacting monomer molecules together in a chemical reaction to form polymer chains or three-dimensional networks. Nylon is made by polymerisation of caprolactam with certain additives like amino acids and dicarboxylic acid salts and certain heat stabiliser such as copper based organic compounds[16,18]. The polymerisation process involves ring opening poly condensation and poly addition reactions. All the three polymerisation reaction steps are equilibrium reactions.

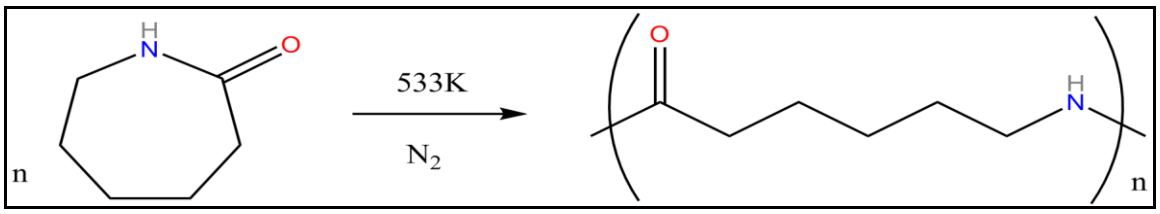


Fig. 1: Nylon Filament Yarn

2. Objective & Methodology

Due to process instability, miscut generation incidents are noticed and due to which choking in the chip line and tripping of centrifugal pump leading to high production loss and high scrap generation. For solving, the issue problem location and solution by quality tools implementation are considered to achieve zero miscut generation. The focus of the paper is to improve the process by eliminating miscut chips in granulation process. Following is the miscut chip incidents happened in granulation process. Miscut Incidents were observed till March 2015.

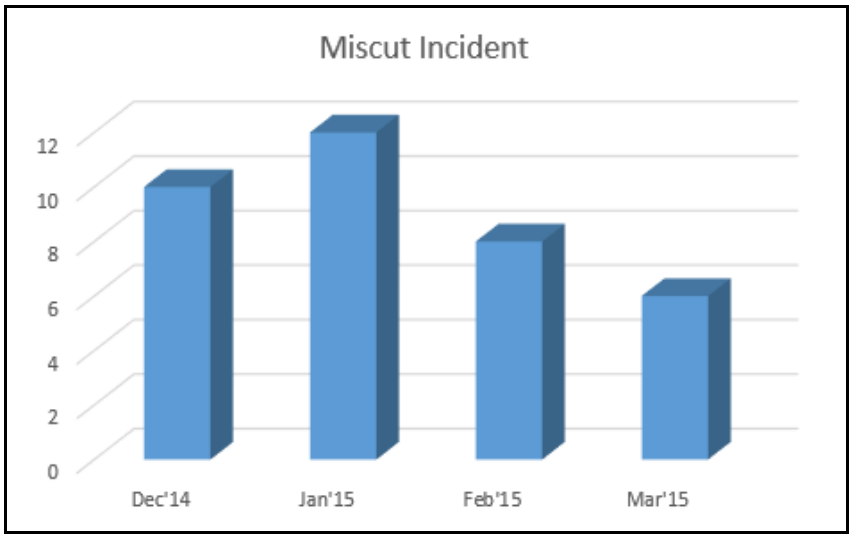
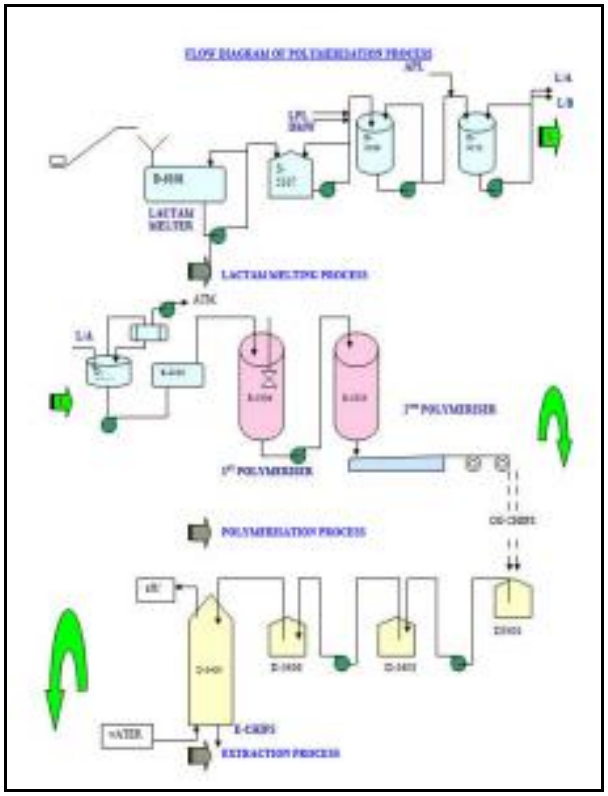


Fig. 2 : Miscut Incidents in Granulation Process

In the Granulation process, the polymer strands are cut into small chips. There will be tension in the strands according to the dimensions. Feed rollers are used to reduce the diameter of the strands. The rpm of the feed roller and cutting speed in the granulator decides the "size of the chips" diameter 2.2 mm and length 2.0 mm. The granulator consists of two cutters normally a stationary cutter and rotary cutter. There are two rollers in between in which the strands are allowed and they are cut into chips of uniform size by the two cutters. The following is a 12 step process for problem solving, namely Identification of problems, Selection of problems, Definition of problems, Analysis of problems, Cause and effect analysis, Root cause analysis, Data analysis on the root cause, Development of solution, Foreseeing problem resistance, Trial implementation & checking performance and Regular implementation and Follow up/ review & recurrence prevention. The following QC tools are used for problem solving-Cause and Effect Diagram, Check-sheet, Control Chart, Histogram, Pareto Chart, Scatter Diagram, Flow Chart. Fig 3 & 4 are the process flow diagrams.



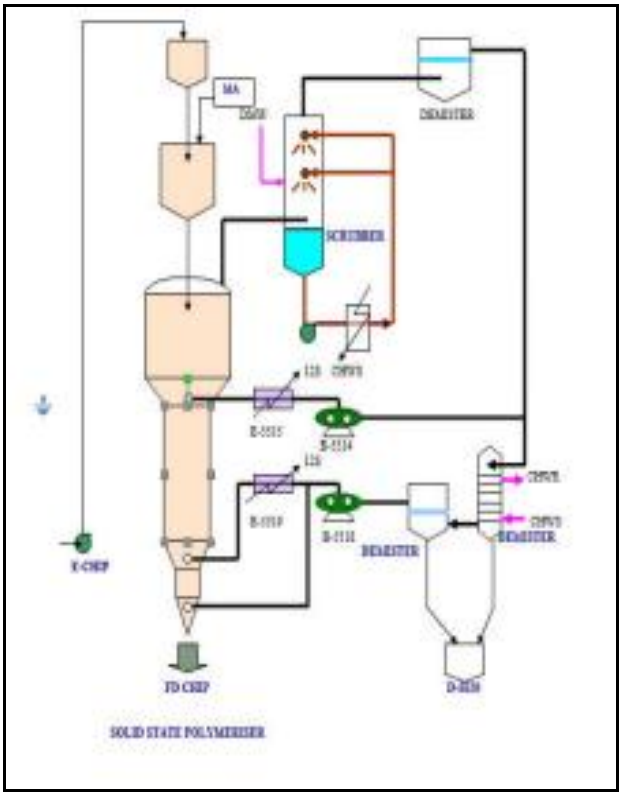


Fig 3 : Process flow diagram-I **Fig. 4 : Process flow diagram-II**

3. Literature study

Granulation is a form of particle design. Properties of granulated powders are affected by both formulation compositions, i.e., choice of excipients; and process parameters, e.g. impeller speed. Extensive understanding in several areas of wet granulation is required to fully predict product properties and performance. [1] HSWG granules have been observed to undergo substantial loss of the ability to be compressed into tablets of sufficient strength, a phenomenon called "over granulation". [2,3] Studies on the compaction properties of microcrystalline cellulose (MCC), a commonly used pharmaceutical excipient, have shown that granule size enlargement, surface rounding, decreased granule porosity and densification all contribute to reduction in tabletability by reducing granule deformability and intergranular bonding area.[4,5,6] One effective approach to address the over granulation problem is the granule size reduction.[7,8,9] Brittle excipients predominantly undergo brittle fracture when deformed during ordinary powder compaction process. [10,11,25] Since granule size reduction can effectively improve powder tabletability through creation of larger surface areas available for bonding in a tablet,[12] we hypothesize that the incorporation of a brittle excipient in an otherwise plastic powder can enhance brittleness of HSWG granules, which will lead to more extensive granule fragmentation,[13,14] hence overcoming the over granulation problem. In this study, we test the stated hypothesis by incorporating brittle excipients (lactose monohydrate and dibasic phosphate calcium) in a plastic MCC matrix[23, 24]. The results show that tabletability of MCC granules deteriorated rapidly with increasing granulating water as expected. Intact tablet could not be made for MCC granules prepared with 55% granulating water or higher. However, the rate of granules tabletability reduction by water addition was lower with increasing amount of lactose. For mixtures containing 20% lactose or more[20, 21, 22], tabletability improved with increasing amount of granulating water after passing a minimum. It is concluded that the addition of brittle excipient to an otherwise plastic powder is effective in reducing or even eliminating the over-granulation propensity in HSWG. Quality tools [15, 17, 19] can be attempted to solve the miscut generation.

4. Analysis & Results

The carried out analysis and results are presented below.

4.1 In the brainstorming sessions following possible problems were generated.

Strands slipping out of roller, Cooling vat alignment found disturbed, Cutting blades edges not good, Quality not meeting the target, Un reactable monomer coating on to the guide roller, Improper monomer suction, Cooling vat oligomer formation, Quench water poor circulation, Air leak in take up roller cylinder, Gap high in between two rollers, Chips duct height less, Emergency switch not working, Interlock system not working, SOV failure in pneumatic valve, Polymer lump enter in to the cutter, Cooling water temp high frequent tripping of cooling tower fan.

4.2 Action plan:

It was generated for completion of the activity to be done within 3 months which deals about planned activity schedule.

Table 1: ActionPlan

Activity Schedule		**TTBM NYP-POLY II - Elimination of Miscuit generation in Granulation from 7 incidents to nil**														
Activity			**15-Jan**			**15-Feb**					**15-Mar**				**15-Apr**	
			2W	**3W**	**4W**	**1W**	**2W**	**3W**	**4W**	**5W**	**1W**	**2W**	**3W**	**4W**	**1W**	**2W**
1	Identification of Problems	P	W													
		A														
2	Selection of Problems	P														
		A														
3	Definition of Problems	P														
		A														
4	Analysis of Problems	P														
		A														
5	Cause and Effect Analysis	P														
		A														
6	Root Cause Analysis	P														
		A														
7	Data Analysis on the Root Cause	P														
		A														
8	Development of Solution	P														
		A														
9	Foreseeing Problem Resistance	P														
		A														
10	Trail Implementation & Checking Performance	P														
		A														
11	Regular Implementation	P														
		A														
12	Follow Up/Review & Recurrence Prevention	P														
		A														

4.3 The Cause and Effect diagram:

The Brainstorming ideas were plotted on the Cause and Effect diagram based on Man, Method, Material, Design and Assembly process. By eliminating non relevant causes on current situation based on

engineering judgement for miscut generation in granulation process. The elimination of probable causes gave way so as to concentrate on few causes.

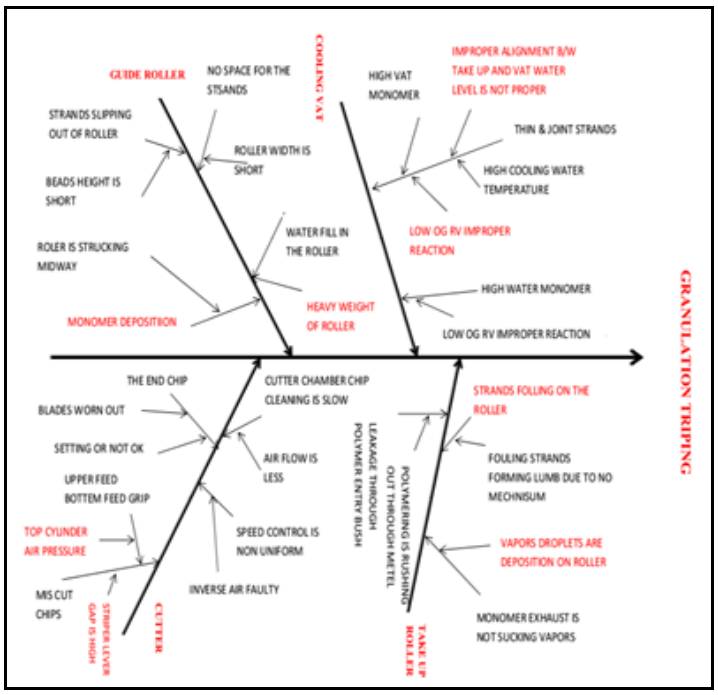


Fig 5: Cause & defect diagram

Given below are the causes eliminated based on engineering judgement. - Unreactable monomer coating on to the guide roller, Improper monomer suction, Polymer lump enter in to the cutter, Improper strands feeding in to the cutter ,Cutter Striper lever gap very high. Validation for elimination of causes is based on quality inspection of parts of Engineering judgements which contributed in elimination of causes was done. It was validated that parts used in Granulator rotary cutter, take up roller case are meeting the design requirements.

The Table 2 presents the validation of cause of material in which most severe is given a value of 5 and the least severe is given a value of 1.

Table 2: Validation of Causes on Material

Total no. of Causes identified and validated						
Effect	**YSS**	**SF**	**SA**	**KB**	**KV**	**Total**
Strands slipping out of roller	1	1	1	1	1	5
Cooling vat alignment found disturbed	1	1	1	0	1	4
Cutting blades edges not good	1	1	1	1	0	4
Quality not meeting the target	1	2	1	2	1	7
Un reactable monomer guide roller coating	5	5	5	5	4	24
Improper monomer suction	5	5	5	4	4	23
Cooling vat oligomer formation	1	1	1	1	1	5
Quench water poor circulation	1	1	1	1	1	5
Air leak in take up roller cylinder	1	1	1	1	1	5
Gap high in between two roller	1	1	1	0	0	3
Chips duct height less	0	0	1	1	2	4
Emergency switch not working	1	1	1	1	1	5
Interlock system not working	1	1	1	1	1	5
Polymer lump enter into the cutter	4	5	4	4	5	22
Improper Strands feeding into cutter	4	4	4	5	5	22
Cooling water temperature high	2	1	2	3	1	9

Eliminating machine relevant causes were - Guide roller getting struck due to wearing of bush, Heavy weight of the guide roller, Monomer deposition on roller, Low tension on rollers

Cutter tripping due to miscut/Tail ends/over load. Eliminating non relevant causes based on current situation were essential because of the input parameters are standard one. Hence the following non relevant causes were removed namely Improper Solidification of strands due to high cooling water temperature, Low Strands, Relative Viscosity, High monomer content in vat, Cutter tripping due to miscut/Tail ends/over load, Interlock system not working, Gap high in between two rollers, Chips duct height less and Cutter Striper lever gap very high.

4.4 Validation and Analysis of Causes

The problem analysis of miscut generation is presented in Table 3.

Table 3: Validation of Causes on Machine

Issue	Cause	Action to be taken	Analysis /Status
Tripping due to guide roller	Guide roller getting struck due to wearing of bush	Brass bush to be replaced with Teflon bush on all 4 position	Teflon bush has been installed on all 4 positions
	Heavy weight of the guide roller	SS 304 roller to be replaced with Al roller	Al roller has been installed on all positions
	Monomer deposition on roller	Monomer suction hood design to be modified	New Monomer suction hood fixed on all 4 positions
Tripping due to Cooling Vat	Improper Solidification of strands due to high cooling water temperature/ Low Strands RV/High monomer content in Vat	Temperature of cooling Vat to be maintained at 12 degree centigrade trough. OG RV spec to be maintained and there should not be any variation Cooling Vat water monomer content should be as low as possible	Regular checkup of temperatures Upstream control of RV Schedule cleaning of Vat
Take up Roller Tripping	Low tension on rollers	Low air supply pressure	Pressure to be between 4 to 6 bar
Cutter Tripping	Cutter tripping due to miscut/Tail ends/over load	Cutter settings at Bed knife to Rotor Cutter settings Top feed to Bottom feed Stripper plate design modification Top feed roller Pneumatic cylinder stiffness Tail ends – Cutter regrinding	Settings – 0.04 to 0.05 mm Stripper Plate side lever design to be modified to ensure gap less than 1.5 mm Air supply should be 4 to 6 bar Regrinding of rotor on scheduled basis

Causes which affect the Granulator leading to Miscut generation in Granulation process is taken for Root cause analysis. By asking why-why 5 times it can be found that the exact causes for Miscut generation. By doing Root cause analysis it is possible to find the exact reasons for Miscut generation. Major causes identified for miscut generation in granulation process were as follows:

Un reactable monomer coating on to the guide roller, Improper monomer suction Polymer lump enter in to the cutter, Improper strands feeding in to the cutter, Cutter Striper lever gap very high.

4.5 Development of solution:

It discusses about Analysis and corrective action provided of Un Reactable Monomer Coating on to the Guide Roller, Improper Monomer Suction, Polymer Lump Coated on the Strands Guide Roller, Polymer Lump Enter into The Cutter, Improper Strands Feeding in to the Cutter, Cutter striper lever gap very high and Tangible & intangible benefits

(i) Unreactable Monomer Coating On To the Guide Roller

Monomer contents in polymer were high, Monomer vapour escaped along with polymer. Improper Reaction took place in second polymerization, Polymerization mass temperature varied, Frequent Heat medium venting in second Poly reactor and also it was suspected that the venting valve might pass and created temperature difference. The corrective action taken was to replace the second poly reactor heat medium venting valve due to valve passing.

(ii) Improper Monomer Suction observation & corrective action:

The monomer fumes came out from the polymer filaments were sucked by a blower through duct. The duct which carried the monomer particles was often choked with lactam. The lactam choke happened due to improper steam flushing into the duct and frequent breakdown of blowers. The monomer got deposited on the blower impeller and corroded it. Due to corrosion of impeller, the blower impeller was unbalanced and made heavy vibration was noticed due to direct drive of blower. The heavy vibration caused damage to bearing, which led to improper sucking. The duct did not cover the entire area. The capacity of the blower was less. (100 m^3/hr).

The Corrective action taken to avoid improper monomer suction was as follows.

The capacity of the blower was increased. The material of the impeller was changed to Stainless Steel (SS Impeller).The blower drive was modified to belt drive. On the casing a sampling valve was provided for draining the deposited monomers in the blower casing.

Fig 6: Direct Driven MS Body/ Impeller monomer suction blower

Fig. 7: Belt Driven SS Body/Impeller monomer suction blower

(iii) Polymer Lump Coated On the Strands Guide Roller

The Polymer filaments come out from the Spinneret was quenched in the cooling vat. The filaments of polymer were guided by a roller. Due to Static load and rotating of roller into the chilled water causes the water might enter into the roller. Water entered into the roller might not come out due to closed surface of roller. The weight of the roller acts vertically downwards and disturbs the free flow of strands into the cutter.

Fig 8: SS 304 roller with closed surface **Fig 9: Al roller with holes**

The corrective action taken to avoid Polymer lump coated over the strands guide roller was as follows. The Strand guide roller material changed from SS304 to Aluminum which was a light weight one. The Aluminium roller was coated with chromium to avoid monomer coating over the roller. Small holes were provided over the side of the roller for balancing of roller which is immersed in water.

(iv) Polymer Lump Enter Into The Cutter

Polymer small lump and joint strands were fed in the cooling vat. Strands flow disturbed from spinner head. Due to pressure difference joint strands come out. Lump and joint strands together entered into the cutter and made cutter stoppage. Joint strands and lump catcher comb guide provided for the segregation of strands before it enters into the cutter. This eliminated the polymer lump entered into the cutter.

Fig 10: Joint strand / lump catcher

(v) Improper Strands Feeding into the Cutter

While running the strands jump was noticed due to tension. Twisted strands entered into the cutter. Strands are not equally fed into the cutter.

Fig. 11: Stationary strands Guide Fig. 12: Rotating Multi-Groove Strands Guide roller

To overcome the joint strands jumping and twisting, a rotating multi groove strands guide roller was provided.

(vi) Cutter Striper Lever Gap Very High

Cutter area miscut generation was high. Polymer strands got twisted. Polymer strands entered into the lever gap. Cutter strip lever gap was very high as per design. A Modified lever is fixed that ensured gap in the range of maximum 1.5 mm and did not allow miscut chip.

Fig. 13: Modified lever plate

Tangible and Intangible Benefits

The scrap generation was reduced was approximately equal to Rs 12, 09,000/- per annum.1 kg of Nylon cost = Rs.210,

Generated scrap during one miscut incident was approximately equal to 60 kg per incident.

In a month at average of 8 incidents were noticed. Therefore Saving by avoiding waste is given by,

Saving for 12 months in Rs = Rs 210x60x8x12= Rs 12,09,600

Roller purchase of Rs 10500/-(due to damaging) is eliminated by purchasing lightweight Aluminium roller of Rs. 3000. Production is increased –from 32 MT to 36MT/Annum. Quality of the product could be

maintained as intermittent disturbances due to stoppage are eliminated. Reduction in human fatigue, Satisfaction with respect to enhanced working, and improvements in communication skills were realized.

5. Conclusion

Granulation process improvement was made. Production was increased by reduction in waste. The quality of the product was improved. The problem of Miscut generation was eliminated by providing a new light weight Aluminium roller with chromium plating, lump separator, new modified stripper plate and rotating multi groove strands guide roller. This avoided line choking and pump tripping. By using modified lever the gap was made in the range of maximum 1.5 mm and did not allow any miscut chips into the rotary cutter. Enhanced working provided increase in operator morale and reduction in Customer complaints led to Customer satisfaction.

References

1. Allen, E. and Brady, R. (1997), "Total quality management, organisational commitment, perceived organisational support and intraorganisational communication", Management Communication Quarterly, Vol. 10 No. 3, pp. 316-41
2. Beer, M. (2003), "Why total quality management programs do not persist: the role of management quality and implications for leading a TQM transformation", DecisionSciences, Vol. 34 No. 4, pp. 623-43.
3. Brah, S.A., Lee, S.L. and Rao, B.M. (2002), "Relationship between TQM and performance of Singapore companies", International Journal of Quality & Reliability Management, Vol. 19 No. 4, pp. 356-79
4. Chenhall, R. (1997), "Reliance on manufacturing performance measures, total quality management and organisational performance", Management Accounting Research, Vol. 8 No. 2, pp. 187-206
5. Dias, V. H., Pinto, J. F., Identification of the most relevant factors that affect and reflect the Quality of Granules by Application of canonical and cluster Analysis. J. Pharm. Sci., 2002, 19 (1), 273 – 281.
6. Dunk, A.S. (1993), "The effects of job-related tensions on managerial performance in participative budgetary settings", Accounting, Organizations and Society, Vol. 18 No. 7/8, pp. 575-85.
7. Fok, L., Hartman, S., Patti, A. and Razek, J. (2000), "Human factors affecting the acceptance of total quality management", International Journal of Quality & Reliability Management, Vol. 17 No. 7, pp. 714-29.
8. Govindarajan, V. and Gupta, S. (1985), "Linking control systems to business unit strategy: impact on performance", Accounting, Organisations and Society, Vol. 10 No. 1, pp. 51-66
9. Hendricks, K.B. and Singhal, V.R. (2001), "Firm characteristics, total quality management and financial performance", Journal of Operations Management, Vol. 19, pp. 269-85
10. Iveson, S.M; Lister, J.D; Hapgood, K.P, "Nucleation, growth and breakage phenomena in agitated Wet granulation processes: A review" Powder Technology, vol. 117, pp 3-39, (2001).
11. M.Z.Abdel – Wahhab, The behavior of fluidization as a Granulation Technique for Solids, Plenary papers complied by Sarat, Recent Advancess in Chemical Engg., pp 113-120 (1996)
12. Scholz, A., Abrahamson, B., Diebold, S. M., Kostewicz, E., Polentaratti, B. I., Ungell, A. L., Dressmann, J. B., Influence of hydrodynamics and particle size on the absorption of felodipine in Labradors. Pharm. Res., 2002, 19(1), 42 – 46.
13. Stefan, H., Schaafsma and Nico, W.F..Kossen; Marinus T. Mos., Levy Blauw and Alex C. Hoffman, , AICh E Journal, vol. 45, no. 6, pp. 1202-1210, (1990).
14. Wells, J. I., Aulton, M. E., Preformulation, In: Aulton, M. E. (ed), Pharmaceutics- the Science of Dosage Form Design, Churchill Livingstone, Edinburgh, 1993, pp.223-253.
15. Lakshmi Sankar S, Manoj kumar A and Joel henry K,"A case study on Scrap reduction of Transfer pump in common rail Fuel pump", Applied Mechanics and Materials Vols. 766-767 (2015) pp 1168-1173.
16. S. Murugavel, M. Malathi, Morphological and electrical conductivity properties of unsubstituted polythiophene nanostructures prepared by surfactant-assisted chemical polymerization method, International Journal of ChemTech Research CODEN (USA): IJCRGG ISSN: 0974-4290 Vol.9, No.03 pp 616-622, 2016.

17. G. Mageshwaran, Jeya Jeevahan, G.Britto Joseph, Teladevalapalli Narasimham, Lubrication Improvement in Internal Combustion Engines, International Journal of ChemTech Research CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555 Vol.9, No.05 pp 705-711, 2016.
18. Koteswara Reddy G, Kiran Yarrakula, Analysis of Accidents in Chemical Process Industries in the period 1998-2015, International Journal of ChemTech Research CODEN (USA): IJCRGG ISSN: 0974-4290 Vol.9, No.04 pp 177-191, 2016.
19. Deepak Pokharkar, Varsha Jadhav, Sachin Gholve and Vilasrao Kadam, Six Sigma: Golden Opportunity for Pharmaceutical Industry, International Journal of PharmTech Research, Vol.2, No.2, pp 1160-1164, April-June 2010.
20. G.Himabindu, Process Integration Route For Water Conservation In Industrial Plants, International Journal of ChemTech Research, Vol.5, No.3, pp 1124-1128, April-June 2013.
21. S.Gobinath, D.Elangovan, S.Dharmalingam, Lean Manufacturing Issues and Challenges in Manufacturing Process– A Review, International Journal of ChemTech Research, Vol.8, No.1, pp 44-51, 2015.
22. Sandip R. Baviskar*, Snehal H. Patil, Solid Phase transformation considerations during process development and manufacture of solid oral dosage forms – A Review, International Journal of PharmTech Research, Vol.6, No.7, pp 1963-1969, November 2014.
23. Sugapriya S, Lakshmi S, Senthilkumaran C.K Effect of Thermal Growth on Strutural And optical Properties, International Journal of ChemTech Research, Vol.8, No.6, pp 303-308, 2015.
24. Anandh.S*, K.Bogeshwaran, G.N.Manikandan, P.Jamuna, S.Sandhya, Failure Analysis - Watanabe Model, International Journal of ChemTech Research, Vol.6, No.9, pp 4333-4336, September 2014.
25. Palani Shanmugasundaram, Prathyusha Vikram, Total Quality Management, Process Analytical Technology, five basic principles and Pharmaceutical Industry: an overview. International Journal of PharmTech Research, Vol.8, No.6, pp 178-185, 2015.

*****