Spare Parts Stock rationalization for rotating equipment based on companywide interchangeability; an inventory cost reduction strategic technique-Perspective to Petroleum & fertilizer industries across India & Gulf

Sandeep Sharda
Faculty & Research Scholar, Mechanical Dept. (Program of Management Studies)
Rajasthan Technical University, Rawatbhata Road- Akelgarh, Kota- Rajasthan-324009(India)
sharda201067@gmail.com & ssharda.phd@rtu.ac.in

Prof. Sanjeev Mishra
Professor& Head, University Teaching Department of Mechanical Engineering, Rajasthan Technical University, Rawatbhata Road, Akelgarh, Kota- Rajasthan-324009 (India)
smishra@rtu.ac.in

Abstract

Spare parts stock control is crucial to inventory research. Current practice of spare parts stocking is based on individual plant's equipment. Identical spare parts could be rationalized based on companywide having different plants. It requires a dedicated review through drawings and documents of manufacturer's data for interchangeability. Primary objective is to contribute in inventory cost reduction on the basis of rationalization of stock levels for identical spare parts. Identical spares rarely require simultaneously for maintenance in relevant equipment among different plants. The methodology is based on three stages which include gathered opinion through questionnaire for companywide stocking policy from above industries in India and Gulf. Subsequently followed by conceptual methodology of companywide codification includes reviewing through an adequate Spare parts Interchangeability record (SPIR) formatted document. The final stage is validation which is supported with case studies based on secondary data collected from one of SABIC affiliate, KSA and other from Fertilizer industry at India. The approach of companywide is applicable for Petroleum & fertilizer industries Globally since having more than two plants at a business unit like Reliance & KRIBCO at India & SABIC & ADNOC affiliates at Saudi Arabia and UAE respectively.

Key words- Companywide codification, Spare parts Descriptive Statistics and Interchangeability

I. INTRODUCTION

Spare parts are significant resources for continuous equipment availability [1]. Keeping in view the equipment availability inventory management system needs to review with strategic policy and to reduce zero stock out condition with continuous production and minimum investment on spare parts administrative cost [2]. It is envisaged that spare parts inventory need should be treated as different from work in process (WIP) and other finished product inventories in stock control approaches. [3]. Handbook of Petroleum Processing indicates that the total cost of spare parts should be between 2-3% of project cost of petrochemical plants companywide. [4]. Practically, due to lack of systematic review of spare parts interchangeability and historic base calculation during first time order and subsequently the stock levels cost of spare parts is always more and there is scope of using different methods and techniques for reducing stock cost of spare parts.

The average cost of a petroleum complex is about $10.0 billion. Which include two ethylene plant, propylene Plant and related offsite & utilities based on U.S. Ethylene construction cost update (2015) [5].

Based on the current practice the Stock level cost of Spare Parts 2-4% of the companywide plants cost hence total Cost of Spare Parts at 2% level is 200 Million USD and at 4% level is 400 Million USD respectively.

It indicated that there is a large cost of stock variation from 2 % to 4% and it needs a rigorous exercise to control total stock cost of spare parts to keep it minimum level and at the same time ensure the system of plant production not to held up because due to stock out condition.

2. Objective

This strategic policy & procedure empirically investigates for the reduction of spare parts inventory on current practices perspective to Indian and Gulf petroleum and fertilizer. The contribution in the present paper is significant in terms of seven hypotheses formulation in which first two hypothesis are related to need for spare parts stock control pertains to first objective and later five are related to formulation for reducing stock level by strategic method of companywide spare parts interchangeability policy keeping same service level which pertains to second objective.

2.1 To explore and analyze, there is need for study for spare parts inventory stock and cost control current methods and improvement scope perspective to fertilizer and petroleum Industries

2.2 Study & analysis that proposed strategic companywide stocking policy and procedure using Spare parts interchangeability record (SPIR) for spare parts items for rotating equipment reduces stock levels and sustainability with the same service level

3. Related literature review

Different techniques are suggested by authors in the following papers which are primarily for the control and management of spare parts and secondary aspect for cost reduction.

3.1 Spare Parts Classification Review [6]

This is the approach in which items are classified based on ABC analysis. However, other criteria simultaneously may also play a significant role in classifying stock keeping units such as lead time & rate of consumption, etc

3.2 Based on the EOQ analysis [7] & [8]

From the original work by Harris (1913) on Economic Order Quantity (EOQ), different inventory models have been developed; including the following classic models:

3.3 Continuous Review (R, Q): [9]

In this model the inventory is continuously monitored and, when the level reached the order point “R” a lot size of “Q” (economic order quantity) is placed;

3.4 Periodic Review (T, S): [9]

In this case, orders are placed in fixed interval of time “T”, in an amount to replace the inventory position to the maximum Inventory level “S”

3.5 Base Stock (B): [9]

At each withdrawal from inventory, an order of the same amount is made for replacing the baseline, keeping the inventory position constant and equal to "B".

3.6 Criticality analysis [10]

A systematic technique is used here to evaluate equipment Criticality based on the evaluation process into a three-level hierarchy. The definition of failure of consequences is based on the level of loss in terms of production, system down time, plant safety and down time loss. The equipment failure could be due to spare part failure or malfunction. The consequences have been amplify and delayed further on non availability of the specific spare part in stock, and reflect major concerns of the organization.

3.7 Decision to stock or not to stock [11]

In This approach to reduce spare parts inventory levels, a critical revision of the need is carried out by modeling on which to decide upon to maintain or not.

3.8 Paradox for offshore spare parts management [12]

Maintenance personnel from individual plant would like to have their own stock of spare parts for the equipment which is having interchangeability among spare parts of other plant equipment. They believe availability of spare parts for plant wise will ensure safer practice. Actually, it is not a good decision to have more quantity of same spare parts in the warehouse.

4. Research hypotheses development

Based on the literature review and objective derived from research work there are six hypotheses respectively.
It has been practically analyzed that complex wide codification keeping in view of interchangeability is one of the technique for achievement of reduction of stock levels of spare parts, duplication of codification and finally total Cost reduction of spare parts inventory.
Table 1.Hypothesis based on objectives

Hypothesis	Hypothesis
H01.1	There is no significant relation between the stock of spare parts and number of equipment in fertilizer & Petroleum industries
Ha1.1	There is significant relation between the stock of spare parts and number of equipment in fertilizer & Petroleum industries
H01.2	There is no significant difference between of stock of mechanical spare parts and stock of other spare parts in fertilizer & Petroleum industries
Ha1.2	There is significant difference between of stock of mechanical spare parts and stock of other spare parts in fertilizer & Petroleum industries
H01.3	There is no significant relationship between spare parts companywide interchangeability and rationalization of stock of spare parts at the same service level
Ha1.3	There is a significant relationship between spare parts companywide interchangeability and rationalization of stock of spare parts at the same service level
H01.4	There is a significant relationship in identification of interchangeable parts and SAP

	MM module platform
Ha1.4	There is no significant relationship in identification of interchangeable parts and SAP MM module platform
H01.5	There is no significant impact of using SPIR by LSTK or OEM's for correct identification of companywide interchangeable part during project stage and / or first time ordering of spares
Ha1.5	There is significant impact of using SPIR by LSTK or OEM's for correct identification of companywide interchangeable part during project stage and / or first time ordering of spares
H01.6	The use of thumb rule and past experience for replenishment of spare parts is a significant way instead of adequate formula based on failure frequency in avoiding the overstocking and under stocking of spare parts
Ha1.6	The use of thumb rule and past experience for replenishment of spare parts is not a significant way instead of adequate formula based on failure frequency in avoiding the overstocking and under stocking of spare parts
H01.7	There is no significant consideration for review of left out spare parts for equipment which are not covered in recommended list of spare by manufacturer / supplier of equipment
Ha1.7	There is significant consideration for review of left out spare parts for equipment which are not covered in recommended list of spare by manufacturer / supplier of equipment

5. Methodology

Technique of companywide codification is based on descriptive study. The complete research process covers the three stages. In the first stage a survey questionnaire was developed in two section to measure the need and scope of spare parts stock control aspect and feasibility of companywide strategic technique to ascertain that there is scope for reducing spares inventory stock and duplication keeping same service level. In the second stage a frame work with conceptual data was derived for developing companywide codification using spare parts interchangeability record (SPIR) and a comparison of plant wide and companywide codification for sustainable practices. In the third stage the companywide interchangeability is validated by two case studies of secondary data for spares of rotating equipment (centrifugal pumps) pertaining to different plants of same business unit (companywide).These data pertains to one of SABIC affiliate and a Indian fertilizer plant respectively and performance outcomes perspective to fertilizer and petroleum industries across India and Gulf sector. Collected data has been analyzed with the help of excel and statistical tools and techniques by using SPSS 20 version software. Details are provided in following sub-sections.

5.1 Instrument development and data collection

The selection of sample and sample size are an extremely important for achieving adequate and superior data by questionnaire survey. The target population of this research was made up of Petroleum and fertilizer industries in India and Gulf. Questionnaire pretesting was made by taking feedback from various experts (two academicians and four managers of maintenance planning and stores in charge). Pretesting helped us to make improvement in the questionnaire. In present study, judgmental and random sampling has been used to collect the data from Indian and Gulf industries. For data collection, questionnaire was administered in two steps: judgmental sampling through email to various organizations of India and gulf to the concerned supervisory level managers /engineers of maintenance as well as stores personnel were enquired and 55 valid responses were received in first stage of three months. Further by collection of email address and mobile number of other organizations in stage II, a random survey (through e-mails) has been used and valid 15 more responses were received in another three months

after reminder emails and war sap follow-up. It also tests the random sampling bias. After a number of emails reminders, 70 completed questionnaires were received in a year.

The details of the number of industries and data received are summarized in below table.

Table 2 Summary of Fertilizers and Petroleum Industries and response received- Indian and Gulf [13 & 14]

Country	Fertilizer	Petroleum	Total Industries	Expected response of total population (A)	Response Received Industries (B)	Response Received personnel (different levels) (C)	Response Rate based on total population (D)= C/Ax 100
India	30	16	46	96	17	39	40%
Gulf	4	31	35	70	16	34	48%
Total	34	47	71	142	31	**73 (Valid 70)**	**49%**

Note: The number details of industries are based on web directory references

5.2 Data analysis techniques

Based on illustrate methodology in the first stage the need and scope of companywide interchangeability survey by questionnaire was made to collect the data and the collected data was analyzed using statistical software – SPSS Version 20.0. Reliability, descriptive study followed by factor analysis and hypothesis testing was carried out to ascertain the above objectives.

5.3 Data analysis and results

Population of the study is 71 organizations cumulative at India and Gulf as per web reference of directory. Response of personnel from maintenance as well as stores were expected minimum as total population were 142 one from each respectively. 70 valid and usable responses were received from the expected of total population 142. This gives an overall response rate of 49%. A response rate of 20% or above has been considered appropriate for positive assessment of questionnaire based study (Malhotra and Grover, 1998)

5.4 Profile of respondents and sample organizations

Responded from various organizations are at senior level of management 40%, middle management 30% and lower management of 30% with an experience level of more than 15 years, between 10 to 15 years and below 10 years respectively belonging to maintenance, planning and stores.

6. Analysis of questionnaire data

The questionnaire was designed in to two research groups. The first group as named **"Macro inventory strategic management model"** to concur the first objective that there is need of spare parts inventory strategic control consisting of two null hypotheses H01.1 & H01.2 with a set of six questions respectively. Similarly the second group as named **"Micro inventory strategic management model"** to concur the second objective that there is scope of companywide interchangeability for spare parts along with set of sub objectives consisting of five null hypothesis H01.3,H01.4,H01.5,H01.6 & H01.7 with a different set of questions. The analysis follows the reliability testing of each group followed by non parametric test carried out based on indicative mode and skewness in descriptive study using SPSS version20. Macro inventory strategic model covers the study of spares parts inventory at level of complex basis as total numbers of equipment, spares and inventory total cost and spares respectively. Micro inventory strategic management model covers the study of all required spares cover of equipment level and total cost of spares on each equipment also to study companywide interchangeability of spares for reducing inventory levels and cost keeping same service level based on consumption and lead time of procurement.

6.1 Reliability Testing – Macro inventory strategic management Model

Internal reliability of survey questionnaire is checked using Cronbach's alpha value. The value of Cronbach's alpha is 0.872 as per table 3 on testing items through SPSS 20, which is more than the minimum acceptable value i.e. 0.6. Also the value of cronbach alpha is more than 0.6 against the individual item is deleted. Hence the reliability of those set of questions pertaining to the Macro inventory strategic management model which ensures internal consistency/reliability of all twelve constructs. Also the mean square value within items is very high and Chi square value 579.775 is more than the calculated table value. Hence items are having importance under the above group and statically sound as per table 4.

Table 3 "Macro inventory strategic management"- Need of Spares parts stock control

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.872	.869	12

Table 4. ANOVA with Friedman's Test

		Sum of Squares	df	Mean Square	Friedman's Chi-Square	Sig
Between People		190.029	69	2.754		
Within People	Between Items	817.081[a]	11	74.280	579.775	.000
	Residual	268.086	759	.353		
	Total	1085.167	770	1.409		
Total		1275.195	839	1.520		

6.2 Hypothesis Testing – Macro inventory strategic management Model

The Below table no 5 & 6 indicates the following results of non parametric testing of null hypothesis number H01.1& H01.2 rejects, which covers all six questions and indicates that there is a significant relation between the stock of spare parts and number of equipment in fertilizer & Petroleum industries and accept an alternative hypothesis Ha1.1 & Ha1.2 which is part of macro inventory strategic management model.

Table 5 Non parametric test results of null hypothesis - H01.1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of How many plants are there in the unit (companywide) is normal with mean 3.63 and standard deviation 0.82.	One-Sample Kolmogorov-Smirnov Test	.000	Reject the null hypothesis.
2	The distribution of tagged equipment combining all plants (companywide) is normal with mean 3.86 and standard deviation 0.35.	One-Sample Kolmogorov-Smirnov Test	.000	Reject the null hypothesis.
3	The distribution of percentage wise average yearly total cost of inventory in is normal with mean 1.99 and standard deviation 0.77.	One-Sample Kolmogorov-Smirnov Test	.000	Reject the null hypothesis.
4	The distribution of Average number of total inventory items in the mainstores on yearly basis is normal with mean 3.34 and standard deviation 0.98.	One-Sample Kolmogorov-Smirnov Test	.000	Reject the null hypothesis.
5	The distribution of what is total cost of inventory items in the stores on yearly basis in the main stores? is normal with mean 3.79 and standard deviation 0.81.	One-Sample Kolmogorov-Smirnov Test	.000	Reject the null hypothesis.
6	The distribution of average number of total Spare Partsinventory items in the main stores on yearly is normal with mean 3.00 and standard deviation 0.98.	One-Sample Kolmogorov-Smirnov Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 6 Non parametric test results of null hypothesis - H01.2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories of frequency of use of spare parts is more in tagged mechanical equipment than electrical & instrumentation equipment? occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
2	The categories of Which types of Equippments fails mostly? occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
3	The categories of what is the average number of total mechanical Spare Parts inventory items in the main stores? occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
4	The categories defined by The number of mechanical spare items issued is more than electrical and instruments on yearly basis from stores? = Strongly Agree and Agree occur with probabilities 0.5 and 0.5.	One-Sample Binomial Test	.003	Reject the null hypothesis.
5	The categories defined by The research work as pilot study is to be focused on mechanical spare parts and related stock items to reduce inventory cost = Strongly Agree and Agree occur with probabilities 0.5 and 0.5.	One-Sample Binomial Test	.550	Retain the null hypothesis.
6	The distribution of Tentative number of tagged Mechanical equipment in all plants is normal with mean 3.86 and standard deviation 0.35.	One-Sample Kolmogorov-Smirnov Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

6.3 Reliability testing & Descriptive statics – Micro inventory strategic management Model

Internal reliability of survey questionnaire is checked using Cronbach's alpha value. The value of Cronbach's alpha is 0.795 as per table 7 on testing items through SPSS 20, which is more than the minimum acceptable value i.e. 0.6. Also the value of cronbach alpha is more than 0.6 against the individual item is deleted. Hence the reliability of those set of questions pertaining to the Micro inventory strategic management model, ensures internal consistency /reliability of all ten constructs. Based on table 8, the parameters value of descriptive study indicated that values are more skewed towards right side hence an nonparametric individual sample test could be carried out to test the hypothesis.

Table 7 "Micro inventory strategic management"- Reliability statics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.795	.838	10

Table 8 "Micro inventory strategic management"- Descriptive statics

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
19.86	15.342	3.917	10

6.4 Hypothesis Testing – Micro inventory strategic management Model- five group of hypothesis

The Below table no 9, indicates that null hypothesis number H01.3 is rejected by on three questions and indicates that There is a significant relationship between spare parts companywide interchangeability and rationalization of stock of spare parts at the same service level and accept an alternative hypothesis Ha1.3, which is part of micro inventory strategic management model.

Table 9 Non parametric test results of null hypothesis - H01.3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories defined by Spare parts stock levels could be rationalised based on companywide interchangeability policy, since those all equipment (having interchangeable spare parts) would not fail simultaneously = Strongly Agree and Agree occur with probabilities 0.5 and 0.5.	One-Sample Binomial Test	.001	Reject the null hypothesis.
2	The categories of Do your company used such Spare Parts interchangeability form (SPIR) which could provide an insight to rationalize the stock levels occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
3	The categories of A pilot study which is based on companywide interchangeability of spare parts among equipment of different plant will reduce the duplication and indicate the stock line number occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

The Below table no 10, indicates that null hypothesis number H01.4 is rejected by on a questions and indicates that There is no significant relationship in identification of interchangeable parts and SAP MM module platform and accept an alternative hypothesis Ha1.4, which is part of micro inventory strategic management model.

Table 10 Non parametric test results of null hypothesis - H01.4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories defined by SAP-MM module would not indicate interchangeability for spare parts if it is not established prior to first creation in the SAP MM system = Test Strongly Agree and Agree occur with probabilities 0.5 and 0.5.	One-Sample Binomial	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

The Below table no 11, indicates that null hypothesis number H01.5 is rejected by on two questions and indicates that There is significant impact of using SPIR by LSTK or OEM's for correct identification of companywide interchangeable part during project stage and / or first time ordering of spares and accept an alternative hypothesis Ha1.5, which is part of micro inventory strategic management model.

Table 11 Non parametric test results of null hypothesis - H01.5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories defined by To codify items based on companywide interchangeability,it is to be identified since at project stage with SPIR = Strongly Agree and Agree occur with probabilities 0.5 and 0.5.	One-Sample Binomial Test	.120	Retain the null hypothesis.
2	The categories of Do the manufacturer / supplier of equipment provide adequetely the companywide interchangability of spareparts amoung all plant during project stage to nullyfy duplication of codification and adequate stock of same spare parts? occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

The Below table no 12, indicates that null hypothesis number H01.6 is rejected by on three questions and indicates that use of thumb rule and past experience for replenishment of spare parts is not a significant way instead of adequate formula based on failure frequency in avoiding the overstocking and under stocking of spare parts and accept an alternative hypothesis Ha1.6, which is part of micro inventory strategic management model.

Table 12 Non parametric test results of null hypothesis - H01.6

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories of The Stock level quantity for spare parts during indenting for first time or refill is decided? occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
2	The categories of Do you have formula for calculating spare stock quantity which is based on frequency of failure especially for rotating equipment like pumps, compressors? occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
3	The categories of The overstocking and understoking of spare parts is due to not having an adequate formula occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

The Below table no 13, indicates that null hypothesis number H01.7 is rejected by on three questions and indicates that There is significant consideration for review of left out spare parts for equipment which are not covered in recommended list of spare by manufacturer / supplier of equipment and accept an alternative hypothesis Ha1.7, which is part of micro inventory strategic management model.

Table 13 Non parametric test results of null hypothesis - H01.7

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories defined by The spare parts which are not covered in the recommended list of equipment supplier, should be reviewed by owners SP Team , since in the beginning so that in time order / stock will be available of such parts = Strongly Agree and Agree occur with probabilities 0.5 and 0.5.	One-Sample Binomial Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

7. Conceptual procedure for creating companywide item codification

With current practice the structure of plant wise spare parts codification structure is:

Plant code
↳
Parent group / family group code
↳
Sub-group code
↳
Item code

7.1 Codification Example:

Petrochemical / Petroleum downstream complex in which there are several plants like Ethylene, Ethylene Glycol, Polypropylene and Polyethylene plants. An illustration of plant wise codification for mechanical seal which is a subunit and spare part for a centrifugal pump is defined as plant code as Code for ethylene plant E, code for centrifugal pump is P, code for service is 10, code for sub group is 1 and item code for mechanical seal is 10.

. The complete code for mechanical seal is defined as **EP10110** and similarly for the Ethylene glycol plant in which first prefix as plant code will be different and it is G and the finally item code for mechanical seal will be **GP10210.**

It is to note that both mechanical seals are same and stocked in two codes due to codification system and require minimum one complete seal is to be stocked per plant basis. Approximate average cost of complete cartridge mechanical seal of size 2.875'' is USD 8000/-(John Crane make).

This stock cost can be reduced by codify spare parts based on companywide codification policy as a revised and proposed structure.

Revised and proposed codification structure is as below

Company code

↳

Manufacturer code (E.g: John Crane: interchageabilty code)

↳

Equipment family code / Subgroup code

↳

Item

Code for company: C, Manufacturer code: J, Equipment family Code for Centrifugal pump: P1, Sub group code for mechanical seal: 01& Item code for mechanical seal: 10, Hence Revised Code for complete mechanical seal: **CJP10110.**Items under this structure of code will be Stocked companywide and will be available for both plants. It will reduce the stock quantity for mechanical seal since have interchangeable. This concept could be used for codification for all other mechanical seal its parts and also other parts of centrifugal pump and rotating equipment.

8. Schematic diagram to show the centrifugal pump & mechanical seal parts

To have a ready reference for the mechanical seal parts details, a sectional drawing of mechanical seal is shown below and also sectional drawing of centrifugal pump to indicate location of mechanical seal and other parts of pump.

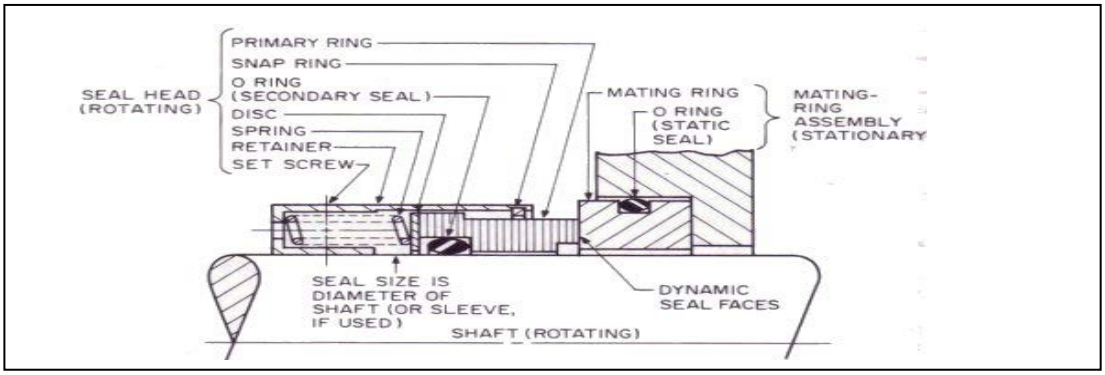

Figure1. Sectional View of Mechanical seal on shaft [15]

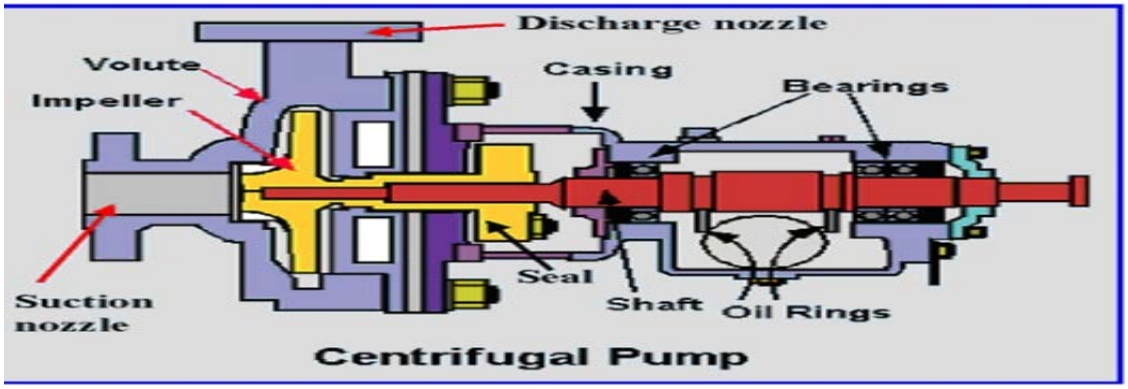

Figure 2 Schematic View of Mechanical seal on pump [16]

9. Practical case study - SABIC Petrochemical plant in KSA

An exercise for companywide interchangeability was carried out by researcher during his working with one of the SABIC affiliate. This is for the mechanical seal which were of John Crane manufacturer and procured during project stage for the Ethylene plant. Later a review and analysis was carried out for companywide interchangeability with the mechanical seals used in the pumps for Ethylene Glycol, Utility & offsite plants which are in the same campus.

The seals for other plants were also procured separately and separate item code was generated. The following table number 7 indicating the companywide interchangeability for mechanical seal includes the following column, Column number 2 shows ethylene plant Pump in which Mechanical seals installed, column number 3 Indicate the item codes of mechanical seal of that pumps, column number 4 indicate service of pump, column number 5 shows the quantity of stock and column number 6 indicate pumps for other plants in which these mechanical seal are interchangeable. Later the stock levels of these mechanical seals were rationalized and one item code was kept active and this saves a lot of inventory cost at later stage and carried out for all mechanical seals and other items.

Table 14 Case Study for SABIC Affiliates- Interchange ability- Company wide

Mechanical Seal - Review for companywide interchangeability for ethylene plant pumps					Date: 12-08-04
Column No 1	Column No 2	Column No 3	Column No 4	Column No 5	Column No 6
SR. NO.	PUMP TAG # (ethylene plant)	SSL # (item code- Mechanical Seal)	Service of pump	Pumps installed Qty.	Mechanical Seal Interchangeable with following pumps of other plants
1	P1104A, B Process Side.	559442	DMDS Injection Pump	2	Interchangeable with P-1211A/B & P-1407 both side
2	P-1104 A, B	559443	DMDS Injection Pump	2	Interchangeable with P-1211A/B & P-1407 both side

	Process Side.				
3	P-1142A,B	560823	Process Condensate Pump	2	Interchangeable with P-1750
4	P-1143A.B	576136	Residue Pumps	2	Interchangeable with P-1147 A/B
5	P-1145	560824	Quench Water Return Pump	1	Interchangeable with P-1148 , P-1205 A/B & P-1760 A/B
6	P-1146	559621	Quench Water Tank Oil Pump	1	Interchangeable with P-1218
7	P-1147A,B	576136	Residue Transfer Pump	2	interchangeable with P-1143 A/B
8	P-1148	560824	Residue Drum Recycle Pump	1	Interchangeable with P-1145, P-1205 A/B & P-1760 A/B
9	P-1202A,B	560825	Weak Caustic Pump	2	Interchangeable with P1203 , P-1204 A/B & P-1217 A/B
10	P-1203	560825	Strong Caustic Pump	1	Interchangeable with P1202A/B, P-1204 A/B & P-1217 A/B

Table 15 Case Study for Fertilizer industry from India- Interchange ability- Company wide

SR NO	Spare of Pump Tag # AGA 955	Interchangeable with Spare of Pump Tag # AGA 953	Remarks
1	Impeller	Impeller – could be	Could be procure of max diameter since material and type are same, however codify and kept in different item code as 5521730002 & 5521700002 respectively
2	Impeller wear ring	Impeller wear ring	kept in different item code are 552173003 & 5521700003

10. Conclusion

Based on questionnaire survey, hypothesis design and testing , it emphasized that the companywide interchangeability strategic policy for spare parts inventory in the fertilizer and petroleum industries could rationalized the stock levels and reduce the duplication, long time inventory holding and reduces the average yearly spares inventory cost respectively. It also further reflected in the above case study and proves that the formulated research objectives could be achieved by macro and micro level strategic policy models and procedure to get advantage of companywide interchangeability of spare among different plants of same business unit. It has also indicated that ERP packages like SAP R/3 materials management module is data based codification tool and could not reveal the interchangeability of parts once it is codify in different item codes. Hence companywide codification should be generated using structured E SPIR and later these item codes should be recorded in the ERP system.

11 Future Scope

The study could be carried out for other items like for electrical as well as instruments spare items for companywide interchangeability.

12. Acknowledgements

The authors of this paper are obliged to SABIC affiliates, KSA and fertilizer industry India for including a case study.

10. References

[1] Bedi, Krishna, *Production and operations Management*, 2nd Edition, Oxford University press, 2007, pp 316-374.

[2] Chitale, A., K., Gupta, R., C., Materials *Management*, Text and Cases, 2nd Edition, Prentice Hall , India, 2007, pp,207-210.

[3] Muller, Max, *Essentials of inventory management*, 10th Edition, American Management Association, 2003, pp 115-143.

[4] J., S., Jones, David, P., Peter, *Handbook of Petroleum Processing*, Springer, 2nd Edition, 2006, Ch.17.2 Economic Analysis - pg no 858.

[5] Prospects, US Ethylene Complex Construction Costs, Petrochemical update, June 2015, Available: http://www.petchem-update.com/petrochemicals-construction/pdf/Report2015Prospectus.pdf

[6] Eman, M., Wahba,, Noha, M., Galal, S., Khaled, and E., Kilany, Framework for Spare Inventory Management, *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, Vol.6, No8, 2012.

[7] Roberto, do, Regoa, José, Marco Aurélio de Mesquitab, Spare parts inventory control: a literature review, Produção, Vol.21, No., 4, out. /dez. , p. 656-666, 2008.

[8] Noor, Ajian, mohd., lair1, Faqih, anas muhiddin2, et al., The spare part inventory management system (spims) for the Profound heritage SDN BHD, a case study on the eoq technique, IJRET, Vol. 2, Issue 1, pp 7-14, Jan. 2014.

[9] Eric Porrasa, Rommert Dekkerb, An inventory control system for spare parts at a refinery: An empirical comparison of different reorder point methods, EJOR, Jan. 200.

[10] René Botter and Leonard Fortuin, Stocking strategy for service parts;a case study, Report of a special assignment, Eindhoven University of Technology, Dutch, Sep.1998.

[11] Vankata Ranga Sri Rama, Optimal Decision making for spare parts management with time varing demand, M. Engg., Thesis,Batchlor of Engg, .Andhra Univ., India, Dec.2007.

[12] Zhigao Shangguan, Spare Parts Management in Bohai Bay, M. Engg. Thesis, Univ. of Stavanger

[13] Directory of fertilizer industries in India, 2017,

Available : www.fert.nic.in

[14] Directory of petroleum industries in Gulf, 2016,

Available: http://gpca.org.ae/congulf/complete-directory/

[15] Sectional drawing, Mechanical Seal, 2006

Available: www.google.co.in/search?q=sectional+drawing+mechanical+seal&biw

[16] Pump Schematic view, 2012

Available: https://www.google.co.in/search?q=sectional+drawing+centrifugal+pump&espv=

BIOGRAPHY

Sandeep Sharda is a faculty member at Rajasthan Technical University, Rajasthan, India. He is currently working as faculty member and research scholar in the management program, department of mechanical engineering. Also associated as corporate trainer in the core area of Inventory & Project Management since last 10 years. In the past he has served industries of fertilizers & petrochemicals for 15 years in India and Saudi Arabia. He has bagged with performance award constantly from highest authority of organization and simultaneously enriched his working knowledge in the above area. He has done his B. Tech. in Mechanical Engineering from Rajasthan University, India. Master of Business Management from NIBM, Chennai and from Jaipur National University, in stream of materials management and Human resource respectively. Currently doing his PhD in the area of Inventory Management under the supervision of Prof. Sanjeev Mishra. He has published four papers in Journal through the conference. He is member of Indian society of Training & Development, Kota Chapter. He has a vision of universities should have well connected with industries in enhancing usable students resource

Prof. Sanjeev Mishra is currently Head of department of Mechanical Engineering at Rajasthan Technical University. He has served for multi facit functional head positions which includes chairman of Board of Studies (BOS), DRC, Management Studies, Convener of Board of Studies, Registrar and coordinator of university admission process of B. Tech., M. Tech, MBA & PhD at Rajasthan Technical University. He has also worked as head of Training & placement cell wherein he has developed various student development cells and provides remarkable performance in campus placement. Published papers in the international journal & conferences in double digit. He has earned his PhD from Indian Institute of Technology, Kanpur, India, Master of engineering from JNV University Jodhpur and B. Tech. (Hons.), Mechanical & MSc (hons.) physics from BITS, Pillani, Rajasthan. His area of interest is Operations Research, Operations Management, Computer Integrated Manufacturing System, Stochastic Modeling, Simulation, Quality Management, Mechatronics and Nanotechnology. Students have done M.Tech. Program in the above under his supervision and also pursuing PhD.