Chapter 1

Introduction

This chapter discusses the relational aspects of Industries, Maintenance and Reliability of equipment with respect to the state-of-the- art practices, methods and models employed towards ensuring process industry. After presenting the literature survey and review on these aspects, author presents the objectives set for this research work. Besides, this chapter briefly outlines the approach used to fulfill the set objectives.

1.1 Introduction

In the 21st century, there has been a tremendous development and phenomenal growth on Industrial front. High technological systems have been replacing the outdated technologies to meet the market demands both in terms of quantity and quality. In today's context, the competitive world demands that industries must be operated at high efficiency levels with an effective utilization of their capacity and resources wherein the major shares of assets are represented by the process industries. Consequently, the process reliability and product reliability aspects are of utmost importance not only to its customers but for industry as well and they can not be looked into isolation.

Industries may be classified into many categories based on their process, product, size, safety etc. Hayes and Wheelwright, (1979) developed a product-process matrix, which highlights these differences as shown in Figure 1.1.

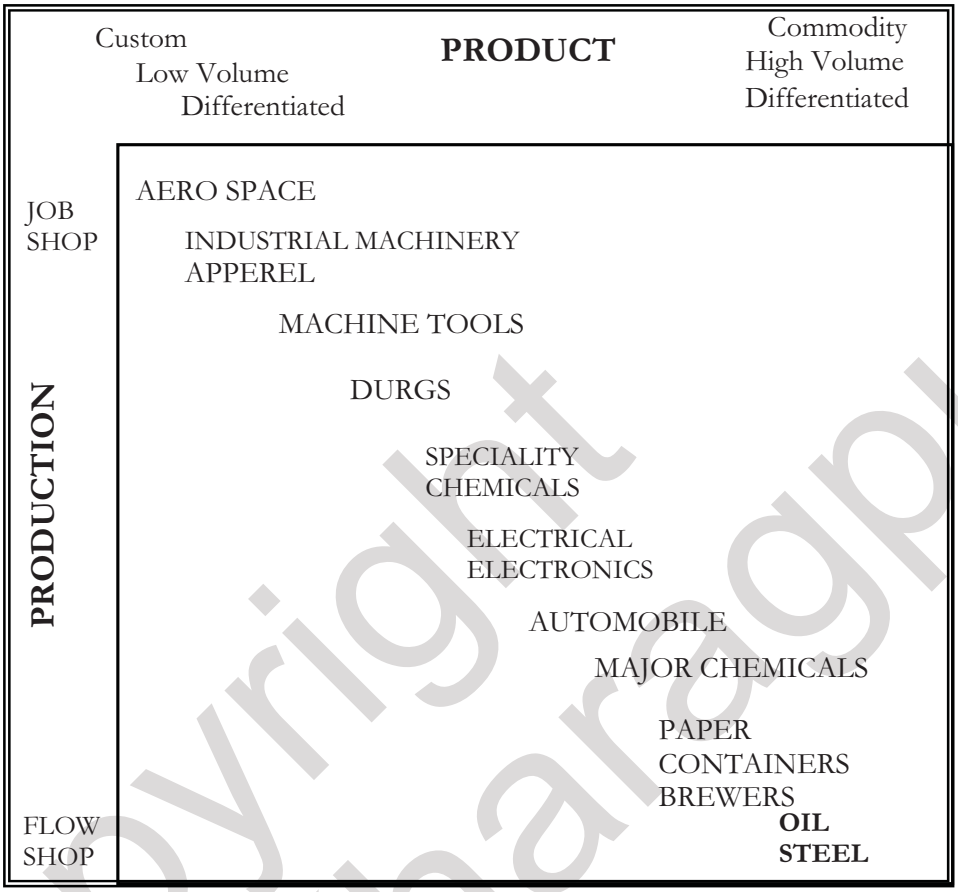

Figure 1.1: Product – Process Matrix

In this regard, American Production and Inventory Control Society (APICS) has defined process industries in 1987 as, *"Process industries are business that add value to material by mixing, separating, forming or chemical reactions. Processes may be either continuous or batch and usually require rigid process control and high capital investment"*. Therefore, the methods, strategies and various techniques required for a process industry widely differ from one type to another type of industries. As industry (Plant) becomes more complex and large, its maintenance management assumes higher importance. Besides, a more automated and high-speed process industries

have resulted in such a complex systems that demand maintenance organization to be a more scientific and methodical. Taylor, (1981) discussed about specific issues relating to the process industries from others and with reference to product mix, process, investment and product flow etc., to impress upon that the 'Business Management' is specific to type of the industry as shown in Table 1.1.

Table 1.1: Some Differences between Process Industry and Discrete Industry

	Process Industries	**Discrete Industries**
Relationship with the market		
Product type	Commodity	Custom
Product assortment	Narrow	Broad
Demand per product	High	Low
Cost per product	Low	High
Order winners	Price	Speed of delivery
	Delivery guarantee	Product features
Transporting costs	High	Low
New products	Few	Many
The production process		
Routings	Fixed	Variable
Lay-out	By-product	By-function
Flexibility	Low	High
Production equipment	Specialized	Universal
Labor intensity	Low	High
Capital intensity	High	Low
Changeover times	High	Low
Work in process	Low	High
Volumes	High	Low
Quality		
Environmental demands	High	Low
Danger	Sometimes	Hardly
Quality measurement	Sometimes long	Short
Planning & Control		
Production	To stock	To order
Long term planning	Capacity	Product design
Short term planning	Utilization capacity	Utilization personnel
Starting point planning	Availability capacity	Availability material
Material flow	Divergent /convergent	Convergent
Yield variability	Sometimes high	Mostly low
'Explosion' via	Receipts	Bill of material
By and Co products	Sometimes	Not
Lot tracing	Mostly necessary	Mostly not necessary

The present research treats industries in two categories as well in view of the maintenance needs and research*, i.e.*

1. Process industry; where the product is produced in a continual manner and the process involves huge and complex machinery, operates on continuous time scale and highly automated. The process interruption of any kind at any point in the process line will hamper the continuation of production process and amounts to a huge loss. Many times, safety and risk issues dominate production losses in industries like, Petrochemical, Steel, Power plants, food & beverage and paper etc.
2. Discrete Industries; where a process is mostly a batch process and uses simple machinery operated on fixed time slots. The process interruptions are less severe and manageable. For example, pharmaceutical, machine tools, apparels, specialty chemical, paints, aerospace etc.,

During early 1980's, maintenance based on condition monitoring has gained wide popularity due to the availability of techniques, electronic gadgets, and skilled manpower. Earlier to this period, most of the industries (including process industries) had been practicing a blend of corrective and preventive maintenance programs which had rather been more towards corrective maintenance. The inclusion of condition based maintenance program has made a greater impact in reducing the unwanted outages and improving maintenance efficiencies. Many other strategies like Total Quality Maintenance (TQM), Total Productive Maintenance (TPM), and Reliability Centred Maintenance (RCM) etc., made an entry into process industry to some specific applications like automobile, military and aviation.

The RCM uses structured development of maintenance strategy for given equipment. The maintenance tasks are so identified that each maintenance task should be a manageable activity and results in either eliminating a failure mode or

reducing its failure consequences. The RCM approach can be summarized in the following chain of activities:

- Identify and record all equipment functions.
- Identify functional failures and their causes, to help to establish failure effect classification according to classification of most critical functional failures.
- Identify the relation of functional failure caused by certain failure mode, whether it is Hidden, Safety, Environment and Operational with reference to equipment and/or personnel.
- Prioritize failure modes using logical tools like Fault tree, Failure Mode Effect and Criticality Analysis (FMECA) etc., and map all the failure modes with a suitable maintenance action.
- Identify a maintenance task, so that the function is retained for a specified time with the maintenance task or reduce functional failure consequences. The task selection is to be based on technical and economic considerations.
- Draw a maintenance task schedule and implement.
- Review and incorporate changes to improve maintenance effectiveness. This process helps in auditing the maintenance requirements.

The above steps help to identify/schedule a set of maintenance tasks on equipment in a process plant. The maintenance task classification in terms of RCM terminology is as follows.

- On – condition task (Condition Assessment)
- Restoration task (Repair)

- Discard task (Replace)
- Redesign task (Modify Design)
- Failure finding task (Fault Identification)
- Combinational task.

On-condition task is the one which is normally carried out after ascertaining the equipment/component condition either qualitatively or quantitatively. In process plant applications, the condition assessment is usually done with the help of monitoring pre-specified condition indicators during equipment operation and comparing them against norms/standards. The maintenance task is then planned according to the assessed condition.

However, irrespective of the approaches followed or adopted, the major concern has been to keep the equipment in healthy condition. Since 1980, with the revolutionary computerized technologies and electronics, the monitoring technologies have drastically improved and made available commercially at low prices making condition monitoring as an integral part of the industries.

Being in industry for the past 15 years, the author is more inclined towards doing his research in the area of CBM to make maintenance functions more effective and economical. In author's view, despite having all these technologies, there exist a lot of scope in the field of maintenance and condition monitoring with its applicability in the process industries. Therefore, the literature survey is conducted with an objectivity of finding out the development in the field of condition monitoring in the past and their application to the industries to improve maintenance and reliability.

1.2 Literature Review

Literature is collected and surveyed with a view to find out the state of art techniques, approaches, frameworks, methods and models available and their practical applications and implications in the maintenance.

The literature is organized in four areas.

1) Process Industries-RCM- Implementation-Results.
2) PDM-Expert Systems-Equipment Health Monitoring.
3) Integration of PDM-Prognosis-Reliability Modeling.
4) PDM -Fuzzy Logic-Reliability.

1.2.1 Process Industries-RCM- Implementation-Results

Maintenance functions have gained attention in process industries in late 1980's and researchers developed many models on cost and resource optimization. The vital issues related to maintenance cost, scheduling etc., have been discussed by Kelly, (1984) with an attempt to establish generic guidelines. Some researchers Gits, (1984) and Blanchard, (1992) etc., also have proposed maintenance concepts. However, their approaches could not catch up with the industry. Due to diversity in process plants many industries have developed their own customized strategies, but very few led to a success. Model proposed by Bruvold and Evans (1985) has primarily dealt with production planning and maintenance scheduling. Later, Ashayeri *et al.,* (1994) extended this model, which integrates the condition based maintenance while scheduling the maintenance tasks.

The RCM approach evolved due to the pioneering work of Nowlan and Heap, (1974-78) for the US aviation industry, and later a standard has evolved known as *"Evaluation Criteria for Reliability –Centered Maintenance"* (SAE JA 1011, 1999). With the availability of the RCM standard SAE JA 1011, (1999) thrust on identifying the failure modes and failure diagnosis gained momentum. Pintelon *et*

al., (1999), have discussed the issue of basic research question that, how to determine the optimum maintenance requirements in an industry and impressed that the RCM can well be customized to suit to process industry by citing an application in a paint industry. The RCM has made a greater impact in process industries out of all other strategies due to its flexible and customizable nature as per custom needs. The condition monitoring is immensely interlaced with RCM to arrive at on-condition tasks.

In 2000, Phil Clarke and Murray started customizing the RCM to match with requirements of specific industry and proposed a Cost Minimization Algorithms (CMA). Turner (2000) concludes that using RCM is more advantageous than the CMAs and presented a comparative study on how reliability concepts could be helpful on improving plant availability by increasing uptime of the equipments rather than improving maintenance. *Using RCM, either the failure is expected to be removed before it occurs or it is allowed to occur in purpose.*

Murphy and Paasch, (2001) have improved the RCM model developed for aircraft engine with diagnostic modeling, which focuses on reliability metrics, such as MTBF, MTTR and availability. This model considered maintenance planning with inputs derived from condition monitoring gadgets. Later on RCM was applied in most of the industries on variety of equipment, including even less failure prone electrical switch Gear also. Deshpande and Modak, (2002) have demonstrated the ease and usefulness of the RCM in a medium scale steel industry and presented stepwise approach for tilting table of steel rolling mill. However, in developing countries like India, the implementation of RCM in major process industries like steel, petrochemical, power plants, etc., is in nascent stage, since the propagation of reliability concepts in these core industries have been so far limited. The maintenance engineers have been less exposed to reliability theory based maintenance concepts hence the acceptability ha been less.