CHAPTER 1
Introduction.
Aims and Objectives of the Work

1.1 Introduction

Widespread automation, the use of highly complex systems, tight schedules of personal private and public life in the society all these have of late led to the recognition of the importance of achieving high reliability of goods and services. The internal combustion engine/diesel engine has captured a very vast area of application in the modern industrial world, most significantly in the marine and rail transport and both captive and standby electricity generation plants. As of date the importance of diesel engines in the areas of co-generation and transportation cannot be overestimated. To cite the Indian scene alone, even as early as 1984 the installed generation capacity with I.C. engine plants was 1632 MW. A look at the 'U.N. publication on electric power in Asia and the Pacific' would show that the use of I.C. engines for cogeneration has been tremendously increasing over the years. Application to surface transport, particularly to diesel electric traction is of paramount importance especially in the case of the developing countries (as also the developed countries) where normal life of people is so much dependent on rail traffic. When the day to day life of man has become too much dependent on diesel engines, and while the proportion of time the engines are in operable condition is of great concern, any amount of thought and action towards improving the reliability, nay availability, of the internal combustion engines cannot be unwarranted. Operation time before first failure should be considered a very prime factor of service for any mechanical equipment/ repairable/ maintainable system. Users of large machinery and equipment are becoming more and more conscious about the implications of maintenance cost. At least in some countries, customers have started demanding guarantee/assurance on whole life cost. Condition based maintenance for optimal reliability/availability is gaining wider acceptance including among diesel users.

1.2 Outages of Diesel Engines and Losses

That the world countries are facing energy crisis only asserts the need of better efficient operation of machines and equipments. Leaving alone the oil producing countries, liquid fuel is liquid gold and waste of fuel by way of lesser efficient operation of internal combustion engines as well as external combustion engines/machines should be of grave concern. Economy of fuel oil and lube oil consumption must be receiving more attention from researchers, manufacturers and practitioners. A noticeable part of the GNP of any country nowadays is backed by liquid fuel power pack of which a good share is of diesel engine plants. Obviously outages due to unexpected failures can show-up even in the GNP, not to speak of micro - level production losses, repair/ replacement costs, and other losses of opportunity costs.

1.3 Need for Study of R.A.M. Aspects

Sophistication and hence complexity of any type of machinery are tremendously increasing because to have the former the latter is generally inevitable. An inversion of the four bar chain, reciprocating machines are inherently a bit more complex in comparisons with any other type of rotating machinery. Efforts to produce more energy with better fuel efficiency and with better power-weight ratio have constantly added to the complexity of engines because of the inevitability to use more complex sub-units and feed-back or feed-forward controls. Experience of the past would only show that failure proneness is more than proportionate to complexity. Even more so is the situation with thermodynamic machinery and other hot-processing equipments which have to operate in high-temperature environments.

As is also the general case, the financial penalties associated with engine down time and maintenance have only spiralled ever upward. The need to pre-empt failures has steadily grown. The increasing cost of labour/replacement/parts (spares), and inventories continuously demand operation and maintenance to keep pace with the advances in technology that could reduce maintenance activity or simplify the operation of the diesel plants. Assessment of reliability, availability, and maintainability have to be an ongoing process in order to operate for optimal availability or for optimal maintenance planning.

Life time maintenance costs are determined by the different ways in which a product can fail to perform properly, the frequencies with which these different failures can occur, the nature of the repairs required for correcting each type of failure, and the extent of the routine servicing prescribed by the manufacturers. R.A.M. studies can only offer clues for improving or altering designs for better reliability. RAM studies will also help evolving designs for minimal maintenance expense.

1.4 Early Diagnosis and Advantages

Maintenance costs totalled over the useful life time of a product would in many cases exceed the original purchase cost. Over and above the maintenance costs, there are the opportunity costs because of no 'production' during down-time. The maintenance cost is only a major constituent of the down-time cost. The downtime can be split into the following fractions:

(i) Administrative time; time for managerial decisions and sanctions, waiting time for the repair facility; time for movement to and from the repair works; delay due to non-availability of spares, etc put together,
(ii) Diagnosis time,
(iii) Actual repair time, and
(iv) Testing and recommissioning time.

Literature on industrial maintenance would show that a big chunk, around

60% of the down-time is diagnosis time. The payoff corresponding to a given percent reduction will be the biggest if it is in the more weighty constituent of the down-time. Clearly it is the diagnosis time one has to hit at for cutting down down-time costs. And this is where lies the importance of the quantitative techniques of condition monitoring.

Early diagnosis of imminent failures - prognosis - would cut down-time very significantly. It would also help avert further propagation of a fault and hence more severe and costly damages. Condition monitoring can direct posting of major maintenance to times when more economical handling would be possible. It is vastly reported that the British Industry has cut down-time costs drastically by the application of condition monitoring. C.M. enables to avoid unnecessary preventive maintenance schedules, which in turn subscribes to better reliability. Raj B. K. N. Rao, in his introduction note to COMADEM'88, mentions 'unless top management adopt a holistic practice to monitor, detect, diagnose, and prognose the undesirable symptoms in every part of their system, it will be difficult for them to keep up with the rapid pace of development of technology and to reap the maximum benefits from it'.

1.5 Premise to this Work and Objectives

While engine failures - degradation and catastrophic - are mostly the cause of outages of diesel plants, the attention and activity of the maintenance seem to be around the classical approach. Interdisciplinary specializations like Reliability Engineering and Condition Monitoring techniques founded on Digital Signal Processing do not seem to have percolated significantly to practice level to improve the maintenance scene at large. Consistent and persistent conscientious efforts are required for deriving extended periods of failure-free operation and reliable service out of diesel engine applications.

Failure-free operation and reliable service are not only considerations for economy but also for unperturbed psychological well beings. It is felt that there is need to reemphasize engineering more reliability into internal combustion engine designs. Availability and maintainability are images in different perspects. Some of the aspects of mechanical reliability in the context of I.C. engines are highlighted in this work.

A clear vision of the failure mechanisms of a system is required for a comprehensive qualitative vision of its reliability scene. A very convenient and easy way to have this is already available, the fault-tree. But how far this is consciously used in practice is not much known. At least in the context of this work it has been observed this was not truly taken advantage of in the diesel practice. Fault-tree analysis would be very much useful for assessing reliability at the time of design and development provided failure data for all the components/parts are at hand. Standard failure data-base for a substantial number of mechanical parts having not been generated, fault-tree cannot be of much use this way. However atlases of fault-trees can be a very powerful aid for trouble-shooting and for training and imparting skills to maintenance personnel especially novices. Sample fault-tree for a model loco diesel engine is worked herein hopefully to draw the attention of diesel practitioners to the value of such a simple and convenient tool and impress upon them the need to make such standard fault-trees and propagate through their men for education on better maintenance actions. Closely allied with fault-tree is another technique, FMEA (failure modes and effects analysis). FMECA (failure modes effects and critically analysis) is also there. These have also similar uses as fault-tree. A Delphi version of the FMEA which can be used for ranking failure modes in the order of severity has been attempted.

Though trials were made in the past for the development of vibrometry-based diagnostic testing methods for internal combustion engines, till now no emphasis has been placed on such investigations. Because a view prevailed that the condition of internal combustion engines could be relatively simply, and more reliably, diagnosed with other methods which were considered classics. The method of testing cylinders, valves, the ignition system, and the fuel supply system were deemed to be fully developed. Technologists seemed to have refrained from making further vibrometry investigations because of the many difficult problems that had to be confronted in the case of I.C. engines. The engine is a dynamic mechanism in which, besides the crank mechanism, there are other moving parts (e.g. timing), that may excite intensive vibrations, even if the engine is in good condition. The vibration of a host of auxiliary systems (water pump, dynamo, oil pump, fan, generator, etc all of which must be operating harmoniously for the proper functioning of the engine) add to the already complex vibrations excited by the engine. In mobile engines the vibrations arising in the chassis (truck), shock absorption, and carriage are further additives. All these make the identification of the characteristic vibrations of the individual parts very difficult. But, of late, it could be noted that, intense-efforts to find out ways of exploiting vibration observations for diesel fault diagnostics were going on. The shafting of an internal combustion engine with all its cranks, pistons, flywheel, and driven machinery is too complicated a structure that determination of exact torsional natural frequency is near impossible. Yet it is felt that angular velocity fluctuations of the crank shaft can serve a most uncontaminated and powerful signal that can be used for the early detection of impending failures especially those pertaining to the cylinders. Recently some work related to angular velocity monitoring has been reported. Attempt to actually measure angular velocity is a difficult proposition before commercial versions of angular velocity sensors are available on the market. Of course for experimental work, angular velocity measurements are being done using indirect ways. Again this work only attempts to reemphasize the prospects for condition monitoring techniques, particularly, vibrometry techniques in health assessment/ fault diagnosis of I.C. engines. Included are some demonstration of fault diagnosis by simulation using approximate p.v- diagrams.

The objects of this study had been set as :

(i) To collect, classify, and study and critically review the available literature on RAM studies and fault diagnosis of I.C. engines.

(ii) To highlight some of the aspects of RAM techniques in the context of diesel practice.

(iii) To explore the possibility of diagnosing cylinder related faults which are fundamental through monitoring angular velocity signature.

(iv) To conduct vibrometry experiments to be able to draw inferences/clues which would help assess the health condition of the engine and decide the timing of next major overhaul/ maintenance so that unnecessary preventive maintenance actions can be forsaken.

The work could be carried out to fulfill more or less the set objectives. The report on the work is presented in the subsequent chapters. An amount of theoretical background text-book material is also quoted in some of the chapters for the sake of continuity and extra clarity. Here follows the second chapter of a brief summary of the relevant available literature studied in this context.

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