ABSTRACT

Concurrent Engineering is a systematic approach to the integrated concurrent design of products and their related processes including manufacturing and support. Concurrent Engineering is a topic of recent times in the field of product development. Eventhough, it is used as a concept for new product development in the developed countries, the approach is equally applicable for areas such as design modifications, non-standard range of regular products, special purpose machines manufacturing, advanced job order industries etc., including, for new product development, in developing countries, like India.

Reduction speed gearboxes find extensive applications in various fields. Due to widely varying customer specifications to suit their requirement, and complexities involved in the basic design process, achieving 'right-at-first' appear 'difficult to achieve' in their design and development, based on traditional sequential approach.

Concurrent Engineering is widely seen to be the methodology that can satisfy the strenuous demands of industry and keep the profitability and the viability of product developers, manufacturers and suppliers high. The concept is recognised by an increasingly large portion of the manufacturing industry as a necessity in order to compete in today's market. It is also identified that Concurrent Engineering is a vehicle to improve the overall quality leading to total quality management (TQM).

Thus the need for the application of Concurrent Engineering concept to the design and development of reduction speed gearboxes is identified.

A total computer aided environment for the design and development of reduction gearboxes based on the Concurrent Engineering concept is developed in this research work.

The research work is concentrated on the following three major aspects :

- Concurrent Product Design
- Concurrent Process Design
- Design of Activity Based Cost Estimation system

Based on analytical procedures, a computer aided design environment for the design of gear-pair for reduction gearboxes is developed. This gear design module is integrated with expert systems designed for (i) automatic selection of material, based on gear tooth strength, and (ii) To suggest appropriate heat treatment process for gear tooth strength and durability.

Finite element analysis tools for gears and gearboxes, operable in PC environment are developed in Turbo C. The static stress analysis and mode frequency analysis of spur gears are done using the developed tool. The actual profile of the gear is generated using a software developed in C. The stress distribution and deflection in the gear tooth due to application of load is studied. Frequency and model analysis are the most often applied forms of mechanical testing. The first four natural frequencies of the gear model and corresponding mode shapes are obtained. Similarly using the developed tool the stress analysis using finite element analysis is carried out.

The gear finite element analysis is also carried out through solid modeling in Pro/Engineer R-12 package and then transporting by IGES files to ANSYS 5.0 for stress analysis and static deflections.

Expert systems are developed, (i) for the design of reduction gear box shafts and (ii) for the selection of appropriate bearings, based on the output of the above shaft design module. The standard design procedures are automated for speed and accuracy of these designs and are interfaced to the gear design module.

In gearbox design, the thickness of the casing is generally based on the experience of the designer rather than on scientific principles. Hence it is proposed in this thesis to optimise the casing wall thickness. Using the PC based finite element analysis tool mentioned above,

the analysis is carried out. Based on the analysis, iso- stress plots and deformation pattern of both sides of the gearbox casing are plotted.

Optimisation studies are undertaken to minimize the weight of the gearbox casing. Parametric studies are used to find a relation between different controlling parameters in order to optimise the design. This methodology provides a casing of reduced weight, at the same time keeping the stress and rigidity levels constant. Shape modifications of the gearbox casing is suggested which reduces the volume and hence the weight of the casing. The new model can be also be subjected to finite element analysis using the developed tool.

Tribology of gears which deals with lubrication, friction and wear has been considered for "interacting surfaces in relative motion", in gearboxes. Expert systems are developed to calculate minimum film thickness, quantity of lubricating oil requirement, lubrication factor along with the suggestion for standard SAE equivalent oil.

Knowledge of possible gearbox failures and their causes at the time of design is essential for proper design, material selection and design calculations of gearboxes. To fulfil this requirement, an expert system integrated with the design module is developed to undertake failure mode and effects analysis (FMEA). This system is designed to undertake both design and process FMEA aspects connected with reduction gearboxes.

Among the process design aspect, the system for inspectability accounts, 'design for inspectability' considerations.

The virtual product development is brought as reality over the computer screen, through, parametric design analysis and assembly of reduction speed gearboxes in the CADDS V environment. The cost and product structure analysis of designed gearbox is tried through the 'Design For Assembly' software developed by Boothroyd and Dewhurst, which also accounts ease and economy of assembly.

The fundamental requirement of Concurrent Engineering (viz.) integrating product design alongwith process design is achieved through, a semi-generative CAPP system

developed in C. A sound 12-digit alphanumeric codification system is developed to facilitate the above system.

Subsequent to the concurrent product and process design activities , it would be relevant if the designer is exposed on the cost implications of the developed gearbox. This requirement is fulfilled through an integrated activity based cost estimation system (IABCES) designed to operate in the Oracle RDBMS 7.0 atmosphere. This system is designed both to account and control costs.

Thus the work provides a complete computer aided Concurrent Engineering environment for the design and development of reduction speed gearboxes. The system is a boon to the reduction gearbox manufacturing industry as a whole. The practice of the system to result in the following major advantages to this industry :

- Compressed design and development time
- Improved product quality, as the entire analysis is aimed indirectly at it
- Optimum cost

The natural benefits, to follow to the organisations due to the above referred key advantages of the system are, good market share in the line of business, enviable market positions with good profits and hence rapid growth rate.