6.1 Conclusions

In this thesis AI and knowledge based modeling and control strategies based on fuzzy logic for motor drive position control applications are presented. The work presented in this thesis is a result of the intersection of three major disciplines of fuzzy logic systems, electric motor drives, and control theory. The design and real-time implementation of fuzzy logic control is based on the integration of the concepts and technology available in these three major disciplines. The objective of this investigation has been analysis, design and development of fuzzy controller for electric motor drives. The PMDC motor has been selected for position servo applications. Attempt is made to apply fuzzy control to improve PMDC motor drive performance under static and dynamic load conditions.

Design methodologies of the conventional linear controller (lead compensator) and PI used for position and speed control of PMDC motor drive have been presented to provide a basis for comparative performance study with FLC. Real-time setup for implementation of the above using analog technique for lead compensator and microcontroller based digital technique for PI controller has been developed and tested under static and dynamic (step and frequency response) test conditions.

Design methodologies in the form of rules/meta rules for distributed fuzzy logic controller (FLC) and adaptive self-organizing fuzzy logic controller (SOFLC) architecture have been investigated for real-time application of position control of PMDC servomotor drive with friction and gearbox backlash nonlinearities. The basic design procedures of FLC have been presented along with types of fuzzy knowledge based controller (FKBC). Design details of fuzzy-PI controller for PMDC motor drive based on the new methodology introduced by Han-Xiong Li for designing and tuning the scaling gains of the conventional fuzzy logic controller has been presented. Using the concept of the shrinking-span membership function, the membership functions of the proposed FLC have been generated. The unique approach of development of the fuzzy control rules based on the expert experience and after studying the various responses obtained from the classical PI controller and fuzzy-PI controller has been presented.

The real-time implementation details (hardware and software) of the PC/AT (80486DX4, @ 100 MHz) based fuzzy controller (FLC) using the high performance
data acquisition and control card (DAS) for PMDC servomotor drive has been presented. Subsequently, the feasibility of implementing the microcontroller based fuzzy logic controller (FLC) in a cost-effective manner has been studied. The effectiveness of the proposed controller algorithms (FLC and SOFLC) in the thesis has been examined through simulation and real-time experiments.

A summary of the main results obtained is presented in the following paragraphs:

Chapter 1 is being introductory chapter it contains the introduction and scope of the thesis.

Chapter 2 has reviewed the concepts involved in motor drive applications using conventional control techniques. Theoretical background necessary for the basic understanding of fuzzy logic based control techniques has been given. The state-of-the-art technology in the fuzzy logic based controllers applied to motor drives has been reviewed.

Chapter 3 presents an outline of the analysis and design of the conventional linear controller (lead compesator) and PI used for position and speed control of PMDC motor drive. The chapter describes the design and development of lead compensatory controller and PI controller for PMDC motor position control drive. Functional test results obtained viz., step response, frequency response, linearity, dead zone, stall torque, etc. on an actual real-time setup have been presented.

Chapter 4 has investigated the applicability of fuzzy logic control (FLC) for permanent magnet dc (PMDC) motor drive. Design details of fuzzy-PI controller for PMDC motor drive based on the new methodology introduced by Han-Xiong Li for designing and tuning the scaling gains of the conventional fuzzy logic controller has been presented. The thesis provides alternate design approach of the fuzzy logic controller (FLC) using the concept of the shrinking-span membership function for describing the membership functions and generation of fuzzy control rules based on the expert experience and performance responses obtained from the classical PI controller and fuzzy-PI controller to improve the performance of PMDC motor drive.

The feasibility of the proposed FLC has been demonstrated by implementing a real-time PC/AT (80486DX4, @ 100 MHz) based system using the high performance data acquisition and control card (DAS). Subsequently, implementation details of the microcontroller based fuzzy logic controller (FLC) in a cost-effective manner have been presented. It was also found that the execution time required for control algorithms using PC/AT-486DX4 based DAS card system is much less (approx. 350μs) compared to using 80C196KC microcontroller option.
The results of various static and dynamic tests conducted on the proposed FLC system have been presented in this chapter. It can be seen that the experimental results are sufficiently close (± 6 %) to the simulation results. The difference is mainly due to assumptions/approximations made in simulation and modelling of the FLC system. Further, to emphasize the merits and demerits of the FLC, some comparisons have also been made between the fuzzy-PI controller and linear PI controller under load and supply disturbances. It was found that use of FLC results in smoother step response with response time comparable to PI controller system and much better than the lead compensator. The frequency response results of FLC are much better than the PI controller and the lead compensator particularly at the small reference inputs. Further the effect of load disturbances on step response is less in FLC system compared to PI and lead compensated system.

Chapter 5 has presented the comparative study of proportional-integral (PI), adaptive and fuzzy control for friction compensation approach to improve the performance of the PMDC motor drive with friction and gearbox nonlinearity. The design and development methodologies of self organizing fuzzy logic controller (SOFLC) for friction and gear backlash compensation in the PMDC motor drive have been presented.

It is observed that for large reference input signals in both FLC and SOFLC the step response results are similar to PI, but are better than the lead compensator results. However, for smaller reference input signals the frequency response of SOFLC and FLC is much better than the PI and lead compensator.

The thesis also presents the development of software for real-time implementation of the FLC and SOFLC control algorithms for PMDC servomotor drive. The algorithms have been developed using Turbo C++ and Assembly (Macro Assembler) under MSDOS and Windows-95 environment. Simulation and experimental results for FLC and simulation results for SOFLC under different static and dynamic load conditions have been provided to show their suitability for real-time applications in position control motor drive system.

6.2 Suggestions for Further Work

In this thesis, the possibility of applying Fuzzy logic control to improve the controller performance of the PMDC servomotor drive under static and dynamic test conditions and with friction and gearbox nonlinearities was studied. However, even for developing the ideal position control it is far from reaching the optimization of the machining
process. The main reason is that the uncertainty of drive system depends on the use of preprocess developed control (NC/CNC) programs, based on unreliable pre-process data. Besides in practice, the merit index will not always indicate improved performance. Other merit indices exist such as an economic function which in many circumstances may be more important than the other possible merit indices, which could be used, for example, quality of product or precision and the productivity increase, etc.

Adaptive control has been the first approach to achieve the system optimization. It has been shown that with these techniques, the control information comes from only one source, the operation sequence is fixed, the control process is numerical and process data are not obtained in real time. Nowadays, uncertainty and lack of complete knowledge of motor drive systems are the main problems. Manufacturing systems and particularly machine tool and position control drives are fields in which fuzzy logic control techniques could be applied to solve many of these problems. The knowledge can be expressed imprecisely and an incomplete set of rules is available. A very important reason to choose fuzzy control is the simplicity of obtaining a multi-index control by using a set of fuzzy control rules. By applying fuzzy control, one can obtain an “intelligent” machine controller working under multiple objectives. This is accomplished by setting some control rules under a merit index and other control rules under a different index.

All this leads us to design a hierarchical intelligent control system for motor drive applications. The lower level contains the position and/or speed loops. The higher level is composed of different controllers, one per each merit index. These would be:

- Fuzzy controller for maximizing productivity
- Fuzzy controller for minimizing cost
- Fuzzy controller for energy efficient motor drive system.
- Fuzzy controller for intelligent fault diagnostics of the drive system
- Fuzzy controller for multi-motor drive operation

The system could work under multi-index optimization criteria. The coordination of different objectives will be made by fuzzy reasoning. One example of optimization criteria could be “reasonable cost and best quality”.

Note that the system requires the existence of a multi-sensorial system, which has to provide information about process-state in real time. In view of above, the system shown in Figure 6.1 is proposed for future multi-motor drive operation.
Figure 6.1 Proposed control system for multi-motor drive application

For implementation of the proposed system there are issues which need further investigations.

These includes:

➢ Hybrid control techniques viz., modern linear/non-linear along with fuzzy-neuro controllers.

➢ Investigation on new control methodology for fuzzy logic control for deciding shape and number of membership functions, fuzzy inferencing apart from Mamdani and Sugeno, optimization of control rules, etc.

➢ Fuzzy modeling and control for nonlinear, complex drive operations.

➢ Applications of these AI control techniques to other motor drives viz., switched reluctance (SRM), brushless dc (BLDC), etc., and

➢ Use of recent parallel processors, DSP and fuzzy-neuro processors (Hardware) for multiprocessor control implementation for multi-motor drives.