Computer Integrated Manufacturing Education to Mechanical Engineering Students: Teaching, Research and Practice

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Abstract*- This paper details the research and development of Computer Integrated Design and Manufacturing at Islamic University of Technology (IUT), Bangladesh, a subsidiary organ of the Organization of the Islamic Conference (OIC). IUT is basically an educational and research institution offering undergraduate and postgraduate degrees in the field of Engineering and Technology. The objectives of Computer Integrated Manufacturing (CIM) education are to provide industry with a new generation of engineers having interdisciplinary skills necessary to deal with state of the art technology in designing, manufacturing, maintenance, selecting, and procuring manufacturing engineering systems. The research activities on CIM systems, the course coverage and laboratory facilities are discussed in the paper. The available programs are four-year Mechanical Engineering degree program specialising in production engineering, Masters Program, and PhD. There is a thirty-two-weeks research project at the undergraduate curricula of mechanical engineering. Areas of research topics include CAD (computer aided design), CAM (computer aided manufacturing), CAPP (computer aided process planning), CNC (computer numerical control) machine tools, DNC (direct numerical control machine tools), FMS (flexible manufacturing systems), ASRS (automated storage and retrieval systems), use of robotics and automated conveyance, computerized scheduling and production control, and a business system integrated by a common database in the Department of Mechanical and Chemical Engineering at IUT.

I. Introduction

Islamic University of Technology (IUT) offers a number of engineering and technological courses at postgraduate and undergraduate levels. The Masters degree and Postgraduate Diploma in Mechanical Engineering courses involve varying hours of research, projects, course works requiring 36 and 24 credit hours and will require 3 and 2 semesters respectively. The B. Sc. In Mechanical Engineering program comprises of four years study consisting of eight consecutive semesters of sixteen weeks duration each. However, there is a provision for award of Higher Diploma in Mechanical Engineering as well. The course curricula contain computer integrated manufacturing engineering of high level as well as include components for hands on skills, to produce engineers of international standard having relevance to the development needs of the OIC member states. The course curricula are regularly reviewed and upgraded to meet the needs and requirements of the member states, as well as, the international standard of the curricula.

Harrington [1] described computer integrated manufacturing as a control and communication structure to integrate manufacturing systems. Later on, Foston et al. [2] proposed the interpretation of computer integrated manufacturing as an enterprise to achieve effective integration of advanced technologies in various functional units to achieve corporate objectives. Tavakoli and Jawaharlal [3] reported educational institutional changes to their curricula in response to rapidly changing industrial practice. Several universities took initiative to integrate design into the engineering curricula [4]. Many of them have proposed to introduce design for manufacture and design for assembly in the curricula [5]. Nagalingam and Lin [6] summarised the evolution of manufacturing technologies that are associated with development towards CIM systems and reviewed some of the new terminologies and technologies that have been granted during the past four decades.

The technological advances during the last two decades have made it necessary to reconsider the classical engineering curricula at tertiary levels. This paper discusses about current research activities and project works undertaken to educate and train the next generation engineers in the interdisciplinary field of Computer Integrated Manufacturing. From the point of view of classical engineering disciplines, a degree level course which aims to impart a CIM dimension to an engineer should typically contain topics related to Computer Aided Design and Manufacturing, Computer Programming and Applications, Manufacturing System and Automation, Computer Aided Numerically Controlled Manufacturing, Robotics and Computer Integrated Manufacturing System, Advanced Topics in Manufacturing, Expert Process Planning for Manufacturing, Computer Integrated Manufacturing and

Database Management System. IUT is currently offering the courses related to the above topics.

II. Laboratory Facilities

The Mechanical Engineering Department collaborate with other departments at IUT to integrate the laboratories into the courses under the manufacturing options and to provide practical design skills to the students. The developed projects introduce industrial applications and real-life control design and analysis issues. The projects also aid the students to assimilate some of the more abstract concepts covered in the control courses. Due to the highly applied nature of the topic, CIM courses are supported by well equipped laboratory facilities at IUT. Some of the essential facilities are used as technology demonstrators for research activities are as follows:

- A flexible manufacturing cell with one small industrial type robot, CNC software, etc.
- A quality control application using machine vision,
- Programmable process controllers
- Man/machine interface equipment,
- CAD/CAM/CIM and Artificial Intelligence software packages on workstations.

The other essential and conventional equipment such as CNC controlled lathes; mills are used to run laboratory experiments and to support students' projects and research projects in areas of CIM.

III. Students Projects

At IUT in Manufacturing Engineering areas research is carried out in the field of machine tools design and dynamics, machining processes optimisation and design, and manufacturing systems. It is mainly directed towards improved machining accuracy, productivity and optimal production scheduling as well as processes design and management. Some of the latest research projects are listed below:

- The design of a computer aided process planning tool (CAPP-S6) for shaft type components using AUTOLISP and C/C++;
- Synchronizing the operations of a conveyor belt and computerised control of the conveying system;
- Construction of a coordinate measuring machine and computerized simulation of objects;
- The formation of the surface with computer simulation of the stress condition during work hardening by surface rolling;
- Design and construction of a vacuum surface coating machine and automatic control of coating layer thickness;
- Development of a low cost PC control Lathe and its operation by CNC program;
- Designing, construction and controlling of a pick and place machine;
- Designing and construction of a feedback control system for a converted CNC lathe;
- Designing and construction of robot gripper;
- Application of vision technology in controlling parameters of material flow in forming processes;
- Development of a post processor for FEM simulation of metal forming process.

The following section highlights on some prototypes of latest undergraduate students' projects that have been fabricated by the students in the university workshops and laboratory. Most of the computer integrated manufacturing projects and exercises are used in the production engineering courses for running undergraduate laboratory classes. These allow students to be familiar with more complex applications compared with the traditional analytical methods and to strengthen the ability to apply a modern method of computer integrated engineering.

A. Construction of a computer assisted co-ordinate measuring machine (CMM)

CMMs have been widely used for precision measurement in XYZ coordinates and these machines consist of three mutually orthogonal slide mechanisms. The CMM (Fig. 1) recently constructed as a students' project is comprised of a measuring probe, control / computing system, measuring software and the machine's mechanical structure. The reading data from the probe are stored in a computer memory and the data can be used for other purposes. In annual project presentation ceremony, it was demonstrated, how the constructed CMM can be used to measure the surface dimensions of a given object. The dimensions are evaluated using an encoder which is connected to a servomotor in series for X and Y direction and for the Z direction one stepper motor with another encoder. The purpose of the encoder is to determine the distance moved in each direction. The angular movement of the motor shaft is calibrated in terms of distance in the encoder. The data collected through the CMM is linked up with computer memory. With the help of CAD software using the stored data, the surface distribution of the given object can be drawn. Thus the three-directional dimension of the given object surface is measured which was the aim of the project.

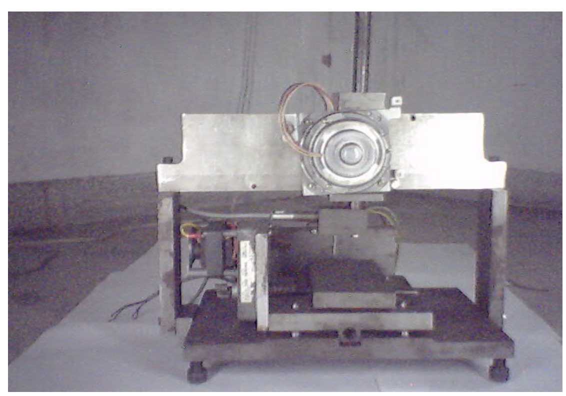

Figure 1. Coordinate Measuring Machine

B. Design of a conveyor belt and a bucket elevator and Synchronization

In large industries where there is an integrated conveyor system for transporting goods within the industry or for transferring finished products to the departure centre, or in coal mines or such other places, speed synchronization is an important consideration. If the speed of the belt is not synchronized then there will be a lot of disturbances and the industrial system of transporting goods may collapse. So the speeds of the various belts should be such that the process should not be interrupted. If one belt speed is higher or lower than the other belt speed then there will be disturbances in the processes. If the conveyor is moving faster by some reasons or the supply in the conveyor is more than the estimation then the bucket will not be able to pick up all of the grains, it dumps on the floor off the bucket elevator, as well as, the accumulated grains hamper the movement of the bucket, which is not desirable. In annual project presentation ceremony, it was demonstrated applying the utilization of a LDR and a controller. This has been done mainly to avoid the dumping of extra grain in the elevator boot.

The major components of the constructed conveyor belt (Fig. 2) are pulling member (belt), belt drums, idler rollers, centering device, drive unit (pulley, motor and transmission gear reducer), mechanical (screw-type) or counterweight (gravity-type) take-up, discharge device (tripper), belt cleaners, and conveyor frame. Bucket elevators are specified for conveyance of various powdered, granular and lumpy materials. Transverse compactness, ability to raise loads to considerable height and capacities ranging from 5 to 160 m^3/h are the main merits of manufactured bucket elevator. The major components are buckets (there are 11 buckets and the gap between consecutive buckets is 0.3m. Each bucket has the capacity of about 215gm, pulling member (belt), shaft, drum pulley, casing, base, hold back brake, take ups, elevator boot, drive unit (geared motor and belt).

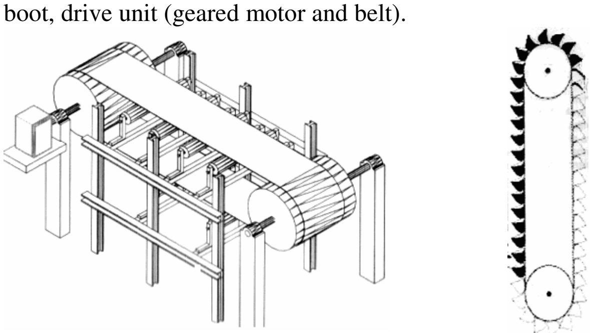

Figure 2. Conveyor belt and Bucket Elevator

C. The Pick and Place Robot

The material used for fabricating the robot structure is 4mm thick plastic sheet. Plastic body makes the robot lighter and it looks nice. Plates of plastic were jointed with a special type of glue made of plastic dusts mixing with chloroform. The pick and place robot has three different motions: waist movement, first link movements, second link movement. Fig. 3 illustrates the assembly of the pick and place robot available in IUT workshop.

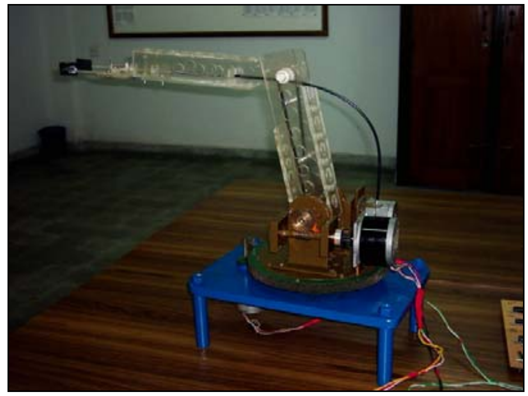

Figure 3. Pick and Place Robot with Gripper Hand

D. Development of a low cost PC controlled lathe

With the entrance in new millennium, e-manufacturing has become one of the modern way of improving the efficiency and productivity in the manufacturing industries. But now a days e-manufacturing hardware for instance CNC milling, drilling are expensive to be used in small workshops. Beside this e-manufacturing needs flexible changes of product design. For that purpose industry needs low cost PC controlled based machinery. The designed machine, a PC controlled low cost lathe as indicated in Fig. 4, has an open loop servo drive control system as there is no change in load conditions. The motor control circuit for the machine is designed on the principle that as the pulse rate increases, the speed of the spindle increases and vice versa. The fixed functions of this machine and program are full floating zero, fixed block format, continuous path control system, incremental mode of listing the coordinate positions, and no restriction of giving dimensions up to three decimal places. Programming format contains absolute dimensioning mode, dimensions in millimetres.

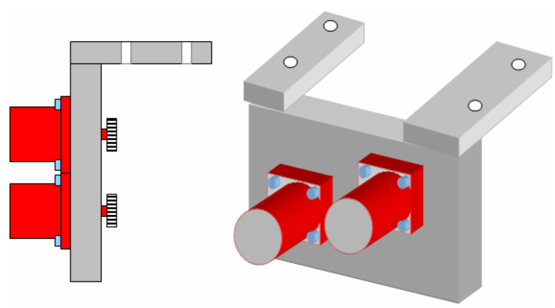

Figure 4. Adapter plate with arrangement of servomotors

E. Development of a feedback control system for a converted lathe

A real-time control system for a conventional lathe has been developed and utilised. The developed system allows a faster measurement with lowers risk in decision making, as well as, it possesses reasonable degree of agility and flexibility to take advantage of opportunities. This system can be used for optimization and the identification of other parameters that would cause out of tolerance conditions. The system is capable of measuring the work piece diameter on process, reducing reworking time and the range of dimensional variations. Using automatic error compensation, the system is capable of maintaining narrow dimensional tolerances. It can reduce rework problems by doing it while the work piece is still clamped in the chuck of a lathe machine. It boasts precise accuracy and repeatability specifications; this means that once a program is verified, two, ten, or one thousand identical work pieces can be easily produced with accuracy and consistency. By comparing the results obtained through experiment, a considerable improvement on the dimensional accuracy of machined work pieces can be observed. It is expected that the industries will be benefited using this type of innovative and more flexible form of automation.

Figure 5. Encoder assemblies with the adapter plate of the feedback control system.

IV. STUDENTS PROJECTS ASSESSMENT

Assessment of the students projects were divided into the following elements:

- Progress report - 30 points: Presentations, term reports, attendance and discussion participation, and relevant laboratory work.
- Final report submission - 30 points.
- Final report Presentation - 40 points.

Independent assessment committee of relevant academic and industry experts judges the project outcomes. This committee fills up an evaluation sheet to evaluate team presentation and project demonstration. Each report is evaluated on the basis of its scientific and technological achievement, effective presentation, and appropriateness for the assignment. The report reflects analysis, originality, and insightfulness as well as the scientific merits ie. correctness, significance, novelty, non-triviality, and completeness of the project undertaken.

The CIM activities at IUT now range from education in the BSc Eng / MSc Eng courses to research activities in PhD projects under the mentorship of Post Graduate Committee (PGC) and Committee for Advanced Studies and Research (CASR). In addition there are a number of projects that aim at supporting the industry in developing CIM skills or producing advanced CIM systems. CIM deals with the integrated and optimal design of a mechanical system and its embedded computer control system can only be performed well in an environment where Mechanical, Computer and Information Technology are combined in a synergistic cooperation. These are being regularly reviewed and updated in accordance to the needs of the industries and recommendation of these committees are duly examined and scrutinized by the Academic Council and approved by the Governing Board.

V. SHORT COURSES ON COMPUTER INTEGRATED MANUFACTURING

An industry oriented short course on Computer Integrated Manufacturing (CIM) was organized by the Department of Mechanical and Chemical Engineering at IUT and run successfully for industry and academic partners during 29 December – 02 January in 2003. The topics dealt with Introduction to CIM, software applications in CIM, Mechatronics, Automated Process Planning (structure of process planning software and operation of a typical computer aided process planning software, group technology, coding structure), Numerical Controlled Manufacturing, Conventional Numerical control of motions, NC procedure, NC coordinate system, economics of CIM applications, Computer Numerical Controlled (CNC) Manufacturing, Material Requirement Planning and Manufacturing Resource Planning, Computer Aided Quality Control and Integration in a CIM System, Robotics and General consideration in Robot Application, Development, Nature, Evaluation, and Role of the elements of CIM system (Hardware, Software, Network and Implementation, Computer Numerical Control and Direct Numerical Control Machine tool and combination), Requirement for MRP, MPS. Bill of Material, Aggregate Production Plan and the detailed MPS, MRP structure, MRP management, Total Quality Management, Quality control, Statistical Process Control, Computer Numerical Control Coordinate Measuring systems, Non Contact Inspection Method, Post Process Metrology, Integrated Computer Aided Inspection system, Flexible Inspection System, Computer Aided Inspection using robots, Robotics and other relevant topics.

Another a week long short course on NC and CNC Machine Tools was organized by the same Department at IUT in 1999. The topics dealt with Traditional Machine Tool, Numerical Control machine tool, CNC Programming and machine operation, manual programming, automatic programming, computerized numerical control machine tool, stored program to CNC, manual-input controls, range of function for CNC, construction and power unit of feed drives, mechanical transmission, transmission behaviour, gear boxes for feed drives, linear and angular measurement, analogue and digital measuring system, adaptive control system, distributed numerical control system, flexible manufacturing system, elements of Techtronic's technology, computer aided planning, computer aided manufacturing technology, proximity, range, tactile, visual, application and future trends.

The above mentioned short courses were designed and ran for practising engineers of OIC partner states; the courses were highly successful and ended up with lots of appreciations.

CONCLUSIONS

An attempt has been made to uncover excellent teaching, learning and research facilities within IUT located in Bangladesh. Some examples of students' research projects have been highlighted discovering the research and teaching capabilities in the said university. IUT is deeply involved in technological and engineering teaching and research as well as in organizing seminars, short courses, symposiums, conferences and workshops.

Teaching Computer Integrated Manufacturing courses is a challenge for faculty members. CIM process design course is most appealing, yet most difficult to teach when various projects are allowed to take place in a single term. However, there are definite advantages for budding engineers. The analytical and theoretical works performed by the students towards manufacturing engineering provides them hands skills on design, manufacturing and product development. It is believed that the computer integrated manufacturing processes have potential to increase interest of the local industries and industries of OIC partner states considering it as one of the fundamental tools for the manufacturing engineers.

The information provided in the paper may be helpful for academics involved in the mentioned areas to design their courses in CIM areas. This also may inspire local and overseas students interested in learning modern manufacturing engineering.

REFERENCES

[1] J. Harrington - Computer Integrated Manufacturing. New York: Industrial Press Inc., 1973.

[2] A. L. Foston, C. L. Smith, and T. Au - Fundamentals of Computer Integrated Manufacturing. Englewood Cliffs, NJ: Prentice-Hall, 1991.

[3] M. S. Tavakoli, and M. Jawaharlal - Concurrent Teaching of Engineering Design, Analysis and Manufacturing. International Journal of Mechancial Engineering Education ,vol. 28 (4), pp. 321-333, 2000.

[4] P. M. Wild, and C. Bradley - Employing the Concurrent Design Philosophy in Developing an Enginering Design Science Programme, International Journal of Mechanical Engineering Educatioin , vol. 26 (1), pp. 51 – 64, 1998.

[5] S. Ambrose, and C. Amon - Systmatic Design of a First Year Mechancial Engineering Course at Carnegie Mellon University, Journal of Mechanical Engineering Education , vol 25, pp. 173 – 181, 1997.

[6] S. V. Nagalingam, and G. C.Lin - CIM - Still the Solution for Manufacturing Industry, Robotics and Computer Integrated Manufacturing ,vol. 24, pp. 332 – 344, 2008.

[7] N. Singh – Computer-integrated design and manufacturing. Wiley, NY, 1996.