CNC Timber Processing in Research and Teaching

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Abstract

Applications of a CNC timber processor at the University of British Columbia in research on timber joinery and teaching and manufacturing of timber structures are presented. The feasibility of traditional timber joinery was governed by practical considerations such as carpenters skills and available tools. Modern CNC wood-processing machinery has changed these constraints and almost any desired geometry is possible; therefore, traditional joinery becomes feasible and affordable again. High-tech manufacturing machinery like automated CNC timber processors can be readily adapted to produce traditional timber joinery and thereby create value added timber building components. Furthermore, the use of advanced CAD/CAM systems in combination with CNC timber processors allows an integrated, streamlined and paperless design approach assuring high quality. The integration of knowledge in the areas of wood mechanics, architectural design, CAD programmes, and CAM technology is leading to new developments, increased use of value added components, and finally change in timber construction.

Keywords: CNC, timber structures, traditional timber joinery, interdisciplinary teaching

Acknowledgement: Cooperation received from Hans Hundegger Maschinenbau GmbH on the Hundegger K2 5 axis CNC mill machine at the University of British Columbia is gratefully acknowledged.

Introduction

CNC Technology

CNC (computer numerical controlled) technology is a computer-controlled manufacturing method. The direction, speed and time interval of the machine activity is numerically controlled. The era of the numerical control technology began around 1950 in the USA. A venture between the US Air Force and Massachusetts Institute of Technology unveiled the first successful numerically controlled machine (NC) -a three-axis milling system. It was a major development in the ability of machines to produce complex and intricate parts accurately without any variability of human intervention. It has then evolved into a mature CNC technology that radically changed the manufacturing industry. Curves are as easy to cut as straight lines, complex 3-D structures are relatively easy to produce, and the number of machining steps that required operator intervention has been dramatically reduced.

CNC Technology in the Wood Manufacturing Industry

CNC machines were first developed for metalworking. Only with the development of special software was it possibly to use CNC machinery for wood processing. Substantial differences had to be considered: the grain of the wood, the danger of splintering and splitting at the corners, the danger of "burning" with inevitably slow feed speeds at the corners, substantially higher feed speeds and numbers of revolutions and the complicated work piece outlines, etc. Over the years, the price performance ratio of these machines became more favorable and consequently they became popular in wood processing. These machines can fundamental be divided in two groups: stationary machines and run machines. In stationary machines, such as routers, drill presses and processing centers, the work piece is fixed on the machine table for processing. In run machines, such as timber processors, the work pieces are positioned by the machine and processed in different places.

Traditional Timber Joinery

Joints are arguably the most important part in any structural timber system governing their serviceability and durability performance (Snow et al. 2006). The structural performance of timber joints is affected by the manufacturing quality and the moisture content of the timber members amongst other factors such as wood species and the existence of defects in the wood. Wood-to-wood joints rely on interlocking of their form to provide stiffness and strength; therefore, it is essential to have accurately cut components. Until the middle of the 20th century, wood-to-wood joints were commonly used with their design and manufacturing based on the experience of carpenters. High labour costs, high degree of workmanship required, assembly difficulties and inefficient use due to over dimensioning made traditional joinery too expensive and timber less competitive as construction material. However, important development of wood processing machines has created the possibility to produce wood-to-wood joints cost effectively (Bamford 2003). Timber joinery has experienced a revival in the past two decades and traditional style joinery is being used to connect a growing number of

buildings, in both residential and commercial applications. Traditional joints like mortise and tenon joinery and new designs like rounded dovetail joints (Tannert 2008) are studied.

Application of CNC-Technology in Timber Processing

With the introduction of CNC timber processing technology, the carpenter's trade experienced an upsurge of exciting opportunities. Utilizing automated beam processors, traditional and contemporary timber joints can be easily processed at a very high speed providing an impressive cut quality and accuracy of the components. Although the manufacturing of timber structures and in particular joinery already had been mechanized to a large extend, the use of CNC-technology forces a traditional carpenter to completely reorganize his enterprise from a handicraft to semi-industrial business. In addition to changes in the business infrastructure, CNC-processing of value-added timber components should preferably be done with high-grade wood products with more constant dimensional stability, such as kiln-dried lumber, Glulam or structural composite lumber. With the increasing demand for timber-frame construction in the residential building market, carpenters have more and more reclaimed traditional wood-to-wood joinery. CNC-processing had been introduced into the secondary wood industry and the prefabricated housing industry already before carpenters started utilizing this technology. In the 1980s, amongst others, Kessel and Natterer promoted the application of CAD/CAM technology in timber construction, initiating software developments in heavy-timber construction. In the last 20 years wood has been increasingly applied in larger structures, requiring state-of-the-art design, CAD and processing tools. Timber frame buildings have always had visual appeal but today's structures have become more complex while also embracing modern building science concepts, which is possible because of better building envelopes, introduction of sophisticated joinery, CAD software and CNC technology.

CNC Timber Processor at the University of British Columbia

CNC machines, interfaced with 3-D modeling software, are the most recent innovation in timber processing. The market leader in North America with over 50 machines in use is Hundegger with its fully automated K-2 beam processor. In 2004, the University of British Columbia (UBC) installed a Hundegger K2-5 beam processor and since then, the overall feedback from students, research groups, industry partners and government officials has been enormous. The Timber Building Technology Group, a new interdisciplinary research group led by Prof. Frank Lam, incorporates the departments of Wood Science, Civil Engineering, Architecture and the Center for Advanced Wood Processing and supervises all activities related to research and education involving the CNC timber processor. Expressing their great interest towards this new timber processing technology, a large number of architects, structural engineers, lumber and value added wood products manufacturers, housing developers, researchers and government representatives have been introduced to the machine. The K2-5 has become an indispensable tool in various research projects, course curricula and workshops in an interdisciplinary setting.

Interdisciplinarity and Application of CNC Technology in Timber Engineering Education

Engineering educators worldwide have witnessed changes in students' interests, career goals, perspectives, and study habits. As well, universities at all levels have put increasing pressures on faculty research productivity and have often sacrificed some scientific and technical detail to the point of alarm. This suggests that old pedagogies and traditional teaching approaches and even timber engineering education may not sustain through the next decade and beyond (Cramer et al 2008). These changes present challenges to the education in timber engineering but also the opportunity to choose a different path in an interdisciplinary setting. The process of bringing a building into being requires communication and collaboration between architects, engineers and builders. Problem solving is at the very essence of these professions in satisfying all regulatory requirements, performance criteria and economic constraints on any one project. Yet, at most Universities, collaborative learning is not a mandatory part of the education for any of these professions, and traditionally, engineering and design programs are worlds apart. But the benefits of interdisciplinary learning - having students from diverse academic backgrounds work together in one class - are becoming well accepted. The design, build and engineering professions have much to gain from the interaction of their students as it gives them invaluable experience and skills for their future careers, however the management and successful implementation of an interdisciplinary course, can often be challenging (Clouston 2008). At UBC, over the past few years several courses and workshops that involved CNC technology combined students from the departments of wood science and civil engineering as well as from the school of Architecture where they engaged in complex tasks to integrate the insights of their disciplines.

CNC Timber Processing in Research

Research on innovative wood-to-wood joinery

The wooden dovetail is a centuries old connection that was developed as a simple yet effective means to join orthogonal members when other more complicated connections were not feasible. Different configurations of the dovetail have been extensively used throughout Europe and Asia, primarily governed by practical considerations such as carpenters skills and available tools. Modern CNC processing machinery has changed these constraints and almost any desired geometry is possible. The rounded dovetail joint (RDJ – Fig. 1 left) is a relatively new concept specifically adapted to be processed with a CNC machine. Another shape of interest is the double rounded dovetail joint (DRDJ – Fig. 1 right) that was developed at UBC. The K-2 timber processor was used to produce a wide variety of RDJ shapes in a series of research projects. Steiniger (2004) compared structural composites and and solid timber as well as varying joint geometries, Anastas (2007) evaluated the effects of manufacturing tolerances, and Tannert (2008) studied different loading conditions, geometric parameters und with the help of the finite element method proposed a new design guideline.

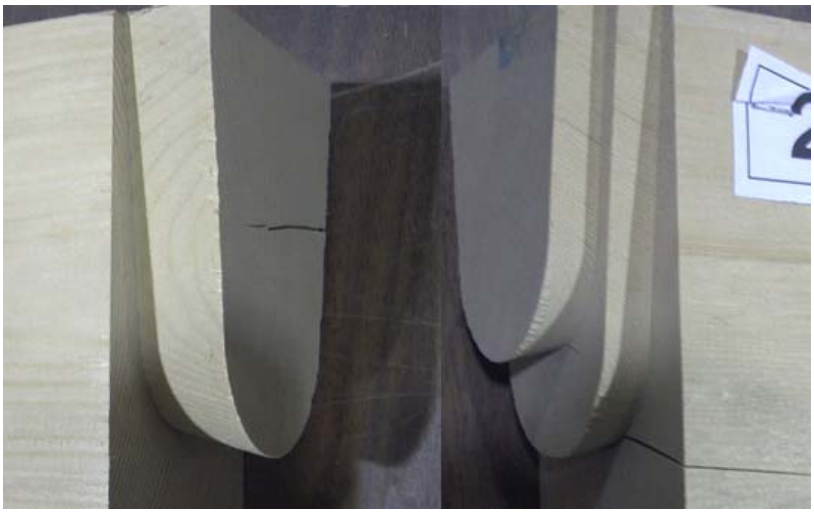

Figure 1: Single (left) and double rounded dovetail joint (right)

Research on Japanese Post and Beam Structures

A project carried out by the UBC timber building technology group investigated the performance of Japanese post and beam constructions, including research on joints, roof structures and entire houses. The project involved the development of sophisticated structural analysis model and full scale static tests (Fig. 2 left). All necessary timbers and corresponding joints to build a single story house were cut using the Hundegger K-2.

Design Concept for a Timber Shed

The purpose of a student thesis (Wagner 2007) was to provide a design concept to an industrial client to enable them to move forward with the manufacturing of a prefabricated, ready-to-assemble CNC cut timber frame shed kit. The work included a comprehensive financial analysis, information of the viability of using CNC automated technology in the market, 3D renderings, preparing CNC machine files, and prototype constructions (Fig. 2 right).

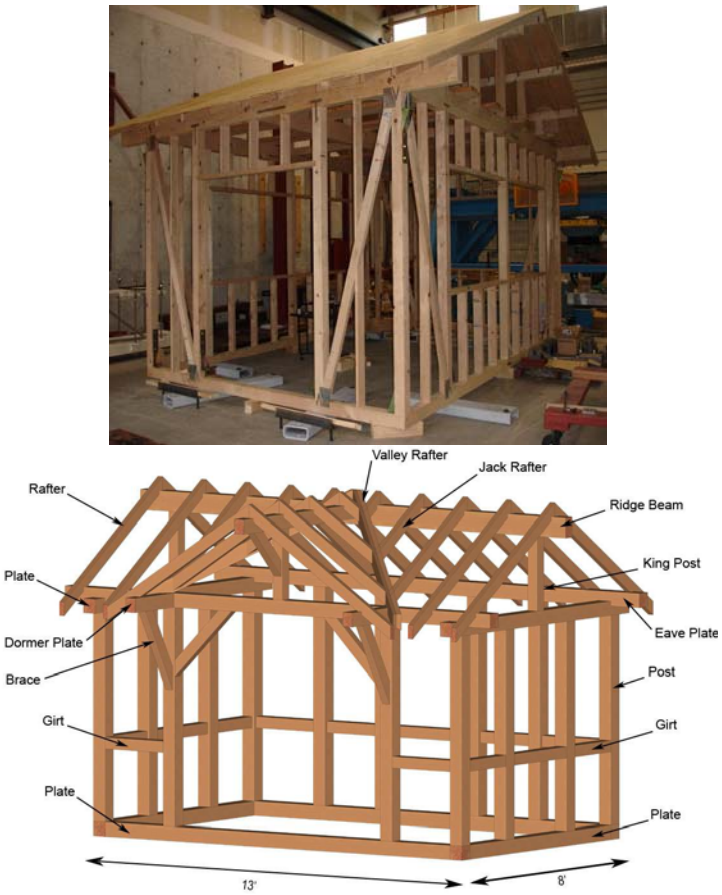

Figure 2: Japanese Post & Beam structure (left) and Concept for a Timber Shed (right)

CNC Timber Processing in Teaching

Interdisciplinary Course Projects

The UBC undergraduate courses WOOD 386 - Applied Mechanics of Materials, MECH 492 - CAD/CAM, and CIVL 439 – Timber Structural Design encourage student participation across the departments and students from different departments are grouped together to work on assignments. Additionally workshops on the application of CNC machinery in timber processing are offered and amongst other projects, a timber-frame structure for a sports field was designed, the components processed and the structure completed (Fig. 3 left). Students are introduced to computer assisted design and manufacturing with a focus on the fundamental issue of gaining an understanding of machine tools and software.

Parametric Modeling and Digital Wood Fabrication Workshop

New tools, techniques, products and practices are revolutionizing the use of wood in architecture, design and construction. To help design professionals take advantage of the opportunities presented by these innovations, the Canadian Design Research Network, in collaboration with the School of Architecture and the Centre for Advanced Wood

Processing at UBC, and the School of Interactive Arts and Technology at Simon Fraser University, presented a series of events that explored the potential of digital media and CNC fabrication technologies. The focus of these events was on the integration of parametric modeling and digital fabrication techniques into the design, manufacturing, and construction processes. Parametric modeling is an emerging technology that allows designers to interactively investigate multiple design alternatives and provides a new and innovative approach to design. In the context of this workshop, students designed and produced a wide variety of projects (Fig. 3 right)

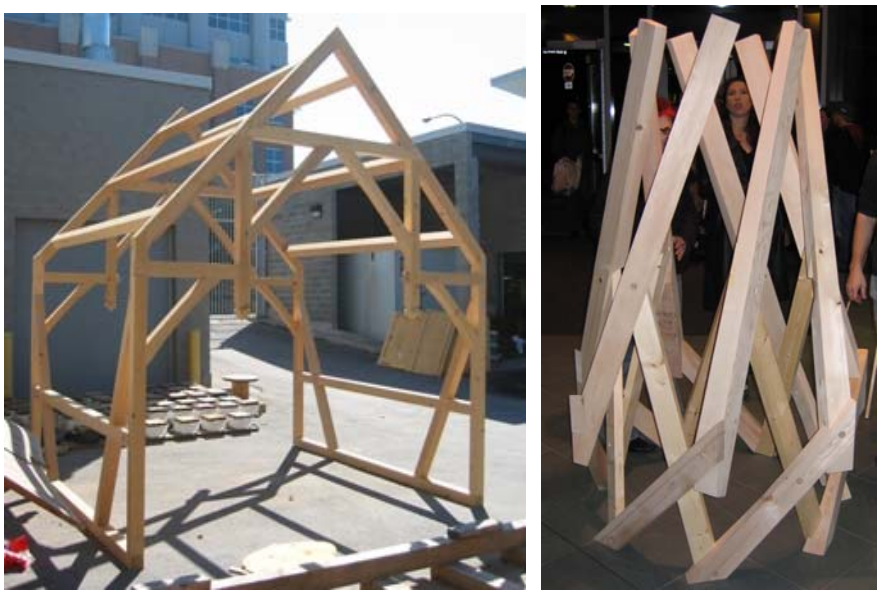

Figure 3: Timber-frame (left) and creative design (right) produced during workshops at UBC

International collaboration

Regional building cultures are a result of local and global influences. Associating technology with notions of region constitutes a shift away from attitudes towards technology that considered modern interventions detrimental to the preservation of local identity. Today, CNC technological developments should be understood as one of the means of design and construction that figure prominently into regional building cultures. A seminar offered by the UBC school of Architecture focused on the use of digital fabrication tools in design and fabrication. The course introduced to the discourse on the effects of digital media and fabrication technology on the design and building process, digital wood fabrication technology and software, and the development of the design and fabrication data for a small wood structure. Ideas and experiences from the introduction to concepts and technology were applied to the design for a small wood structure for a site in Temuco, Chile. Students had the opportunity to participate in the fabrication and assembly as part of a research trip to Chile. The project was developed in coordination with the Architecture School at the Universidad Mayor in Temuco, Chile, where students developed a similar design project and collaborated on the subsequent fabrication and assembly.

Conclusions and Outlook

Applications of a CNC timber processor at the University of British Columbia in research and education of timber joinery and the manufacturing of timber structures demonstrate that modern CNC wood-processing machinery has changed previously existing constraints regarding the production of traditional timber joinery. High-tech manufacturing machinery can be readily adapted to produce traditional joinery and thereby create value added building components. Using advanced CAD/CAM systems in combination with CNC timber processors allows an integrated, streamlined and paperless design approach. An interdisciplinary approach where the knowledge in the areas of wood mechanics, finite element modelling, architectural design, CAD programmes, and CAM manufacturing technology is integrated can lead to new developments and finally change in timber construction. Depleting natural resources and compromised environments lead to opportunities to conduct new research on sustainable designs methods and building practices and materials. In order to generate innovative design that contributes to the preservation of the environment, timber design needs to be based on an interaction between material science, manufacturing and assembly technology. CNC fabrication technologies can play a significant role in the transformation of design and building methods.

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