J. W. GOTTSTEIN MEMORIAL TRUST FUND

The National Educational Trust of the Australian Forest Products Industries

IMPROVED HIGH VALUE-ADDED FURNITURE MANUFACTURING IN AUSTRALIA USING COMPUTER NUMERICALLY CONTROLLED (CNC) EQUIPMENT

PHILIP ASHLEY

2003 GOTTSTEIN FELLOWSHIP REPORT

Joseph William Gottstein Memorial Trust Fund

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund *is "to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organisation (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust has had three major forms of activity:

1. Fellowships – each year applications are invited from eligible candidates to submit a study programme in an area considered to be of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate.

2. Study tours – industry group study tours are arranged periodically and have been well supported.

3. Seminars – the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

Further information can be obtained by writing to, The Secretary, J.W. Gottstein Memorial Trust Fund, Private Bag 10, Clayton South VIC 3168 Australia. Email Gottstein.trust@ffp.csiro.au

Mr. Philip Ashley is a senior lecturer in furniture manufacturing at Holmesglen Institute of TAFE. His major teaching fields are high technology wood processing, C.N.C. machining and CAD-CAM. He has an extensive industry background that includes high volume part processing.

He has twenty-two years teaching experience in furniture manufacturing, and more recently high technology CNC manufacturing. In 1998 he was a member of a multidisciplinary research team assessing young, plantation-grown eucalypts for furniture manufacture. The project included extensive trials on the machinability of selected Australian hardwoods.

Recently, he was a member of the Victorian Furnishing Training Advisory Group and the National TAFE "expert" advisory group for the 2003 National Furnishing Training Package. He is a current member of Australian Standards Committee SF-007 (Guarding of Wood Working Machinery).

Philip is a past president and honorary life member of the Australian Institute of Wood Machining. He is a regular contributor of technical articles to Australian and New Zealand trade magazines, and is the technology editor of Australian Wood Review magazine.

The award of a 2002 Gottstein Fellowship enabled Philip to study first hand World's best practice in CNC manufacturing of solid timber furniture. Philip was able to discuss equipment, software and application issues with educators, researchers, technicians and shop-floor operatives in four countries.

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Statement of limitations

The major furniture manufacturing sectors in Australia are timber, lounge-suite, metal, project, flat-panel and mattress. CNC woodworking machinery is used in the timber, lounge-suite, project and flat-panel sectors. Stairs, doors, windows and other joinery products are also manufactured with CNC machinery.

The use of CNC machinery in the flat-panel sector is reasonably well advanced. In addition, the production of components using flat-panel construction is a (generally) much simpler process than solid wood based manufacturing. Flat panels (manufactured board) require only edge treatments, borings for proprietary mechanical fasteners, and small amounts of routing using mainly straight tools. **The focus of this report is based more on solid timber and this includes manufacture of bedroom, lounge-suite, dining room and other occasional furniture, doors, stairs, windows and joinery manufactured primarily from solid timbers.**

CNC woodworking machinery is available in many forms. Solid timber machines include edge-profiling machines such as tenoners, moulding machines and CNC window production lines, and CNC profiling machines such as "point to point" and "routing" machines. Profiling machinery is generally used in the solid timber furniture, stair making, window, and joinery and door sector. **In Australia the most used CNC profiling machine is the CNC "point to point" machine, or processing centre and this was the principal machine considered in this study."**[1]

Mr. Antonio DiConza of Homag Australia recently advised, "Ninety percent of CNC processing centres sold in Australia are three-axis machines. Of the remaining ten percent, nine out of ten machines are sold with only a sawing option as the fourth axis." **This study is therefore limited to CNC machinery using three axes.** A machine of this type will be capable of drilling in the vertical and horizontal planes (5 faces of the piece),

[1] The CNC "point to point" machine will be referred to as a CNC processing centre throughout this report.

performing saw cuts in one and possibly two directions, and moulding or edge profiling using circular rotating cutting tools selected from a tool magazine.

Executive Summary

CNC processing machinery is widely used in Europe to improve production of a range of wooden items in the furniture and related industries. CNC manufacturing provides opportunities to improve flexibility, quality, short delivery times, operator safety and control over the end product. The industry is similar to Australia in that a high percentage of machines are of the three-axis type and are used in industries employing less than twenty persons. Similar also to Australia is the impact of imports from countries with low labour costs, able to supply low-cost product to a consumer market where cost, the latest design and shorter furniture "lifespan" are current issues.

It was interesting to note the scarcity of solid wood used for furniture manufacture. Painted and veneered panels, glass, aluminium and other materials are used extensively. Solid timber is difficult to source locally, especially of consistent high quality. Competition from imports has forced manufacturers to seek out alternative manufacturing opportunities such as kitchen and bathroom manufacture. This is an area that importers have difficulty in supplying due to the very specific "project oriented" nature of the installations. Production based on panel products is (usually) a simpler process and materials supply lead times are much shorter.

Where timber was used quality was paramount. Only the best timber was purchased and every effort was used to ensure every piece was used well. There was much advice and evidence of standardisation of components and edge profiles. Small job lots were common and were evident in both small and large companies. CNC machines were used to perform the maximum number of operations in the one cycle. There was more evidence of CNC machine sanding, and efforts made to apply sophisticated tooling to avoid the sanding process (almost) altogether.

Software was extensively used in companies with CNC installations. "Open-architecture" programs were used to take the initial CAD drawing through design, manufacturing and

assembly. The concept was referred to on one occasion as “fly by wire”. No company used “stand-alone” software.

Machine down time was always reduced to an absolute minimum. Quick changeovers were achieved through software, documentation, training and appropriate tooling. In addition, some products had been identified as being unsuitable for CNC manufacturing, and were still processed using standard machines.

The training culture in Europe differs from Australia in that persons are more likely to view education and training as a lifelong issue. It was not uncommon to see middle aged students in further training programs. Companies do however find it difficult to attract young people into the trades. Training in German institutes was mostly “theoretical”. The view is that practical training on machines in the trainee’s own company will be taught on-site. Formal “off-the-job” training is more about the “what and why”, rather than the “how”.

The single most effective way of improving the efficiencies of CNC manufacturing will be achieved by looking at how the material is processed, or actually cut. It is here that we will be able to achieve the greatest improvements in processing speed and quality of finished product, the two major production needs of the furniture industry. The application of appropriate tools in the correct way will require some expenditure by management and some input from training institutes and suppliers.

The German furniture industry has focussed on quality product. It also has a reputation for providing well-trained technicians for the industry. The Italian furniture industry remains a model for other European countries with a well-developed system of sub-contracting components and product development through a close association with designers. It would appear that this model would only succeed in Australia if enterprises were more aware of design as a sales tool, and were able to share manufacturing resources and skills across the industry.

Recommendations for CNC manufacture

1. Purchase machines and software wisely. Machines and software should be purchased for a recognised manufacturing need. Seek advice or use an independent consultant to advise on appropriate requirements. Despite the best intentions of the seller, machinery and software may not always do what the seller said it would. A mistake at this stage will cost the company for years to come. For instance, it makes no sense to purchase a machine with inferior SK (ISO30) tool holders. The costs are the same as HSK that are (arguably) twice as good at reducing tool runout.
2. Think small. Look for ways to reduce batch sizes. This will include quick-change tooling, variable (parametric) programming, and training.
3. Standardise components where possible. Many companies should be able to look for components that are similar, and re-design some pieces to create same-size components over several product ranges. Start with shelves and drawer sizes and then move on to other components.
4. Keep all profiles less than 20mm deep. This will allow the use of "system" tooling with constant diameters that simplify tool data entry. System tool bodies can be used to quickly mount different profiles and reduce tool change over time to less than thirty seconds. In addition, cutter heads mounted on an arbor will eliminate the collet that is the weak link in a collet chuck.
5. Mounting PCD tools in new-generation "Tribos" or "Thermogrip" chucks will improve chip removal and extend the cutting life of the tool. Some CNC processing machines are capable of 24,000rpm and both collet chucks and hydro chucks tend to "open up" at this speed and increase runout factors. The Tribos and Thermogrip chucks remain rigid to 40,000rpm.
6. Purchase tooling as an investment, not an expense. Cheap tools usually serve a single purpose, are difficult and time consuming to manage with CNC, do not always offer a quality finish and can be inflexible, costing machine down-time and productivity. Investigate micro grain carbide that lasts longer, with the same quality finish.

7. Most CNC machinery is under-utilised. Many are programmed to perform far below their capabilities (feed speed and cutting depth). Training should not just be about setting up the machine but include the application of the cutting tool to the work piece. The capabilities of existing tooling may be much greater than thought and the application of "advanced" tools could in many cases double the production speed and material output of the machine.
8. Quality should not be confined to the output of the CNC machine. Quality principles should also be applied to maintenance, cleanliness, tool holders and cutting tools. A CNC quality system will set a standard and the finished product will benefit.
9. Get the right people. The operators can double (or halve) the production output of any CNC machine. Appropriate training, remuneration and a career path will ensure the loyalty of key employees and ensure high outputs.
10. Employers must become partners with training institutes. Industry should actively seek the latest equipment and software for training, and support the training providers when applying for it. Employers must provide more practical training on in-house processes and allow the institutes to explore the "why" rather that the "how-to". Australia is in danger of producing "operators" when we need "technicians". We need thinkers as well as doers.
11. High technology is suited to high-value manufacturing. Using CNC machinery to combat low-cost imported goods is futile. Manufacture quality goods with a focus on good design. Switch production if necessary. Educate the public about "Australian-made" and good quality.
12. Investigate what components should be made on CNC machines and what is best done on standard machinery. Learn what your machine can and cannot do. Don't just run jobs; integrate the machine into the production line. The CNC processing centre can become a bottleneck in the production line. Know your set-up and production times and planwork sequencing accordingly.
13. Increase the use of veneer board and manufactured panels, and reduce the solid wood component of your production. Environmental issues will gradually change the public's acceptance of solid wood furniture. Design often follows European

trends, and the trends there appear to be modern looks and functional design using alternative materials.

14. Learn to use the expertise of other companies. It may be possible to include some other materials such as steel, glass or plastics into the product range. Your designs could be seen as more “modern” and appeal to a wider consumer base.
15. Software is a powerful tool. Use it as much as possible from design through manufacturing to assembly. If your software does not “talk to all other programs and your machinery” then it’s costing money. CNC machine software is not real CAD; it is workshop-oriented and limited in design capability. Consider the purchase of a proper CAD system to design a product, then post-process this design directly to the machine. This eliminates much of the set up time (reported to be an average of nine minutes in Australia). The right machines and software can build a manufacturing “system”, where many companies just have “machines”.
16. Be creative. There are other ways to make furniture and it may not always be like “Dad” made it, or the way you were taught in trade school. Look for a cost effective way rather than a “trade” way.

Technology and the Australian Furniture Industry

Australia is (per capita) reported to be one of the largest users of CNC machinery in the world[2]. High-technology machinery in Australia is generally of the following machine types. CNC beam (pressure) panel saws; CNC routing machines; CNC processing centres; “low-cost” flat-bed NC routers; NC moulding machines; PC controlled edge processing machines and other programmable machines including wide belt sanders and shaping machinery. The two main types of solid wood CNC processing machinery are the CNC router and the CNC processing centre. While the CNC router (Figure 1) is arguably more suited to the working of solid wood, the CNC processing centre (Figure 2) is the more popular machine due to its lower purchase cost and perceived ease of programming. Recently, the low-cost NC router (Figure 4) using a flat table, tool change and light-construction overhead gantry system is gaining popularity due to its favorable pricing.

Figure 1 Typical CNC router used for furniture manufacture in Australia.

[2] Source: Allwood machinery company (machinery suppliers)

Figure 2 Typical 3-axis CNC processing centre.

Before the results of this study can be fully appreciated and implemented, an understanding of the current technical position of the Australian Furniture Industry is essential. To this end the study "Analysis of current production practices" (May 2001) was commissioned by the Furnishing Industry Association of Australia (FIAA) and the Department of Industry, Science and Resources (DISR). Dr. John Mo, Mr. Stuart Woodman, Mr. Sean O'Brien, Dr. Laszlo Nemes and Mr. Brian Scudds of CSIRO Manufacturing and infrastructure Technology conducted this study. Their report identifies the high-technology production issues that affect the Australian Furniture Industry as follows:

- Unsatisfactory use of computer systems and CNC equipment.
- Piecemeal use of technology.
- Lack of knowledge of CNC use and application
- Poor training regimes.
- The use of trade practices instead of production practices.

Author's Discussion

CNC machinery is often purchased mainly to replace current hand-fed production equipment. In addition, price and a relationship with salespersons are often determining factors when it comes to making a final decision on the technology to purchase. In many cases, purchases are made without the use of consultants or fully exploring the available market in CNC equipment and software. In most cases a machine is purchased to simply replace basic static machinery with little planning as to the future manufacturing needs of the machine shop.

Components that are considered "too difficult" are usually retained on existing machinery so that often no additional floor space is achieved by the disposal of "obsolete" equipment. Some investment is made on CAD-CAM software to assist in the development and programming of prototypes and component parts, but this is often supplied with the machine and is not always compatible with other software used by the company. There is often no difference between manufacturing techniques used on basic and/or CNC machinery. The "Analysis of current production practices" report found that the industry perception is that CNC machinery is good for batches of 50 or more, or repeat orders. This perception prevents further exploitation of technology. The machine set up times are also interesting in that it takes an average 9.4 minutes to set up a basic machine and 9.0 minutes (average) to set up a CNC machine. There appears to be minimal reduction in set-up times due to technology in the Australian furniture industry.

In many cases manufacturers spend little additional funds on tooling (cutters) or jigging to fully achieve the potential of the new machine. Standard cutting tools are used extensively on CNC machines. Screws and staples are often used to hold product to the worktable. Operators are chosen from the existing workforce and given basic training by the machine supplier, usually on a "need to know" basis. Some manufacturers make use of training provided by TAFE Institutes, often on different brands of machinery.

Industry leaders

Leading furniture-manufacturing enterprises are committed to maintaining a technological edge. They have invested in, and integrated technology; to ensure continuous improvement in their production systems. In some cases equipment was purchased at higher cost due to the perceived "future-proof" technology of the machine(s). These companies recognise, however, that technology can only contribute to their competitive edge if it is effectively integrated into the workplace and this includes work practices. The most common use of technology is Computer Aided Design (CAD) and Computer Numerically Controlled (CNC) machinery. In addition, local computer networks and manufacturing planning solutions are sometimes developed and used.

Existing technology drives most woodworking enterprises. Leading companies however are more likely to determine their technological needs from a business plan. It is recognised that technological benefits will be evident when it is appropriate to the needs of the enterprise, and it is used to its optimum potential. A high percentage of leading companies believe their technology is appropriate for manufacturing needs. Companies using traditional technology are less likely to recognise the benefits of CNC technologies.

Wood working machinery imported into Australia

The 2001 Annual report of ACIMALL (Italian Wood Working Machinery and Tools Manufacturers Association) records 18,392,000 € (AUD$33,105.600) of Italian wood working machinery sales to Australia. This is higher than that from all Asian countries other than China (50,409,000 €). Imports of wood working machinery from Italy had remained static for the previous five years, but dropped 20% in the period of this report, as did most other Asian countries with the exception of China that increased its imports of Italian machinery by 20% during the same period.

Machinery imported into Australia is principally from Italy, Germany, Japan, Taiwan and the United States of America. (Figure 3). In 2001 Italy and Germany clearly led the race in imports to Australia. This report does not provide data on machinery types imported

but it is the opinion of the author that more basic machinery would be purchased from Italian companies. This is due to the lower cost and more plentiful Italian basic-machine manufacturers. While no specific data is available, it is likely that the supply of CNC machinery from Germany and Italy is somewhat equal. Of the other importing countries, Japan and the United States (Figure 4) would have a small share of the CNC market. The author visited Taiwan in 2000 to investigate wood machinery production and at that time there was no manufacture of CNC profiling machinery evident.

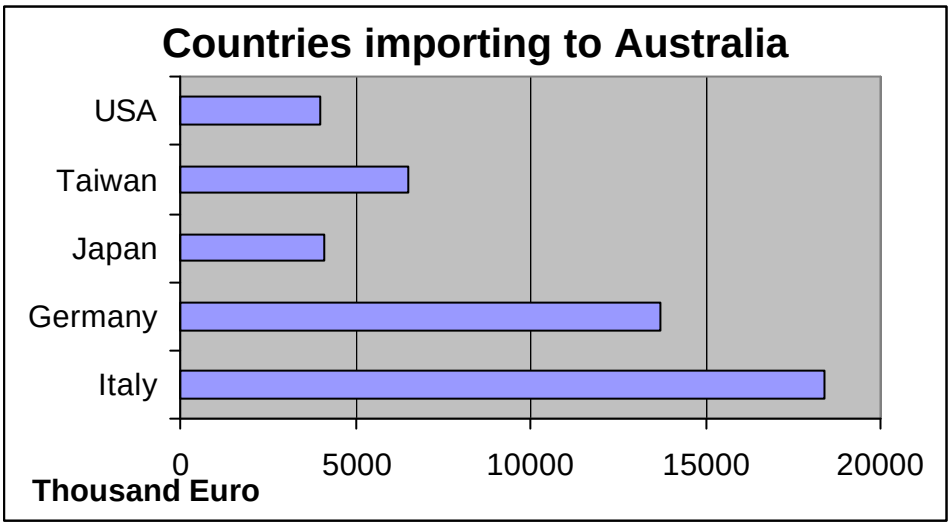

Figure 3 Woodworking machinery imported into Australia (ACIMALL – 2001 Annual report)

Figure 4 Typical CNC machine imported from the United States of America

Historical overview of the European Furniture Industry

The European furniture industry has a long and successful history. Many fine pieces are housed in museums throughout Europe, and are now regarded as examples of fine art. Names of fine designers and craftsperson's such as Chippendale, Sheraton, Boulle are universally regarded. In the post-second World War period the demand to re-build drove the building and furniture industries, and local craftspersons made furniture. It is a fact that many of the World's leading furniture makers and machinery manufacturers are located in continental Europe.

In the 1960's an economic boom saw the furniture industry successful primarily in replacing old products. Up until the 1970's Italians in particular continued to dispose of valuable furniture pieces, replacing them with the latest "fashion". Mass-production furniture companies prospered, often at the expense of quality and taste.

Woodworking machinery was developed mainly in Germany from the mid-1960s when the major suppliers were established. Italian companies followed some ten years later. The introduction of manufactured boards created a need for new machinery and processes and many of the early "craft" skills have gone to artisans or companies fulfilling the needs of niche markets.

The 1970's saw a boom in kitchens. The latest electric appliances and a change in lifestyle from small workspaces to entertaining areas saw the introduction of the "American" style kitchen. In the 1980's the cost of raw materials increased, and many of the furniture companies of the 1960's had disappeared, replaced with enterprises that were able to adapt to changing market demands. Design, marketing and sponsoring were new tools that made all the difference. Companies specialising in one type of furniture production used improved technology to develop a flexible production based on smaller orders. The 1990's saw the introduction of regulations in product and machinery. New materials, fittings and manufacturing technology were the driving factors.

A snapshot of the European furniture industry

The "perception" of the European furniture industry will vary depending on personal observation, acquaintances, and what persons with vested interests want you to believe. The brief snapshot presented here is therefore derived more from published literature, reports and media, and what Europeans involved in the industry itself have consistently reported. Observations were made that were consistent with what had been recounted. The opinion(s) of training institutes and research centres were considered to be somewhat "independent" and were highly valued.

Materials

The use of solid timber for furniture manufacturing in Europe is diminishing. Solid timber furniture is expensive due to the high cost of the raw material. Where solid timber is used it was always observed to be of the highest quality. There was no evidence of knots or any other "feature" in the material at any of the places visited. Manufacturers are moving more towards veneer board as the primary material, with the use of solid edges on panels and tabletops to improve edge life. It was interesting to observe low-cost timber profile-wrapped for interior doorframes (Figure 5).

Figure 5 Profile-wrapped doorframes at Nordemann

Manufacturers use a variety of materials, such as plastic and aluminium in the construction of furniture products. One example is cabinet doors with wood and clear Perspex strips to give depth. Aluminium sections, glass, plastic and other materials are used extensively. No material is considered outside design possibilities. Successful companies are able to identify customer needs, and to quickly adapt to the changing marketplace.

Supply and demand

The ageing European population is said to likely affect the retail market. While ageing, the population is growing and the demand for increased housing will be significant. Future housing will, however be smaller because of demands on space, and furnishing these smaller homes will be a challenge to designers. The demand is for furniture to be more functional than visual, multi-purpose and easier to maintain. In particular, furniture as a fashion commodity is having a reduced life expectancy, or shorter replacement cycles for furnishing products. Good design is also used to simplify manufacture and shorten lead-time. Environmental issues are growing in importance, and the furniture industry needs to appear to be environmentally responsible. There has been a deliberate shift in materials usage from solid timber to manufactured boards in recent years
Figure 6). The supply of raw materials is a priority for manufacturers and will continue to be so in the future.

Figure 6 Manufactured board used extensively in this bedroom setting seen in Valencia

Skills and Globalisation

Young school leavers seek out more "glamorous" employment and the present skills shortages will reportedly continue. In addition, the ageing workforce will place pressures on manufacturing labour in the near future. The use of CNC machinery is often seen as a means of reducing skilled labour however there is a perceived need for highly skilled "technicians" able to set up complex programs, solve problems and make shop-floor decisions. Germany in particular has a requirement for a joinery or furniture business to employ a "meister" (six months full time course). In large companies around ten percent of employees are skilled to this level.

Global trade is increasing. The effects of the manufacturing boom in emerging countries are being felt throughout Europe. The output from Asia and Eastern Europe where wage costs are low is affecting most furniture manufacturers. Most responses to questions on issues for furniture manufacturers stated imports as a primary concern. Locally, Russia, Hungary and Poland were cited but Asia was a concern for all respondents. One example is that in five years to 2000, furniture imports to the United Kingdom increased by 60% while exports grew by a mere 7%. While domestic growth cushioned manufacturers from this increase, a slowing of the market will see a significant future impact[3].

[3] Competitiveness of the UK furniture manufacturing industry, FIRA/UK department of trade and industry 2002

CNC manufacturing in Europe

CNC machinery is used in almost every type of solid wood manufacture. Furniture, stairs, entry and cabinet doors, joinery and window production are some examples. Companies using CNC range from the largest companies employing 1000 people to small local enterprises with less than ten employees. Some of the largest factories can be found in Germany, Italy and Spain. In Italy in particular a large percentage of furniture is made on automated production lines.

Quality is one of the most important manufacturing considerations, and great lengths are pursued to achieve consistent quality. This extends to strict control of the moisture content. One company was observed blowing moisture laden air into the factory from outside to maintain 6-8% relative humidity. Where the climate requires factory heating it is applied with consideration to the stored materials. While the use of solid wood is diminishing, where it is used it is treated with great care to gain the maximum benefit from every piece.

Flexibility is an important manufacturing issue. Some large companies have actually removed conveyor systems and replaced them with wheeled trolleys to improve flexibility of manufacture. Job lots are reducing and as few as three or four kitchen doors are considered normal. With these small job lots, trolleys are an ideal solution. Small companies with large amounts of stock are considered unusual.

Equipment

Larger companies tend to be more automated and have sophisticated computer controlled manufacturing similar to vehicle assembly lines. Smaller companies similar in size to Australian manufacturers will have one or two major pieces of CNC equipment and mostly produce components as required (just in time). Equipment use in Europe is similar to Australia. There are large manufacturers using large-capacity four and five axis machines to process product, but generally, three axis machines are most common, being

75% of the market[4]. Similar to Australia, a fourth axis is normally used to provide a sawing option. These machines are more evident in the production of window components and stair manufacture.

Nested based manufacturing (NBM), a production concept gaining popularity in Australia, is little used in Europe. NBM was originally an American development where low-cost flat bed machinery processed components from entire sheets of panels in one program. This suited cabinet door manufacturers, lounge-suite frame manufacturers using plywood, and certain applications in office furniture and kitchen manufacture. Panel sizes used in European companies tend to be larger than the 2400mm by 1200mm bed of these machines. In addition, there are many companies book-cutting panels at competitive prices and on-selling cut-to-size product to smaller companies for further processing into finished product. There is also more dust generated with NBM cutting and an increase in the amount of waste. European machinery manufacturers build this type of machine mostly for export to the United States of America.

Software is a major consideration with the purchase of a CNC machine and in many cases is the determining factor. “Open architecture” software is preferred to enable the use of data generated during the design stage to be used as much as possible throughout production. This includes cutting lists, part drawings and specification sheets. CAD drawings are post-processed to machine code, or drawings are saved in a format compatible with the machine CNC system. There is little use of “stand-alone” software.

The concept of “Batch size one” is only applied to panel furniture manufacture. In this type of manufacture (panels) the changeover from one product to another is a simple task. All panel products are clamped with the use of vacuum devices and set against mechanical stops. The use of variable programming through software is now commonplace and variations in product dimension is now easily accommodated.

[4] Source: Weeke Bohrsysteme GmbH

There is some reluctance to seriously consider the manufacture of a whole piece of solid timber furniture (that is the entire set of components) as a batch of one, in the one machining cycle. There is however a definite focus to combine as many machining operations as possible into the one program for single components. This minimizes the cost of moving components between machines for additional operations.

Some companies were observed to be maintaining production on traditional machinery. Management was of the opinion that some product was more efficiently processed using traditional methods.

Training

Staff employed in furniture manufacturing are generally well skilled. Germans in particular have a culture of continuing education and in many companies all employees are regularly evaluated for effectiveness in the workplace. Persons wishing to start their own business are required to hold at least a meister certificate, or to employ a person who has. In Europe, as in Australia, the value of the CNC technology varies with the skills of staff. Persons responsible for the operation of the CNC machine are invariably well trained. This does not always extend to the person feeding wood to the machine.

Apprenticeship systems similar to Australia produce well skilled men and women able to work effectively on all types of equipment and manufacturing processes. In addition, further education in the form of "masters" and other University courses are well supported in most countries. For example, the meister course offered by the Holzfachschule in Bad Wildungen (Figure 7) requires six months full time study and costs the equivalent of twelve thousand Australian dollars, yet is highly regarded as a career stepping-stone. Government subsidies are available and these are means-tested.

Much of the training offered in German schools is theoretical. Practical training is mostly delivered in the workplace. The ratio is 20% practice and 80% theoretical delivery. Seminars are different with 90% practical delivery. Unlike Australia where training has mainly been oriented to practice, high value is placed on an understanding of materials

and processes. It's more focused to the why, rather than how. Week-long courses in operating safety are well attended.

The training cost in Australia and Germany is the same at approximately $10 per student contact hour. In Australia advanced courses are mostly part-time but in Germany advanced training courses are often full-time with little possibility of employment during the training.

Figure 7 CNC machine shop at Holzfachschule Bad Wildungen

Tooling

Tools (cutters) used on CNC machinery are seen as a vital investment in improving productivity. Tooling costs range from 5% to 30% of machine costs, and in some cases exceed hundreds of thousands of dollars. Where specific profiles are required, the customer contributes to the cost of tooling and maintains exclusivity for a profile for a given time.

The use of carbide-tipped tools is increasing in Europe. High-speed steel tooling was traditionally used for cutting solid wood because of the favorable sharpness angle of 37 degrees. This benefit is now minimal as micro grain/micro finish carbide can now be sharpened to 40 degrees with an edge of one micron. Micro grain has a higher wear resistance that results in smaller damage to cutting edges under normal cutting conditions. However larger grain carbide is recommended when machining wood with foreign particles.

Due to the (usually) small job lots, flexibility and quick tool changes are crucial factors in tool purchases. On cabinet doors for example, the Leitz “profilcut” system tools (or a similar tool system) was observed to provide quick changeover times resulting in more flexible CNC production (Figure 8). The tool management can be handled in-house with little dependence on tool suppliers.

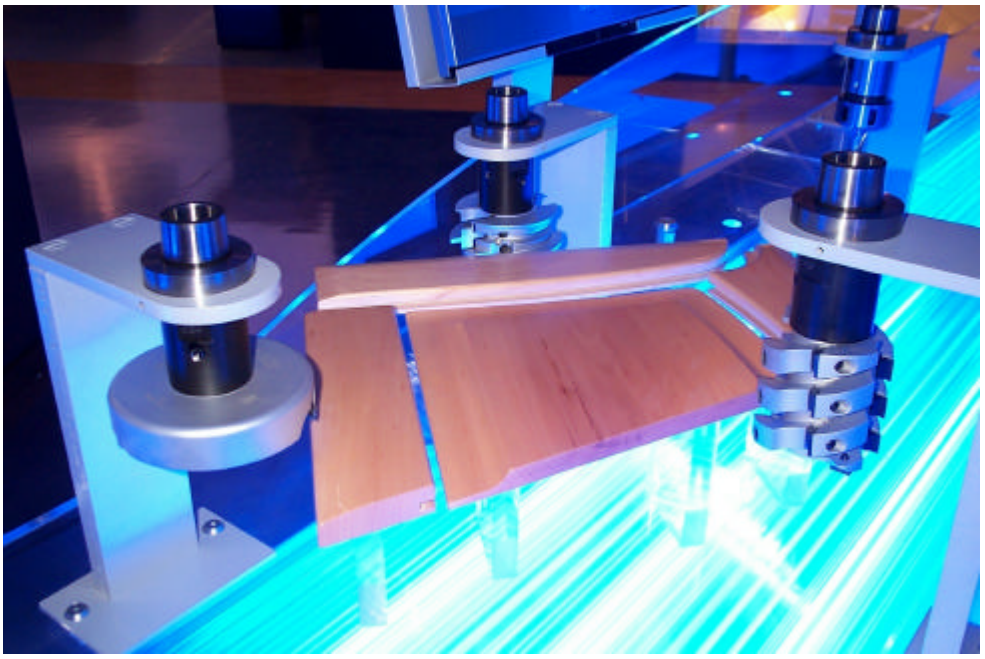

Figure 8 CNC System tools for cabinet door manufacture in solid wood. Left to right: “Profilcut” panel raising tool, “Profilcut” counter profile tool, and copy shaping cutter set.

Where furniture shaping is necessary, many companies standardise profiles as much as possible to reduce the number of profile tools needed. While waste is an issue, the

production of offcuts is minimised. This is achieved with tooling capable of "cutting to dust". "System" tooling is expensive but because the tool bodies are a one-off purchase, the ensuing production benefits far outweigh the initial tool cost.

Polycrystalline diamond (PCD) tools are used for machining hardwoods, but softwoods contain more defects (knots) and are considered unsuitable for processing with PCD. PCD tools are ten times more efficient in eliminating heat due to friction meaning there is less burning of the cut edge. PCD is used at higher RPM's to improve edge quality, but not to achieve a higher feed rate.

Some of the latest developments in European tooling are focused towards reducing runout. "Runout" is an imbalance of the tool caused by the collet chuck and results in only one of the two cutting edges actually contributing to the quality of the machined surface. This means that optimum tool feed rates are not possible, and lower feed rates used to factor in a quality standard will tend to reduce the life of the cutting edge. Aluminium tool bodies are used to reduce the amount of unbalanced weight in the tool body but the interface of the cutting tool and tool holder (chuck) is where most of the imbalance occurs.

New tool holding technologies such as the Leuco "Tribos" and Leitz "Thermogrip" systems are beneficial in reducing runout to the levels possible with the traditional hydro clamping system. The hierarchy of tool holding systems is as follows (best to worst):

1. Monoblock tool (Tool mounted directly to the spindle interface)
2. Hydro clamp chuck AND Tribos or heat shrink chucks
3. Balanced collet chuck
4. Unbalanced collet chuck (least effective in reducing Runout)

Traditional collet chucks have been tested to a Runout value of .025µm. This is 25 million parts of a metre, or 25 thousand parts of a millimetre. Technical advice supplied by the Leuco Company is that 15 µm runout is the limit for good cutting quality. Hydro

and “Thermogrip” type chucks tested to a runout value of 3 µm. However, hydro chucks are three times more expensive than Thermogrip or Tribos type chucks and the feeling is that in time the industry will adopt the new chuck technology to reduce costs. The new chucks are also a slimmer design that has a tendency to improve chip flow (extraction).

High Speed Cutting

The term “HSC processing” (high speed cutting) originates from the metalworking sector, and means the cutting or machining of materials at enhanced (higher) cutting speeds. Current CNC machine spindle speeds are supplied in the order of 18,000rpm to 24,000rpm with 18,000rpm being the most common speed. Improvements in the edge quality of wood furniture components can be achieved by increasing the cutting speed of the tool. The cutting speed refers to the actual speed of the tool edge, not the revolutions per minute of the spindle although a higher RPM will achieve a higher cutting speed.

It is possible to increase the cutting speed of tools by increasing the tool diameter but unfortunately the greater the tool diameter the greater the possibility of unbalance. Increasing tool diameter also means that more teeth are required, as the tooth progression (distance between each cutting tooth) will change. In the woodworking sector today, cutting speeds of up to 80 m/s are achieved when trimming with large diameter profile tools (Figure 9). Knowing this, it is evident that the cutting speed of profile tools in the range of 80mm to 90mm diameter is optimal.

The optimum wood cutting speed range of routing tools is 50 to 80 metres per second and small diameter tools are unable to achieve even the lesser speed. A 25mm cylindrical router cutter has a cutting speed of only 23 m/s or less than half that recommended. It is in the area of small diameter tools that gains in quality and productivity due to greater spindle speeds is most apparent. To achieve optimum performance it is necessary to lift spindle speeds to between 30,000 and 40,000 rpm. The mechanical engineering requirements for HSC processing are a high degree of rigidity in the machine frame, improved axes drives for greater response accuracy, high spindle speed and tools designed for high-speed rotation.

The higher kinetic energy presents some increased risk if tools were to break. Human error in installing the wrong tool and accelerating a large tool to very high speeds will also be a serious risk. Expensive CNC tool management systems using microchips

embedded in the tool itself is currently the only sure way of preventing this. Future developments will see torque momentum sensors on the machine spindle.

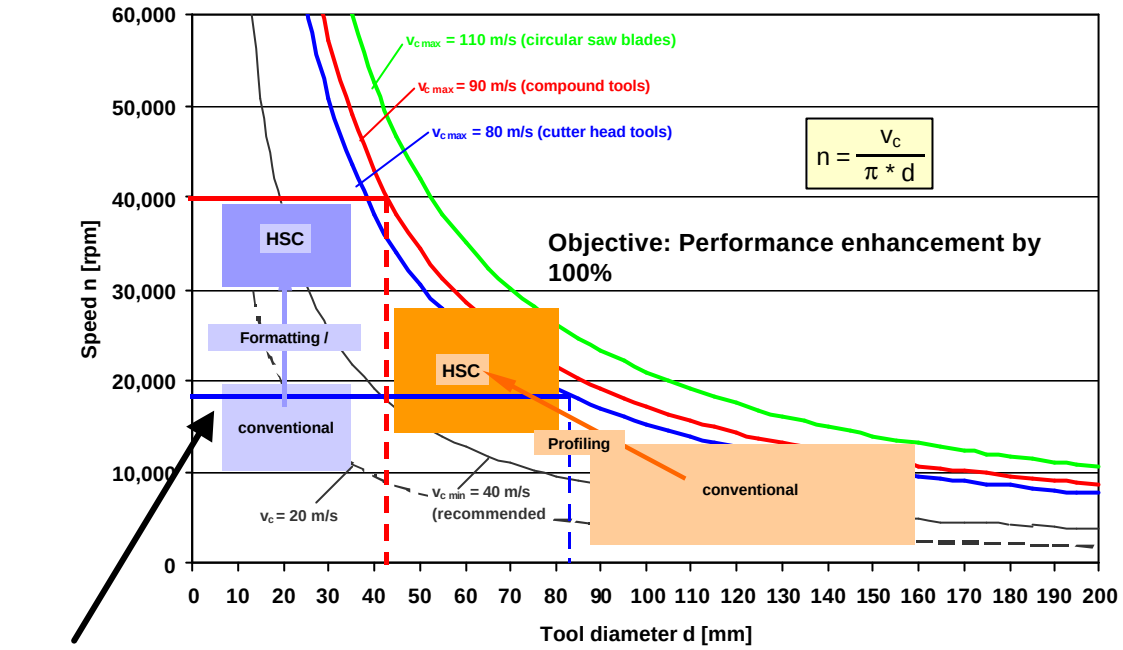

Figure 9 Possibilities of HSC technology

The HSC project is currently in year two of its four-year government funded program. Companies involved are Homag (machinery), Leitz (tooling), Leuco (tooling), Benz (spindle development), IFW (University Stuttgart), FH Rosenheim (University Rosenheim), Reichert (manufacturing trials) and Wossner (manufacturing trials). The German ministry for education, development and research funds the program. Current research includes spindle development, safety and the removal of waste (chip flow) at high cutting speeds.

The benefits of HSC are that when higher RPM brings the cutting speed to an optimum level, higher feed speeds can be used to reduce the cutting time, increasing material output.

Organisations visited during the investigation

Weeke Bohrsysteme GmbH, Gutersloh, Germany

Weeke Bohrsysteme GmbH is a traditional machine manufacturing company established in 1945. At that time Gustav Weeke & Son founded a locksmith's company in Herzebrock that had the aim to solve the requests of the woodworking companies. Weeke developed the first revolutionary worldwide lock insertion machine in 1954. The next milestone was a machine that allowed multi-spindle drilling into work panels, eliminating the costly and difficult groove-and spring connecting method that was used up to that date. Since that time, CNC-Technology and chaining with other processing aggregates has become State-of-Art at Weeke. In May 1986 the family-owned company was integrated into the Homag Group. Weeke took over the role in the special range of drilling, routing and assembly technology for lower-cost processing.

Weeke is typical of most European manufacturers in that sub-suppliers produce basic parts that are re-machined by Weeke prior to assembly. The company is currently developing through-feed panel machinery with the capability of top and end drilling in addition to gluing and dowel insertion to a capacity of eight thousand panels per shift. In the area of CNC processing of timber products the company has a range of machines based mainly on table size. Three axis machines are the largest production volume.

Weeke is currently doing some research into producing an entire product on the one machining cycle (batch size one) (Figure 10). The product was a small high-backed adjustable-height chair made in this case from marine plywood. This product was produced on a four-axis machine. They were also willing to demonstrate the potential of three-axis machinery to exceed "normal" process expectations, in this case a three-dimensional wooden "ball" manufactured in two halves on a three-axis machine (Figure 11).

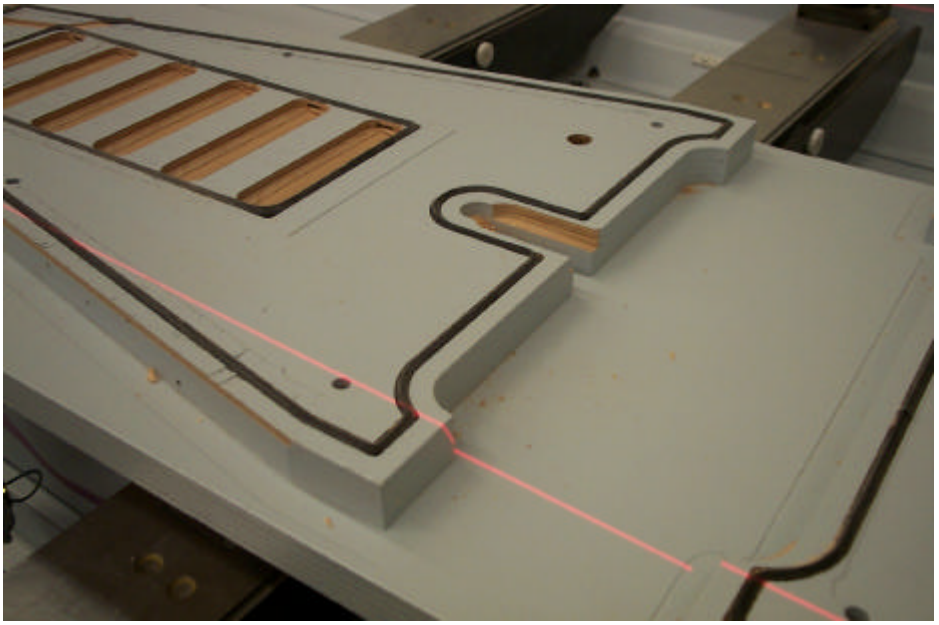

Figure 10 Detail of jig for "Batch size one" concept at Weeke Bohrsysteme GmbH. The laser is used to position the component parts.

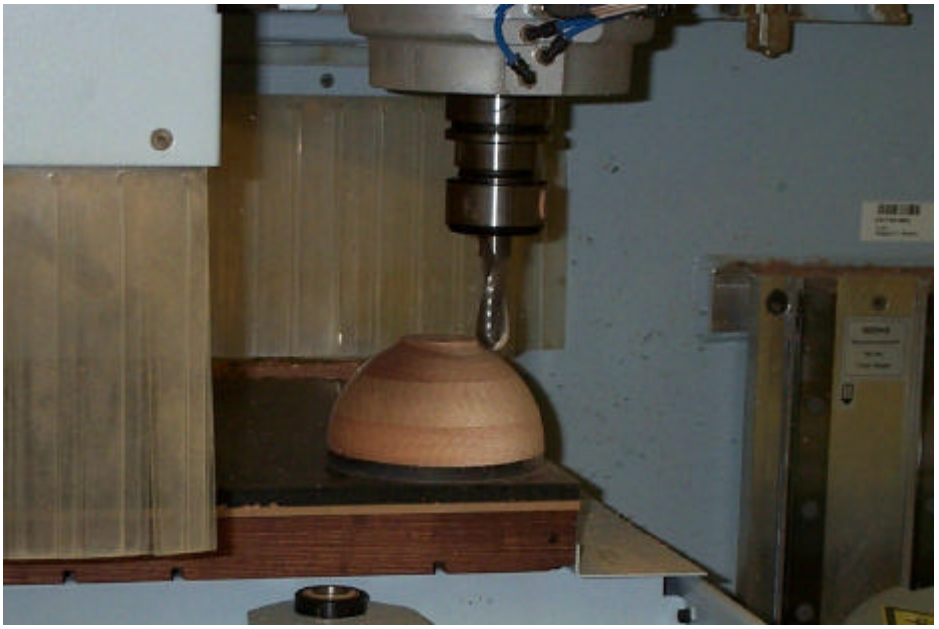

Figure 11 Work in three dimensions performed on a three-axis machine at Weeke. The wood is held in place by a single screw.

Holzfachschule Bad Wildungen, Germany.

This school trains apprentices, "masters" and University type students. Apprenticeships are three year duration but eleven weeks full time (55 days) compared to Australia's one day a week (38 days). Master students attend six months full time for a course length of one thousand and eighty hours. Days are often ten hours long with the exception of Friday that is six hours. The university course is two years full time. Students are well motivated despite having to undertake some courses full time with no income from employment. Government subsidies are sometimes available but these are means tested.

The school is 65 years old and its 16 buildings occupy 40,000 square metres of land area. Fifty-five staff are employed and this includes only sixteen teachers. Class sizes are similar to those in Australia. Workshops are small in size and designed usually for a single purpose. A fully equipped sawmill, saw-sharpening shop, cabinet shop, several machine shops, lecture theatres, cad rooms and CNC workshops occupy the site. Students live in due to the full-time nature of most of the courses, and very comfortable motel-style accommodation and facilities are provided.

The school has a close affinity with wood. Heating is provided from boilers fuelled with wood waste. Wood is used extensively for furnishings, fittings and in the buildings themselves. Floors are usually wooden blocks placed end-grain up, and extensive use is made of interior wooden construction beams. The school is capable of training from sawmilling to the finished value-added product.

The CNC workshop is equipped with two German CNC processing centres. In fact the school buys German machines exclusively, and upgrades every one or two years. An annual upgrade guarantees the highest resale value for the used machine, and the lowest overall cost to the school. The school currently has a three-axis and a four-axis machine, and dedicated CAD laboratories. Basic programming using G-codes is still taught prior to actually using any CNC equipment.

Nordemann Tischlerei GmbH (Joinery) Harsewinkel, Germany.

Nordemann produce stairs, entry doors and cabinetry (kitchens). Some furniture is made for local demand. The company started in business building staircases and moved into entry doors several years ago. Stair making is no longer the primary business and the manufacture of entry doors occupies much of the factory. The company has an unusually large stock of standard door components. Almost half the factory floor space is taken up with floor to ceiling component racks. The company is able to respond quickly to demand.

CNC equipment consists of two different brands of CNC processing centres. Production of stairs is done on one and door components on the other. The owner has a passion for collecting old machinery and these are stored in dark corners. Some work is done on these old machines and the owner says this is quicker and more efficient than with CNC machines.

Some components (door stiles) are actually several pieces of cheap pine-type wood laminated together then covered with a plastic or higher value veneer foil. This allows good strength and screw holding characteristics. Timber grain foils are also used for these products.

Reichert Holztechnik, Pfalzgrafenweiler, Germany.

Reichert manufacture doors in solid timber and other materials for the furniture and cabinet industry. The company employs 85 persons who are highly skilled. Beech, Oak, Poplar and Birch are sourced locally but are difficult to obtain. Only the top 20% of quality clear wood is used and is sourced from as far away as France and Scandinavia.

The company's CNC machine shop is not ideally located. This is because concrete flooring is not available throughout the factory due to the two levels. The company uses vacuum devices to hold all timber products while machining, saying this is their most flexible solution. As few as three doors are produced in an order, but the norm is closer to

seven doors. Wheeled trolleys are used extensively to move stock as this allows most flexibility.

The company has an unusually high stock of cutting tools for both basic and CNC machinery. A tool room is maintained full-time to set tools for the many small orders. Reichert is actively involved in the development of high-speed cutting (HSC) technologies, supplying the manufacturing environment for the project. The company attracts customers with its huge range of door styles and mouldings so the investment in tooling is seen as a marketing ploy. There were no low-cost tools evident. All profile tips were fine grain carbide. Standard machines were used within the machine shop and these machines were used mostly for tenoning operations.

Documentation is generated from CAD drawings and is used throughout the factory. Nothing is done by word of mouth; there is a procedure for every action. Finishing (polishing) of the product takes the most time and the machining process on CNC reduces chips and other defects. Fine sanding is then applied before water-based lacquers (Kyoto protocol) are sprayed by robotic spray equipment. The shiniest finish is much sought after by customers.

Nestle Fenster, Waldachtal-Tumlingen, Germany.

Nestle Fenster manufacture windows and doors in solid wood and other materials. The company is 375 years old and currently employs 25 persons. The CNC machine is one of only a few woodworking machines in the factory, and carries all the programs and tools to produce the entire range of complex window profiles and length variants in the window range. Laser positioning is used to locate the raw material and an aggregate (fourth axis) is required for sawing and drilling holes through 360 degrees. The company keeps no stock of finished components; each frame is produced to order as required. European window frames are complex designs (Figure 12) and in addition to edge

moulding and end profiling (slots, mortices, tenons, dowels), intricate machining is required to accommodate the range of automatic closure devices.

Figure 12 Complex window profiles produced with CNC at Nestle Fenster.

Holzma Maschinenbau GmbH, Calw-Holzbronn, Germany.

In 1967, Holzma began operations with the production of horizontal panel dividing saws. Today, with over 500 employees and a production area of approx. 26,500 m², Holzma is the world's leading manufacturer of panel saws. Holzma's success is based on experienced staff, forward-thinking and reacting to industry needs. Holzma is part of the Homag group and machinery produced at this company is software-compatible with other machines produced by the group. The company’s expertise extends to the stacking and movement of large volumes of panel product, and flexible processing.

Homag, Schopfloch, Germany.

The foundation of Homag AG in the year 1960 had its beginnings in the village smithy run by Eugen Hornberger and the consultancy firm of Gerhard Schuler. While their initial efforts were directed towards simple transport devices and processing equipment, they delivered the first edge banding machine only two years later, making the beginning of what was to be a rapid upward development.

Homag's progress over the following years was marked out by innovative technology and an aggressive market strategy. The first foreign subsidiary was soon followed by additional company acquisitions to selectively extend the company's performance range - and so strengthen its market position.

In the eighties, the company stepped up its integration of producing companies: Homag the system supplier was trimming its sails to assume world market leadership. As one of a whole string of pioneering developments, Homag is now underpinning its leading role with the world's first robot-controlled assembly cell. Added to this is the fact that no model in the Homag range exceeds three years of age before it is redesigned. Homag is actively involved in the development of high-speed cutting (HSC) technologies, supplying machinery for the project.

Mr. Eberhard Schee of Homag sees product quality, getting the right (skilled) people, ease of machine programming, the ability to process different materials and to be competitive in price and quality as the most important issues a manufacturer using CNC machinery needs to get right. CNC provides the user with the opportunity to be number one in the market, offers fast delivery times and is a step ahead of your competitors.

Gebr. Leitz GmbH, Oberkochen, Germany.

Albert Leitz founded Leitz in Southern Germany in 1876. The birthplace of the Leitz tool factory was in the East Württembergian village of Oberkochen in the Kochertal region. During these spartan pre-industrial times, the forest was the most noticeable part of the

landscape producing the most important material: wood. A little later, another natural element gained importance: water, which powered the mills and steam boilers. Wood, waterpower, and a tradition of iron working in Kochertal were the three most important components in the early formative years of the Leitz Company.

The company that began as a craftsman's workshop is now a global company with manufacturing and sales companies worldwide. Leitz is an international supplier of precision tools, tooling systems, and services for the wood and plastics processing industry. Leitz customers include both industry and craft.

Leitz, as do most major tooling companies, reacts to customers' needs for products and services to provide complete solutions for specific problems. The Leitz Group is a leading worldwide manufacturer of machine tools for processing wood and plastic. Leitz and Leuco are the two principal tool manufacturers in Germany, and contribute significantly to technical improvements of tools and tooling systems. Both companies are actively involved in development of high-speed cutting (HSC) technologies.

Rosenheim Institute of Applied Sciences, Rosenheim, Germany.

The Rosenheim Institute is Germany’s and arguably the World’s leading Institute for technical education in the wood working industries. Similar in scope to Bad Wildungen, Rosenheim is larger and blessed with a wider range of equipment provided mostly by machinery and products manufacturers. A sawmill and tool shop; panel manufacturing shop; machine shops; CNC workshops; CAD laboratories; furniture testing laboratory; veneer and wood bending facilities are attended by over 500 full-time students enrolled at the Institute.

Professor Scholz (Dean of school) stated “Engineers are needed in the wood working industries to optimise the processes”. He said, “Half of the CNC applications in Germany are ineffective due to lack of knowledge of the equipment or the processes” and you “cannot produce low value products, even with CNC technologies (to compete with low-

cost imports)". He said that most wood working shops could use the potential of CNC machinery and should look at moving from a low-value product to a high-value product base. Companies should realise they cannot compete on a cost basis (Hungary's labour rates are presently 30% that of Germany). The tendency in Germany is for larger, smarter companies to buy smaller, less-innovative companies.

Rosenheim's CNC equipment includes CAD laboratories, three and four-axis CNC machines, automatic furniture assembly machines and robotic handling equipment. CNC training at Rosenheim is well advanced (Figure 13).

Aicher Holzhaus, Halfing, Germany.

Aicher Holzhaus currently does not use CNC equipment, but is currently looking at suitable machinery to improve production. The company produces wooden framed houses in a factory situation that are then assembled on-site. Many of the components have special joints for accurate assembly. All wood used is "moon-wood" cut at a certain phase of the moon when the moisture content of the wood is reduced. The company uses an interesting glass-fronted slat wall-panel system to capture the heat from the light, stating annual house heating costs at only $AUD80- per year!

Figure 13 Students faces carved using CNC machinery at Rosenheim Institute.

Werndl Steelcase, Rosenheim, Germany.

Werndl Steelcase produces office furniture from a range of materials, primarily manufactured board, but including solid wood, plastics, steel and aluminium, "perspex" and glass. The company outputs one million dollars of product per day and is an example of the top-end use of CNC technologies. Six metre long sheets of board are fed into a CNC processing centre cutting in an NBM situation. Parts are lifted from the outfeed table by a PC controlled robot-handling system. An additional dozen CNC processing centres produce components from smaller boards and other materials. The factory features plenty of space for product and roller-conveyors for stock transport. In spite of the volume, many orders are small, especially custom-designed office layouts.

Technologic Institute for Furniture Making (AIDIMA) Valencia, Spain.

AIDIMA was founded in 1984 and is a private research, non-profit organization with a membership of over 600 companies. Its areas of activity include applied research, quality certification, industrial consulting and information technologies, training and environmental issues. The site in Valencia houses training rooms and workshops, research and development rooms and testing laboratories. AIDIMA also monitor industry trends, research new manufacturing technologies and are involved in technology transfer through diplomas in furniture and environmental technologies in addition to post-graduate training. Expertise in product prototyping, electronic and on-line cataloguing and e-commerce, CNC training and CAD-CAM applications is also provided.

AIDIMA advise that 60% of Spanish companies employ less than ten persons. 40% of companies are located in the Valencia region. There are 20,800 furniture companies employing 131,000 persons and some have a history dating from the 19th century (3-4 generations). 94% of "wood and furniture" companies employ less that 20 persons and 65% of these have 2 persons or less (mostly joiners). The Spanish follow the Italian model where parts are sub-contracted out to other companies. Most companies do one

thing well. Spanish companies use pine sourced from Eastern Europe and the Baltic countries, and local radiata pine cut from privately owned plantations to fund weddings. Chile imports cheap softwoods to Spain.

In the area of CNC technologies, AIDIMA sees high machine movement speeds of 100 metres per minute, high-horsepower motors (to 21Kw) and high-speed-cutting (HSC) as the future for furniture manufacturing. Their motto is "If you do not change, the World will change you."

Modern style furniture using panels and veneers is increasing in popularity; the use of solid timber is declining. This is due to lifestyle changes and design/style that result in a shorter life of furniture pieces. Bathroom and kitchen furniture is currently booming but classic furniture is static. Smaller homes now being built will not fit or suit the classic style. One opportunity is to export high-value classic solid wood and veneered furniture to Arabic countries. Furniture is bought by eye, and must be aesthetic; top-selling product is light, straight-grained wood with no knots. Functionality is the highest priority for the consumer and in Spain 3D "feel" created with cavities on "stuck-on" pieces is popular.

Furniture Industry Research Association (FIRA), Stevenage, UK.

FIRA is recognised internationally as a leading testing, research and consultancy association supporting the furniture industry. The association has an excellent overview of the furniture industry in the United Kingdom and Europe, and is an active participant in the activities of the industry.

In the United Kingdom and other European countries as in Australia, a large percentage of the industry employs 10 persons or less. There are reported to be only about 50 British manufacturers with 50 employees or more. FIRA sees the car manufacturing industry as a good model for furniture manufacturers. Here parts are interchangeable between different brands of vehicles, some even having the same floor "pan". Furniture parts should be made to be interchangeable between product lines and styles, and this will limit stock and

processing times. British consumers buy on price and imported furniture (much of it from China) will affect the furniture industry when market growth subsides.

Mr. Bill Rolfe consults in industry technology throughout Europe. He sees getting the right equipment, employee skills and technical support as the most important issues a manufacturer using CNC machinery needs to get right. Opportunities that CNC can provide are quick manufacturing times, flexible production and accuracy of work. Bill's 5 steps to CNC excellence are:

1. Buy CNC equipment to satisfy a need and to specifications, do NOT buy because of a relationship with suppliers.
2. The operator contributes 75% of the machine's performance and the training given by the supplier of the machine is not sufficient. Training must be individualised as much as possible.
3. Services including extraction, tooling and technical support must be considered equally to the purchase of the machine.
4. Management must fully understand the equipment's capabilities (and limitations) and potential. Also, workflow to and from the equipment and employee learning curves must be fully realised.
5. Don't be complacent once the machine is installed.

University of British Columbia, Vancouver Canada.

The Centre for Advanced Wood Processing (University of British Columbia) is Canada's national centre of excellence for education and research related to wood products processing and advanced wood products manufacturing. CAWP conducts applied research, offers a wide range of continuing education, training and extension programs, and assists industry by supplying undergraduate students with specialist knowledge of wood products manufacturing for cooperative education placements.

Historical background

In the past, high quality old-growth timber sustained forest-based economic prosperity in Canada. As this comparative advantage has waned, economic prosperity has required a

new commitment to become a knowledge-based, value-added industry. These forces are driving commodity wood-products producers to manufacture more specialised and higher value wood products. To foster job creation, stabilise forest dependent communities, encourage increased value recovery and ensure sustainable development of Canada's forests, governments are supporting this transition to a value-added industry.

All segments of the industry want the value-added sectors to grow. However, several factors stand in the way of this growth. These factors are a lack of a highly skilled workforce possessing the requisite knowledge and skill profiles and an inadequate knowledge base to educate and develop and apply the technologies needed to sustain competitive positions.

The Centre for Advanced Wood Processing (CAWP) was created, in consultation with the University's Forestry Advisory Council, with input from the National Education Initiative on the Canadian Wood Processing Industry (NEI), to address these needs. CAWP is an interdisciplinary initiative administered by the Faculty of Forestry in collaboration with the Faculty of Applied Science at The University of British Columbia.

A Director who is a regular member of the UBC faculty heads CAWP. The Director is responsible for developing and delivering CAWP's research and development, continuing education and extension programs. CAWP personnel also include Faculty Associates, lecturers, staff, researchers and associates who contribute to its mandate. CAWP's goal is to produce high quality education, service, and research activities, with a strong emphasis on value-added wood products manufacturing, thus meeting the objectives of the supporting industry.

CAWP is identifying and responding to the needs of the continuing education, management and technical staff development, extension and research, focusing the intellectual resources of the University. To accomplish this, the Wood Products Processing Program was developed, and CAWP is collaborating with partners from around the world on issues related to advanced wood products processing in Canada.

CAWP's mandate includes contributing to the undergraduate Wood Products Processing Degree Program in Forestry and Applied Science. It administers the co-operative education component of the Wood Products Processing program. Graduate student development is targeted at advanced wood products manufacturing. Short courses, workshops, certificate programs and seminars on topics related to value added manufacturing is regularly conducted. Industry technical support and consulting services are provided and applied research and development projects with industry collaboration.

Mr. Iain MacDonald advises that buying the right machine for the type of production, understanding the capabilities, and ensuring the machine has enough "machine hours" to justify the investment are major considerations. He also advises that training is a huge issue, and hand in hand with this is the problem of recruiting management-calibre and skilled technical persons because high-school students are not attracted to the industry. The biggest problems manufacturers face are availability of skilled personnel, competition from China and trade disputes. The opportunities of CNC users are quality and less reliance on skilled cabinetmakers who are becoming scarce in Canada.

British Columbia Institute of Technology (BCIT) Vancouver Canada.

BCIT is a multi-disciplinary organization that delivers a broad range of courses from business, health sciences, computer studies and transportation through construction, electronics, industrial processing, energy and natural resources and manufacturing.

Courses are conducted as full time technology programs, full and part-time vocational (apprentice), part-time certificate and degree programs. There are approximately 15,000 full time and 30,000 part time students at the Institute. Student numbers in furniture training are similar to Australian Institutes.

Vocational and Industry training combines off the job instruction at BCIT and on the job training, much like the Victorian model. Students are paid a wage and some government

assistance is available. Training programs can be up to four years duration and graduates receive a certificate of proficiency. An apprenticeship commission oversees the training programs within a quad partite system of industry, labor, government and (unlike Australia) educators.

Technology programs are usually 2 years in duration. These programs generally have more applicants than places available and in this case BCIT selects those most likely to successfully complete the course.

Furniture courses

Furniture courses range from apprenticeship to certificate courses of 2 to 28 weeks duration. In addition, short "equipment" courses from as little as 2 hours are offered. The Canadian industry and training sector has traditionally been concerned with the primary industries of forestry, logging and saw milling but global environmental and native title issues have reduced the accessible portion of state forest. In addition, increasing competition and the current economy have shifting the focus to value-added wood processing.

BCIT has advanced links with major European machinery suppliers. A major advantage of this alliance is the supply of CNC equipment to BCIT for industry training and promotional reasons.

Mr. Dave Dunn of BCIT sees technical support and skilled operatives as the most important issues a manufacturer using CNC machinery needs to get right.

Author's Discussion

In an ideal situation, the goal for CNC technology is to make one complete set of furniture components ready to assemble and eliminate batches of components on the shop floor. This is a concept that appears not to have been considered in Europe, or is seen to be unrealistic. Dr. Rado Gazo of Purdue University advises that due to the possibility of parts being damaged during subsequent processing or assembly, the principle of batch size one may be unworkable. "Batch size of nearly one" could be more appropriate. The European viewpoint is that there are several issues that could be insurmountable.

- The principle requires the use of specially manufactured templates (jigs) and this is time consuming and requires some specialist skills to produce an acceptable result.
- Product changes cannot be accommodated if the components are held by a fixed dimension jig.
- Jigs may be heavy, difficult to handle, and not accurately positioned.

These issues will need to be addressed. Solutions must be developed so that:

- Jigs can be developed easily and at low cost.
- Jigs must be able to be positioned within an accuracy of 1mm maximum.
- Replacement jigs for alternate sizes must be able to be developed speedily.
- Appropriate tools should be used that will allow some variation to the design without affecting the dimensions of the piece.

This certainly should not discourage us in investigating this concept, in fact we should be encouraged to pursue a "batch size of one." It is an area of CNC manufacturing that Australia could become World-leaders in. CNC technology should be used to increase flexibility/variety/controllability in manufacturing processes and this enhancement would give significant advantage to manufacturers by having all components in one go and eliminating errors or defects.

A mistake that manufacturers sometimes make when installing CNC processing centres is to expect too much too soon. There is a learning curve that varies with the production type and existing levels of expertise in the company. The support of management is essential is shortening the learning curve. This support includes appropriate manufacturing conditions, documentation and manufacturing support. Appropriate training not only from the equipment supplier but from a recognised CNC training centre or Institute to provide "education" rather than "what buttons to press and when". The President of "Innovawood" said, "In an environment which is characterised by an increasing uncertainty and competitiveness, knowledge is and will be the true motor for an effective enterprise policy of research, technological development and innovation".

CNC machinery has changed little over the last ten years. The most significant change is in the software. Previously, software was written for a machine, and a controller was built to house the software. If something went wrong it was expensive and time consuming to repair. All modern machines now run on a windows® platform on a standard personal computer (PC). Software supplied with CNC processing centres is usually more CAM (computer aided machining) oriented and has limited design capabilities. A fully functional CAD-CAM program is a small investment compared to the cost of a CNC machine, and is capable of increasing the machine productivity far beyond the initial software cost, that is usually recovered within a few months of use. Any software purchased should be capable of saving files in a neutral format such as .DXF and the Autocad® (or similar) software is very evident in European manufacturing and training. Most CAD programs offer this facility. It is also possible for suppliers of CAD-CAM software to write a post-processor to output the generated tool path to any CNC machine.

What has changed in recent years is CNC tooling. Most major suppliers now offer a range of CNC tools, but not all of them have been designed purely for CNC applications. Some of the characteristics of a CNC tool are high cutting capacity, dimensional consideration for CNC tool data input, interchangeability, long tool life and rotational stability. CNC processing centres can be equipped with large tool magazines, but tools

that could quite easily be condensed with the use of a more appropriate tool system could still quickly fill even the largest magazines. If a tool needs to be replaced it must be done quickly, eliminating the human error possible when modifying tool data.

The latest developments such as high-speed cutting (HSC) may have little impact on our industry for the next decade but the technical developments supporting this new technology will be easy to apply. When HSC finally becomes an issue in this country we should be well prepared to take up the new technology. These new developments are as follows:

- Machinery with HSK compatible spindles. The HSK tool holder (Figure 14) was developed by the automotive industry, and guarantees a flat seating surface for high performance tooling. This tool interface has an accuracy of 2 µm each side, or a total of 4 µm. The ISO30 tool holder will produce double the unbalanced mass (10 µm) of the short HSK holder[5].
- Use cutter heads mounted on arbors wherever possible. An arbor-mounted tool eliminates the use of a collet, that is the weak link in the collet chuck. Where collets are used the German manufacturers advise they should be replaced every six months because of wear and tear.
- Thermogrip and Tribos chucks are less expensive than even collet chucks but offer accuracy and rigidity comparable to Hydro chucks, at one-third the cost. It makes no sense not to use this technology if possible. The only down side is the need to send the tool back to the manufacturer for cutter installation. It is also recommended that high-rotational tools be sharpened in the tool holder.
- Constant diameter tools with quickly interchangeable knives mounted on an arbor offer an initially expensive, but foolproof method of changing profile tools on a CNC machine. Every profile has the same tool data meaning no data modification is necessary.

[5] Gittel (2001)

Figure 14 CNC tool holders left to right. Long HSK, Short HSK, SK (ISO30)

An issue facing the furniture industry in Australia is engineering versus design. While engineers are required to optimise production processes on CNC machinery, this will not in itself ensure the continued development of the furniture manufacturing industry. Manufacturers should form partnerships with other companies and share the use of machinery and skills. The Australian method of doing it all by yourself has resulted in a system where machinery is under-utilised due to lack of understanding of equipment and processes. In order for the industry to prosper, a more integrated approach to manufacturing where design-focussed niche markets are targeted should achieve more success.

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