Faculty of Engineering and Surveying

University of Southern Queensland

CRITICAL ISSUES IN PRECISE MACHINING OF OVERSIZE MOULDS IN POLYSTYRENE

A Dissertation submitted by

Muhammad Razif Mahadi

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Abstract

Parts made from fibre reinforced plastics (FRP) are first laid up on a polystyrene mould. Hence dimensional accuracy is dependent on the quality of the mould. If the parts are oversize, larger than a metre or so, the moulds must be machined in sections and fitted together. There is therefore substantial advantage in a new machining system that can manufacture the mould as one piece. Currently, moulds are machined on a multi-axis robotic or CNC machine that removes material using a milling cutter. When an observation of the current system was conducted on site, the industrial partner gave permission to use their CNC milling robot for cutting expanded polystyrene. A medium density board was also tested. The cutting forces were recorded. It was found that adapting the same cutting strategy was inefficient. The design of such a machine must be based on a new set of requirements.

A number of design factors must be considered. The new machine would be massive and expensive unless three critical issues were resolved at the design stage; cutting approach, instrumentation for control of accuracy, and innovation in the drive.

For removing polystyrene, slicing was considered as an alternative to milling. The fundamental operations of slicing are discussed, from simple pushing of the blade to the incorporation of sideways forces and motions. When using a straight blade, the cutting action can be assumed to act along a straight line. For a curved blade, the straight line was replaced by an effective sector curve, measured from an imaginary centre. While a curved blade and a disk blade work with the same principle, the central axis of a disk blade is fixed, thus the effective sector curve is constant. This

allows the disk blade to provide constant sideways force uni-directionally. For slicing, the cutting surface has been evaluated by carving polystyrene with a variety of blades. Later, the force required for cutting with a disk blade was analysed. It was confirmed that a higher cutting speed generated higher cutting forces, but for equal feed rates the cutting force was substantially lower than that required for milling.

The size of the machine was set at five metres by five in plan and two metres in height. It was necessary to devise a position transducer that could operate over these distances, while giving a resolution of a tenth of a millimetre. A transducer was devised based on the visual interpretation of graduations on a precision tape with markings at two millimetre intervals. The concept was embodied using a self-built line-scan camera. The camera performed scans at one or two millisecond intervals, leading to the choice of two millimetre graduations as a compromise between precision and the risk of aliasing at a speed of up to half a metre per second.

A Cartesian gantry configuration was selected as the base platform for the cutting machine. A light weight solution was studied. Traction was provided to each axis using a soft rubber wheel and a pair of DC motors, mounted on the slider. It was possible to combine more than one motor for actuating the slider, if necessitated by heavier loads. In the development of the transducer, a displacement of five metres was achievable with the required placement accuracy. The embedded microcontroller that formed part of the transducer was equipped with an algorithm for precise movement control. Using a nonlinear velocity demand strategy enabled the motion parameters to be optimized.

In summary, construction of a full-sized prototype axis has enabled the critical issues to be researched thoroughly. This had created a clear path to the final design.

CERTIFICATION OF DISSERTATION

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

_____ _____

Signature of Candidate Date

ENDORSEMENT

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Signature of Supervisor Date

ACKNOWLEDGEMENTS

Fresh from graduation of Bachelor of Science in Mechanical Engineering from the California State University, Sacramento, I was working as process engineering for a manufacturing firm in Malaysia. Then, I was offered a tutor position at the Department of Biological and Agricultural Engineering, Universiti Putra Malaysia. Part of the job is to conduct research and development in the application of mechatronics in agriculture. In order to enhance my knowledge, I had successfully completing a Master of Science Degree in Biosystems Engineering at the University of Manitoba Canada. Upon returning home, I have planned for a future research that integrates agriculture with mechatronics. The field is new in Malaysia. Therefore, the best way is to learn from an international expert. Then, a scholarship was successfully secured from the Ministry of Higher Education of Malaysia.

In mid 2006, Professor John Billingsley of the University of Southern Queensland, Australia had accepted my application to conduct research in mechatronics under his supervision. It was a great pleasure for me to have him as my mentor. While preparing for the dissertation proposal, we were informed that the Buchanan Advanced Composites (BAC) was proposing a new machining project. A meeting was set between Mr. Norm Watt (Managing Director of BAC), Professor Billingsley and I. The project was not directly related to agriculture, but the concept was similar. Hence, the Advanced Control Research group of the Faculty of Engineering and Surveying, USQ and BAC had agreed on a collaboration.

Mr. Tim Harris of BAC was appointed as the liaison officer between the research group and BAC. As a liaison officer, Tim had provided valuable input about the operation and major problems with the current system.

Under the guidance of Professor Billingsley, I had developed a general framework for the research. Initially, the overall plan was too wide for a research person to handle within a reasonable time frame. Then a committee that consisted of Professor Billingsley, Dr. Sam Cubero, the Associate Dean of Research David Buttsworth, Dr. Paul Wen, Mr. Tim Harris and Mr. Rex Parmenter had advised that the research scope should be narrowed down to the most critical issues that challenge precise machining in oversize polystyrene large moulds for fibre layup.

As the research was progressing, some components were needed and fabricated. The support team of the Faculty, Bratt, Terry, Chris, Brian, Mohan and Adrian were always there to provide assistance. There were times when I had problems with the circuit board that I had designed. It was Dean Beliveau who helped me in troubleshooting.

As time passing by, Tim had moved on to another firm, Jake Williams had taken over the position as the liaison officer. In the beginning, the transducer was tested under the lab condition. Then, the time had come when the performance of a full scale prototype gantry need to be observed and verified. Utilizing his skills as a machinist and a designer, a full size prototype gantry was finally fabricated. Resourceful, creative and patient, Jake was the greatest ally I ever had during this entire journey.

Commuting between the BAC plant and the campus was a huge problem. Fortunately, Wendy Watt was more than happy to give me a lift.

While working on the cutting characteristics of expanded polystyrene, two practical training students from the local high school, Cody and Morgan, were more than willing to assist in the experiments. In return, I had provided some basic introduction to AutoCAD. They were very pleased, and I really appreciated the time we had spent together.

Working on the project was part of the requirement; the other was translating the entire process into a dissertation format. I would like to thank to Dr Selvan Pather for his comments on my earlier drafts. I would also like to thank to Juanita Ryan for helping me with the administrative issue.

A day at work was sometimes very stressful. I was blessed to have Fariza, my lovely wife and Hassan my little one. They were always there to support me, in good times and bad times.

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