Track Design of Woodworking Rip-Saw Chain

Wei-long Chen, Cheng-chi Chang, Chen-yu Tsai, Fang-lin Chao
Department of Industrial Design, Chaoyang University of Technology, Taichung, Taiwan
Email: flinchao@gmail.com

***Abstract*—Rip saws are used for first stock preparation. The sawing speed of a rip saw is important from the viewpoint of increasing production rate. A buffing wheel and track can be designed for holding the log stably to ensure that the circular saw performs a complete cut. The chain pieces are pulled rapidly by adjacent pieces, engendering shaking and reducing the effectiveness of cutting. Digital data transfer to SimDesigner for kinetic simulation can help predict pitfalls. By changing the distance between the end-to-end rails and the clearance of the chain in the model, one can predict possible collisions. In this study, we propose an improved rip-saw track design by adjusting the simulation parameters. The results indicated that the slope of the track induced a backward pull on the chain by the other pieces when sliding down, causing the timber in the process to move upward. Computer-aided engineering helped improve the efficiency and design parameters of the track.**

***Index Terms*—track design, rip saw, feeding chain, simulation, woodworking, cutting.**

I. Introduction

In log processing, logs are first cut along the longitudinal direction into plates of different widths and thicknesses (first stock preparation). The volume of logs is considerably large, and log preparation requires large-scale equipment. Moreover, the number of stuff is small and concentrated. Rip saws for woodworking are equipped with link chains that have no gaps during running for ensuring safe operation [1]. No-gap running prevents the danger of hand clamping. A pressure plate holds the workpiece firmly for maximum cutting stability. After a log is cut into plates of different thicknesses and widths, the plates can be transported and processed easily.

The aim of secondary cutting and processing of wood is to achieve the desired quality and size specifications. Multiple saws are used to cut a solid thick sheet to a specific width. For the production of planned flats or plywood, several sewing machines are mostly used. Multidisc saws have removable inserts that can accommodate specific widths for different applications by means of optimization techniques. Multiple saws are important for secondary stock preparation and wood processing.

In a cutting machine, the feed system is the key to secondary wood processing. The motor drives a wheel that runs the track in the workbench. The wood board is placed in the feed port and clamped by the pressing wheel and the crawler belt. Subsequently, the saw blade coupled to the main shaft cuts the board. The board pass through cut components and the standing pinch roll assembly. From the pinch roll assembly, the wood components are received at the exit [2]. An adjustable device is used for feeding workpieces of different thicknesses past a rip saw for cutting, in which a guide rail is attached to an adjustable fence on the rip saw table. A member that engages and moves workpieces slides along the guide rail for moving the workpieces into cutting engagement with the rip saw [3]. This stage determines the accuracy and quality of wood cutting. Poorly designed tracks and saw blades cause sawing deviation and wood tail flicking and even shorten the life of the track.

Figure 1. Buffing wheel and track for holding a log. Circular saw cutting requires space for chain sag to ensure complete cutting. When the chain pieces move forward, they are pulled by the preceding adjacent blocks.

Figure 2. Drifting in sawing process creates noticeable saw marks. Rapid pulling between adjacent pieces of the chain may cause vertical shaking, which reduces the effectiveness of cutting.

II. Simulation and Design Process

A study developed a simulation model using an object-oriented procedure to ease the process of converting a real wood product manufacturing system into a computer

Manuscript received September 15, 2018; revised July 10, 2019.

doi: 10.18178/ijmerr.8.5.719-724

model [4]. Chen proposed an approach for the analysis of sand casting by integrating CATIA and the casting process analysis software ProCAST to simulate stress changes during solidification [5, 6].

A study [7] reviewed the relevant literature to highlight the extensive applications and benefits of discrete-event simulation in forestry. Simulation enables the assessment of the impact of changes on processes and productivity. Another study applied a new visualization technology to locate the positions of knots within logs by using computed tomography images in order to support decision-making about the optimal rotational angle of beech logs. The study employed the software InnoSIM to virtually saw the 3D-reconstructed logs in 12 different rotational angles [8]. In another study, the MSC SimDesigner work platform was used to analyze motion constraints, and it identified sports vice constraints on users [9]. A study defined motions of revolute joints by using CATIA V5 and exported them to an ADAMS workbench through SimDesigner. The robot trunk body was made of aluminum alloy [10].

To simulate multibody manufacturing systems, a study applied the dynamic and cybernetic characteristics of driving systems. Models were established and driven by controllers developed using Matlab/Simulink through cosimulation. The researchers in the mentioned study reported that their results can be used to review complexly effective factors [11]. Another study defined the motions of each revolute joint of a system by using the STEP Function before motion analysis; the study verified the correctness of diamond sawing based on finite-element modeling (FEM) of friction deformation [12]. The natural frequencies of the system’s shaft with the saw disk were calculated using FEM. The study suggested that the surface layer of a workpiece sawn from hard materials can be achieved by reducing the friction coefficient of the saw disk.

A digital model based on previous chain pieces and tracks was established using the CATIA CAD system. Data were digitally transferred to the SimDesigner computer-aided engineering (CAE) module for kinetic simulation. Collision and impact force data help predict any possible pitfalls in chain movement. By changing the distance between the end-to-end rails and clearance of the chain, we could predict possible collisions by using the rigid body model. Track guidance and transmission were improved through simulation. The design process can help engineers find practical methods of maintaining stable operation in order to enhance the quality of wood cutting and extend the lifetime of the saw blade.

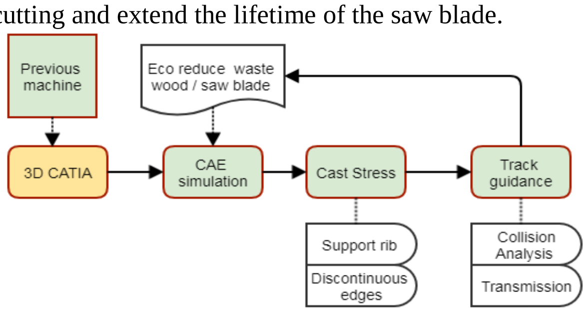


Figure 3. CAE-supported design flow of track collision.

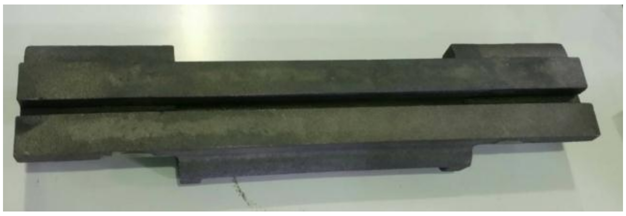


Figure 4. Reduction of defects in saw piece assembly.

Through adjustment of geometric shape and addition of ribs, the flatness of the cast chain could be improved. This modification reduces sloshing during movement and related defects. We simulated dynamic mechanisms to observe the dynamic response of the chain pieces moving on the rails in the case of pulling in order to select the most appropriate design parameters.

III. Chain Pieces and Rails

A. Link

Chain pieces can be driven and rotated in the axial direction. Roller chains consist of roller links and pin links. An offset link is a combination of a roller link and a pin link. A chain unit consists of one offset and one roller link. Pins are press fitted into the link plates, and the unit is highly suitable for heavy impact loads and high-speed driving.

A chain piece is a symmetrical structure with two v-shaped grooves on both sides of the structure. The v-shaped groove is in contact with the track. Internally, close to the central recess, there is a raised semicircular block-shaped connecting shaft on each side of the recess. A corresponding upwardly extending structure exists above the chain piece, and each of the two outer sides has a convex semicircular block-shaped connecting shaft. When the outer side of the structure is repeatedly joined to the other chain piece, the convex portion coincides with the concave portion. Similar to the offset link, the joint structure can be fixed by applying an impact force to the part where the two link pieces meet.

B. Supporter

While the chain piece is driven, many forces act on the wood workpiece. The cross-sectional structure shown in Fig. 5 indicates the movement and several forces acting from the top roller toward the bottom track; these forces are as follows:

- The roller shaft presses downward on the wooden strip.
- The saw blade cuts downward. The force acts in the direction opposite to the direction of motion of the wooden strip. The wooden strip withstands the force along the +x direction.
- The force acting on the wood is transferred downward to the chain piece.
- The chain piece is subjected to a force in the −y direction and is transmitted to the track through the v-shaped groove. We can assume that the track is fixed, and the chain piece is simply supported by the v-rails.

At this point, the chain piece is again driven by the motor and moves along the −x direction. The normal force must generate adequate friction to avoid sliding and prevent instability during cutting.

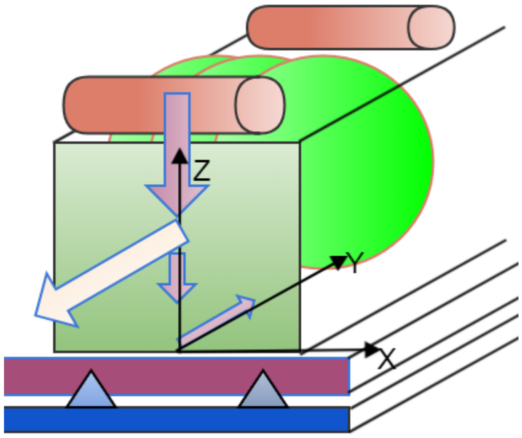


Figure 5. Iron chain piece with a rough surface with high levels of friction. The pressure on the wood provides the holding force on the working plane. The structure is fixed on the working surface while the saw blades cut the wood.

C. Driver

A gear motor drives the chain piece, which moves along the −x direction at a speed of v (m/min). As the movement speed of the chain increases, the cutting speeds of the block increase, which is an advantage for the producer. If the wood strip cannot be clamped stably, it may become offset or it may oscillate owing to the complex forces acting on it, which may result in poor cutting and a decrease in the value of the resulting sheet wood.

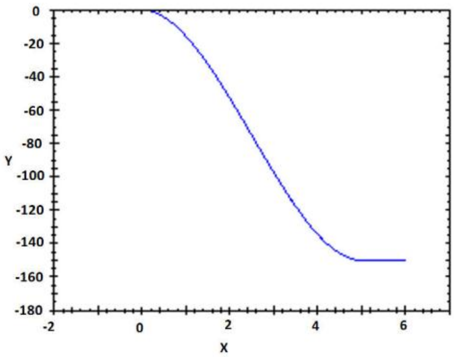
Conventional cutting tools operate at speeds of approximately 20 m/min. When the speed is increased to 40 or even 50 m/min, the sound from the machine increases, and the quality of cutting deteriorates. Thus, maintaining cutting quality at relatively high speeds is a problem that tool designers must solve.

IV. Collision and Impact Simulation Using Simplified Model

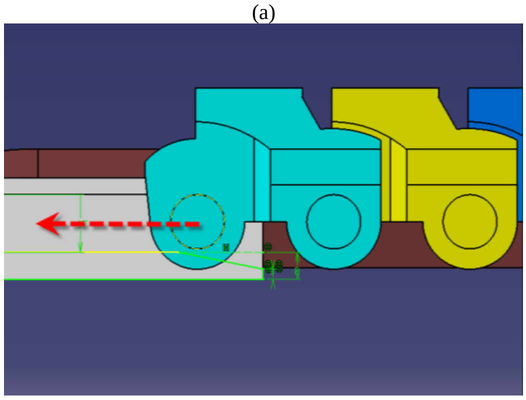
The sloshing during movement is revealed with kinetic simulation to find possible structural collision. Vibration is highly beneficial in mechanical workshops; for example, vibration can be applied for improving machining efficiency. Decoupling treatments can reduce the transfer of problematic excitations. The use of viscoelastic damping layers in rotating machinery was analyzed previously [11]. Most defects associated with rotating machinery can be detected using a continuous monitoring system. Real-time monitoring reduces breakdowns with the help of sensors and data analysis. Turbine shaft displacements are maximized when the temperature of the lubricating oil is higher than its designated safe value [12].

To achieve track improvement, a kinematic simulation was conducted. A track and guide slot analysis model is illustrated in Fig. 7. To analyze the movement and force status under different track spacing and slot clearances, the SimDesigner motion rigid body analysis module was applied to sections of the track, guides, and five chain units. The track and the connected chain pieces with ball bearings were considered separable rigid bodies. The last chain piece was attached horizontally to the track (plane sliding, no rotation), and it did not enter the guide slot.

To observe the correlation of the chain pieces during motion, we used a simplified model of chain pieces under the existing constraints. The excitation force (pulled to the right) moved the chains on the track. The excitation force was applied at a 5-s time step (Fig. 6), and the magnitude of the exciting force was up to 150 N.



(a)



(b)

Figure 6. Excitation force simulation: (a) x is time and y is force; (b) motor-driven force acting at the center of the front chain.

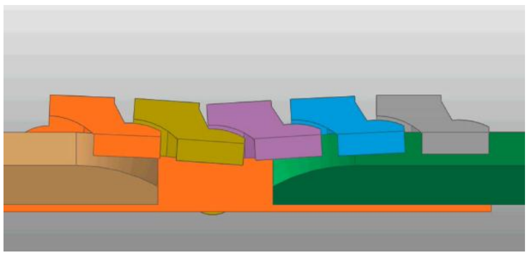


Figure 7. Chain hits lower guide while simultaneously hitting track. This causes the rear side of the front end link to top up and the front side of the rear piece to be pushed up. The wood on the chain may be lifted up instantly.

The original design was determined to have a track pitch of 136 mm. When the towing force was increased, the reaction force generated by the collision could be overcome, and the chain could pass through the track smoothly. Results of a motion simulation (Fig. 7) revealed that when the designed track pitch was too short, the rear end of the chain was topped up and the front end of the latter piece was lifted up. When the original design entered the guide, the angle of the chain was lower than the preset angle owing to the collision. When the guide was separated, the angle of the link caused the chain to fall below the set angle because of the collision. According to these results, the addition of a guide groove is necessary to control the rotation angle of the chain.

V. Track Improvement Design

Adding a guide track can control any excessive rotation of the chain angle. The problem of jacking up of adjacent links when the angle of the chain is excessively rotated can thus be avoided. This study set the upper and lower gaps of the guide track to 0.2 and 0.8 mm, respectively. The track distance between the inlet and the outlet end was increased by 6 mm. A more detailed representation is shown in Fig. 8.

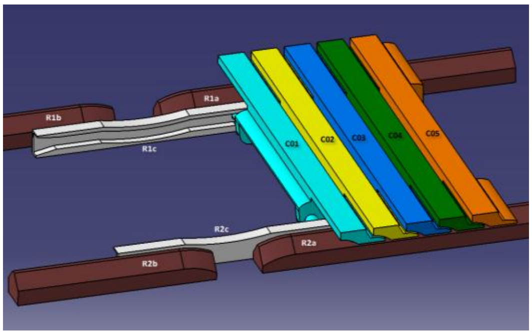


Figure 8. SimDesigner simplified model for rigid body collision analysis. The track is denoted by R1a, R1b, R2a, and R2b; the guide slot is denoted by R1c and R2c; the five chain pieces are denoted by c-01.. c-05.

The results of a motion simulation indicated that when the design track pitch was increased, the rear end of the chain did not rise in the upward direction. Under the same traction force, the front end did not interfere with the impact when entering the guide track and did not hit the track or cause an interference impact when leaving the guide rail. Thus, any accidental movement of the chain piece could be avoided, and the wooden board could be lifted. Figure 9 shows a section view of the track and the guide channel used in the SimDesigner rigid body motion analysis. The effects of the guide track on chain piece movement are explained in Fig. 10.

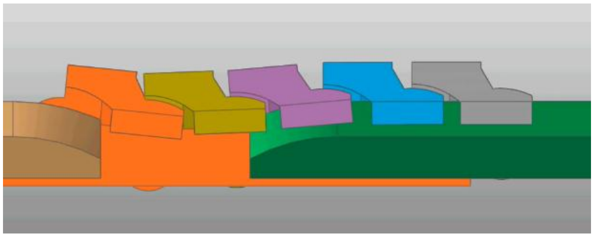


Figure 9. Section view of track and guide channel used in SimDesigner rigid body motion analysis. Under the same traction force, the front end did not interfere with the impact when entering the guide track and did not hit the track.

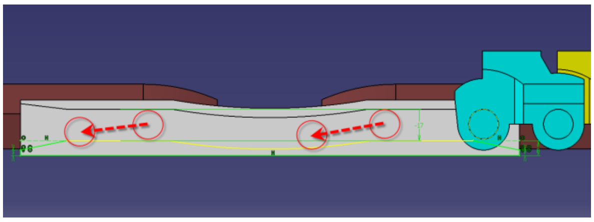


Figure 10. Effect of guide track on chain piece movement. We could adjust the design parameters of the detailed structure according to the relative position between the chains.

As can be inferred from Fig. 9, the problems arising from the previous designs are outlined as follows: (1) The track pitch is excessively short, and the saw chain hits the lower guide and the track simultaneously. (2) Such hitting of the saw chain causes the back end of the chain to rise. Concurrently, the front piece of the rear chain is lifted upward. (3) When the reaction force generated by the collision is overcome by an additional force, the chain piece can smoothly pass through the track.

A. Normal Impact

If the track pitch is short, the chain hits the lower guide and the track simultaneously, causing the rear end of the string to rise; concurrently, the front end of the rear chain is moved upward. Because the previous design cannot control the excessive rotation of the chain angle, the piece may be linked to adjacent pieces. Through SimDesigner rigid body collision analysis, we could adjust the design parameters of the guide track. Figs. 11 and 12 show the simulation results of impact amplitude with different design parameters.

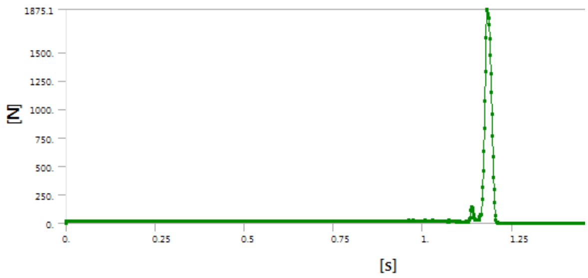


Figure 11. Calculation results for normal impact force of chain c-01: by adding the guide channel (upper and lower gaps were 0.2 and 0.8 mm, respectively) and increasing the length of the entrance track by 5 mm, we observed that the amplitude of the impact at the first saw chain (5 mm) changed. The impact amplitude was 1875 N.

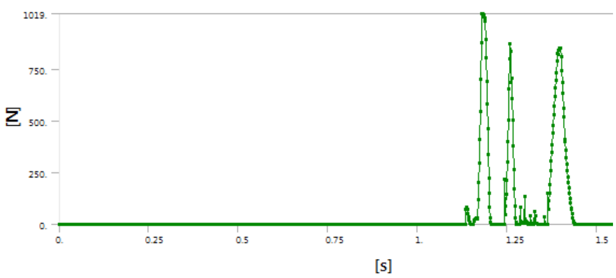


Figure 12. Calculation results for impact force of chain c-02: by adding the guide groove (upper and lower clearances were 0.2 and 0.8 mm, respectively) and increasing the distance between the end-to-end rails by 6 mm, we determined that the impact amplitude at the second chain piece (6 mm) changed. The impact amplitude was 1019 N.

B. Effect of Track Pitch

By changing the design track pitch (5–8 mm), we could observe the variation of the forward impact force. The forward impact force gradually decreased as the pitch increased. The first curve in the figure shows the changes in the first chain, and the lower curve shows the changes in the second chain. The second chain exhibited a slight decrease in impact, and the greatest impact occurred at the first chain.

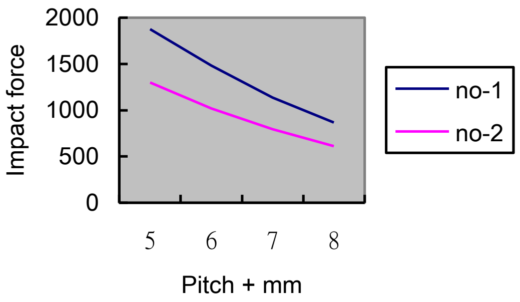


Figure 13. Effect of track pitch on different chain pieces

C. Rotation Angle of Chain

The theta (rotation angle) values of chain c-01 (with the added distance of 6 mm) are presented in Fig. 14. The guide track controls the rotation angle of the chain. The rotation angle was varied between 13.6 ° and 5.5 ° without excessive rotation, which would cause object offset problems.

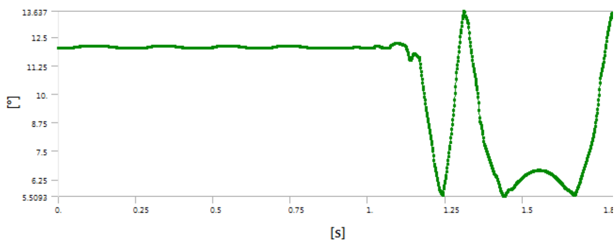


Figure 14. Rotation angle of chain c-01, where the added distance was 6 mm.

According to the results obtained from the simulation of the impact amplitude (Fig. 8), we can summarize our findings as follows:

- In the rigid body crash analysis of the saw chain, the maximum impact amplitude decreased from 1875 to 866.7 N.
- The maximum impact amplitude of the redesigned saw chain piece decreased from 1298.4 to 613.5 N; when the distance added was 8 mm, the collision value decreased significantly.
- When the gap of guide groove was decreased (upper and lower clearances were 0.2 and 0.3 mm) and the distance between the entrance and exit of the track was increased (6 mm), the wood interfered when the front end entered the guide groove under the same force. The chance of leaving the channel and hitting it decreased.
- When the angle of the chain was controlled adequately, track stability improved, which improved the quality of the feed system.

VI. Conclusion

This study implemented a design that primarily improved the guide track structure and the chain piece. The slopes of the front and rear track heads in the original machine were designed poorly, causing the chain to slide backward and pull back the saw chain toward the rear. This phenomenon would cause the timber to bounce in the process. Simulations revealed that the wood in the process bounced when the chain climbed into the rear track. Under the same traction force, the front end did not interfere with the impact when entering the guide track and did not hit the track or form an interference impact when leaving the guide rail. The preferred parameters were determined; therefore, engineers can increase the speed of wood preparation and sawing. Adjusting the design parameters through CAE analysis and design procedures can reduce the development period significantly.

References

[1] Oavequipment. [Online]. Available: https://www.oavequipment.com/zh-tw/product-294920/

[2] T. W. Hahn, Buss Automation Inc, 1990. Automated multiple rip saw feeding apparatus. U.S. Patent 4,945,797.

[3] L. R. Livick, Adjustable device for feeding workpieces of different thicknesses past a rip saw for cutting purposes. U.S. Patent 4,026,173, 1977.

[4] S. Saxena, C. H. Tyagi, and S. Kumar, "Heat treatment of Al-Si-Cu-Mg casting alloys for the manufacturing of light weight machines/ vehicle parts with increased strength," *International Journal of Mechanical Engineering and Robotics Research*, vol. 3, no.3, pp. 706-715, 2014.

[5] W. L. Chen, "CAE supported improvement of chain casting of rip-saw for woodworking," *International Journal of Materials, Mechanics and Manufacturing*, 2019.

[6] O. Luke and T. Sowlati, "Applications of discrete-event simulation in the forest products sector: A review," *Forest Products Journal*, vol. 67, no. 3, pp. 219-229, 2017.

[7] R. Rajora and H. K. Dixit, "Effect of lube oil temperature on turbine shaft vibration," *International Journal of Mechanical Engineering and Robotics Research*, vol. 2, no. 2, pp. 324-334, 2013.

[8] Stängle, Stefan M., et al. "Potentially increased sawmill yield from hardwoods using X-ray computed tomography for knot detection," *Annals of Forest Science*, vol. 72, no. 1, pp. 57-65, 2015.

[9] L. Peng, et al., "Simulation research of the unfolding process for UAV folding wings based on CATIA and ADAMS," *Advanced Science Letters*, vol. 14, no. 1, pp. 73-76, 2012.

[10] M. Abhijit, A. Chatterjee, and S. S. Roy, "Modeling and simulation of a ball throwing machine," in *Proc. 14th National Conference on Machines and Mechanisms (NaCoMM09)*, NIT, Durgapur, India. 2009.

[11] H. Yunn-Lin, Jung-Kuang Cheng, and Van-Thuan Truong, "Computer-aided dynamic analysis and simulation of multibody manufacturing systems," *Applied Mechanics & Materials*, vol. 764-765, pp. 757-761, 2015.

[12] P. N. Bogdanovich, D. A. Bliznets, A. O. Shimanovsky, and V. I. Yakubovich, "Theoretical and experimental analysis of the sawing process for hard and ultra-hard materials," in *Proc. International Journal of Mechanical Engineering and Robotics Research*, vol. 7, no. 2, pp. 120-125, March 2018.

Wei-long Chen received the Ph.D. degree in Aerospace engineering from the University of Oklahoma. He was a researcher of MSC software. He also served as consultant in companies such as Pro-Iroda, Grand Mate and aerospace institute.
He joined National Center for High-Performance Computing, Hsinchu, Taiwan. Since September 1999, he has been an Associate Professor with the Department of Industrial Design at Chaoyang University of Technology, Taichung, Taiwan. His research interests include CAE and product development.

Fang-lin Chao He received the Ph.D. degree in electrical engineering from National Taiwan University. He joined the Industrial Technology Research Institute, Hsinchu, Taiwan, in 1982. In 1994, he joined Da-Yeh University. Since 2004, he has been an Associate Professor with the Department of Industrial Design at Chaoyang University of Technology. His research interests are design integration and product development.

Cheng-chi Chang graduated from the department of industrial design at the Chaoyang University of Technology. He is a design assistant in the R&D department of woodworking machinery company. He is a master student supervised by Prof. Chen. His research interests include machine design, CAD and product development.

Chen-yu Tsai graduated from the Department of Industrial Design at Chaoyang University of Technology, Taiwan in 2017. He wins the grand prize of the design competition. Currently, he is a master student supervised by Prof. Chen. His research interests include creative-design, CAD and product development.