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Application of Modular Fixture Interface in CAD Software for Jigs and Fixtures Design Teaching Aids

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ABSTRACT

Jigs and Fixtures Design are (is) among the core subjects offered at the diploma and degree level of Manufacturing Technology programs. Each student is assigned to create a specific jig design in their assignment task. The scope of the assignments covers a range of processes starting from the generation of ideas, sketches, technical drawings and eds with the prototype development. However, in previous batches of students, they were struggling with the issue of limited equipment and prototype development skills which consequently affects the quality of prototype being produced. To overcome this problem, a modular has been developed using CAD software to help students applying the components that are ready to be used as a jig to hold the workpiece. Through this idea generation method, students just need to select the existing components to develop the jig. They can also use the modular to assist them in their presentation. The results obtained from the use of modular show that students are able to reduce the time taken in developing the jig and are able to visualize the final product based on the proposed ideas.

1. Introduction

Jigs and Fixtures are devices used to facilitate industrial production work, particularly those that require manufacturing process. Jigs are machine shop devices that include the mechanism of guiding tool as an independent device to which the component is clamped in a specific position to perform one or more operations [1]. They are mostly applicable to operations performed on drilling machining and combine with operational machining. Fixtures are special holding devices that are aided to hold the workpiece together firmly and easily, and they may include operational instructions of the cutter [2]. Fixtures are commonly used for milling, turning, grinding and other similar manufacturing operation. Perfect jigs and fixtures yield repeatability and interchangeability to produce similar parts in production [3]. In manufacturing, jigs and fixtures are the most vital device that ease the workers in their production process. But beyond their evident benefits, conventional jigs and fixtures also

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present a few shortcomings especially when the production volume is less and does not run on a regular schedule.

Accordingly, rapid changing in manufacturing practice creates newer provisions as users need to change the components applied to each different process. Hence, this scenario discharges a quick production cycle, fluctuating volumes, and products variety [4, 5]. To cope with these pertinent issues, industry needs to have a generic system which copes with the desired products [6]. At this point of time, modular fixturing is an alternative that production can benefit immensely from the quality fixturing [7, 8].

Modular and flexible fixtures represent another variant of jigs and fixtures which are completely standard parts [9]. These devices are completely detachable which means they are often being assembled and dis-assembled. Normally, modular fixtures are mainly used with computer numerical control (CNC) machines. The position of plugging the locators and clamps often crops up as a troubling issue during assembly of the modular fixture. Modular work holders, at their core, are often described as special-purpose work holders assembled from general-purpose components. A modular fixturing system (or dedicated fixture) could be a versatile alternative to a single–purpose. Instead of being a departure from conventional fixturing methods, the concept of modular fixturing represents a mixture of the simplest attributes of both special and general-purpose work holding methods. Modular fixtures are built with the same accuracy and precision of the special-purpose work holders, but implement reusable and universal components. Moreover, these fixtures are relatively cheaper compared to the general-purpose work holders [10].

The reliability of new design is a very crucial parameter that will affect the chances of failure and contribute to additional cost [11]. Hence, the economic benefits from new design are curbed. The additional cost incurred during the adaptive process of design is an excessive investment [12]. Since modular fixtures design are constructed from a kit with interchangeable components, its application in industries is widely used. It is commonly used in many production sectors that demand for enormous number of parts with complicated shape. Often, workers are required to configure the work holder in any configurations needed, and later dismantle them for convenient storage when not in used [13]. Any requirements of human interaction are more prone to an error and variation during the procedure with direct influence over product quality [14]. The career development is a process of increasing employability achieved in order to realize the desired career [15]. Therefore, in manufacturing technology programme at higher learning institutions, jigs and fixture design is identified as one of the core subjects whereby students will be exposed to the process and development of jigs and fixture involved during the practical sessions. On the job training, such a hands-on approach will prepare students to be better employees in the future since they will acquire the crucial practical skills therefrom [16, 17]. This is because having good academic qualification only is not a guarantee for them to secure a job due to a competitive job market [18, 19]. However, it was also found from the programme educator that the necessary lab instruments and jigs equipment are too limited for students to explore further potential and development. In addition, students need to create a design from scratch, such as using a mock up, each time they need to fabricate a given task. Students would face time constraints and the outcome would be varied too much. These problems are evident from the results shown in the continuous quality improvements (CQI). The data shows that in four years back (2018 to 2021) the Continuous Learning Outcome for the construct the product (CLO 2) and demonstrate the product (CLO 3) which are psychomotor and activities in average is less than 50% as shown in Figure 1.

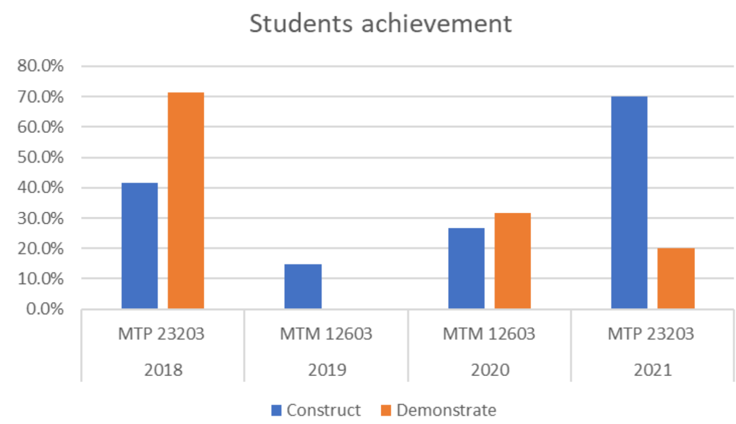

Fig. 1. Students Achievement in 2018-2021. MTM 12603 is refer to diploma programme and MTP 23203 is refer to degree programme.

To overcome this problem, this study was conducted to fabricate a modular jigs and fixtures as teaching aids. This study focused on implementing a simulation of modular jigs and fixtures for teaching using the CAD software (Fusion 360). The study was conducted to make a modular fixture for students' use during the practical learning teaching process. The aim of this research is to develop an interface model of a modular jigs and fixture using computer aid drawing (CAD) for teaching purposes.

2. Methodology

This research was conducted by taking preliminary data from modular jigs and fixtures literature, interviews with programmed instructors, and also secondary data sources. By the collected data, we were able to identify inherent problems of the existing products. The ideation of product is then induced through the gathered information. Next, came the product development that evolved in bringing a product from the conceptual stage – concrete products with new or different characteristics that offer an additional benefit to the students in jigs and fixtures subject. This may involve modifications to the existing product, or formulation of an entirely new product development. The purpose is to solve problems on the existing product. Finally, the modular jigs and fixture interface was tested by several product configurations for a machining process.

From the survey, the information is collated as the product features that will address the customers' needs. It was listed down as follow:

i. Unlimited fixture configurations
ii. Make it simple for operators to add a measurement feature or alter a fixture configuration even for large or complex parts.
iii. Variation of accessories.
iv. Compatibility with the available measuring and machining tools.

Product ideation is performed based on the preliminary study on this project. There are few main components used to develop the jigs and fixture such as V-block, several types of clamps and bolt and nut for fitting. This basic component is drawn as a sketch in Figure 2. As a basic, a base plate with a grid pattern threaded holes is developed by using milling machine to locate the components and workpiece positional accuracy [20]. From these sketches, each component was reviewed and validated to evaluate how many components and the optimum size for platform could be used. This is because the standard size for each component is followed the actual size in the market. Please note that the scale 1:1 is important for students to be familiar with the design of jigs and fixture development. Then, the sketch that incorporated the idea was converted to the 3D drawing using software Autodesk Fusion 360.

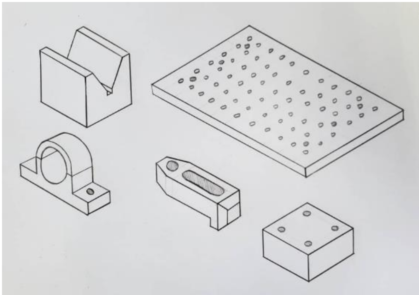

Fig. 2. Product Sketching

The components of the product are designed based on the existing components in machine shop and the market. The selected components are, mostly, consists of regular and standard parts as used in modular jigs and fixtures. The shape, dimension of the components, and platform are standardized. However, these could be re-adjusted to scale uniformly using the command in Autodesk Fusion 360 software. In addition, the components could be replicated to align with the design needed to configured. Table 1 shows the regular components selected.

Table 1
List of Components

No.	Component	Function
A	Fixture Plate	Modular work holder base, used to hold several components for assembly of the work holder.
B	Tube Holder	Used to tighten the work piece with cylindrical shape
C	Strap Clamp	Clamp that has adjustable 3-axis movement
D	Locating pin	Used to lock work piece in place in several positions
E	Pin Holder	Used to hold locating pins in horizontally. To enable holding even more tricky parts.
F	Riser	Used as a support of work piece to lift the work piece up from the plate, to avoid damaging the fixture plate from the drilling or any similar operation.
G	V Block	Used to hold cylindrical object to perform drilling operations

All the 3D components and platform constructed in Fusion 360 were kept in a single file. The 3D model consists of a number of components that are used in modular fixtures constructions. In these files, the components are arranged in library format as shown in Figure 3. The purpose of this arrangement was to show that the components are in a ready condition of pick and use, and users can quickly fetch, even duplicate, any desired components for their fixture design and assembly.

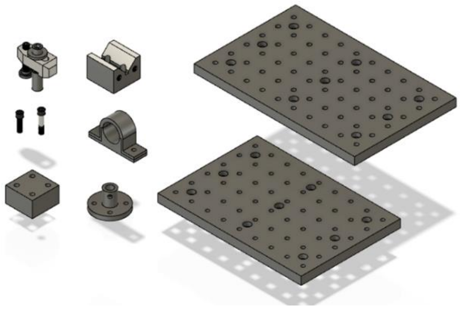

Fig. 3. User Interface of Product

According to the standard manual, to apply the modular jigs and fixture interface, user needs to identify a workpiece as a sample. The selected workpiece should produce an actual dimension in 3D model. First, the user accesses the CAD software (i.e., Autodesk Fusion 360). Secondly, the user opens the modular fixture file that is produced from this research. After that, the user can insert their own 3D model work piece to apply the modular fixture work holding. The user is advised to save the file of the new work piece as to avoid losing their own or the modular fixture files.

Thirdly, after selecting the work piece, the user can drag the work piece or components to their respective position and rotation to start the assembly. They can highlight any required components and hide the rest. Conversely, they can also highlight hidden components if needed later. During the assembly process, the user positions their work piece on the fixture plate and secure the best components arrangement for the work holder. Fourthly, user places the work piece along with the necessary components to lock the work piece in place. If more components are needed, they can use the software function to modify and duplicate extra components.

The user can place the components and work piece roughly at their desired points and subsequently use the software functions to make a restraint such as mechanical restraints, or tangential restraints, and even make a joint for the components to lock them in place. Finally, after placing and locking the components, the user can verify the work holder arrangements to verify whether or not it conforms to their desired designs. They can repeat the assembly process if needed; otherwise, the user can proceed to finishing the process. After that, the user can save the files for future use. The outcome from these stages is documented for a presentation to and consultation by the instructor. In addition, users could have several other proposal designs before the final decision. Hence, this could reduce the processing time of designing and developing the jigs.

2.1 Experimental

The comparison experimental for modular fixture interface and regular process is based on an actual problem encountered by students. In jigs and fixture design subject, the instructor asked students to design and develop a jig prototype that holds an irregular work piece. There are three types of tasks given and jigs that have been developed to apply to a measurement process such as measurement using Coordinate Measuring Machine (CMM), drilling operation and combination operation setup.

2.1.1 Existing jigs and fixtures design learning process

In normal practices, every student is assigned to a group and each group has 5 students. Each group was given a work piece in a technical drawing complete with a dimension. From that, each group needs to come up with an ideation, conceptual design and fabricate it using the prototype concept. These three stages approximately take several days to complete. In addition, before they start to fabricate the prototype, they have to present the concept to the instructor for approval. After completing the given tasks, it was found that most of the groups experienced the following problems.

i. Increased time in ideation
ii. Increased time in sketching the fixture ideas before redrawing the selected design to 3D model.
iii. Wasted time in tangible prototype development.
iv. Rejection because several tasks are rejected while setting the fixture.
v. Increased fatigue to operator

2.1.2 Concept of modular fixture interface in CAD software

Considering all of these problems, the process of modular interface fixtures was applied. By following the same given instructions, the methodology details were followed through to complete the development of the jigs and fixture design. Since the product are developed by using the CAD software whose purpose is to give some exposure of modular fixture to the user. Hence, students need to redraw the work piece to a 3D CAD model so that they can produce and use it as their own work piece in their project. Next, students will apply the modular fixture application by selecting suitable components and applied them to the platform. While deciding which components to use, students could discuss with other team members the advantages of their own design by following the design methodology of jigs using the modular fixtures. In addition, each group could design more than one designs for the presentation purpose which are followed by obtaining approval from the instructor.

2.1.3 Setup the components

This section demonstrates the process of interchangeability in assembly process in the 3D CAD software. Three fixture setups were made using the product from operation such as drilling, inspection with CMM and as a regular work holder. This activity involved the process of design development and presentation session. Once the user is done with the setup, the user can also use the software functions such as rendering, manufacturing (for drilling), drawing, and animation. The three setup processes are as follow.

2.2. CMM Inspection Setup

In using CMM inspection, the work piece needs to stay locked in place. At the same time, there need to be less distraction in the surrounding of the work piece. Hence, the component used in the assembly needs to be minimum and locks the work piece Degree of Freedom (DOF) at the same time. Figure 4 shows a sample of assembly of a mouse to be used for CMM inspection and the assembly of the fixture components that will be used. The component of the fixture is colorized to differentiate the components from one another.

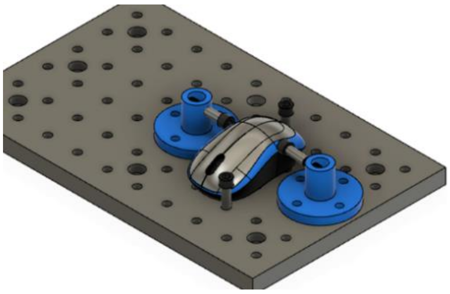

Fig. 4. CMM Inspection setup

However, the CMM inspection usually requires the operator to measure the part from the bottom of the work piece. Hence, the work piece has to be elevated either by a riser or a tower. In this setup, however, none is used since neither tower components nor suitable risers were available.

2.3. Drilling Operation Setup

In drilling operations, a work piece needs to stay locked in place and the point where the drilling goes should be clear of all obstructions. If a hole must be drilled through the work piece, the work piece must be elevated to avoid any damages to the build plate. Figure 5 shows the assembly setup for a drilling process. The work piece is colorized to represents wood and the components are colorized to differentiate from each other.

In this setup, the usage of strap clamp is demonstrated by using the software joint function to replicate the functional mechanism of the strap clamp. This is because this software allows the user to only design a 3D model based on the listed components. However, if a user needs to add other components, they have to draw those in a 3D model, and this task could spell troublesome. Hence, these additional components can be considered as a future improvements matter.

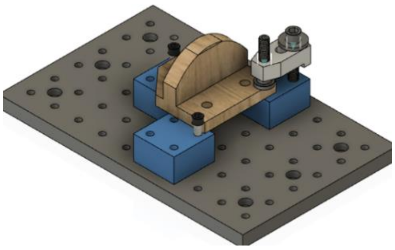

Fig. 5. Drilling Operation Setup

2.4. Combination Operations Setup

Combination operation represents an operation which requires the operator to combine together two or more parts. Examples of combination operations that uses the modular fixture are welding. Welding setup requires the work piece to be locked and remain fixed in place to produce a better quality and more precise welding. Figure 6 shows the setup for welding assembly of a section of metal tube with 45 degrees cut.

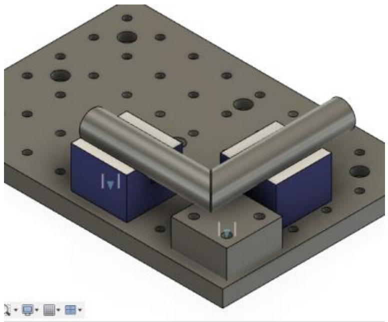

Fig. 6. Welding Setup

There are some difficulties during this designing process where there are limited components that can be used for the locking mechanism. By only using the V Block, the tube can still rotate during a welding process. So, a stopper or a clamp is needed to lock the tube rotational movements.

Based on this tested sample, there are some limitations identified from the product. These include the lack of components such as towers, clamps or vises. On top of those, the fixture plate also poses some problems such as a big gap between the holes that compromises the precision of holding smaller work pieces.

3. Results

Testing was conducted to compare between the manual activity in design the jigs and fixture with the one using interface modular fixture software as demonstrated in this study. The inputs came from the students and instructor involved in Jigs and Fixture Design subject. Three criteria are chosen: i) design process flow; ii) time measurement to complete the jigs and fixture design and iii) product finishing. The results obtained are presented as follow.

Table 2
Design Flow Process

Parameter	Manual	Modular fixture
Brainstorming and sketches	Yes	Yes
Component's selection	Yes	No
3D drawing	Yes	No
Multi design possibility	No	Yes
Material selection for a prototype development	Yes	No
Improvement needs after presentation	Need to start from beginning	Just realign existing components
Design Fatigue	High	Low

Table 3
Time Measurement

Parameter	Manual	Modular fixture
3D drawing (work piece)	40 min	40 min
Selection components and material for prototype development	2 days	20 min
Prototype development	300 min	15 min
Set up components	60 min	10 min
Cycle time to change a design	60 min	8 min
Presentation set up	60 min	8 min
Time taken to redrawn 3D model	120 min	8 min

Table 4
Product Finishing

Parameter	Manual	Modular fixture
Simulation	No	Yes
Rendering	No	Yes
Prototype presentation	Tangible Model	Power point etc.
Final Presentation quality	Low (static)	High (variety)

The findings discovered that this modular fixture interface data in CAD software have successfully supported instructors and students in their teaching and learning processes. Basically, this learning aid has eliminated a few processes for students to design the jigs and fixture. This includes reviewing the suitable material, components selection for prototype development, time cycle and also redraw the technical drawing after the comments given by instructor. All these processes were time-consuming in completing the flow of design process. Hence, such a delay would distract the focus of the students from more important matters such as ideation, concept and design variety. Also, the creativity of the student could have been limited to develop the prototype and would be an obstacle for them to deliver the actual idea in a tangible product. As a result, this would affect their presentation and performance.

4. Conclusions

The scope of this research was focused on the learning aids for the instructor to enhance the knowledge transfer. Therefore, several limitations have been identified such as the measurement of forces on a work piece is not counted. This will neglect the information of the student on suitable components selection which would have damaged the assembly part. Also, the limitations on the components of fixtures listed would pose constraints to have a variety of design to be developed. Lastly, the requirement in real manufacturing operator in jigs design to calculate the pressure given to work piece is not counted yet because the calculation will only follow after the design approval.

For future research, the variations of regular components of jigs can be increased and extended with the irregular components. By having this, the users can apply the actual jigs in machine shop according to their design. Next, the development of the calculation process can be done using software applicable to apply on the modular fixture interface. Overall, the combination of the above suggestions would significantly improve the quality design of jigs and fixture using the modular fixture interface for fully supported as a robust teaching aid in the relevant subject.

The applications of modular fixture for teaching aids make it very distinct that this method might be needed to help students' understanding and experience in delivering the design. Also, more efficient job at handling tricky operations for irregular work piece from early stage of ideation until product presentation session. By using this teaching aids students can design any type of assembly required as long as the component needed is available. Furthermore, for the post processing, the students can use the function that are built in the software to produce detailed drawing of their design. Other areas including animation of the parts assembly, producing a simulation or making a 3D rendered view of the design are also applicable. This will certainly enhance the variety and performance quality of the student during the presentation session

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