Designing of welding jig for productivity improvement and cost-savings in thresher’s cover assembly: A Case Study on CV Citra Dragon Assembly Plant

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Abstract. Needs for efficient assembly process has led CV Citra Dragon, a medium-scale manufacturing enterprise of agricultural machinery, to utilize welding jig for assembly one part of thresher component as their high demanding product. That component is thresher’s cover that has the potential for productivity improvement hence cost savings. Due to categorize as a specific work-holding device for particular purpose and conditions, design processes of a welding jig has been carried out. This has resulted in the development of a welding jig for assembly of thresher’s cover. The design of welding jig has been evaluated from possibility to deflect during its operation, and it was identified that deflection magnitude of welding jig construction was relatively low. Thus, it can infer that this welding jig can resist operational loads. Furthermore, the productivity and cost-effectiveness analysis were also conducted to ensure the welding jig having fulfilled the objective of the proposal. The analysis indicated that the assembly process becomes efficient as a welding jig deployed. It was contributed by shortening of assembly cycle times that increase the production rate. Also, affordable cost savings can also be obvious especially for labor cost salary.

1. Introduction
Welding jig is one of substantial supporting equipment required in assembly line especially for those whose associated with thermal joining processes. The use of this equipment as the work-holding device is to ensure the product quality can meet a specific standard, particularly for high repeatable assembly processes. Besides, the existence of welding jig can also be attributable to process cycle times reduction thus production cost savings and productivity improvement [1].

Many agricultural machinery industries are classified as medium-scale manufacturing industry that sometimes is recognized operating at low productivity level. Therefore, the assembly processes tend to be conducted without adopting the best manufacturing practices. This is commonly by negating the utilization of work-holding devices such as welding jigs. Nevertheless, the requirement for welding jigs for this such industry is still of value primarily for cost savings before improving their product competitiveness.
CV. Citra Dragon is one of agricultural machinery company that is operated and located at Pariaman City of West Sumatera. One of their high demand product is the thresher that is commonly utilized for post-processing of cultivated rice. Driven by the implementation of Indonesian Standard (i.e., SNI) by National Standardized Bureau for all products commercially traded in Indonesia, Citra Dragon realized to meet the national standard requirement by reconditioning of their assembly processes. By which, most assembly processes were previously carried out by skilled labor manually would be restructured by introducing welding jigs. Although without welding jig utilization, the quality of the product can still be maintained at the standard level but in fact, it is failed to be conducted efficiently. This can be seen from the network diagram of thresher assembly stages depicted in Figure 1. Figure 1 shows a bottleneck condition encountered by the currently applied method.

For the production of a unit product, it spent around 7.43 of working hours to complete only for the assembly process [1]. This is mainly contributed by two assembly stations which are 1) assembly of the thresher’s body and 2) assembly of thresher’s cover. Reduction of the cycle times for assembly of the thresher’s body might be relatively difficult to execute due to involving many parts. Meanwhile, assembly duration for assembly of thresher’s cover can be possible to lowering down. The prolonged period of the assembly process of thresher’s body is most likely caused by currently performed on the body of thresher manually. Accordingly, thresher’s cover can be started to be assembly after assembly of thresher’s body completed. Meanwhile, assembly duration for the body is a time-consuming process. Thus it would create a bottleneck condition in whole assembly process before it can be employed as acted welding jig.

![Figure 1](image_url)

**Figure 1.** Network diagram for the occurrence of a bottleneck on assembly process of thresher's body

Therefore, designing a dedicated welding jig would be a sufficient solution for that pre-defined problem. Thus the assembly duration of the thresher’s cover assembly can be reduced. However, welding jig is not a work-holding device that is commercially available. This kind of work-holding device is a specific tool for a particular purpose and conditions. Therefore, designing a welding jig for assembly of thresher’s cover will become the objective of this study. In advances, the performance of the proposed welding jig design will also be assessed by its capability to enhance process efficiency as well as affordable cost savings.

2. **Methodology**
The welding jig for assembly of thresher’s cover was designed based on a survey, anthropometry data, and observation of the assembly process stages conducted in the location of the manufacturer, in this case, Citra Dragon company’s plant. The survey was conducted to listed and defined user requirements for welding jig design. Meanwhile, anthropometry data were measured in situ to fit the welding jig concept with the worker who are responsible for performing the assembly process of
thresher’s cover. Further, from observation of the process, it would be gathered the information related with the process sequences. Based on all those data, the concepts of welding jig design can be proposed through brainstorming and discussions. The ideas of welding jig then were selected to fulfill the user requirements utilizing user experience method and by adopting anthropometry data as well as defined process sequences.

After the concept has been selected, the construction of the proposed idea of the welding jig was evaluated by the strength of the material theory. This is to ensure the creation of the selected welding jig concept would not experience deflection during the process due to operational loads. Deflection would affect the dimensional accuracy of joined parts when they are fitted to the thresher’s cover. From this analysis, the dimension and geometry of material used for welding jig construction can simultaneously be clarified. All materials used in this design were market available in size and shape. If the construction of welding jig can meet very low deflection magnitude, then fabrication processes took place. Machining and joining processes were performed in design realization. In this study, sawing, turning, mechanical and thermal joining were used.

Eventually, the performance of built welding jig was examined regarding its capabilities in shortening the assembly process lead times. In addition, the cost-effective of using this special purposes welding jig was also addressed by comparing the expenditure for labor cost with and without utilization of welding jig.

3. Welding Jig Design
3.1. Concept development
The principle of either any jigs and fixtures are highly based on locators and clampings design[2]. The locator is to locate the workpiece on a definite location so that it can be easy to mark it out during the process. Meanwhile, clamping design is to secure the position of workpiece fixed when the operational forces are applied. Thereby, the welding jig can be developed to meet primary criterion such as ergonomics, simple and easy to operate, distortion proof due to the welding process, time-saving in setup and assembly process, and producing uniform products [3].

Based on the defined criterion, through an intensive brainstorming and literature searches, two concepts for welding jigs were proposed. The first concept was named "In-out from the top." Meanwhile for the second one was called "In-out from the side" concept. Both concepts were adopting the same principle for clamping and locator design. A user experience survey had been carried out to the company Director, Production Head, and Welders who are responsible for the assembly process of thresher's cover. As a result, "In-out from top" concept was selected as a proposed welding jig for the assembly. The design of the chosen concept is given in Figure 2.

![Figure 2. Detail design of welding jig for thresher’s cover assembly](image)
The design of selected welding jig was then be developed following geometry and size fitted with the thresher cover. In additions, the anthropometry data of operators was also considered to adjust the height and width of the jig. This is to ensure adequate with prospective users so that it can be operated comfortably and efficiently. Furthermore, materials used for the built welding jig were market commercially available in sizes and shapes.

Finally, the proposed welding jig was fabricated for prototype realization by utilization of some machining processes and welding process. The prototype consisted of parts as revealed in the legend for the Figure 2. Meanwhile, the real prototype of welding jig built in this study is shown in Figure 3.

![Prototype of Welding Jig Utilized for Assembly of Thresher’s Cover](image)

**Figure 3.** Prototype of Welding Jig Utilized for Assembly of Thresher’s Cover

3.2. Deflection analysis
Deflection analysis was carried out on the construction of the selected welding jig concept. This was aimed to avoid deflection on the structure of jig during its operations. In jig and fixture design, construction of the jig must be ensured rigid. Therefore, the deflection should be retained at the lowest magnitude [4]. The deflected structure may affect in the positioning of the central cover part on the welding jig. Besides, it would also make difficult to weld the support parts on the cover body. As consequences, the assembly quality would be traded off.

To analysis the proposed welding jig constructions, the first welding jig design must be modeled. The model used in this study was a simplifying of the welding jig construction as revealed in Figure 4.

![Free body diagram of simplified welding jig construction](image)

**Figure 4.** Free body diagram of simplified welding jig construction

Using a steel plate for bottom plate retention and square hollow steel for the leg that is commercially available, the deflection value was calculated by using Equation 1 [5]. As expressed in Equation 1, the deflection value is depending on the magnitude of load, P (in N) and square length, l2.
of the element where loads are working (in mm²) and inversely proportional to elastic modulus, E (in N/m²) and moment inertia of selected material, I (in mm4).

\[ y = \frac{5PL^2}{384EI} \]  

Calculations were performed on two main built elements of welding jig which are bottom plate retention and leg of the construction. From calculation, it was determined that deflection magnitude for that two element are around 18.7 µm and 34.2 µm respectively. This signifies that deflection magnitude on bottom plate is relatively low when all assembly parts and working loads are weighing down the construction of welding jig. However, although deflection value for the leg is somewhat higher and possible to impact the accuracy of assembly parts, it is still acceptable for well functioning as welding jig for thresher’s cover assembly. This is owing to less accuracy required in assembly processes [6,7,8].

4. Productivity and Cost-Effectiveness Analysis

To evaluate the performance of built welding jig in reducing the cycle times, the network diagram of the thresher assembly was refined. The revision indicates that utilization of welding jig only for assembly thresher's cover can vanish the bottleneck appeared from the assembly process as shown in Figure 5.

![Network diagram of the improved assembly process of thresher's cover](image)

**Figure 5.** Network diagram of the improved assembly process of thresher's cover

Figure 6 shows that, as the bottleneck disappeared the total cycle times for thresher assembly process can be reduced from ± 7.4 hours to be just ±4.7 hours. Accordingly, production rates of the assembly process can be improved from 2 units/day to be 3-4 units/day. This proofs that utilization of work holding device such as welding jig can enhance the productivity of the process even just implemented at a small portion of the assembly process stage. As such, a 57 % reduction on the cycle times can afford that would improve productivity.

Moreover, with 57 % productivity improvement, it would encounter cost savings especially for labor cost as indicated from Figure 7. From Figure 7, it is highlighted that cost-effectiveness is affirmative with the existence of welding jig in the assembly plant. Hence, the presence of work holding devices such as welding jigs in an assembly plant is absolute of importance if the efficiency of the process is the ultimate goal of the production strategy.
5. Conclusions
Welding jig is an essential work holding device necessary on the assembly plant. Though only implemented on the small portion of work as in this study, it would refine the process sequences to be more productive. This is indicated from the cycle times reduction that approximately reaches the percentage of 57%. As a result, the unit of product can be assembled also increases to 3-4 units per day. This is owing to the capability of welding jig in reducing the cycle times hence cost savings in the assembly of thresher's cover of CV Citra Dragon' thresher product.

6. References
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