ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

A study on the impact of a proximity-sensor-based leaf jig for a flange to enhance productivity

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Abstract.

This article introduces the revolutionary design of a leaf jig equipped with proximity sensors that significantly reduce the cycle time during the flange drilling process. By attaching proximity sensors to a leaf jig, it is possible to drill an array of holes on the flange. It verifies proper seating while locating the jig plate prior to drilling. Reduced cycle times are possible in the mass manufacturing of flanges by lowering the overhead time for positioning, adjusting, and inspecting. Two flow-process diagrams for drilling operations are created utilizing template and leaf jigs. According to the flow-chart analysis, the verification of flange seating using a feeler gauge is eliminated in the leaf jig, while the production rate rises by 17%.

Keywords: flange, flow process charts, leaf jig, production rate

1. Introduction

Leaf jigs are production tools that are identified by their hinged cover, or leaf, which swings open to load or unload the jig. After positioning the workpiece inside the jig, the leaf is

ISSN PRINT 2319 1775 Online 2320 7876

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tightly closed and secured with thumbscrews. Leaf jigs are quick to load and unload and are ideal for complex workpieces with uneven curves. The hinge plate of this jig is precision-machined to assure precise alignments, and the joints comprise heat-treated pins and bushings to prevent excessive wear. The flanges are manufactured by casting, turning, and drilling hole patterns. The drilling of holes is traditionally accomplished by hole-center marking, punching, piloting, and final drilling, all of which require longer cycle times and have inconsistent results. Drill jigs aid in their performance. There will always be a need to reduce cycle times in this process (Donaldson, 2012).

Ashish et al. (2015) and Rama et al. (2016) carried out an experimental study on the design and analysis of a drill jig with variable materials and found that steel experiences less deformation than to gray forged iron and aluminum alloy. Prassetiyo et al. (2019) and Varatharajulu et al. (2020) chose an industrial manufacturing problem and designed a drill jig for the side-plate component. Through the implementation of the drill jig, the part rejection was reduced from 20% to zero, the setup time was reduced from 0.97 min to 0.30 min, and the total production was increased per hour/day. Patil et al. (2016) and Raghavendra et al. (2018) presented the design and development of a drill jig for spinning rings used in the textile industry and an indexing drill jig, respectively. Ritesh et al. (2022) worked on the concepts of delamination and measurement in the drilling process. Francis et al. (2022) further investigated increases in shear strength through chemical processing, in order to overcome the delamination issues encountered while drilling. Apai et al. (2021) emphasized the need for secondary stress conditions while preforming structural analysis in CAE software. Kiran et al. (2018) presented research on the design, fabrication, and automation of an indexing drill jig. The drilling operation was carried out on fiber, aluminum, mild steel, and cast-iron materials, and the machining time for each material was determined and compared with the conventional machining time. It was concluded that high accuracy and a reduced consumption of time were achieved with the automated indexing drill jig compared to conventional machining. Kumar et al. (2020) developed a re-engineered fixture that allowed them to load two jobs into a single fixture, lowering the production time by 4 minutes each job. Rajesh et al. (2021) created a drill jig for brake-lining components of three different sizes. When three distinct jigs

ISSN PRINT 2319 1775 Online 2320 7876

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are built, the aim is to minimize the time it takes to replace a jig for each component for spring hole drilling. Gebray et al. (2018) analyzed how to increase assembly productivity for the AK103 by reducing the assembly time and lowering the production costs, which are high due to crack wastage.

By conducting a time analysis for each of the firm's activities and collecting bottlenecks in each process, Kumar et al. (2020) proposed solutions for greater productivity rates compared to the existing setup.

Mgbemena et al. (2020) created a proximity-warning system that decreases the likelihood of shop-floor accidents by monitoring the distance between an object and a worker and providing both audio and visual feedback.

From the literature review, it is understood that cycle time and accuracy are important factors to maximize the production rates of drill jigs. Therefore, in this work, proximity sensors were integrated into the suggested design to address some of the cycle-time challenges associated with these jigs.

2. Objectives

To investigate the current drilling process of a flange component and suggest a strategy to reduce the production-cycle time and maintain consistency in flange-drilling quality. A further objective was to increase operator safety in flange machining during drilling.

3. Materials and methods

For this experiment, a common industrial component flange was chosen, and its dimensions were measured. The approach presented in this study, involving the drilling of four clamping holes, was examined, and a flow-process chart was developed.

3.1 Component section

The flange component is typically completed on a lathe, with the exception of four clamping holes. The typical procedure involves marking and drilling the hole centers. The component selected is depicted in detail in Figure 1. The purpose of this lesson is to drill using a drill jig.

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Figure 1. Component details of flange selected

3.2 Experimental study

The drilling-cycle time of a flange on a radial drilling machine was determined through an experiment. Figure 2 illustrates how flanges were clamped using a template jig, as well as how their seating was evaluated using a feeler gauge. Plate seating was randomly tested and clamped to ensure there were no gaps in the four quadrants.

	
Figure 2. Inspection of flange seating with template jig	**Figure 3.** Pilot drilling of the flange using template jig

After the pilot drilling, the template jig was removed, the flange was reclamped, and the position of each hole was located to drill the final holes in the correct size. Figure 3 depicts the flange-drilling process.

A flow chart was generated for the flange-drilling procedure. In this drill cycle, the flange was positioned, the template jig was mounted, the seating on the machine table was inspected, and the flange was clamped and drilled. A stopwatch is used to collect and record the average time of 5 samples for each operation. Figure 4 depicts a drill-cycle flow chart employing a flange template jig.

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3.3 Design of leaf jig

This study's major goal was to improve the present drill jig to reduce the cycle time in the completion of four-hole drilling without compromising the quality of the flange. The factors like jig body, component location and clamping, jig bushings were taken into consideration while designing the leaf jig.

3.3.1 Modeling of Leaf Jig

Figure.5 shows the modeling of the leaf jig, which was performed with Auto CAD software.

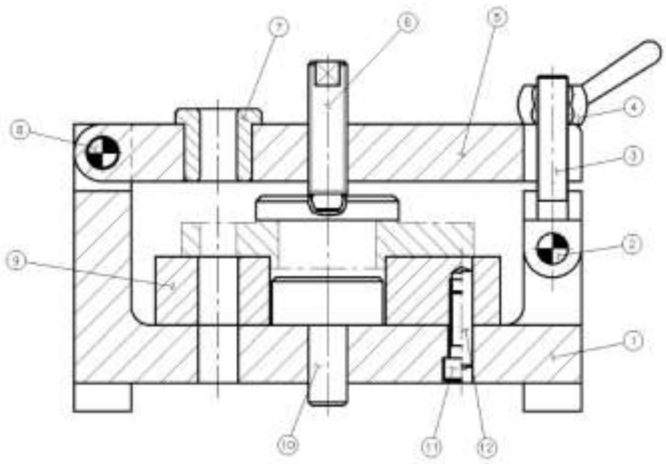

Figure 5. CAD model of the leaf jig assembly

3.4 Analysis of drill jig

The suggested design of the drill jig will result in faster setup times than the existing process. The predicted cycle time was determined using a flow-process chart when drilling the flanges with leaf jig.

The previous flange setup time (i.e., butting surface verification) using a template jig has a direct effect on the working time of the component whose speed is to be increased. The manual method of verification can be further improved by the addition of sensors, which indicate the butting surface throughout the drilling operation. Four Proximity sensors are used for this purpose.

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In the design of the leaf jig, four proximity sensors were included in the locator plate, and they were connected. Once the flange component was located and clamped in the drill jig, the sensor caused the LED lights to glow to indicate the correct seating of the flange. Figure 6 shows the estimated flow-process chart of the drill jig using proximity sensors.

4. Results and Discussion

The objective of modifying the existing template jig was to reduce the production time and the overhead work. In the present drilling process of a flange using a template jig, the workpiece is picked and placed a jig manually and clamped. It is also inspected for seating of workpiece on the jig at quadrants and corrected. It is pilot drilled and enlarged to Ø19.1hole size. For the present system, a flow-process chart was created. The proposed system uses a leaf jig with proximity sensors to drill a flange. During this procedure, the workpiece was positioned on a leaf jig, clamped, and drilled to size using automated sensing of its seating. A flow-process chart was also made for the suggested system. Two flow-process charts for drilling operations were compared with the number of operations to be performed. Their process times in seconds are shown in Figures 7(a) and (b), respectively.

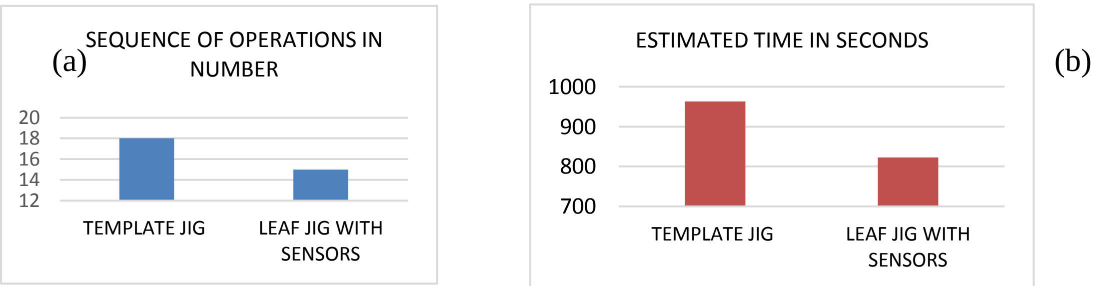

Figure 7. Comparison of two drilling processes using jigs on a flange,

From two flow-process charts shown in Figure 5 and Figure 9, it can be observed that the number of operations was reduced by 3, from 18 to 15, and the cycle time was reduced by 140 seconds, from 963 to 823 seconds, which shows an improvement in the production time. A comparison of the times for the two drill jigs and productivity is given in Table 1.

IJFANS International Journal of Food and Nutritional Sciences

ISSN PRINT 2319 1775 Online 2320 7876

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Table 1. Setup times and productivity.

Drilling Method	Process Time (seconds)	Production/shift (units)	Production/day (units)	Percentage of
Template jig	963	29	87	-
Leaf jig with	823	34	102	17%

FLOW PROCESS CHART			MATERIAL TYPE	
Chart No.1 Sheet No.1	SUMMARY			
Subject charted: Drilling	ACTIVITY	PRESENT	PROPOSED	SAVING
	Operation ●	9		
Chart begins: Work piece	Transport ➡	0		
	Delay D	0		
Chart ends: Inspection	Inspection ■	7		
	Storage ▼	2		
Method: Present	Distance (m)	-		
Charted by :	Time (man – sec)	963		
Approved by : date:	Total Production units (per shift)	29		

Description	Symbols: ●	➡	D	■	▼	Distance (m)	Time (sec)	Remarks
Collecting of work piece					●		10	By Hand
Positioning of clamping bolt and work piece on drilling machine	●						25	”
Placing of Template Jig on work piece	●						12	”
Clamping the Jig assembly	●						15	”
Verification of butting surfaces using feeler gauge at 1st corner				●			12	”
Verification of butting surfaces using feeler gauge at 2nd corner				●			12	”
Verification of butting surfaces using feeler gauge at 3rd corner				●			12	”
Verification of butting surfaces using feeler gauge at 4th corner				●			12	”
Loosen the Jig assesmbly, adjust and reclamp	●						25	”
Verification of butting surfaces at 4 corners				●			24	”
Drilling of pilot holes at 4 places	●						240	”
Removal of template jig	●						90	”
Clamping of workpiece on drilling machine				●			40	”
Locating each predrilled hole and drill to finish 4 holes	●						360	”
Final Inspection of workpiece				●			24	”
Loosen the clamping bolt to remove the work piece	●						30	”
Cleaning of metal chips	●						10	”
Placing the workpiece in tray					●		10	”
Total	9	-	-	7	2		963	

Figure 4. Flow-process chart for flange using template jig

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FLOW PROCESS CHART				MATERIAL TYPE	
Chart No.2 Sheet No.1	SUMMARY				
Subject charted: Drilling	ACTIVITY		PRESENT	PROPOSED	SAVING
	Operation	●	9	9	-
Chart begins: Work piece	Transport	➡	0	0	-
	Delay	D	0	0	-
Chart ends: Inspection	Inspection	■	7	4	3
	Storage	▼	2	2	-
Method: Proposed	Distance (m)		-	-	-
Charted by :	Time (man – sec)		963	823	140
Approved by : date:	Total Production units (per shift)		29	34	5

Description	Symbols ●	➡	D	■	▼	Distance (m)	Time (sec)	Remarks
Selecting of work piece					•		10	By Hand
Opening of Leaf Jig	•						20	”
Load the work piece on Locator	•						15	”
Clamping the Work piece	•						20	”
Verification of butting surfaces				•			12	”
Open leaf jig to adjust of workpiece and reclamp.	•						25	”
Verification of butting surfaces				•			12	”
Drilling of pilot holes at 4 places	•						200	”
Removal of Renewable bushes (4Nos.)	•						120	”
Checking of workpiece position				•			12	”
Drilling to finish 4 holes	•						320	”
Final Inspection of workpiece				•			12	”
Open the Leaf Jig to unload the workpiece	•						25	”
Cleaning of metal chips	•						10	”
Placing the workpiece in tray					•		10	”
Total	9	-	-	4	2		823	

Figure 6. Flow-process chart for drill jig with proximity sensor

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5. Conclusion

In the present study, a template jig is used to drill holes into the flanges for four clamping points. According to our research, this is the first attempt to use proximity sensors in a leaf jig to drill the aforementioned holes. To ensure accuracy, adaptability, and increased productivity by cutting down on inefficient time, four proximity sensors are installed in the leaf jig locator plate at non-drilling sections of the flange. By including proximity sensors in the design and analysis of a leaf jig for flange component, the component positioning may be promptly verified and rectified when compared to an existing design. The new design minimizes the number of operations from 18 to 15. Additionally, this innovative design reduces the cycle time from 963 to 823 seconds, saving 140 seconds for each cycle. The routine output rate improves by 17%. The leaf jig's design with sensors for the flange component makes it significantly safer and faster to operate. It is an excellent design for manufacturing comparable components in industry.

Acknowledgment

We would like to express our gratitude to Venkateshwara Engineerings, Nidamanuru, Vijayawada, for pr

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