A Preliminary Investigation of Interior Door Panel Assembly Improvement by Utilizing Fixture for B-segment Seven-seater Sport Utility Vehicle (SUV)

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Abstract

The major role of a fixture is to allow for exact repeatability and interchangeability of products within the same manufacturing process. This article looks at a different approach to making door trim and demonstrates the proper jigs for assembly. The fundamental objective is to optimize the passenger door assembly process through the decrease in cycle time. A fixture development process is made up of several stages: recording initial cycle time, talking with process stakeholders, and using a design tool to create the fixture virtually. The cycle time analysis method is used to calculate the effect on process performance, and then the data is compared to see how process performance differs. The fixture design has the additional benefit of reducing the total manufacturing time for the door inside trim assembly while also increasing the production line's overall efficiency. While this inquiry is in the beginning stages, further cycle time analysis is required to ensure the validity of the findings.

Keywords: Fixture, cycle time, SUV

1.0 Introduction

The door trim is a component that is installed within the automobile door panel which are usually made from Acrylonitrile Butadiene Styrene (ABS) or Polypropylene (PP) through injection moulding process (Shan, Chen & Huang, 2016). There are different functional aims for door trim, such as providing an attractive appeal to the interior and essential to the passenger's safety. Safety is an essential consideration in creating automotive products and components since it can reduce harm or death in the event of an accident. The creation of interior door trim begins with raw plastic pallets heated to a specified temperature before being injected into a mould under high pressure. Each plastic component is manufactured using an injection moulding machine. It should be noted that plastic parts are prone to flaws such as gas marks, flow markings, and flashing. Furthermore, to minimize downtime, the interior door trim manufacturing rate must be less than the time provided by the customer.

Jigs and fixtures are devices used to aid in manufacturing process for a comparable or identical work piece to reliably producing high quality products repeatedly (Kumar, 2018). A fixture is a tool or device used in the machining or assembly process to support and guide components while machined or assembled. The special-purpose jigs and fixtures is used to aid manufacturing operations, such as machining, assembling, and testing. Fixtures are an excellent addition to manufacturing plants due to their multiple benefits. They are one-of-a-kind guiding tools that are built explicitly for machining and fitting a large number of pieces. The advantages of employing jigs and fixtures in manufacturing parts and components include increased production rates, high product accuracy with no manufacturing defects, conversion modifications, complicated machining parts, and lower quality control expenses. The fixtures are mechanical devices that allow for rapid and precise machining with consistent quality, conversion, and lead time savings. Jigs and fixtures serve as passive devices that do not position, guide, or discover cutting tools, but they do so by modifying the machine. The fixture's principal function is to search, and in other cases, it is used to retain a piece of work during machining operations or other industrial procedures (Kaija & Heino, 2006).

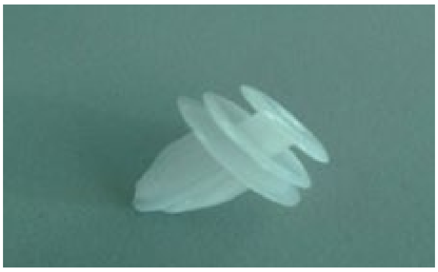

Figure 1: Plastic clip for door interior trim

Figure 2: Interior trim during clip installation process

2.0 Literature Review

In automotive manufacturing industry, fixtures are frequently mounted to a worktable and are designed to securely hold a component of the product and at the desired place during machining processes. Findings by Joshi (2010), discussed provisions in gear to adjust the tool concerning a piece of work fixtures, albeit this device is not directed as in jigs. While the fixtures are continually identified by the machine tool in which they are used, they have a wide range of applications for jigs and are also built for operations where the cutting instruments, such as drilling tools, cannot be directly driven. Boring, lathing, milling, and drilling fixtures are some of the many types of fixtures used in mechanical engineering.

A jig is critical equipment or equipment that aids and guides the object being machined or built during the machining or assembly process (Marzuki, Jaswadi, Mohamed, Musa, & Azmi, 2021). Jigs are specialized tools used to ease manufacturing processes like machining, assembly, and inspection (Rushikesh, Suyash, Prathmesh, Ravin & Patil, 2017). As described by Bem et al. (2008), a vital need of a fixture is outstanding positioning repeatability, system stiffness and multi-configuration especially for automotive component assembly. The design of jigs and fixtures is influenced by various factors that are developed and evaluated to get the best output. Jigs must be made from lightweight material to provide safe handling, as they must be moved independently to allow holes to be drilled from various angles. Jigs and fixtures are composed of numerous components to accomplish the objectives frames or bodies and foundations with clamping characteristics; accuracy and readiness of indexing systems or plates; level of automation support, capability, and variety of machine tools where jigs and fixtures will be used; roof and guide structures for jigs; availability of a device inside the machine (Okpala, 2015).

The fixture can be produced experimentally through trial and error or computationally through a computer-assisted design and development process. The latter is now being extensively investigated in the industry because of its cost-effectiveness and speed of development. Lee and Haynes (1987) pioneered using the Finite Element Method for generating and evaluating fixture designs. Additionally, Kashyap and DeVries (1999) used finite element modelling to determine the optimal clamping and supporting location for the component to guarantee minimum deformation occurred during fixture operation. Tanji, Raiker and Mathew (2017) conducted a study in which they used an integration of CAD and CAM method for designing a fixture configuration for a modular fixture component to satisfy the assembly condition. Not only is the finite element approach well-suited for fixture creation, but it can also be used to explore other engineering systems, as demonstrated by Marzuki et al., (2015), Marzuki et al., (2018) and Marzuki et al., (2017). Additionally, computational fluid dynamics, an advanced approach for simulating fluid flow, may be utilized to examine engineering systems, including fluid dynamics, as demonstrated by Azmi et al., (2017). Flow simulations may be done on the plastic injection process, as Idayu et al., (2020) demonstrated by utilizing a combination of CATIA V5 CAD software and Autodesk Moldflow Insight simulation to quantify volumetric shrinkage, in-cavity residual stress, and deflection.

Optimization is a way to find the optimum answer in a particular parameter setting, and it is a technique to locate an ideal way to do so. The optimization approach may ensure that the fixture design and layout will be adequate in a restricted production environment. The design of the fixture is executed using a nonlinear optimization approach that incorporates an examination. In the optimization process, there are several iterations, and this is mainly done by using mathematical algorithms to identify and improve upon the best fitting fixture design. In order to optimize the ball joint for vehicle steering system, a research was performed by Geren (2017) by utilizing a 3D CAD algorithm for parametric modelling iteration. Dong et al., (2012) analysed a self-adaptive population dimension differential evolution approach for optical glass manufacturing assembly optimization, a computation approach based on changing a population's dimensions using differential evolution. In recent years, computer and software technology has advanced to the point where enhancing processes is now a simple task, especially in the engineering profession. Research published concluded that a highly optimized automobile component can be created using computer-aided design (CAD) and CAE software which utilizes a parametric restriction imposed on the model.

In the preceding discussion, it was mentioned that jig and fixture are a tool that can be used in a mass-production setting and that the final result has a comparable characteristic or standard. A multi-fixture, however can be used in some cases. While adhering to the philosophy of just-in-time (JIT), automobile manufacturers or assemblers might apply an operational JIT concept to guarantee the parts and components are supplied to them while keeping the necessity for storing a large inventory for the component in check. As a result, the production time of the component needs to be on time with the assembly schedule as influenced by the assembler's need. There are two ways to quantify the time between individual steps on the production line; the first approach involves computing the cycle time. Through implementing fixture in the production line, cycle time is improved, and further, to guarantee the level of accuracy, a higher degree of automation is required (Daniyan et al., 2019)

This study aims to conduct a detailed investigation of the interior door assembly improvement by utilizing a jig for the B-segment seven-seater sport utility vehicle (SUV) at the door trim manufacturing line. Several improvements may be explored to help the firm resolve the problem that occurs at the door trim manufacturing line since this line is exclusively employing manual labour. Aside from satisfying customers' requirements, it may also assist the engineers in developing strategies and keeping the manufacturing process running without downtime difficulties. The equipment for this investigation only applies to B-Segment SUV door interior trim parts. This part is a mass-produced component which in turn is provided to the OEM Assembler by the manufacturer. Additionally, simply considering the plastic injection machine is utilized in the specific interior door trim manufacturing line is the whole amount of plastic used in the whole car manufacturing. In the images below, Figures 1 and 2 illustrate the sub-component and significant portion, which are plastic clip and back door trim, which are the focal points of this study.

3.0 Methodology

While production line balancing involves moving work throughout the whole production line to alleviate bottlenecks and surplus capacity, the work or burden can be divided across workstations just on a task-by-task basis to focus better the operation (Zupan & Herakovic, 2015). Helgeson and Birnie (1961) presented an assembly line balancing scheme. Production approaches that employ several different ways to regulate line balance, which change depending on components of the manufacturing process, have been widely employed and utilized for a long time (Battaia & Dolgui, 2013 and Becker & Scholl, 2006). In order to understand manufacturing throughput, it is necessary to understand how long each activity will take on the production line. The line balancing processes yield several difficult results because the distinct and varied requirements in the system force each process to follow its trajectory. Many variables, such as the rapidity of and uncertainty that occurs in each operation, interactions among employees, and the time involved in transferring data from one workstation to another, limit the possibility of efficient processing.

Table 1: Cycle time for door trim assembly process

Process	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Cycle time(s)
Machine Door Opens	5	5	5	5	5	5	5	5	5	5	5
Take Part from Machine	13	12	12	11	12	12	12	13	11	12	12
Place The Part on The Table	4	3	3	2	3	4	3	3	2	3	3
Machine Door Closes	5	5	5	5	5	5	5	5	5	5	5
Cut Off Runner Gate	3	3	2	3	4	3	3	2	4	3	3
Flaming	6	6	7	6	5	7	6	6	6	5	6
Install Clip	9	9	9	9	8	9	9	10	9	9	9
Place Part on The Rack	2	2	3	2	2	2	2	2	2	2	2
Cycle Time	47	45	46	43	44	47	45	46	44	44	45

In addition to line balancing, cycle time analysis is done to determine the amount of time it takes to go through each step in the production line. The cycle time is being taken while the workstation is used during the time it takes to complete door trim work. The amount of time that passes between processes may be measured when moving from one step of the door trim assembly to the final step. The time needed to collect the average data for both portions is ten times that of the cycle time. The amount of time taken of each proses recorded 10 times (T1 -T10) without fixture application is tabulated in Table 1.

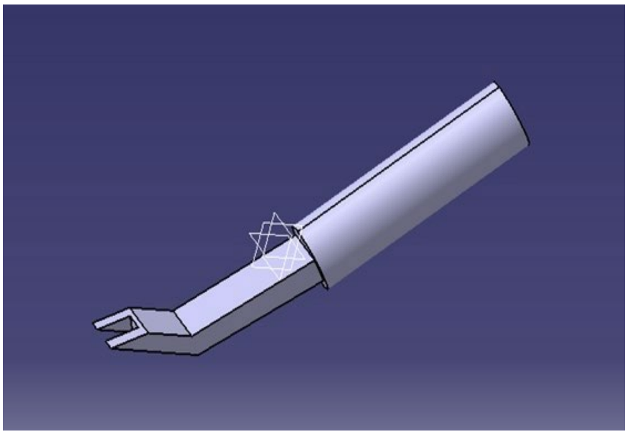

Figure 3: Design Concept 1

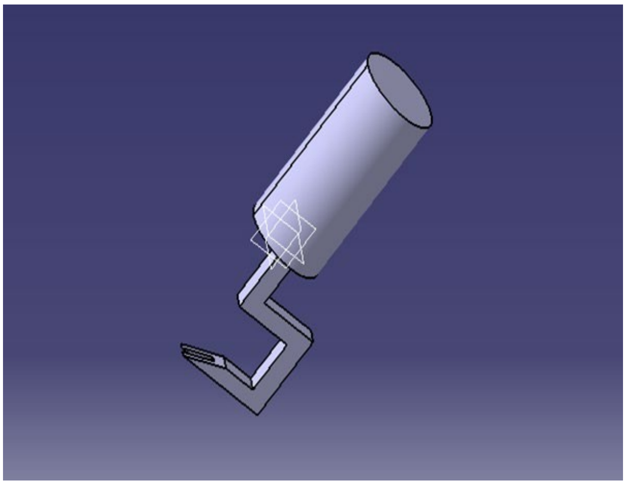

Figure 4: Design Concept 2

CATIA design software package is utilised because the geometric layout of composite components makes designing these parts more challenging, increasing the likelihood of mistakes in design accuracy. Two concepts are represented in Figure 3 and 4 designed by utilizing CATIA software, where Figure 3 depicts the image of the first concept while Figure 4 represents the design of the second concept. Once the jig is designed, it is necessary to measure the child part diameter to be able to accommodate the insertion into the main component through the slot and then proceed to assembly process. The successful design of a fixture begins with a logical and methodical approach. There are benefits and drawbacks to both the two types of these fixture used for the part assembly. A discussion is made of both advantages and disadvantages of the design and the decision to utilize the model with the production section. Apart from that, both design concepts are compared based on the specification as shown in Table 2. Finally, the design is selected based on its practicality when it comes to the jig design and utilization.

Table 2: The comparison of specification between design concept 1 and 2

Product	Design Concept 1	Design Concept 2
Height (cm)	20	20
Weight (g)	200	150
Material	Steel	Steel
Fabrication Time	3 hours	4 hours

4.0 Result and Discussion

The fixture is designed according to the shape and the size interior door panel mounting clip as illustrated in Figure 1 and 2. An automotive vehicle's plastic interior trim panel can be attached to the metal door frame-panel combination using a small plastic clip, as shown in Figure 1. The design of the clip can be modelled and investigated utilizing experimental and simulated methods. As shown in Figure 2, the plastic door trim is connected to the metal car body parts with bolts and several clips. Sixteen plastic clips connect the plastic door trim where the locations are marked with arrows in the figure. The clip is pushed through the hole on the plastic door trim, which keeps them firmly in place to ensure a secure assembly with the door panel. The initial production cycle time without the initiation of the fixture is illustrated on Figure 5.

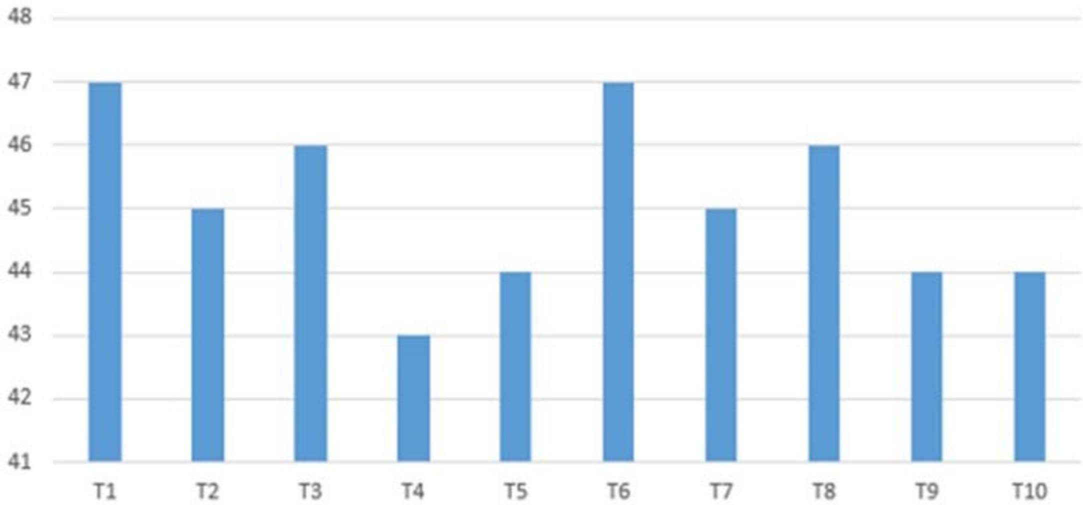

Figure 5: Cycle time analysis of initial assembly process without the utilisation of fixture

A problem manifested during the assembly of the plastic clip and the plastic door trim. The problem comprises increasing defect to interior trim process, leading to delay of transporting semi-finished interior panel assembly to the OEM manufacturer. As discussed in detail earlier in the article, a jig is developed to overcome the problem. The development of the jig is justified by the need for quick-fix and low-cost methods. Even though those factors simplify the development, the designing phase is somehow detailed, ensuring the jig can be applied and practical for the assembly process. An analysis of pre- and post-jig implementation by utilizing concept design 1 is performed at the assembly line to assess the effectiveness. The analysis is conducted by utilizing a cycle time study, which is explained in the methodology.

In order to conduct a process cycle time analysis, the sequential structure system is utilized to ensure the production line is following the standard procedure. The cycle time is recorded for pre- and post-utilization jig in the production line. To obtain relevant information on the amount of time it took to complete the part, a check sheet log is utilized. Figure 5 explains the amount of time it took for the mechanical production system for door trim to do the two exercises with and without fixture. Every process analysis exercise has its process time interval. Figure 6 illustrates the number of assembly units at the clip-to-panel assembly process. Utilizing a graph, the identification and analysis of pre- and post-fixture applications can be conducted.

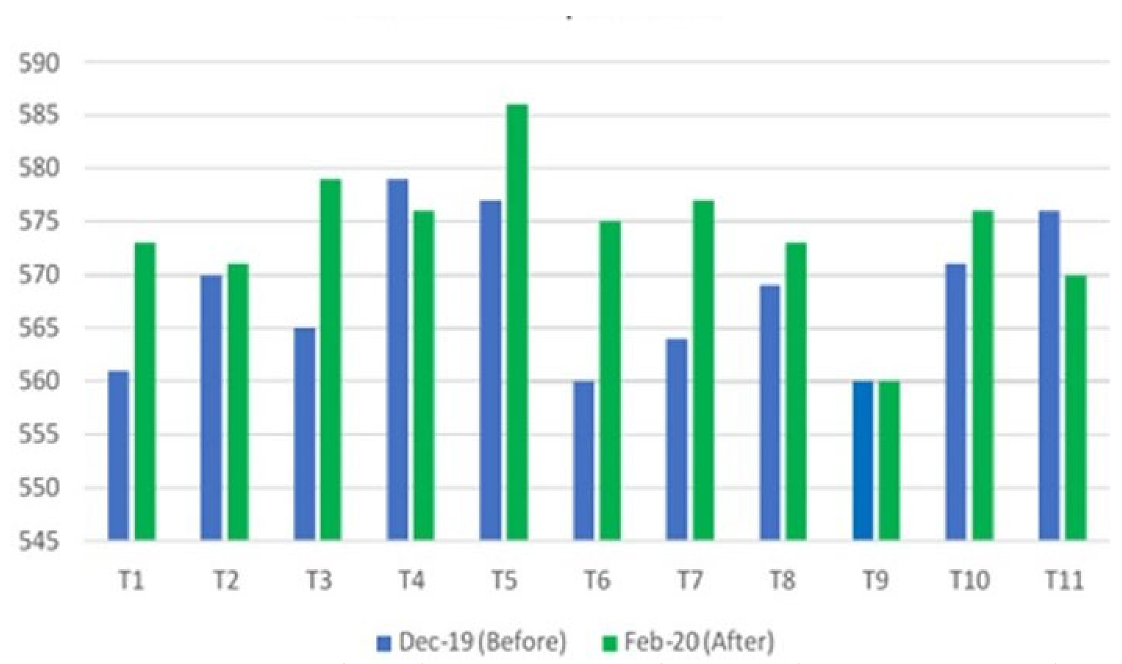

Figure 6: Comparison of production output for SUV door trim pre and post fixture application

The outcome from the analysis shows that, by utilising the developed fixture have produced a significant reduction of cycle time at the door trim assembly production line. The highest improvement can be seen on the T5, T6 and T7 reading, with an average of improvement between 2.1% to 2.8 %. Meanwhile, there are some undesirable results at the T4 and T11 data which recorded between -0.5% to -0.8% decline. On average, the cycle time improvement is recorded at 1.1% from the application of the fixture. It is suggested that the root cause of the issue is mainly due to lack of familiarisation and SOP to use the fixture at the production line. However, the arises issue related to the fixture could be eradicated by improving the SOP and conduct further training on the fixture application.

5.0 Conclusion

The application of the jig is the primary factor in reducing the cycle time and defect of the door interior panel and, as a result, reducing the total operating load on the production line. Furthermore, the operator will have more time to concentrate on producing quality process workflow. However, fixture development for the automotive industry is still primarily based on the fixture designer's experience and a trial-and-error technique. This would lead to excessive expenses, delays, and a lower-than-expected output.

The approach and method for identifying and solving the problem are outlined in the early section of the article, which also includes the fixture creation process. The success of the fixture design was aided by collaboration across critical departments, which included offering ideas and overseeing the production process. The fixture was developed using the CATIA V5 software package, demonstrating that the computational technique is used for a large portion of the design process. Compared to the traditional way, using a computational technique would result in a faster and less expensive solution.

The design's outcome is measured using the cycle time technique, which records the length of time it takes for a single unit component to travel through the manufacturing line, which is connected to the aim of this study. Compared to the previous method, the manufacturing line's cycle time and work process have been improved by employing the fixture at the clip-to-trim assembly process. Further research needs to be conducted by scoping a broader timeframe of the post-application of the jig. In addition, comparing different operators and working shifts might also provide some insight into reducing defect and cycle time for the SUV door interior trim assembly line.

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