# REDUCTION OF PROCESS CYCLE TIME THROUGH THE INNOVATION OF MANUAL OR SEMI-AUTO JIGS & FIXTURES: D.I.A.D.O.I. BASED APPROACH

**Leonardo Z. Sarmiento**
**Carla D. Aday**
ATS-Engineering, Automation Technology Solutions
P. IMES Corp.
Block 16, Phase IV, Cavite Economic Zone
Rosario, Cavite Philippines, Tel.# +63 46437-2401
lsamiento@pimes.com.ph , caday@pimes.com.ph

## ABSTRACT

In this technical paper, we introduce a concept for reducing the process cycle time through the innovation of manual or semi-automatic jigs and fixtures. Our approach, known as D.I.A.D.O.I (Define, Immersion, Analyze, Design, Operate, Improve), provides a clear and systematic guide for creating innovative jigs and fixtures.

The D.I.A.D.O.I method is a new approach to reducing cycle time in manufacturing and automation industries. This technical paper provides tips, ideas, and techniques for decreasing process cycle time.

Thanks to the implementation of the D.I.A.D.O.I approach and the innovation of jigs and fixtures, we were able to significantly reduce our process cycle time. Specifically, we were able to reduce the time from 2223 seconds to 456 seconds, which represents a 79.48% decrease. Furthermore, we were able to transition some of our manual processes to semi-automatic, which helped to further optimize our production.

## 1.0 INTRODUCTION

The production workstation # 1 assembling the Pick-body and one of the processes of it was the Exercising Spline Nuts. The problem comes from the process in Pick Body Assembly when the technicians conduct manually exercise the 24 pcs of spline nuts through their hands one by one to meet a free fall requirement. See Figure 1.0.

Introducing new methods and ideas for creating Manual or Semi-Auto Jigs & Fixtures through **D.I.A.D.O.I** approach will reduce the process cycle time. Meanwhile, many are still confused about terms such as Jigs & Fixtures and the cycle time, the cycle time for single-piece flow items, and the process time.

Figure 1.0 Current Process-Manual Exercising of Spline Nuts using hands to meet free-fall requirement.

The following will explain the difference between these time metrics, the formulas behind them, how to calculate each, and how they can improve production—furthermore, the difference between Jigs & Fixtures and their advantages.

### *1.1 Cycle Time Reduction*

Reducing cycle time (CT) involves using efficient and effective techniques to systematically complete tasks. This process means getting rid of non-value-added activities.

Improving cycle time leads to smoother delivery, better efficiency, faster learning, and ultimately a better product. It's a crucial element of process improvement that can significantly enhance all aspects of process execution.

#### *1.1.1 What is a Cycle Time*

Cycle time is the amount of time required to produce one part, finish one product or complete one standard process. This calculable measurement conveys the fastest repeatable time in which an operator performs all steps of a standardized work process before they start over again.

The mathematical formula behind cycle time is not difficult to understand. Subtract the time the first task was started from the time at the end of the last task.

**Cycle Time for single piece flow item**
**= Finish Time – Start Time**

*Example: If the first step of assembling the PNP Head Matrix Assembly starts at 8:30 a.m. and the completed PNP Head Matrix Assembly is packed and ready to ship at 5:30 p.m. the total cycle time for producing the PNP Head Matrix is nine (9) hours.*

Cycle time can also be used for specific portions of the total process, having one cycle time for assembly, a separate cycle time for test, and a final one for packaging. If dealing with batches of items, instead of one piece flow, simply take the total parts produced and divide that quantity by the production run time to determine the cycle time per part.

**Cycle Time =**
**(Finish Time – Start Time) / Units Produced**

*Example: Let's say the PNP Matrix has a sub-assembly process, a Spline Assembly Exercising by an automatic jig that exercises eight (8) splines at a time in a wave movement. Afterward, the Spline Assembly is placed in the next workstation for the integration process.*

*From the beginning of the Spline Assembly Exercising to the completion of the exercise in the workstation takes 420 seconds, but the cycle time is not 420 seconds since multiple products were worked simultaneously. Divide the total parts produced, eight, into the production run time, 420, to arrive at an actual cycle time of 52.5 seconds per part.*

Another misunderstanding can come from using cycle time and process time interchangeably. Cycle time is sometimes used to describe how long it would take for equipment to complete a movement or process. The process time is the time a workpiece takes to enter and exit a workstation.

**Process Time =**
**(Exit Time in Workstation – Enter Time on Workstation)**

## *1.2 Jig & Fixture*

**Jigs and fixtures** are the devices that help in increasing the rate of identical parts and reducing the human efforts required for producing parts. This work holding and tool-guiding devices are designed for use in the machining and assembly of parts. To get the greatest benefit from jigs and fixtures, a basic understanding of their construction is necessary.

### *1.2.1 What is a jig?*

A device used to maintain mechanically the correct positional relationship between a piece of work and the tool or between parts of work during the assembly.

### *1.2.2 What is a fixture?*

A fixture is a device that holds and locates a workpiece during an inspection, assembly, or any manufacturing operation.

### *1.2.3 Difference between Jig & Fixtures (Example)*

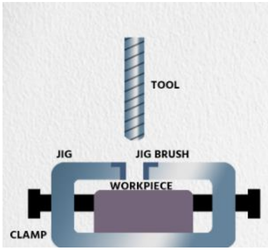



Figure 2.0 Example of a Jig that guiding a cutting tool.

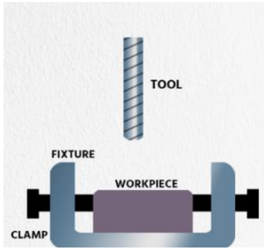



Figure 3.0 Example of fixture holding the workpiece.

| JIGS | FIXTURES |
|---|---|
| A jig controls and guides the machining tool | A fixture holds and supports the component precisely for machining operations |
| Jig ensures accuracy, repeatability, and interchangeability | The fixture provides a reduction in error by holding a component firmly on a table |
| Jigs are usually on the lighter side | The fixture is bulky, rigid, and heavy |
| Jigs can be put in place and held by hand pressure | Fixtures are always placed firmly on a machine table |
| Some of the standard jig functions are drilling, reaming, tapping, and boring | Fixtures are used explicitly in milling machines, slotting machines, and shapers |
| Jigs cost more | Fixtures are not that cost-savvy compared to Jigs |
| Jigs require intricate design operations | Fixture design operations are relatively less complicated |

Table 1.0 Jigs & Fixtures Differences

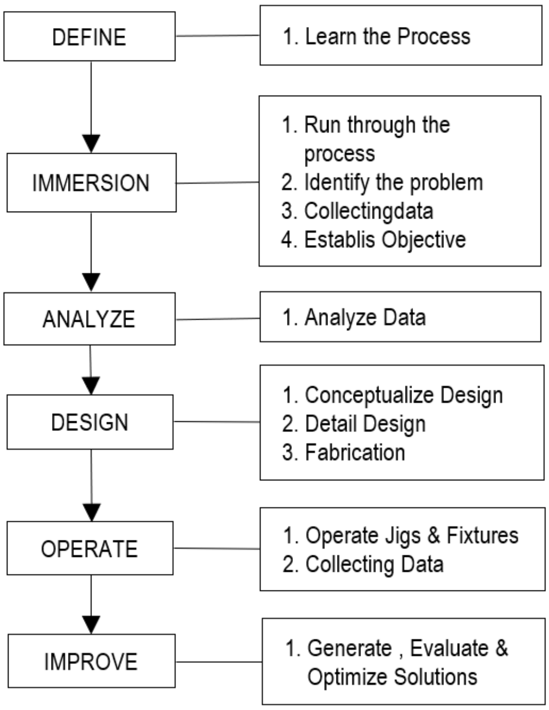
### *1.2.4 Advantages of Using Jigs and Fixtures*

- Better Productivity and Efficiency.
- Decreases Manufacturing Costs.
- Improvement in the Quality of the Product.
- Easy to Manufacture Complex and Heavy Tools
- Improves Safety

## 2.0 METHODOLOGY

In this chapter, the method that has been used will be discussed in the D.I.A.D.O.I. framework as shown in Flow Chart 1.0. We will apply this approach to the Pick Body sub-assembly where the 24 pcs. of Spline Nut is exercised manually.

This flow chart provides a step-by-step guide on how to use the new technique and understand its detailed process. It is designed to help everyone gain knowledge and guidelines on how it works.



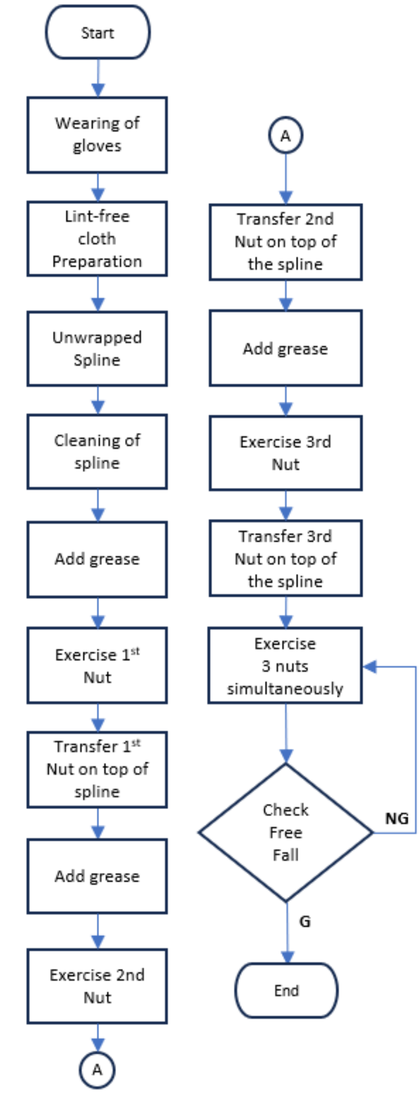

*Flow chart 1.0- D.I.A.D.O.I step-by-step method*

### 2.1 Define

You might not even have identified what problem to work on. During this phase, we select the impactful opportunities for improvement. This phase is also about mapping the process, focus, scope, and goal and understanding how the problem affects all process owners.

### 2.1.1 Step: Learn the Process

To be able to know the process, provide a visual representation of the sequence's steps-by-steps and decisions needed to perform the process, this visual representation is what we call Process Flow Chart.




*Flow chart 2.0 – Process of Manual exercising of spline nuts*

Figures below are the Manual Exercising of Spline

Figure 4.0 Cleaning or removing of manufacturing grease.

Figure 5.0 Adding of grease.

Figure 6.0 Manual Exercising of spline nuts

Figure 7.0 Free fall checking of spilne

## 2.2 Immersion

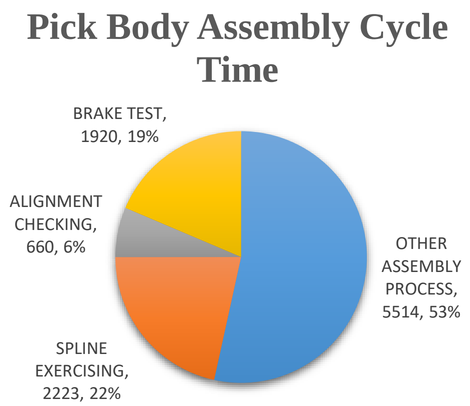
This is the phase of getting close to the problem, researching it, and contextualizing it. The team seeks to dive into the implications of the challenge, studying it from both the process requirement and process owner's perspective and most importantly having full involvement in the process.

Figure 8.0 Run through the process of spline nuts exercising.

In the Immersion stage, you are given the opportunity to directly experience the process to gain a more comprehensive understanding.

### 2.2.1 Collect data.

Collecting data is the process of obtaining or gathering and measuring current data that are related to the target variables. This is to ensure the accuracy of the data and analysis of results. Data collection is an important stage in any type of research study. Inaccurate data collection can give impact the results of a study and ultimately lead to invalid results.




Pie Chart 1.0 Assembly cycle time per process of pick-body total of 10317 secs.

Below is Table 2.0 for the manual exercising of the spline nut current process cycle time.

| Exercising process of Spline Nut Cycle time ( in seconds) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | Process | SPL1 | SPL2 | SPL3 | SPL4 | SPL5 | SPL6 | SPL7 | SPL8 |
| 1 | wearing of gloves | 35 | N/A | N/A | N/A | 35 | N/A | N/A | N/A |
| 2 | Lint-free cloth preparation | 14 | 9 | 9 | 8 | 9 | 9 | 8 | 8 |
| 3 | unwrapped spline | 12 | 11 | 9 | 12 | 11 | 10 | 12 | 13 |
| 4 | remove factory grease using tissue | 40 | 43 | 41 | 45 | 41 | 42 | 40 | 46 |
| 5 | add new grease | 6 | 5 | 6 | 4 | 4 | 4 | 5 | 4 |
| 6 | exercise 1st nut | 36 | 36 | 37 | 37 | 38 | 39 | 36 | 37 |
| 7 | transfer 1st nut on top | 4 | 3 | 3 | 4 | 4 | 3 | 3 | 4 |
| 8 | add new grease | 6 | 6 | 4 | 5 | 5 | 5 | 4 | 5 |
| 9 | exercise 2nd nut | 36 | 37 | 37 | 37 | 36 | 39 | 36 | 37 |
| 10 | transfer 2nd nut on top | 4 | 5 | 5 | 4 | 6 | 4 | 5 | 4 |
| 11 | add new grease | 6 | 5 | 4 | 6 | 4 | 6 | 5 | 5 |
| 12 | exercise 3rd nut | 37 | 37 | 36 | 39 | 36 | 39 | 36 | 37 |
| 13 | transfer 3rd nut on top | 5 | 6 | 5 | 4 | 5 | 4 | 6 | 4 |
| 14 | exercise 3 nuts simultaneously | 54 | 53 | 55 | 55 | 53 | 55 | 54 | 54 |
| 15 | free fall verification | 13 | 12 | 15 | 13 | 16 | 12 | 12 | 14 |

Table 2.0 Exercising of Spline Cycle Time

### 2.1.3 Identify the problem.

The problem during the exercise of the spline part are:

1. Exercising 24 pcs. spline one by one uses more time with 2223 secs. And process in 15 steps.
2. Spline nuts do not smoothly fall.
3. Exercise of spline uses more Lint-free Cloth with 18 to 20 pcs. and grease with 1.10 ml per assembly.

### 2.1.4 Establish Objective

1. Reduce the cycle time of exercising the spline.

2. Eliminate the multiple handling of the spline during the exercise.

3. Eliminate the repetitive process of spline exercising.

4. Eliminate the repetition spline exercising due to failure of the free fall requirement.

## 2.3 Analyze

An effective analysis can be valuable for making informed decisions based on data and research.

In this phase, your goal is to identify the underlying causes of problems to ensure that improvement occurs from deep down where the problems stem from.

| Exercising process of Spline Nut Cycle time ( in seconds) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Process | SPL1 | SPL2 | SPL3 | SPL4 | SPL5 | SPL6 | SPL7 | SPL8 | Process CT |
| 1 | wearing of gloves | 35 | N/A | N/A | N/A | 35 | N/A | N/A | N/A | 70 |
| 2 | Lint-free cloth preparation | 14 | 9 | 9 | 8 | 9 | 9 | 8 | 8 | 74 |
| 3 | unwrapped spline | 12 | 11 | 9 | 12 | 11 | 10 | 12 | 13 | 90 |
| 4 | remove factory grease using tissue | 40 | 43 | 41 | 45 | 41 | 42 | 40 | 46 | 338 |
| 5 | add new grease | 6 | 5 | 6 | 4 | 4 | 4 | 5 | 4 | 38 |
| 6 | exercise 1st nut | 36 | 36 | 37 | 37 | 38 | 39 | 36 | 37 | 296 |
| 7 | transfer 1st nut on top | 4 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 28 |
| 8 | add new grease | 6 | 6 | 4 | 5 | 5 | 5 | 4 | 5 | 40 |
| 9 | exercise 2nd nut | 36 | 37 | 37 | 37 | 36 | 39 | 36 | 37 | 295 |
| 10 | transfer 2nd nut on top | 4 | 5 | 5 | 4 | 6 | 4 | 5 | 4 | 37 |
| 11 | add new grease | 6 | 5 | 4 | 6 | 4 | 6 | 5 | 5 | 41 |
| 12 | exercise 3rd nut | 37 | 37 | 36 | 39 | 36 | 39 | 36 | 37 | 297 |
| 13 | transfer 3rd nut on top | 5 | 6 | 5 | 4 | 5 | 4 | 6 | 4 | 39 |
| 14 | exercise 3 nuts simultaneously | 54 | 53 | 55 | 55 | 53 | 55 | 54 | 54 | 433 |
| 15 | free fall verification | 13 | 12 | 15 | 13 | 16 | 12 | 12 | 14 | 107 |
| Cycle time per spline | | 308 | 268 | 266 | 273 | 303 | 271 | 262 | 272 | 2223 |

Table 3.0 Exercising of Spline Cycle Time

### 2.3.1 Analysis:

1. Exercising spline uses more time to process which has a 2220 secs process cycle time and it is 21.9% of the total process time per sub-assembly of Pick Body.

2. Exercising of spline uses more grease and Lint-free cloth to meet the free fall requirement.

## 2.4 Design

### 2.4.1 Conceptualize design

We analyzed the data to create a design plan with the goal of ensuring worker comfort during the procedure. We considered several factors, including the fixed design. To eliminate the need for software tool design before the detailed process, we created a hand-drawn concept design as shown below.

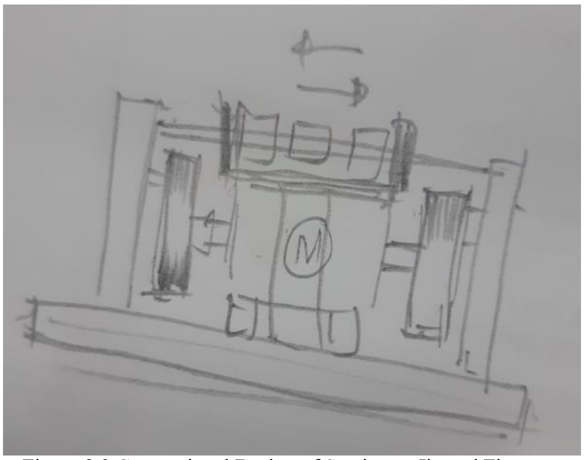


Figure 9.0 Conceptional Design of Semi-auto Jig and Fixture spline exercising.

### 2.4.2 Detail design

Through an immersion and data analysis process, the research team was able to develop a design that fulfills the criteria for a JIG device that can help assembly technicians with their daily tasks. The design was further improved through the use of drawing software, which allowed for easy editing and tracing of any potential issues in detail. Safety, durability, and cost-effectiveness were top priorities when conceptualizing this JIG device. Figure 9 displays the plans, drawings, and algorithms that describe the implementation of this design.

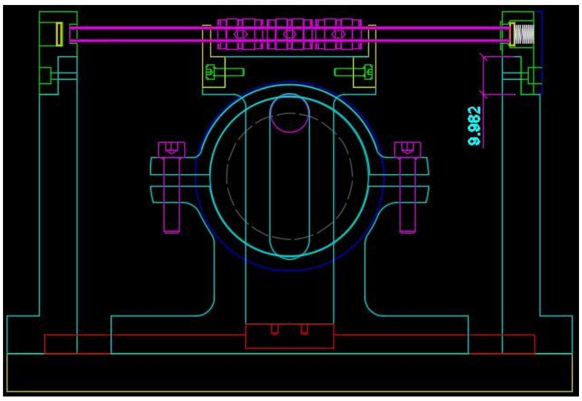



Figure 10.0 Detail Design of Semi-auto jig and fixture of spline exercising.

Designing a jig and fixture. Below is a highlight of the common things you must know:

- Design a jig or fixture that doesn't need human assistance to hold a part during secondary operations.
- Consider how the jig or fixture will fit into the overall production workflow.
- Know the type and capacity of the machine.
- Know the loading and unloading arrangement.
- Get to know the clamping arrangement.
- Study the power devices and safety arrangement devices.
- Know the clearance between the jig or fixtures and their components.
- Study of ejecting devices, table fixing arrangement, and indexing devices.
- Think of manufacturability.
- Think of a long-term expandability

### 2.4.3 Fabrication

Jigs and fixtures can be built using metal or plastic materials, but plastic tends to be more affordable and can often meet all performance requirements.
3D printing jigs and fixtures enable product teams to increase design complexity without increasing part cost, so it will behoove designers to take advantage of this principle during the design phase. Consider what additional functionalities can be built to improve the performance of the part.

The steps prior to fabrication are as follows:
i. Technical drawing
ii. Order material
iii. Marking
iv. 3d print

*Figure 10.0 3D printing machine with sample part processing.*

### 2.5 Operate

A prototype is a simple visualization of the product to test the concept. The operation can indicate the usability of the product in the process.
Establish step-by-step operations to provide guidelines on how to operate the machine.

1. Plug the machine into a power source.
2. Check the parameter of the machine.
3. Place the spline into the holder.
4. Add new grease to the spline shaft.
5. Switch on the machine. Wait for the exercise process to finish.
6. Remove the spline from the machine for the next process.

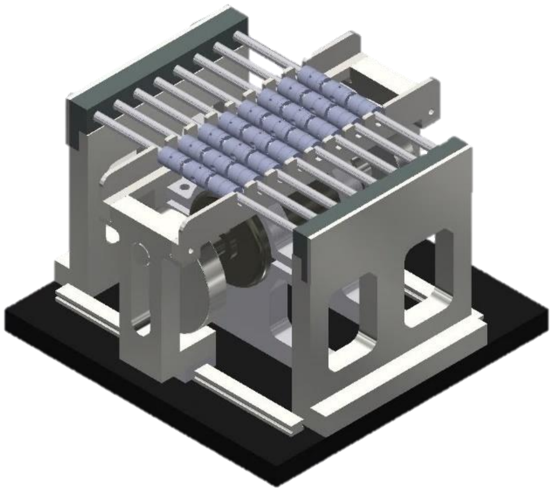


Figure 11.0 Semi-Auto Exercise Jig and Fixture

As a result, the process of exercising the spline was developed from a manual to a semi-auto process.

### 2.1.6 Improve

After completing the analysis phase, you will have a better understanding of the process and what changes need to be made to improve it. In the improvement phase, you will implement the necessary improvements to enhance the entire process. Additionally, you can use the Kaizen approach, which means 'continuous improvement' in Japanese.

A Kaizen event involves a team who gathers at the work site and makes small changes to the process, which are immediately validated for their effectiveness. These gradual improvements are why it's called a continuous improvement event.

## 3.0 RESULT AND DISCUSSION

### *3.1 Process Steps Reduction*

Process steps have been reduced to 8 steps from 15 steps.

***Before***

| Exercising process of Spline Nut Cycle time ( in seconds) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Process | SPL1 | SPL2 | SPL3 | SPL4 | SPL5 | SPL6 | SPL7 | SPL8 | Process CT |
| 1 | wearing of gloves | 35 | N/A | N/A | N/A | 35 | N/A | N/A | N/A | 70 |
| 2 | Lint-free cloth preparation | 14 | 9 | 9 | 8 | 9 | 9 | 8 | 8 | 74 |
| 3 | unwrapped spline | 12 | 11 | 9 | 12 | 11 | 10 | 12 | 13 | 90 |
| 4 | remove factory grease using tissue | 40 | 43 | 41 | 45 | 41 | 42 | 40 | 46 | 338 |
| 5 | add new grease | 6 | 5 | 6 | 4 | 4 | 4 | 5 | 4 | 38 |
| 6 | exercise 1st nut | 36 | 36 | 37 | 37 | 38 | 39 | 36 | 37 | 296 |
| 7 | transfer 1st nut on top | 4 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 28 |
| 8 | add new grease | 6 | 6 | 4 | 5 | 5 | 5 | 4 | 5 | 40 |
| 9 | exercise 2nd nut | 36 | 37 | 37 | 37 | 36 | 39 | 36 | 37 | 295 |
| 10 | transfer 2nd nut on top | 4 | 5 | 5 | 4 | 6 | 4 | 5 | 4 | 37 |
| 11 | add new grease | 6 | 5 | 4 | 6 | 4 | 6 | 5 | 5 | 41 |
| 12 | exercise 3rd nut | 37 | 37 | 36 | 39 | 36 | 39 | 36 | 37 | 297 |
| 13 | transfer 3rd nut on top | 5 | 6 | 5 | 4 | 5 | 4 | 6 | 4 | 39 |
| 14 | exercise 3 nuts simultaneously | 54 | 53 | 55 | 55 | 53 | 55 | 54 | 54 | 433 |
| 15 | free fall verification | 13 | 12 | 15 | 13 | 16 | 12 | 12 | 14 | 107 |
| Cycle time per spline | | 308 | 268 | 266 | 273 | 303 | 271 | 262 | 272 | 2223 |

Table 3.0 Manual Exercising of Spline Cycle Time using hands.

***After***

| Exercising process of spline cycle time ( in seconds) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Process | SPL1 | SPL2 | SPL3 | SPL4 | SPL5 | SPL6 | SPL7 | SPL8 | Process CT |
| 1 | wearing of gloves | 28 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 28 |
| 2 | Lint-free cloth preparation | 9 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 9 |
| 3 | unwrapped spline | 10 | 5 | 5 | 6 | 5 | 5 | 5 | 6 | 47 |
| 4 | remove factory grease using tissue | 38 | 32 | 30 | 30 | 31 | 29 | 29 | 30 | 249 |
| 5 | install in spline | 4 | 2 | 3 | 3 | 3 | 4 | 2 | 3 | 24 |
| 6 | add new grease | 6 | 5 | 7 | 6 | 8 | 5 | 6 | 7 | 50 |
| 7 | switch on and exercising process | 23 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 23 |
| 8 | uninstall in exercise jig | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 26 |
| Cycle time per spline | | 121 | 48 | 48 | 48 | 50 | 47 | 45 | 49 | 456 |

Table 4.0 Semi-Auto Exercising of Spline Cycle Time using semi-auto jig &fixture.

### *3.2 Process Improvement*

Manual Exercise of Spline Nut 1, Nut 2, and Nut 3 to Semi-Auto Exercising through Spline Semi-Auto Exercising Jig and Fixture.

*Before*

Figure 12.0 Manual exercising of Spline Nuts

*After*

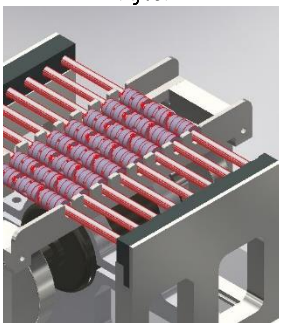
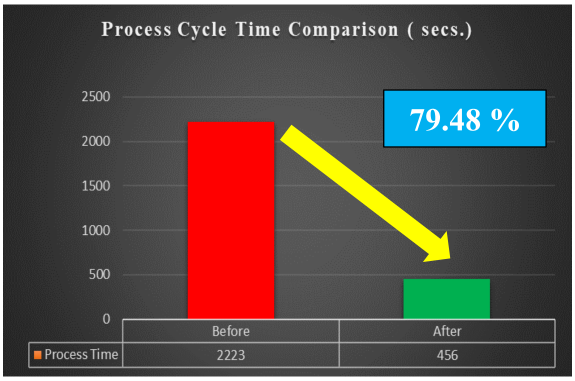


*Figure 13.0 Semi-Automated exercising of spline nuts*

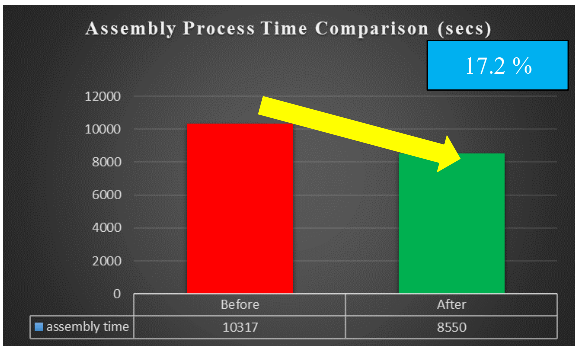
### *3.3 Process Cycle Time Improvement*

Process Time comparison – before and after it shows 79.48% or from 2223 secs. To 456 secs. reduction in process cycle time by using the semi-auto jig.




Line chart 1.0 Process Cycle time comparison

Assembly process comparison – before and after it shows that 17.53% or from 10317 secs. to 8550 secs. reduction in assembly cycle time by using the semi-auto jig.




Line chart 2.0 Assembly process time comparison

## 4.0 CONCLUSION

The use of the semi-auto Exercising Jig and Fixture successfully reduced cycle time by 79.48%. This was achieved by eliminating the need for simultaneous exercising of 24 pcs. of spline nuts during the sub-assembly process, which had previously required a technician to exercise each nut individually.

By solving the Process Cycle time problem, productivity was increased, and the success of the project was demonstrated. The semi-auto-jig and fixtures were designed to assist technicians in improving processes and cycle time while providing support in the workplace.

## 5.0 RECOMMENDATION

Increasing productivity, efficiency, and work quality for technicians can be achieved by reducing process cycle time through the elimination of repetitive processes and combining them. Another way to improve the process is to transition from manual to semi-automatic methods. To further enhance the process, it's recommended to innovate Jigs and Fixtures using the D.I.A.D.O.I approach.

Having technical drawing skills, such as ACAD or any 3D software, would be advantageous in implementing this approach.

## 6.0 ACKNOWLEDGEMENT

The author would like to express his sincere appreciation to **Mr. Danilo David** and Mr. **Jermie De Mesa** for their guidance and advice in the improvement of this project.

To my Co-Author Carla Aday for extending her support in collecting data, and simulating the process needed. To the ATS-Engineering Team for the combined effort and support.

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## 7.0 ABOUT THE AUTHOR

### AUTHOR

LEONARDO ZAPANTA SARMIENTO is a graduate of Associate in Micro-Computer Technology from Philippine Science and Technology. He has been working at P. IMES Corp., under ATS-Engineering. Leo came from Alpha Techno Precision Tooling's Inc. where has experience being a Process Engineer before becoming part of the ATS-Engineering Team.

### CO-AUTHOR

CARLA DE ROXAS ADAY is a graduate of Bachelor of Science in Industrial Engineering from First Asia Institute of Technology and Humanities. She is currently working as Process Engineer at P. IMES Corp. She has been working in the company for more than a year.