



DESIGN AND FABRICATION OF INTERFERENCE PRESS-FIT NUT

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ABSTRACT

Permanent joint such as blind rivet is most widely available and commonly used as auxiliary fastening elements. However, this assembly is permanent joint and need to avoid in design for disassembly. The objective of this research is to design and fabricate Interference Press-Fit Nut named INPRENUT. This novel product used as auxiliary fastener in mechanical assembly and it is able to disassemble for recyclability and reusability. Furthermore, INPRENUT has designed and manufactured to fulfill the needs such as; reduce setup time to pre-assemble, safety due to reduce the number sharp tools used, light-weight, and improve part assembly accuracy. In this study, preferred interference fit based on hole basis system was used to mating INPRENUT with aluminum hollow. Finite element Analysis (FEA) was used to analyse the frictional stress and maximum deformation parameter for selected dimensional fit tolerance. The results show that frictional pressure to push-in INPRENUT into aluminum hollow tube is about 435Mpa whereas to pull-out frictional force is 388MPa. Maximum deformation shows small deformation of 0.4µm occurred due to small interference of shaft and hole. Finally, the INPRENUT was fabricated, tested and assembled to an aluminum hollow tube and modular aluminum profiles. The result shows the INPRENUT was able to improve pre-assembly, safety and disassembly quality.

Keywords: mechanical joint, interference press-fit nut (INPRENUT), mechanical CAD, finite element analysis.

INTRODUCTION

In Higher Technical Vocational Education Training (HTVET), graduates need to have technical competency in course specialization to compete globally (UniKL, 2014). To achieve competency in practical skills, the students need to have opportunity to learn and practice their skills on equipments, machine and tools (Junaidah *et al.*, 2006). During this process, the student's project is seen as a platform for them to apply the knowledge and skills learned. It requires them to develop skills and abilities such as engineering problem solving, creative reasoning, innovation, inventive design, team work, multidisciplinary work, and self-learning and computer software (Rivera-Solorio *et al.*, 2014). However, the student's project involve with designing, producing and test a prototype or product suffers time-consuming, cost, require new learning environments and different specialized faculty competence (Malmqvist *et al.*, 2004).

Method that allow for easy assembly and disassembly was found as the best method to be applied in student's design and build mechanical construction model or project (Brink *et al.*, 2010). This is because the students are constrained with the time allocated and also need to work with the equipment and tools that will reduce the risk to harm them. The model/project need to be disassemble afterwards due to storage constraint's and some parts is needs to be recycled and used by the next group of students. This situation reflect on the importance of disassembly that become as a premise in product recycling and also established important link of product remanufacturing (Tian *et al.*, 2012). Recycling, reuse and reduction (3R) of waste consider product disassembly

pattern and modularity as a strategy to enhance 3R-abilities (Huang *et al.*, 2012). In the other view, generalization of problem in model robot construction or any mechanical construction mainly concern on assembly of the parts. Groover (2002) defined mechanical assembly use of various fastenings to mechanically attach two or more parts together by using discrete hardware components called fasteners.

One example of successful fastener innovation is pin fixture. It is used in automotive industry to obtain accuracy in "positioning" applications. The application offers several benefits such as reduced tooling cost, reduced down time and set-up time, reduced maintenance cost and stable tolerance achieved using pins result in much lower rates of defective product (FRIATEC, 2010).

Figure-1 shows an example of project developed by students for a robotic project initiated by this research. It shows the mobile robot platform construction that requires massive cutting using hack saw produced sharp edges and it requires machine tool operation at workshop. The assembly in Figure-1 uses permanent joint such as rivet. This will cause problem if there are modifications required to meet the functionality of the robot, to disassemble the robot for transportation and during disposal. In safety aspect, Health and Safety Executive (1992) mentioned injuries resulting from the manual handling of objects and materials with sharp edges as in Figure-1 (a) is reported in many cases in engineering industry. From this view, the specification of the fastener, despite being such as a small component is important to reduce the time of parts fabrication, pre-assembly and disassembly.

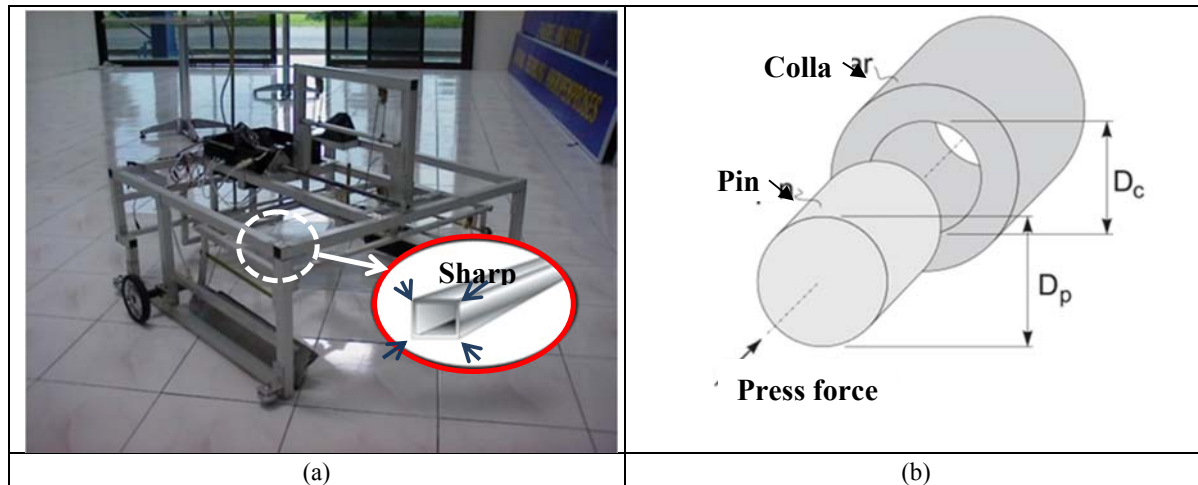


Figure-1. (a) Example of robot developed and (b) Pin and collar press fit.

The parts need to be assemble with the other components and common method employed is by having permanent joint such as rivet. Riveting requires drilling hole and the rivet. Rivet joint is not easy to disassemble and requires re-drilling the rivet to disassemble it.

Over the recent years, interference-fit joint technology methods have become important because its has been applied in a lot of engineering areas application such as collar, gear-shaft, bearing-shaft, wheel-axle, brake disc-axle and bolt-hole (Wang and Lee, (2014); Marinov (2009); Stamenkovic *et al.*, (2001)). Figure-1 (b) shows a pin of a diameter; D_p is pressed into a hole of a slightly smaller collar diameter, D_c . These tight joints give rigid contact to carry static as well as dynamic loads (Sogalad *et al.*, 2012). In view of Cao and Qin (2011), interference-fit assembly selection gives long service life, high reliability and low maintenance cost of the aerospace joint structure. The objective of this paper is to introduce and describe the design, analysis and fabrication and to present a few possible assembly approach of novel mechanical fastener named Interference Press Fit Nut (INPRENUT). An innovative approach in improving mechanical fitting will be able to reduce the unnecessary process, increase safety aspect, allow students to modify the dimension of parts, relatively easy to assemble and disassemble, increase accuracy, reduce weight and reuse the parts.

METHODOLOGY

The morphology of engineering design framework is based on the concept proposed by Lal, Gupta and Reddy (2005) consists of major process such as; preliminary need statement, generation of design ideas, design development, detailed design and implementation and testing. Affinity diagram is a helpful visual technique tool to organize scattered information into meaningful categories by findings relationships between ideas (Ratcliffe, 2013). The Voice of Customer (VoC) obtained

from observation, interview and paper review was then divided into two categories: the product features that need to be improved and also that need to be reduced.

From the Affinity Diagram developed shown in Figure-2, the features that need to be improved in the product design are modularity (Huang *et al.* (2012)), the use of light-weight materials (Wedel *et al.* (2007), reuse the part (Li *et al.* (2010)), manual handling of parts (Boothroyd *et al.*, (2002)), customer involvement in final assembly (CIFA) (Ho and Huang, 2009) and mating part accuracy. Whereas, the features need to be reduced such as reduce sharp object hazard (Kibbe *et al.* (2009), reduce complexity of parts to disassemble (Tian *et al.* (2012); Huang *et al.* (2012), minimum handling time (Boothroyd, 2002), reduce complexity of parts to pre-assemble (Messler, 2004), easy to store and reasonable cost.

The House of Quality (HOQ) was used to translate the voice of customer into product planning and also product design as shown in Table-1. Table-1 shows the charts 'Needs and Requirements' and Technical Response'. The correlation coefficients proposed by Mitsufuri and Uchida (1990) between required quality and quality elements are used as follow:

- 9 is for strong correlation,
- 3 is for moderate correlation and
- 1 is for weak correlation.

From Table-1, joining method selection with 24.3% importance and tolerance of parts with 14.1% importance for assembly or disassembly of parts are major requirements that need to be considered. This requirements are the two highest rank more than 10% importance after multiplying the degree of correlation by the rank order of the quality demand and summing the results characteristic-wise.



Finally, decision selection matrices proposed by (Pugh, 1996) was used to evaluate the proposed INPRENUT conceptual design compare with the other assembly techniques. Design process requires translating

the requirements or needs into the technical specification before any details design involved. A few conceptual designs were brainstormed and reviewed.



Figure-2. Affinity diagram developed to meet the needs.

Table-1. Design requirements translate into quality characteristics (House of Quality).






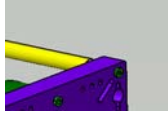
Customer Requirements (WHAT)	Design Requirements (HOW)	Importance (1-5)	Materials	Joining Method	Tolerance	Geometry	Part Size	Number of part	Thickness	Chamfer Part	Cutting tool used	Modularity
		IMPROVE	Light-weight issues	3	9							
Reuse the parts	4		3	9								
Mating parts accuracy	4				9	3			3	1	3	3
Customer Involvement in Final Assembly (CIFA)	3			9			3					3
Manual handling of parts	5			3							3	3
Flexibility in assembly	4										3	9
REDUCE	Sharp object hazard	4				3	3		3	9	3	1
	Complexity for assembly	4		9	9	3	3	3	3	3		3
	Complexity for disassembly	4		9	9	3	3	3	3	3		3
	Handling Time	4		9		3	3					
	Cost	3	3				3	3				
Altogether			48	186	108	60	66	33	48	64	51	100
Importance %			6.3	24.3	14.1	7.9	8.6	4.3	6.3	8.4	6.7	13.1



Table-2 shows decision selection matrices based of joining method. The comparison was made between the aluminum bracket as datum compared with hexagon nut and cylindrical shape nut. Form the selection matrices, the

score for hexagon nut was +2 and for cylindrical shape nut is +5. Therefore, the cylindrical shape nut was selected to proceed into detail design.

Table-2. Decision selection matrices.

		DATUM	Nut	INPREANUT
Joint Part Used				
Extension Part (Hollow)		Aluminum square	Aluminum square	Aluminum tube
Fastener		Blind Rivet	Screw	Screw
Assembly Example				
Criteria	Weight	DATUM	DESIGN 1	DESIGN 2
Method of assembly (fit)	2	0	-	-
Method of assembly step (parts no)	1	0	---	---
Assembly Tool used	1	0	+	+
Method of cutting extension part	2	0	0	+
Precision of cutting extension part	2	0	0	+
Part size	1	0	+	+
Assembly part orientation	1	0	+	+
Able to use crimping tool	1	0	+	+
Preparation for disassembly	2	0	+	+
+		0	6	10
0		13	4	0
-		0	5	5
Net Score		0	1	5

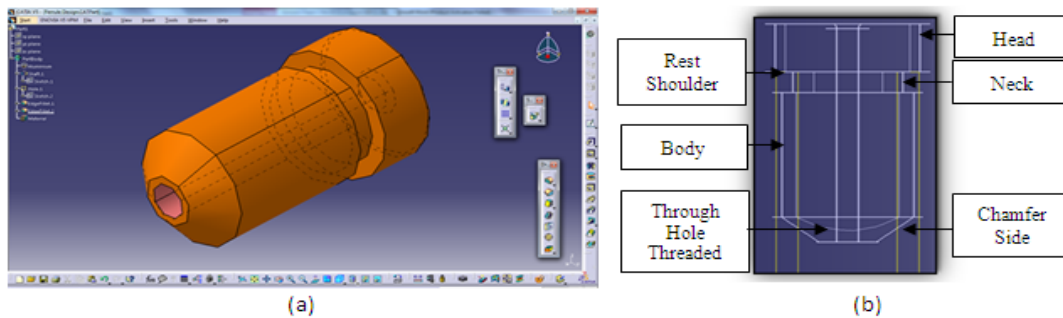


Figure-3. (a) INPREANUT CAD model and (b) INPREANUT nomenclature.



A CAD software was used to convert the conceptual idea for INPRENUT into a detailed engineering design. INPRENUT assembly geometric models could be displayed graphically to visualize and able to be manipulated, analyzed and refined. The design was translated into the part and its nomenclature respectively as shown in Figure-3 (a) and Figure-3 (b).

For the detail specification, the mechanical fastener must meet the fits standard to signify the range of tightness or looseness that may result from the application of specific combination of allowances and tolerance in mating parts (ASME, 1967). For the purpose mating parts with mallet or by light pressure thigh fit or press fit is proposed. Therefore, the INPRENUT was designed followed the standard guidelines based on ANSI.

For the purpose of this research, the tube is has an external diameter of 12.70 mm; basic hole inner diameter is 10.70 mm and wall thickness is 1.00 mm. Dimensional tolerance is the total quantity allowable changes to the dimension of the INPRENUT during the manufacturing process with respect to the nominal measurement indicated in the plane of measurement.

In basis of fits, hole basis system was used because the basic diameter of the hole is constant while the shaft size is varied according to the type of fit. Furthermore, this system also able to reduce production costs because the shaft can be easily machined to any desired size (Thai-German Teaching Aid, n.d). Preferred interference fits hole basis H7/p6 was selected. This selection is to meet the needs to allow the parts can be assemble or disassemble without great force such as using a rubber mallet (Oberger, 1997).

Based on the concept of tolerance, the lower control limit is 10.918mm and the upper control limit is 10.929mm. Therefore, machining of INPRENUT should follow the specification specified.

To avoid unnecessary experimenting during the design process, a numerical model is the best option to be used. This is because the computer models can be used to make simulations and also prediction, uncertainty analyses

or sensitivity studies (De Rocquigny *et al.*, 2008). The traditional method of Lamé Thick Wall model is still a relevant method used in the study. However, Finite Element Analysis (FEA) has drawn attention to further research and in-depth as some deficiencies identified in the model lamé (Zhang *et al.*, (2000); Mucha (2009)). Several studies have identified the interference fit for stress analysis using finite element method. Zhang *et al.* (2000) examines the interference fit in the ring gear-wheel connection states that there is some limitation in the complete 2-Dimensional stress analysis and accuracy through a thick-wall cylinder theory. The interference press-fit of INPRENUT is analysed by using ANSYS software.

From Figure-4 the fabrication of INPRENUT started with cutting the aluminium rod and was machined with a turning machine. The next process is to make the internal threaded by using conventional milling and manual tapping.

RESULT AND DISCUSSIONS

Figure-5 shows the ANSYS FEA analysis result of INPRENUT. The result in Figure-5 (a) shows the lead edge ring indicated with red color with frictional pressure implies to push-in INPRENUT into aluminum tube is about 435 MPa. This edge red color ring shows maximum area of frictional pressure applied at the end of INPRENUT tail. The result in Figure-5 (b) and Figure-6 (b) shows maximum deformation of INPRENUT with aluminum tube with the frictional pressure. Since the analysis considering the linear materials, the behavior of both pull and push exhibited similar pattern and therefore a small deformation of 0.4 μ m occurred due to small interference of shaft and hole. Both result shows the INPRENUT are able to meet desired press fit into the aluminum hole tube without excessive force. Figure-6 (a) shows frictional pressure implies to pull-out INPRENUT from aluminum tube is about 388 MPa and less compared with press-in frictional force.



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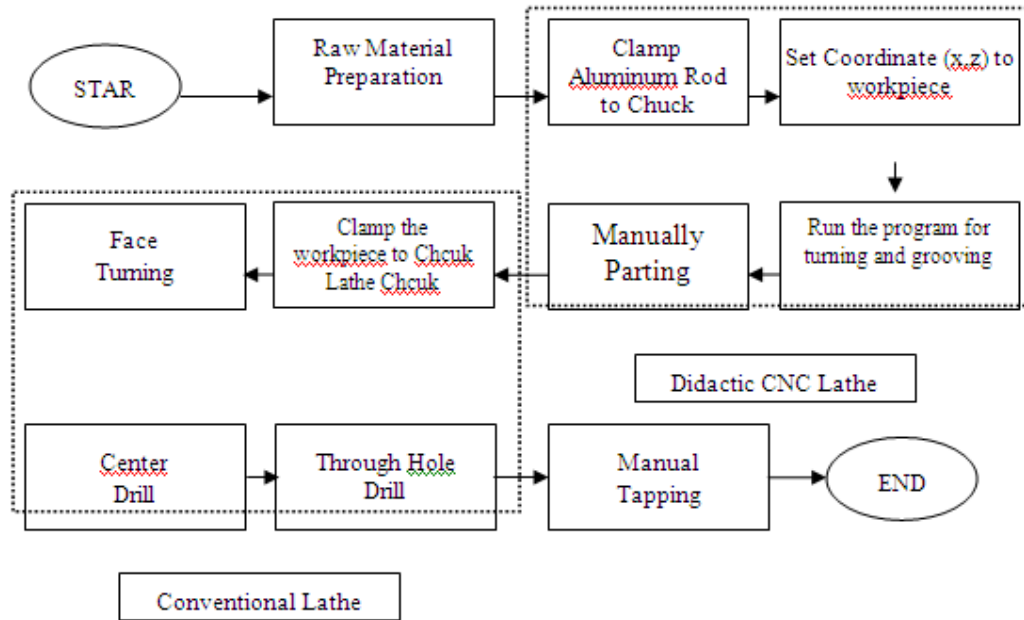


Figure-4. Process layout for INPRENUT fabrication.

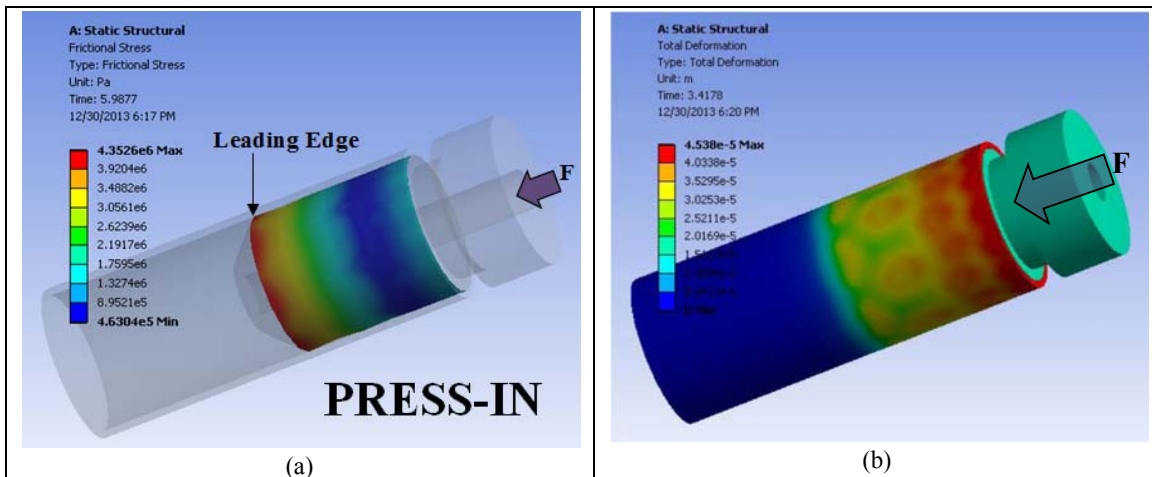


Figure-5. INPRENUT Finite Element Analysis for Press-In into the aluminum tube (a) Frictional force (b) Maximum deformation.

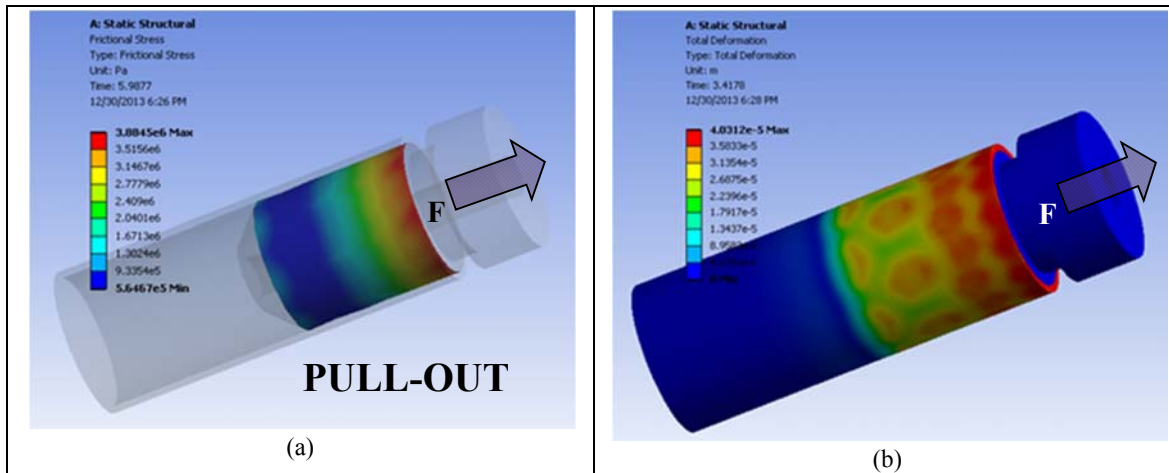


Figure-6. INPRENUT Finite Element Analysis for Pull-Out into aluminum tube (a) Frictional force (b) Maximum deformation.

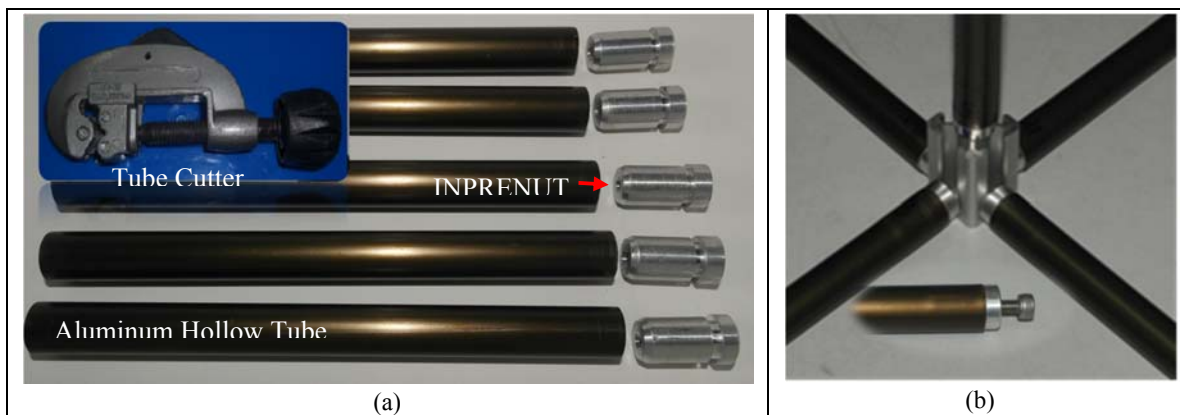


Figure-7. (a) INPRENUT, aluminum hollow tube and tube cutter (b) Example of aluminum hollow tube assembly and modular aluminum profiles assembly.

The INPRENUT after fabrication is shown in Figure-7 (a). The aluminum hollow tube was prepared by cutting it using tube cutter. The aluminum hollow tube was then assembled together with the INPRENUT by press it using hydraulic press or rubber mallet. Figure-7 (b) shows sub-assembly of INPRENUT and aluminum hollow tube that could be assembled with aluminum bracket and modular aluminum profile). This will allow adjustable and increase flexibility in part assembly. Furthermore, the aluminum hollow tube was able to bend using tube bender that increases its flexibility in design of assembly product.

CONCLUSIONS

In the world of Technical Vocational Education Training (TVET), most project requires student to design and produce a prototype or product that will involve installation of mechanical components. Taking into account the difficulties faced to make such pre-assembly,

assembly and disassembly, joining process involved cutting the parts accurately until the components could be mated together.

This research shows that the INPRENUT is a novel fastener to aid in joining parts. The design tools such as Affinity Diagram, House of Quality (HoQ), Decision Selection Matrices, CAD, Finite Element Analysis (FEA) and Geometrical Dimensional and Tolerances (GD&T) was used to design and develop the INPRENUT. Based on FEA, press-in and pull-out of INPRENUT with aluminum tube analysis shows sufficient frictional force and maximum deformation of fit without excessive force to assembly. The small deformation of $0.4\mu\text{m}$ occurred due to small interference of shaft and hole was calculated based on.

The INPRENUT was fabricated and possible pre-assembly of INPRENUT was demonstrated. The INPRENUT was found to reduce pre-assembly setup time, disassembly time, reduce sharp object hazard and improve



the quality of the product developed. As a result of conducting of this research, the INPRENUT should be introduced in technical vocational educational institution in order to speed up design, build and test of the project.

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