Effect of lead angle on push force of snap joint using nonlinear analysis and 3D printing

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Abstract- ***Snap-fit joints are one of the cheapest and fastest connectors available. However, due to geometrical complexity of the joints and the limitations of injection molding, they are used almost exclusively in large-scale manufactured products. Additive manufacturing offers the possibility to create end-user products in small and medium numbers with almost unlimited design complexity In present study the existing snap joint is considered to study the effect of lead angle of snap joint with 13, 15 and 17 degree angle and determine the optimized model for existing design using ANSYS software. Optimized model is manufactured using 3 D printing technique and tested using UTM. Many snap-fits are used in conjunction with sealing elements that produce a constant force that remains in effect after snap fit assembly is completed. The effect of sealing element preload magnitude and stiffness is to be studied using a test station, force deflection measurements, are to be calculated. The analysis and testing results comparison will be carried out and then the suitable future scope will be suggested.***

Keywords—FEA, Snap fit angle, UTM

I. INTRODUCTION

Snap fit is formfitting joint which permits great design flexibility. Snap fit is used to fix two parts together in a certain position. Virtually all consumers and industrial products, utilizing plastic molded components, have multiple components attached together with some form of snap fits. This utilization of snap fit joints for plastic molded component provides an easy and cost-effective method to attach multiple component assemblies. During assembly, the parts are elastically deformed. Joints may be non-detachable or detachable, depending on design. A typical snap fit joint assembly consists of a cantilever beam with an overhang at the end of the beam. Snap fit joints are made possible because of the inherent flexibility and toughness of modern thermal plastics. Thermal plastics used in products are typically 30 to 100 times more flexible than metals like steel or aluminum. The stiffness of thermal plastic can be altered by adding glass fibers or composites to the base resin. While designing a snap joint, most of the focus has been on making sure that the snap doesn't break or fracture upon initial insertion. Equally important to snap failure, is the secureness of the snap joint when subjected to loads by the end user or shock and vibration environments found in industrial applications. The motions required for assembly are also usually simplified, which is beneficial from an ergonomic standpoint. The use of snap-fit features instead of discrete fasteners results in the reduction of the number of different materials in the assembly, which can be helpful for recycling purposes. Snap fits have traditionally been used in toys, small appliances, automotive, electronic field and other consumer products. The below figure shows a typical cantilever snap which gives an overview of mating parts.

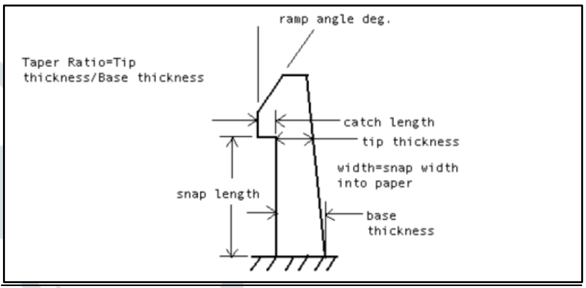


Fig. 1 Typical Cantilever Snap

A Snap-fit (Integral Attachment Feature) is an assembly method used to attach flexible parts, usually plastic, to form the final product by pushing the parts' interlocking components together. There are a number of variations in snap fits, including cantilever, torsional and annular. Snap fits are an alternative to assembly using nails or screws, and have the advantages of speed and no loose parts. Snap fit connectors can be found in everyday products such as battery compartment lids, Snap fasteners and Pens. Snap-together connectors have been used for thousands of years. The first ones were metal. Some of the oldest snap-fits found are snap fasteners, or buttons, shown on the Chinese Terracotta Army featuring soldiers from the late Warring States Period. Metal snap fasteners, spring clips, and other snap-type connectors are still in broad use today. With the development of new flexible yet springy materials, such as molded plastic, and new manufacturing processes, many new variations in these types of connectors have been invented, and are commonly called snap-fits. They can be found in on our phones, laptops, keys, and other household devices. Engineers have studied and developed these snap-fits, creating formulae concerning the amount of deflection allowed on the components, amount of torque one can take, and the amount of space one can allow in order to be detached.

II. LITERATURE REVIEW

Christoph Klahna et al. [1] In this contribution, the existing design guidelines for snap-fit joints are challenged with the design potentials of additive manufacturing. The general working principles of snap-fit joints prove to be simple, clear, and safe independent of the manufacturing process. While the principles remain unchanged, the advantages of additive manufacturing are utilized to improve the integration in the product and the user handling. By applying the design restrictions of the additive manufacturing processes Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS) the existing guidelines are extended for new manufacturing processes. To demonstrate the new concepts and the capabilities of additive manufactured snap-fit joints a showcase is conceptualized, designed in detail and produced using Fused Deposition Modeling and Selective Laser Sintering. A lid of a container, similar to a jar, is designed as an integrated single component. Aspects of haptics and usability are integrated, resulting in a lid that can easily be assembled and disassembled using one hand only. The design features springs and snap-fit joints adapted to the advantages and limitations of additive manufacturing.

John Carrell et al. [2] This paper explores a means to simplify disassembly by engineering a snap-fit that automatically releases upon exposure to a heat field thus limiting manual labor or machine operation for disassembly. Shape memory polymer (SMP) snap-fits were designed and manufactured to actively release upon a thermal trigger. Snap-fits were designed with an added feature known here as a release angle that would allow for an uninterrupted movement for disassembly in the presence of an elevated temperature. SMP snapfits were then manufactured and tested. Testing was performed for demonstration of the active release of the SMP snap-fits and for analysis of active disassembly (AD) process parameters. Taguchi methods were used to analyze the AD process parameters, including heating method and disassembly temperature. The results from this research show the successful demonstration of the SMP snap-fits within a manufactured product housing. AD process parameter analysis shows that both the heating method and temperature affect the AD process. The analysis determines that by increasing the heat exchange rate the snap-fit disassembly time is shortened. From the performed experiments, it was seen that an Oil bath at 150 C produced the best results in regards to disassembly time and signal-noise ratio. The results from experimentation demonstrate the possibility of acceptable heat-releasable fasteners for more efficient disassembly and exhibit benefits over current AD elements comprised of shape memory alloys.

Leonard Rusli et al. [3] The purpose of this study was to investigate the tactile feedback of snap-fit fasteners when used in manual assembly. An important aspect of this assembly process is the assembler’s ability to perceive the snap-fit’s engagement. This sensing of engagement yields a high level of confidence that assembly is both complete and secure. Force and tactile feedback are critical elements in this process. Many snap-fits are used in conjunction with sealing elements that produce a constant force that remains in effect after snapfit assembly is completed. The effect of sealing element preload magnitude and stiffness was studied using a test station, force deflection measurements, and jury pool data. A low value of preload with low stiffness was determined to be most favorable in terms of force and tactile feedback, with no preload only slightly less favorable. In order to sense the engagement signal of the catch, some resistance to assembly was found to be beneficial. A dimensionless term called “engagement signal-to-hold-force ratio” is proposed as an additional way of rating the effect of assembly forces for snap-fits. It was found that higher signal-to-hold-force ratio, as well as higher values of engagement signal, corresponded to higher confidence of assembly among experimental subjects. Relevance to Industry: Both the design of the snap-fit and the presence or absence of preload will affect force and tactile feedback. Many of these applications require the compression of an elastic gasket with a preload needed for air, fuel, or electrical isolation. Preload and preload stiffness factors are examined in this paper with the aim of achieving a better understanding of these effects so that snap-fit confidence of assembly and assembly robustness can be enhanced in industrial settings.

B. Bader et al. [4] Viscoelastic materials can be represented by models consisting of springs and dashpots because the material shows elastic and viscous effects. The two simple models that are commonly used to relate stress and strain are the Maxwell (relaxation) and the Kelvin model (creep). These 2-parameter models are available in commercial FE-codes. The measured relation between stress and strain is generally more complex. Thus combinations or modifications of these models are necessary. An appropriate 3-parameter model (Maxwell/Thomson) was programmed using FORTRAN. To use this model within the MARC FE-program the option user subroutine (HYPELA) was chosen. The parameters of the model are mathematically described as a function of the strain rate. The viscoelastic model is combined with a plastic element which is inactive for stress below the actual yield stress of the material. In a first approach the von Mises yield condition and an isotropic "hardening" rule were applied. To consider the flexural recovery of polyoxymethylene (POM) the parameters of the model werc also be varied. This model was verified by comparing measured and simulated results of simple mechanical tests and the snap-in and snap-out forces of a bali snap-fit. The modified material model can simulate the main effects of non-linear viscoelasticity and plasticity of POM.

III. PROBLEM STATEMENT

Traditionally designed snap fits fail at fixed ends at yield loads. Hence optimization using Nonlinear material and contact analysis helps in achieving robust design. Within the current design restrictions of injection molding good designs of the mating process of snap-fit joints are known and feasible. Locators help the user to align the parts and guide the movement until a snapping sound indicates that the connection is made. But lot of times push force of snap joint are relatively maximum in conventional part. so we will find out if changing lead angle of joint what will be effect.

IV. OBJECTIVES

- Design of snap joint with 13, 15- and 17-degree angle in CATIA software.
- To study the effect of lead angle of snap joint with 13, 15- and 17-degree angle on push force to obtain best optimum model for existing part.
- To develop an optimized model of snap joint for existing model using ANSYS software by nonlinear analysis to determine reaction force.
- Manufacturing of optimized model by 3D printing method.
- Experimental analysis of snap joint using UTM.
- Validation of experimental and numerical analysis results

V. METHODOLOGY

Step 1: - Initially research paper are studied to find out research gap for project then necessary parameters are studied in detail. After going through these papers, we learnt about snap fit.
Step2: - Research gap is studied to understand new objectives for project.
Step 3: - After deciding the components, the 3 D Model and drafting will be done with the help of software.

Step 4: - In manufacturing existing connecting rod is reinforced with carbon fibre for UTM test.
Step 5: -The testing will be carried out and then the result and conclusion will be drawn.

CATIA MODEL

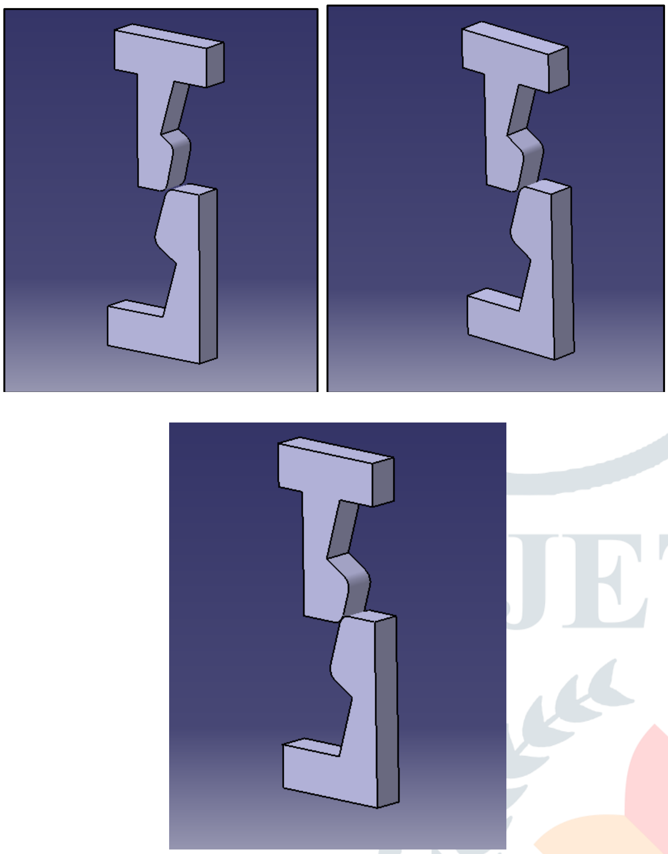


Fig. 1 CATIA model of 13, 15 and 17 degree snap fit

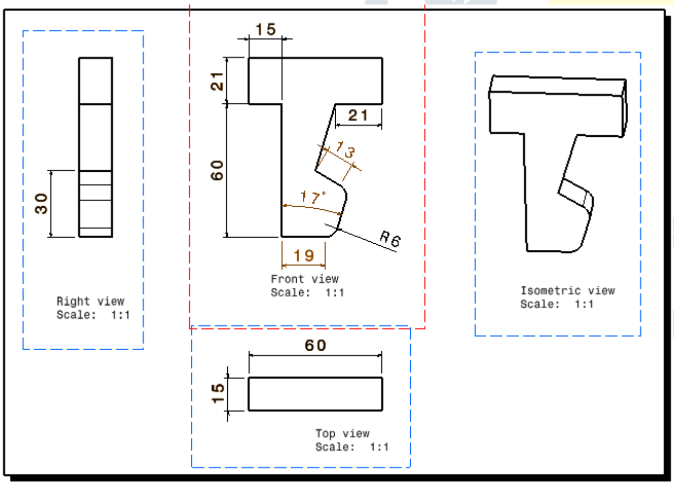


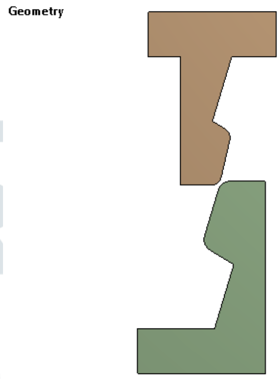
Fig. CATIA and drafting of 17 degree insert assembly

1.Material Properties

Table 1 Material properties of ABS

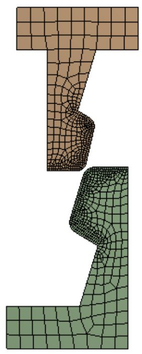
Properties of Outline Row 3: ABS

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	1080	kg m^-3
4	Isotropic Elasticity		
5	Derive from	Young's Modulus and Poiss...	
6	Young's Modulus	2.06E+09	Pa
7	Poisson's Ratio	0.45	
8	Bulk Modulus	6.8667E+09	Pa
9	Shear Modulus	7.1034E+08	Pa
10	Bilinear Isotropic Hardening		
11	Yield Strength	3.8E+07	Pa
12	Tangent Modulus	8.9E+08	Pa
13	Tensile Yield Strength	3.8E+07	Pa
14	Tensile Ultimate Strength	4.5E+07	Pa



MESH

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient multiphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it.



Statistics	
Nodes	2489
Elements	761

Fig. 3 Details of meshing of model

Boundary Condition

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both. The main types of loading available in FEA include force, pressure and temperature.

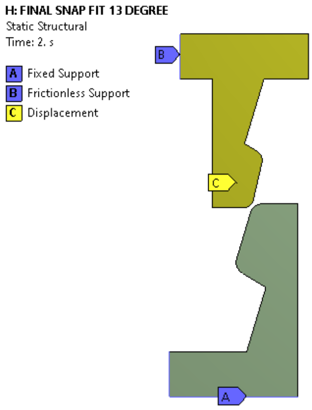
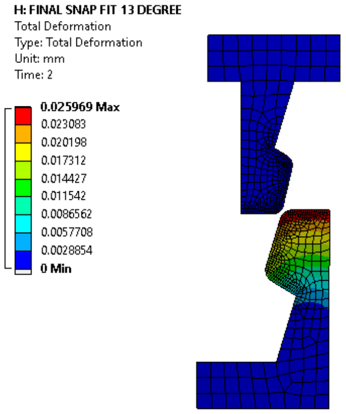


Fig 4 Boundary Condition

In present research different snap angle namely 13. 15 and 17 degree are considered to obtain optimized design. In boundary condition lower snap is fixed with frictionless support applied at edges for movement in downward direction along with displacement of 60 mm to obtain reaction force for specific angles.

Total Deformation

The total deformation & directional deformation are general terms in finite element methods irrespective of software being used. Directional deformation can be put as the displacement of the system in a particular axis or user defined direction.



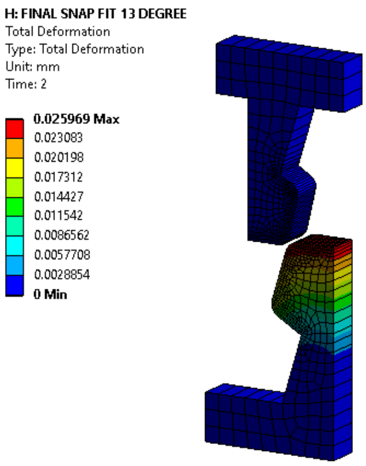
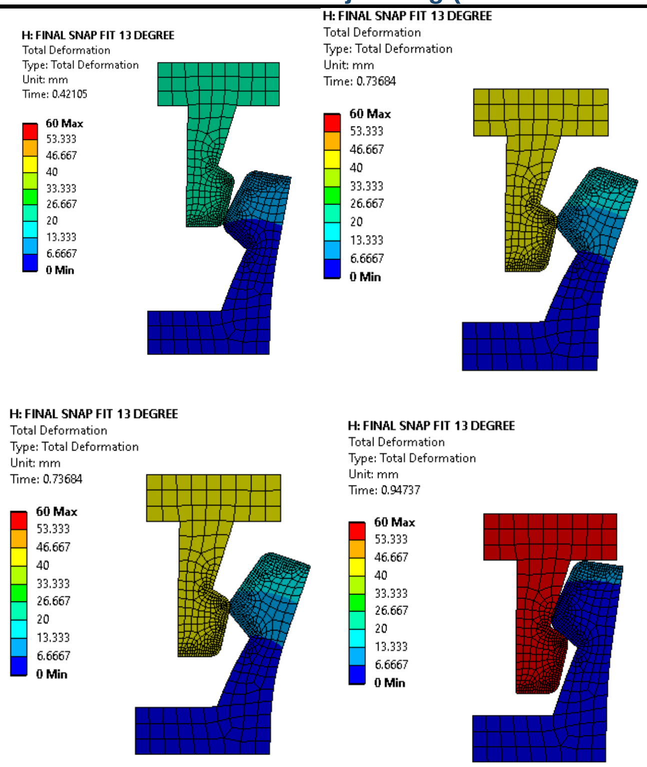


Fig. 5 Total Deformation



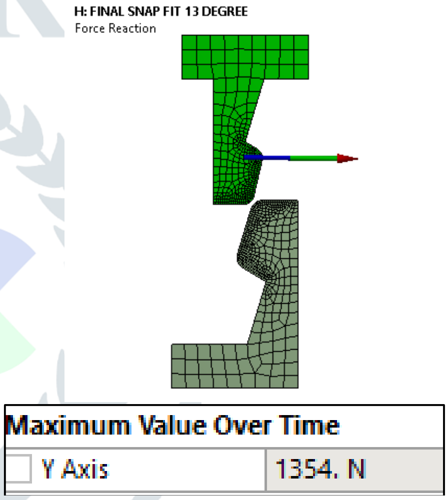
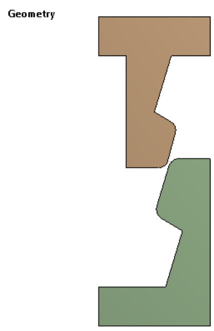
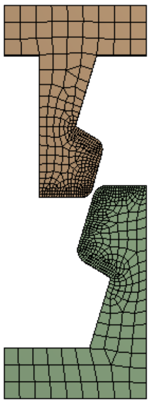


Fig. 7 Force Reaction

15 degree





Statistics	
Nodes	2578
Elements	792

Fig. 3 Details of meshing of model

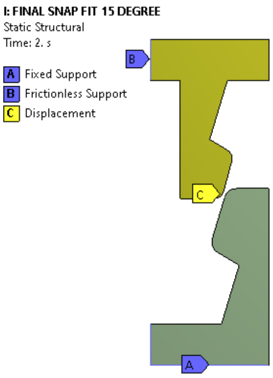


Fig 4 Boundary Condition

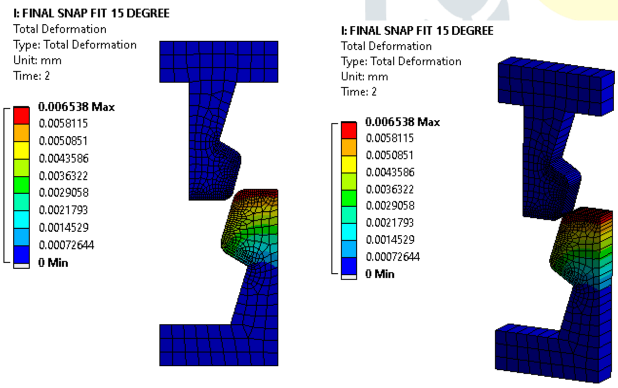
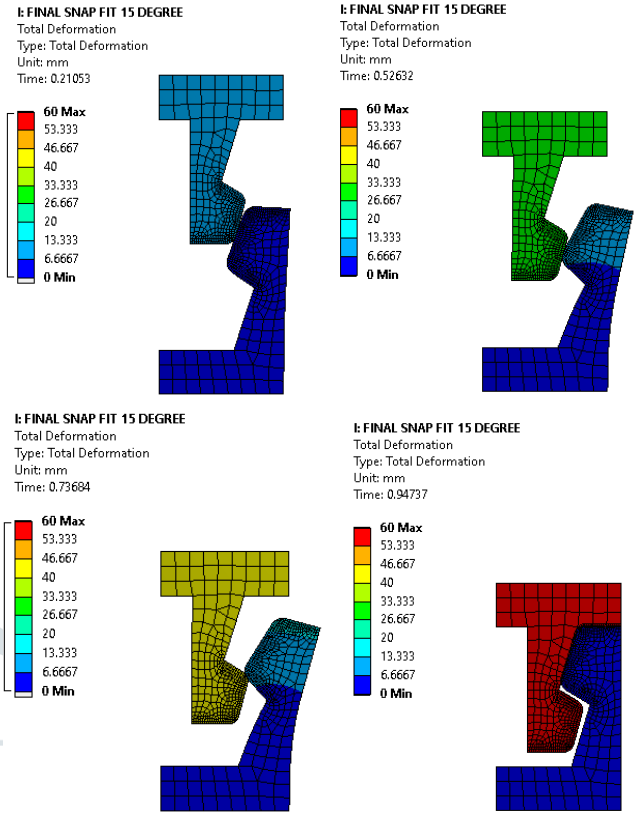
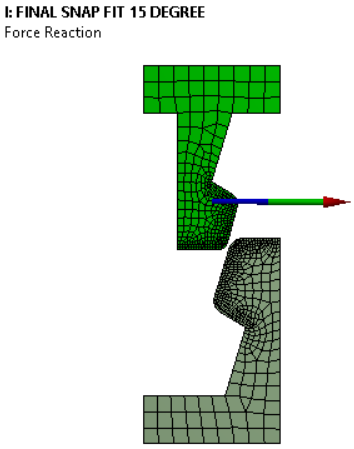


Fig. 5 Total Deformation

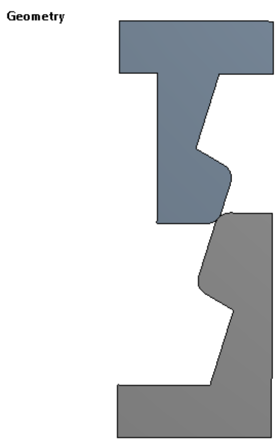


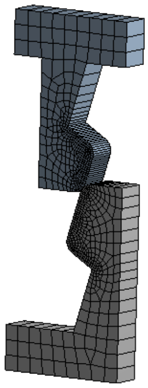


Maximum Value Over Time	
Y Axis	1128. N

Fig. 7 Force Reaction

17 degree





Details of "Edge Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	8 Edges
Definition	
Suppressed	No
Type	Element Size
Element Size	1.0 mm

Statistics	
Nodes	2307
Elements	707

Fig. 3 Details of meshing of model

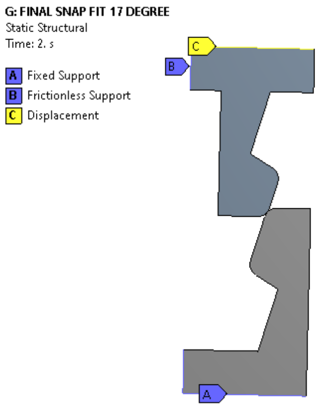


Fig 4 Boundary Condition

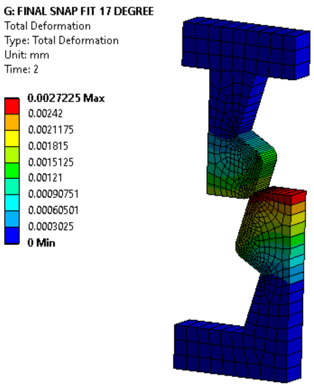
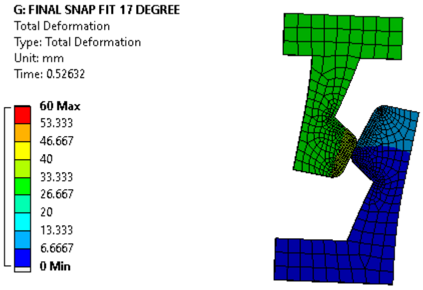
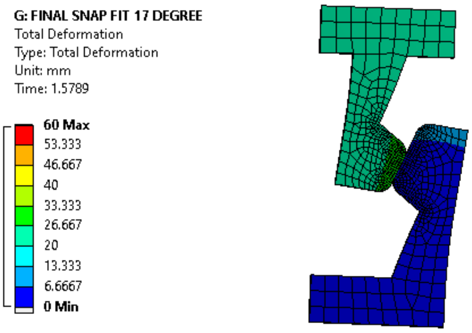
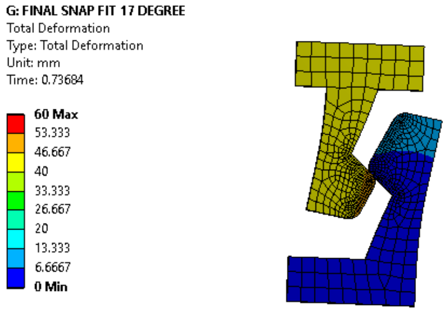
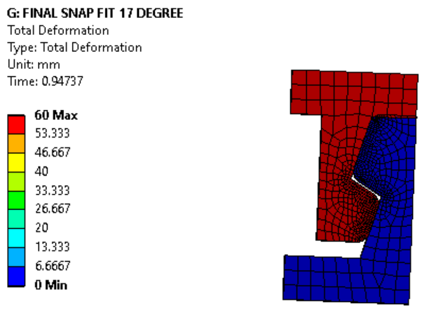


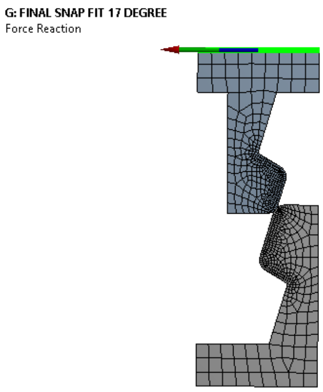
Fig. 5 Total Deformation











Maximum Value Over Time	
Y Axis	855.62 N

Fig. 7 Force Reaction

SNIP ANGLE (DEGREE)	FORCE REACTION (N)
13	1354
15	1128
17	855.62

It is observed that increase in snap fit angle reaction force is decreased.

Fig. 3D printed snap fit

EXPERIMENTAL SETUP

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile). The set-up and usage are detailed in a test method, often published by a standards organization. This specifies the sample preparation, fixturing, gauge length (the length which is under study or observation), analysis, etc. The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips. Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen.

Specification of UTM

1	Max Capacity	400KN
2	Measuring range	0-400KN
3	Least Count	0.04KN
4	Clearance for Tensile Test	50-700 mm
5	Clearance for Compression Test	0- 700 mm
6	Clearance Between column	500 mm
7	Ram stroke	200 mm
8	Power supply	3 Phase, 440Volts, 50 cycle. A.C
9	Overall dimension of machine (L*W*H)	2100*800*2060
10	Weight	2300Kg

EXPERMENTAL PROCEDURE

- Dimension of snap fit is measured at three different places along its height/length to determine the average cross-section area.
- Ends of the snap fits should be plane.
- The snap fit is placed centrally between the two compressions plates, such that the both snap fits are clamped in chuck or jaw of UTM machine.
- Displacement is applied on the snap fit by moving the movable head of insert snap fit.
- The load and corresponding contraction are measured at different intervals. Load is applied until the final result obtain and both snap fit are in contact to each other.

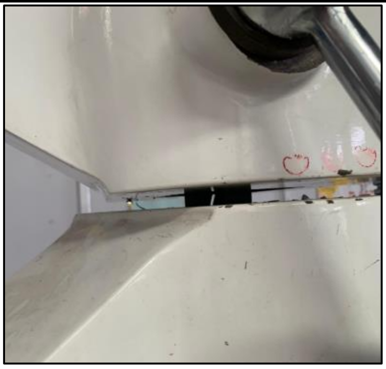


Fig. Experimental testing

CONCLUSION

- In present research snap fit with different angles namely 13, 15 and 17 degree are studied to obtain optimized design snap fit for application purpose.
- It is observed from FEA analysis that increase in snap angle leads to decrease in reaction force to join both snap fits to each other.
- Manufacturing of 17 degree is considered as optimized model and 3 D printing material namely ABS is selected and printed using 3D printing machine.
- In experimental testing similar displacement is applied as per FEA result and is observed that force require to snap fits to contact each other are similar to FEA results.

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