# Analysis of A Case study on Fuel Leakage in a Pre-Filter Bowl of a Diesel Engine Fuel Feed Pump using Ansys

**Priyanka D, B.V.Raghavendra, Subhash P**

***Abstract- Fuel leakage in the pre-filter bowl of a diesel engine feed pump is the common problem in the field. The leakage of fuel is mainly due to the method of assembly and design of the components. Though the threaded fasteners are easy for maintenance and low cost in the assembly of the components, they are not advisable due to its limitation of loosing the threaded fastener under the dynamic loading. A case study has been done in the industry to reduce the rejection of feed pump due to leakage of fuel in pre filter bowl of a diesel engine. In this paper an effort is made to identify the factors which cause the leakage of the fuel. It is found that due to deformation in the wire clip and filter bowl is causing the major problem. Hence analysis of the existing design is made and suggested the improved design using Finite Element Analysis.***

***Index Terms - FEA, Feed Pump, Filter-bowl, Fuel leakage***

## I. INTRODUCTION

Diesel engines have changed dramatically over recent decades in order to provide higher power density, better fuel efficiency, and greater reliability. Clean, uncontaminated fuel is key to maximum fuel system performance and longevity for modern diesel engines. Without high quality fuel filtration and regularly scheduled service, fuel contamination can lead to costly repairs and engine downtime. Dirt and contaminant removal and effective filtration reduces component wear and creates optimized fuel atomization and engine power. More important than the new engines that are being designed to control emissions is ensuring that the fuel going into them is properly filtered. Indeed, using the proper on-engine filter is critical to any vehicle's success.

### *A. Feed pump*

Feed pump is a frequently essential component in heavy diesel engines or other internal combustion engine device, rail road stock, aircraft, marine, motor cycles. Many engines do not require any fuel pump at all, requiring only gravity to feed fuel from the fuel tank through a line or hose to the engine.

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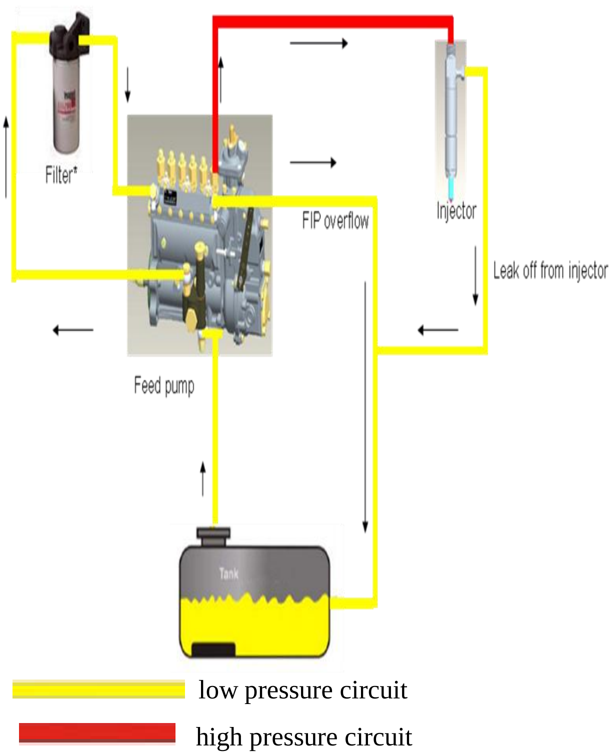


**Fig 1: System Overview**

However feed pump are essential in non-gravity feed designs. The function of feed pump is to deliver the fuel from the fuel tank to fuel injection pump through the fuel filter in diesel engine. The filter is kept inside the bowl and the bowl has attached to the feed pump housing with the tension bracket. The main function of bowl is to collect the dust particles which filtered from the filter. The feed pump is attached to the injection pump and driven by its camshaft. The fuel should be properly filtered before entering the Injection pump. This function is carried out by the fuel filter assembly. The fuel enters the primary filter and then to the secondary micro filter before passing in to fuel injection pumps. The filter cleans the fuel. The impurities which filtered from the pre filter will get collected inside the bowl.

As the fitting of the pump plungers and pump barrels is very precision, therefore, it is necessary that the fuel being forced by the pump must be free from the solid particles of dust and dirt. If greater plunger and barrel wear occurs in the pump, it means a breakage of the filter in the fuel system.


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Fig 2: Feed Pump

The presence of dirt in the fuel is also harmful for the delivery valves, their guides and seating, and the injectors. Therefore to keep the longer life of all the components of the fuel injection system, it is essential to provide the fuel filters at the desired positions. These filters should be inspected timely and they may be drained when felt dirty. After every long journey the sediment plugs should be opened so that any dirt or water collected in the system may be drawn off. On any doubt the filter may be opened and tested. If there is any small hole, cut or tear on the surface of the filtering medium then this filtering medium should be replaced by a new one. In modern fuel systems a series of filters are provided so that practically a finest abrasive particle may be avoided to reach into the pump and injector. In this paper a case study has been carried out on leakage of the fuel through the feed pump at pre-filter assembly which consists of seven parts they are gasket, filter, spring, bowl, round nut, headless screw, and wire clip. Generally, the fuel leakage is near the bowl which gets assembled with the housing.

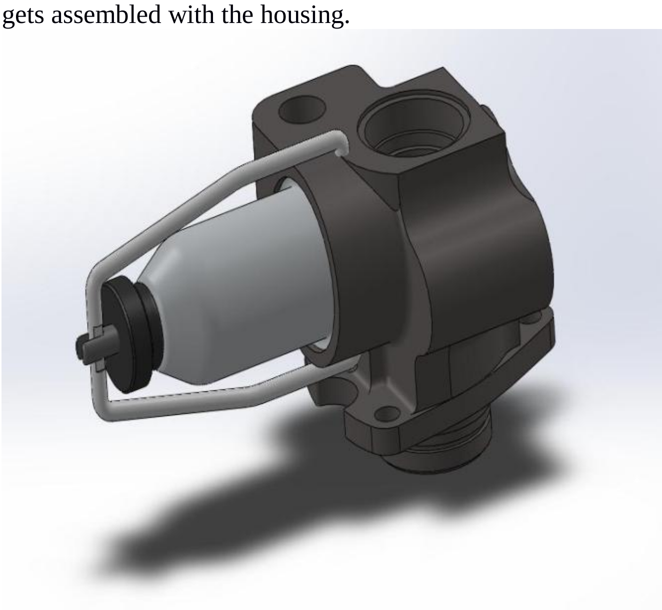

Fig 3: Assembly drawing of feed pump

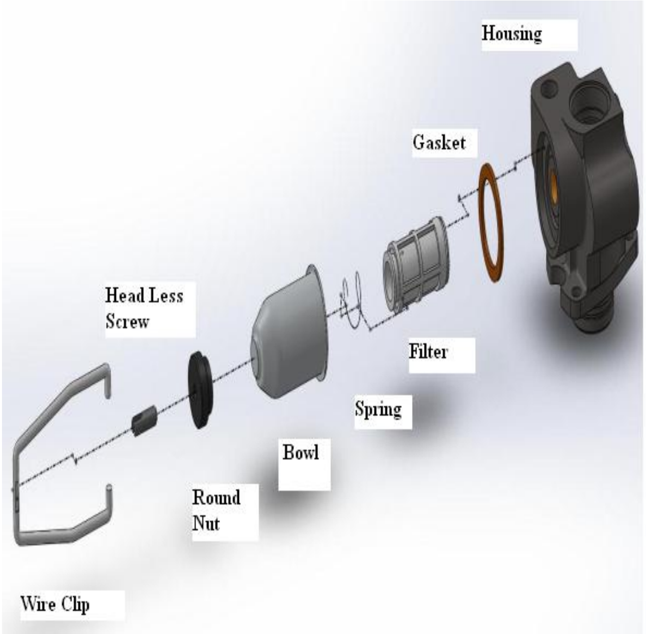


Fig 4: Exploded view of feed pump assembly

## II. LITERATURE REVIEW

The feed pump of pre-filter bowl with the seven different components such as, gasket, filter, spring, bowl, round nut, headless screw, and wire clip are assembled and attached to main housing. Wire clip is fixed to the housing in order to hold the bowl in proper position and tightening torque is used on nut to create the sufficient pressure on bowl and wire clip to avoid the leakage of the fuel in the feed pump.

### *A. Threaded fasteners assembly:*

Threaded fasteners are one of the methods widely used in mechanical structures for assembly process largely due to easy and low cost of disassembly the components for maintenance. The two most widespread causes of failure of threaded fasteners subjected to dynamic loads are fatigue and vibration induced loosening [1]. Normally the load distribution of 1st pitch decreases and that of 4th pitch turns to be the minimum and loosening is initiated when complete thread slip has occurred prior to head slip. Therefore, modification of design in the threaded fastener is needed [2]. The mechanisms of loosening-resistance components are the ability of nut tightening method and spring washer to resist self-loosening due to transverse loading. If locking state is properly achieved in the tightening process, nut shows significant loosening resistance regardless of the magnitude of locking force. The thread surface on the nut retains stuck state even if bearing-surface undergoes complete slip. However, if the locking process is not performed properly, the ability to resist loosening completely disappears. On the other hand, it is shown that spring washer accelerates loosening rotation of nut. The stuck area on the contact surfaces is reduced to two corner edges of the spring washer and the rotational force around these edges thus drastically leads to loosening before complete bearing-surface slip [3].

In the present case study there is only the longitudinal loading, which results in the self loosening of the nut. Due to self loosening of the nut tends to increase the clearance between bowl and the housing leads to leakage of the fuel.

**Table-1: Mechanical Properties of the components used in feed pump**

| Properties | Wire Clip | Rubber gasket | Round Nut | Head Less Screw | Filter | Bowl | Spring |
|---|---|---|---|---|---|---|---|
| Material | Unalloyed structural steel | Acrylonitrile Butadine Rubber (NBR) | Free cutting steel | Free cutting steel | Polyammide ( nylon 6) | Aluminum wrought alloy | Spring steel |
| Youngs modulus | 520-820Mpa | 200-3500Mpa | 460-710Mpa | 460-710Mpa | 36-97Mpa | 65-95Mpa | 2200Mpa |
| Density | 7.8g/cm3 | 0.91-0.98g/cm3 | 7.85g/cm3 | 7.85g/cm3 | 1.09-1.6g/cm3 | 2.7g/cm3 | 7.85g/cm3 |
| Hardness | 155-245 HB | 80HB | 135-210HB | 135-210HB | 110-123HB | 20HB | 135-210HB |
| Poisson's ratio | 0.33 | 0.50 | 0.27-0.30 | 0.27-0.30 | 0.42 | 0.33 | 0.27-0.30 |
| Modulus of rigidity | 79Gpa | 0.0006Gpa | 79Gpa | 79Gpa | 0.5Gpa | 27Gpa | 815Gpa |
| Weight of wire clip | 20g | 1g | 20g | 2g | 4g | 20g | 2g Stiffness 9.3 lbf/in |

### B. *Finite Element Formulation:*

A stabilized mixed finite element formulation for eight-node tetrahedral elements is introduced for robustly solving small and large deformation problems. The uniqueness of the formulation lies within the fact that it is general in that it can be applied to any type of material model without requiring specialized geometric or material parameters [4]. Quadratic tetrahedral elements are very good and can always be used for thin walled structure and these elements are not much sensible as linear hexahedral elements [5]. Therefore quadratic tetrahedral elements are used in this paper for analysis of the structure.

## III. PROBLEM DEFINITION

Leakage of fuel between the housing and the fuel bowl in the feed pump of diesel engine is the common problem in Bosch Ltd., Bangalore. The major rejection around 20% is due to the leakage of the fuel in the feed pump. The major factors affecting the leakage of the fuel are needs to be identified and found that the deformation in the wire clip, bowl and nut loosening are the major factors. Hence an existing design needs to be analyzed and required correction in the design to be made to reduce the rejection of the feed pump due to leakage of the fuel.

## IV. METHODOLOGY

The leakage of pre-filter bowl has been attained in two phases. Phase –I is analysing the existing design of the components bowl and wire-clip and Phase-II is exploring the analysis of the suitable correction in the design.

### A. *Phase-I: Analysis of Existing design:*

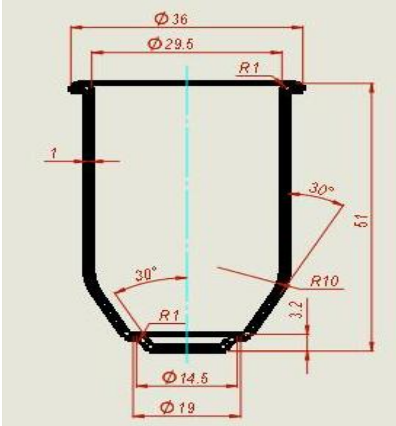


Fig 5: Bowl

**Hand Calculation:**
**Deformation in the Filter bowl:**

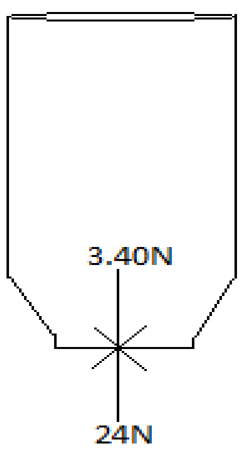


Fig 6: Forces acting on bowl

Self weight of bowl = 0.12N

Oil pressure = 0.03N

Spring force = 3.2N

Upward force = Tightening torque on Nut = 24N

Net compressive force = 24N - 3.40N = 20.6N


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Deformation (Buckling) = dL= PL / AE = - 0.13 mm

**Deformation in the Wire Clip:**

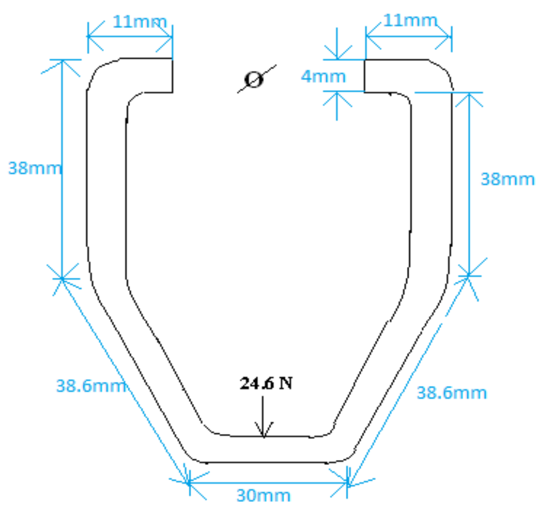


**Fig 7: Wire-Clip**

Downward force = Self weight of bowl + spring force + Oil pressure + Self weight of wire clip + Tightening torque on nut = 24.6N

Deformation will occur in wire clip at vertical hanging length and at horizontal base length of the wire clip.

The force on each vertical hanging length is Force = P = 24.6/2 = 12.3N

Length of vertical hanging wire clip = L = 75m

Area = A = 12.56mm2

Deformation in vertical hanging length [6,7]= dL1 = PL/AE = (12.3*75) /(12.56*520)

dL1 = 0.14 mm.

Maximum Deflection of horizontal base length at the mid-span[6,7] = Y = $PL^3/48EI$

$I = \pi d^4/64 = \pi(3.75)^4/64 = 9.7mm^2$

$Y = (24.6* 30^3)/(48*520*9.7)$

Y = 2.8 mm.

Total Length increases in Y-Direction= Deformation in vertical hanging length + Maximum Deflection of horizontal base length = dL = dL1+Y = 2.94 mm

**Using Ansys-11:**

**Deformation in the bowl:**

Solid model is created in workbench and the Structural element is selected Brick 8node Solid 45, Quadratic tetrahedral free meshing

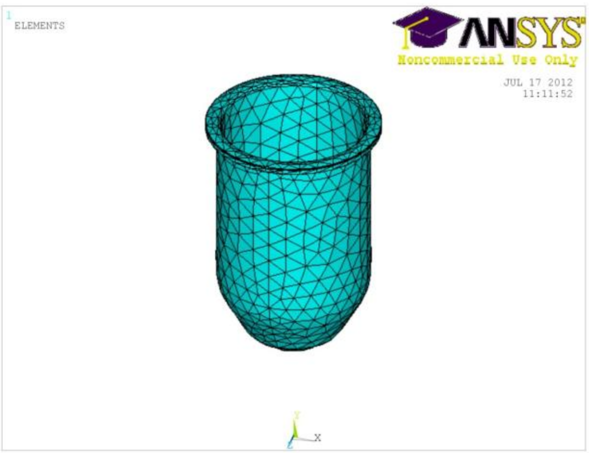


**Fig 8: Tetrahedral free meshing**

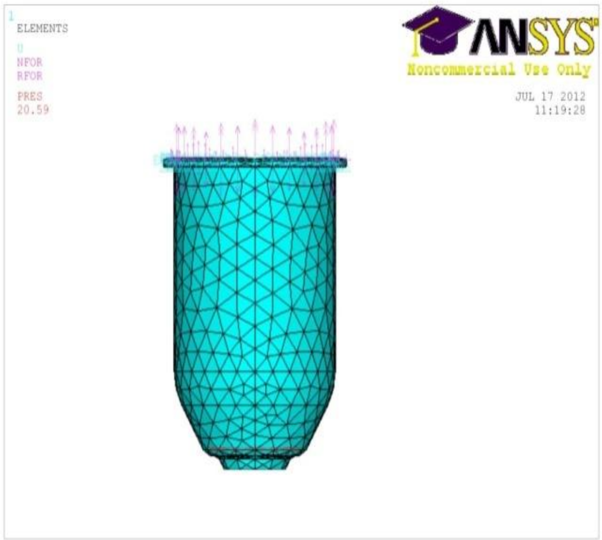


**Fig 9: Boundary condition and load of 20.6N**


**Fig 10: Deformation in the filter bowl 0.1123 mm**

**Deformation in the Wire clip:**

Solid model is created in workbench and the Structural element is selected Brick 8node Solid 45, Quadratic tetrahedral free meshing

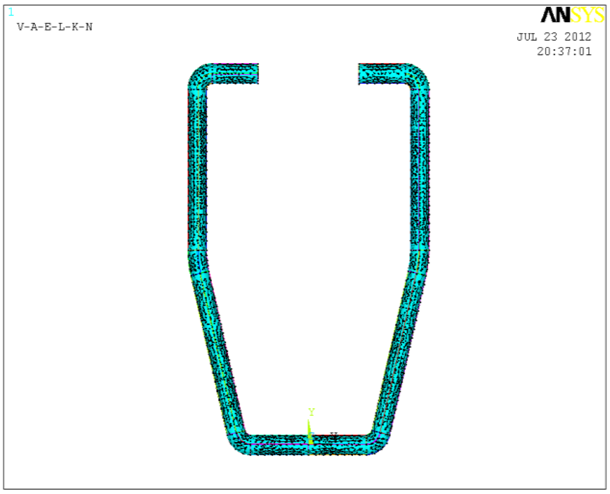


**Fig 11: Tetrahedral free meshing**

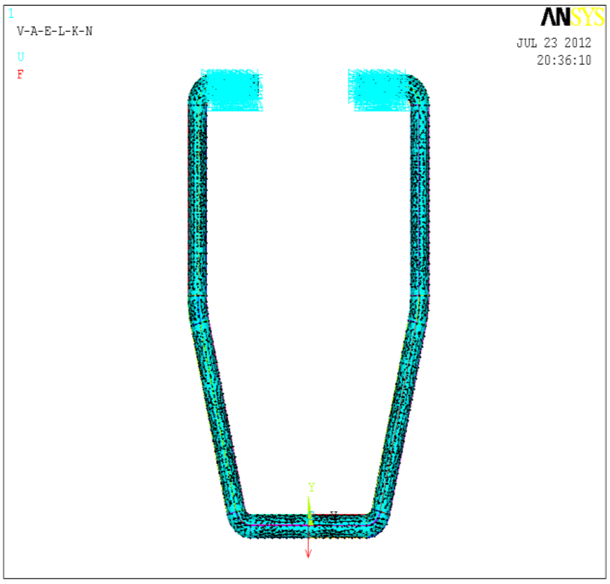


**Fig 12: Boundary condition and the force of 24.6N is applied**

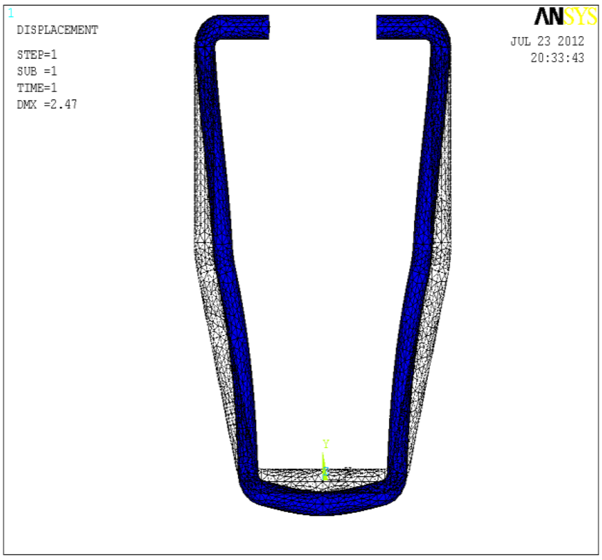


**Fig13: Deformation in wire clip for existing design 2.47mm**

From the above analysis it is evident that the bowl deformation is 0.1123mm and the wire clip is of 2.47 mm. The deformation in the wire clip is the critical which causing the more clearance between the filter bowl and housing hence the primary goal of the improved design need to be addressed on wire clip in order to reduce the deformation.

***B. Phase-II: Suitable correction in the design and its Analysis***

A design modification in the wire clip is suggested to reduce the deformation from the 2.47 mm. The existing material of the wire clip is structural steel with the young's modulus of 520 MPa and the carbon content is 0.05 to 0.25%. It is required to make the correction in the new design that the material for the wire clip should be steel with the young's modulus of 200 GPa and the carbon content is 0.05 to 0.29%. However wire clip dimension is unaltered and the production of the wire clip remains same as existing process. The analysis of the new design is carried with hand calculation and using Ansys.

**Deformation in the Wire Clip:**

**Hand Calculation:**

Deformation will occur in wire clip at vertical hanging length and horizontal base length of the wire clip. Here material has changed to mild steel which is having young's modulus 200Gpa ($2*10^5$Mpa)

The force on each vertical hanging length is Force = P = 24.6/2 = 12.3N

Length of vertical hanging wire clip = L = 75mm

Area = A = 12.56mm$^2$

Deformation in vertical hanging length = dL1 = PL/AE

 = (12.3*75) /($12.56*2*10^5$)

dL1 = 0.0003 mm.

Maximum Deflection of horizontal base length at the mid-span = Y = $PL^3/48EI$

$I = \pi d^4/64 = \pi(3.75)^4/64 = 9.7mm^2$

$Y = (24.6* 30^3)/(48*2*10^5*9.7)$

 Y = 0.007 mm.

Total Length increases in Y-Direction= Deformation in vertical hanging length + Maximum Deflection of horizontal base length = dL = dL1+Y = 0.0073 mm

**Using Ansis-11:**

Solid model is created in workbench and the Structural element is selected Brick 8node Solid 45, Quadratic tetrahedral free meshing and 24.6N force is applied on the wire clip in Y-direction at mid-span of the horizontal base length .

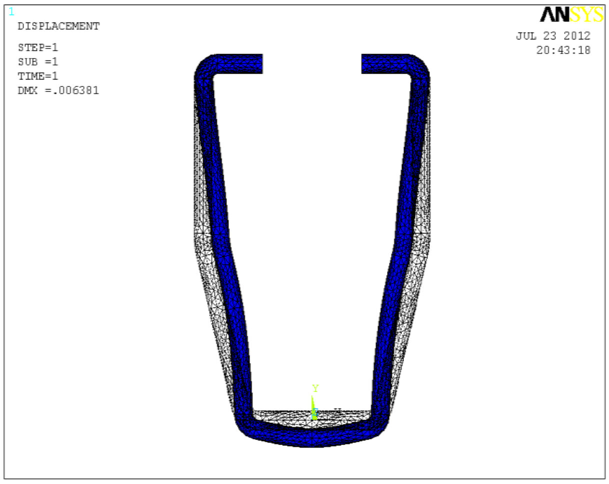


**Fig 14: Deformation in wire clip for new design 0.006381mm.**

By changing the material of wire clip from structural steel to steel with young's modulus $2*10^5$Mpa can reduce the deformation in wire clip.

**Table 2: Deformation in Y direction in mm**

| | Existing Design | | Proposed Design |
|---|---|---|---|
| | Wire Clip | Bowl | Wire Clip |
| Hand Calculation | 2.94 | -0.13 | 0.0073 |
| Using Ansys | 2.47 | -0.1123 | 0.006381 |


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## V. RESULTS & DISCUSSION

The factors affecting the fuel leakage in the pre-filter bowl of a feed pump is analysed and found that deformation of wire clip, bowl and self loosening of the nut due to the longitudinal loading are the critical factors. Existing design of the wire clip and the bowl is analysed. The deformation in the wire clip and the filter bowl is 2.47 and - 0.1123 mm respectively and the deformation in the wire clip is more critical than the filter bowl. Therefore it is found that the modification in the design of the wire clip to reduce the deformation of 2.47 mm is necessary. Hence it is suggested to use steel material whose young’s modulus is 200 GPa as compared to the structure steel of existing material of 520 Mpa. The analysis of the suggested design for the new material of wire clip is carried out and found that the deformation is 0.006381 mm. The analysis for the wire clip and the bowl for the existing and modified design of the wire clip is carried out with hand calculation and using Ansys. The results are compared and found satisfactory. It is also evident in the process that the single nut would have the self loosening characteristic due to longitudinal loading hence double nut is suggested to resist the self loosening of the nut.

## VI. CONCLUSION:

The gasket provided between the bowl and the housing will resist the leakage of the fuel through the bowl though the deformation in the bowl which is 0.1123 mm. Material of the wire clip need to be changed from the structural steel to the steel with the young’s modulus of 200 GPa instead of 520 MPa in the structural steel, improves the deformation to the minimum as 0.006381 mm. The double nut providing in the assembly of the pre-filter bowl to the housing resist the self loosening of the nut which further vanish the clearance between the bowl and the housing thereby arrest the fuel leakage in the pre-filter bowl of the feed pump.

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