

Stress Evaluation of Rotary Injector Pump Parts in MF285 Tractor Using Finite Element Method

M. Azadbakht, Y. Fadakar

Abstract—Since fuel must be injected with appropriate pressure and time for accurate performance of diesel engines, then proper function of engine is influenced by accurate function of injector pump. At first total pump was designed by SolidWorks 2012 software. Then the total relationship of rotor, roller, internal cam ring, pole shoe and plunger in injector pump in MF285 tractor and their performance was shown. During suction state rollers connect with dents in internal cam ring and in pressure course pole shoes have drawer move in rotor and perform tappet action between rollers and plungers. The maximum stress was obtained by using analysis of finite element method. The maximum stress in contact surface of roller and internal cam ring and on roller surface. The maximum amount of this stress is 288.12 MPa. According to conducted analyses, the minimum value for safety factor is related to roller surface and it equals to 2.0477.

Keywords—Rotary injector pump, MF285 tractor, finite element, stress.

I. INTRODUCTION

INJECTOR pump is from main parts and it plays significant role in diesel engines. Since fuel must be injected with appropriate pressure and time for accurate performance of diesel engines, then proper function of engine is influenced by accurate function of injector pump. Hence, injector pump must be repaired and maintained frequently and timely to remove its deficiencies.

Since MF tractor is common tractor in Iran, injector pump of this tractor was reviewed. Injector pump in this tractor is from rotary type (CAV). Repairable parts in this pump are very low and all pump parts are lubricated by fuel engine [4]. In a statistical review about failure causes and debugging of MF285 tractor, the results showed that the highest failure and repair rate in MF285 is related to injector pump failure. So that it allocates itself approximately 26.2% from tractor failures [6]. Also their results shows that main failure causes of this pump consist of being dirty of fuel, failure of filters in fueling system and rubbing internal parts of injector pump, respectively [6]. So, cleaning and or if possible, their replacement sooner that what is done in service manual, can reduce costs related to servicing and maintaining injector pump [6].

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Various researches have been conducted using finite element method which they are mentioned following. Ability of commercial packages like Ansys, Abaqus, and others in numerical analysis field to predict component failures are well established and the results can be justified according to mathematical and empirical models. Failure initiation, maximum load-bearing capacity and lifetime of components can approximately be predicted [10]. Reference [7] used experimental and numerical methods, for the stress analysis of a frontal truck axle beam, and the results were verified with the finite element method which was graphical stress investigation. Reference [8] start numerical and empirical analyzing on front axle of a tractor, according to obtained results by finite element method the redesign for frontal axle was done to reduce weight, improvement and fabrication. Five different models were proposed based on ease of production and weight reduction. The results were obtained on the basis of finite element method and analysis was on the basis of different methods which led to 13 test certificates. Empirical and numerical methods were used to change the design from casting to coating based on welding [9]. Reference [5] worked on stress analysis of front axle of John Deere 955 combine under static loading conditions and they used the commercial finite element package Ansys version 9.0 and reported that the calculated value of safety factor is very low and the front axle of John Deere 955 combine isn't strong enough to be installed on the modified combine. Using generic package ANSYS version 9, it is done to analyze accurate load for connecting rod in MF285 tractor under finite element method [11].

Since the highest engagement and contact and also increasing fuel pressure for injection are done by 5 parts of this pump including rotor, roller, internal cam ring, pole shoe and plunger. These parts are influenced by tensions and loads which are main factor in their abrasion and destruction as the highest abrasions will be related to internal cam ring. So this study analyzes these parts and applied tensions on them.

II. MATERIALS AND METHOD

The solution of decreasing abrasion of internal parts in injector pump, it is required to know completely pump, internal parts and their mechanisms. To do this, at first total pump was designed by SolidWorks 2012 software (Fig. 1).

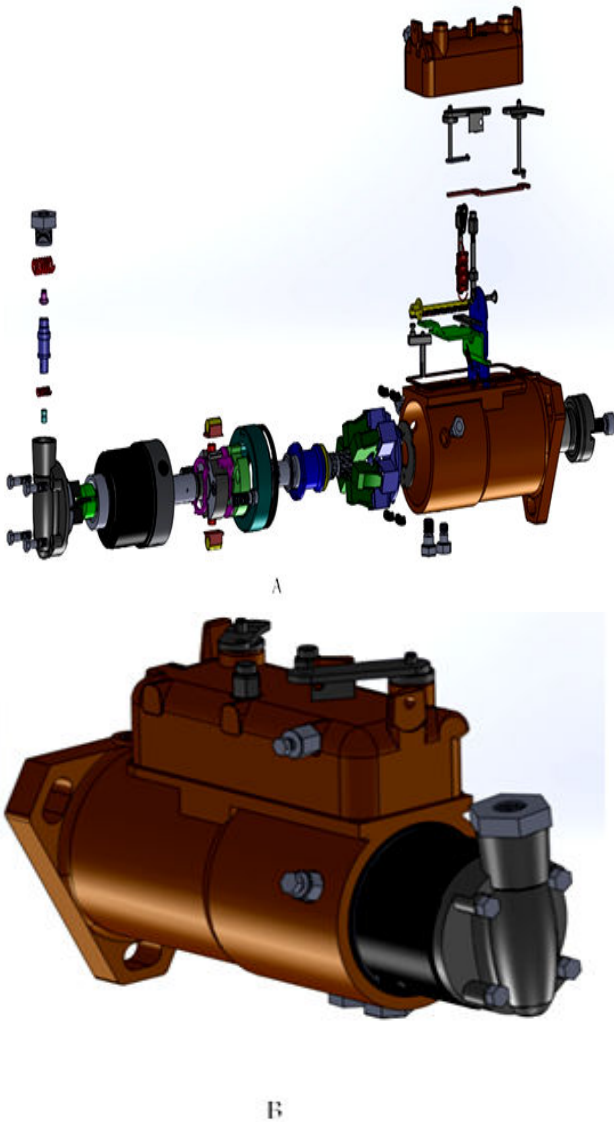


Fig. 1 Rotary injector pump A: Detailed image, B: The overall image

Figs. 2 and 3 show the total relationship of rotor, roller, internal cam ring, pole shoe and plunger in injector pump in MF285 tractor and their performance.

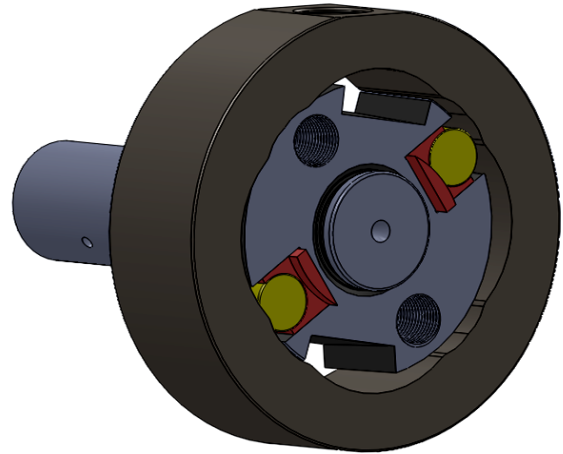


Fig. 2 Arrangement of rotor, roller and internal cam ring

Explosive image of parts has been shown in Fig. 3.

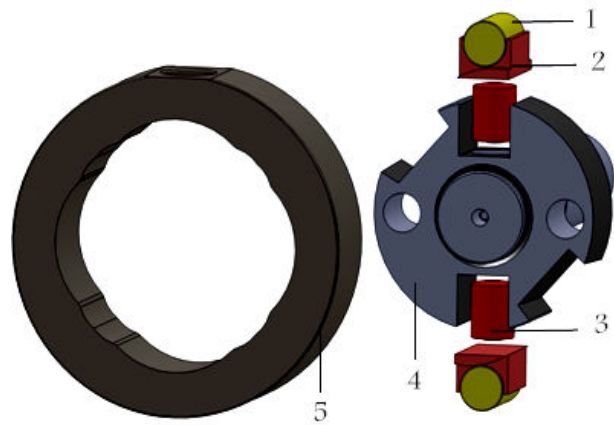


Fig. 3 Detailed image of rotor, roller and internal cam ring 1- Roller 2- Pole shoe 3- Plunger 4- Rotor 5- Internal cam ring

Internal cam ring is placed into pump case and attached to hull by bolt and fixed without movement and rotation. According to Fig. 2, rotor and other mounted parts on rotor including plunger, pole shoe and cylinder rollers rotate into internal cam ring, so that in effect of turning rotor, cylinder rollers also turn on internal surface of internal cam ring. Rotor is moved by splines on drive shaft [1]. The movement of roller on internal surface of internal cam ring and passing it on dents and flanges of internal cam ring lead to recede plungers from each other (suction course) and approach plungers to each other (pressure course) respectively, [2].

A. Suction Course

During suction, plungers are opened from each other in effect of fuel pressure and the case between two plungers is filled in fuel [4]. In this state, rollers are connected with dents in internal cam ring (Fig. 4).

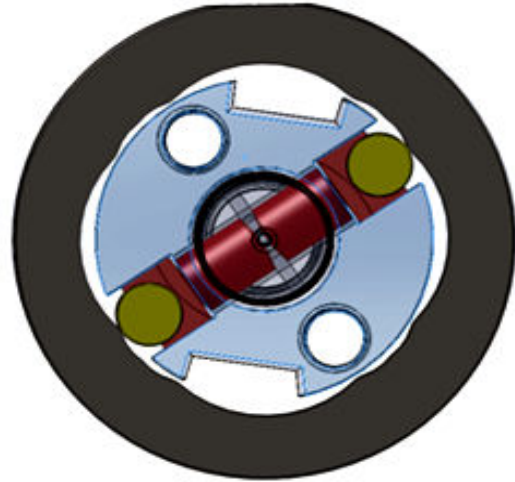
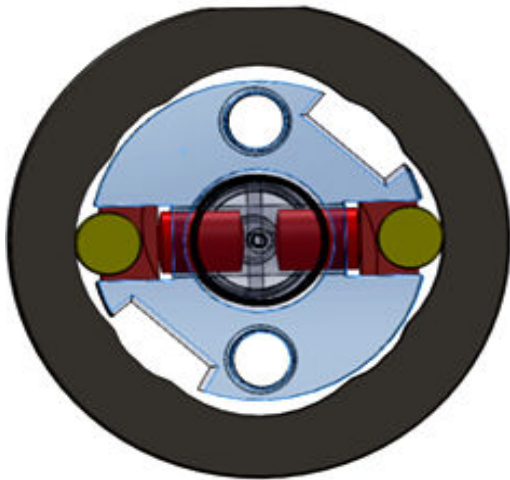
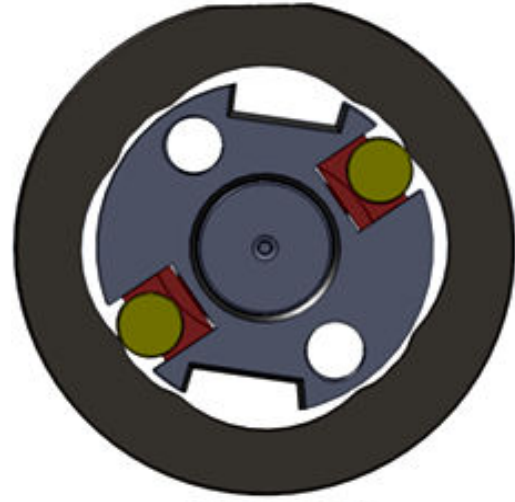
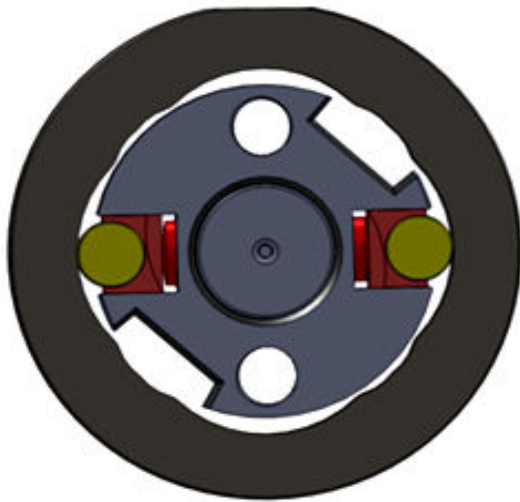


Fig. 4 Suction course (roller in contact with dents of internal cam ring)

Fig. 5 Pressure course (rollers in connecting with dents of internal cam ring)

B. Pressure Courses

With turning rotor and in effect of connecting rollers with dents of internal cam ring, plunger is pressed inward and transmits fuel outward with increasing fuel pressure [4] (Fig. 5). Pole shoes have drawer move in rotor and perform tappet action between rollers and plungers [2].

As can be seen in Fig. 5, rollers are in connect with internal cam ring and in addition to bearing the pressure due to being pressed fuel, they are eroded because of turning rotor of rollers on internal cam ring. This abrasion leads to erode gradually dents on internal cam ring and rollers. If no attention and timely replacement, it can cause severe problems in pump function and fueling to engine. Because most internal parts in MF 285 injector pump are delicate and sensitive and they are made and designed with high accuracy, there is no possibility of repairing them and repairmen often replace worn or damaged parts. As for interconnection of parts in a pump and their influence on each other, failure of a part can cause to make problems for all other parts and cause heavy losses. So the best solution is servicing regularly continuously pump.

Many of internal parts in MF 285 injector pump are mobile and subjected to static and dynamic loads. This study reviews only applied static load in a moment. Because the goal of this study is determining the highest applied stress to parts, so it is considered at the moment when the maximum load is applied.

C. Static Loads

Nominal round of MF285 tractor engine was selected in this study that equals to 2000 rpm [11]. Because drive shaft of MF285 injector pump turns with half rotational speed of crankshaft, then rotational speed of drive shaft in injector pump is 1000 rpm. The maximum bearable pressure of 60 MPa equals to 600 bar in this pump. Plunger has 9mm diameter in this pump and needed energy for any fuel injection by this plunger type equals to 6 J. Because MF285 tractor has 4 cylinders, and then needed torque for this process is 24 N.m based on mentioned information [3]. So in this analysis, the maximum applied pressure is 60 MPa and torque in nominal round of engine is 24 N.m.

D. Material Properties

Reviewed and mentioned elements are made from St 1.7262 (15CrMo5) [12]. This alloy has high resistance against abrasion. The properties of this steel are provided in Table I.

TABLE I
 MATERIAL PROPERTIES OF ROTOR, ROLLERS AND INTERNAL RING

Characteristic	Value	Unit
Young's modulus	E=210000	MPa
Poisson's ratio	ν=0.3	-
Density	ρ=7830	kg/m ³
Yield stress	σ _y =590	MPa
Tensile Strength	σ=780	MPa
Young's modulus	E=210000	MPa
Poisson's ratio	ν=0.3	-
Density	ρ=7830	kg/m ³

E. Analysis

One of the analysis applications with finite element method is ANSYS generic package version 11 that it was used to solve this problem. For reducing analysis time, simplification has been done on model structure such as removing threads related to rotor and internal cam ring. It does not cause any effect on the analysis. In this analysis, internal cam ring is fixed to hull and it has not any movement. As for rotor rotation, rollers move and slide on internal surface of internal cam ring. Torque and applied load was provided and 3D model was drawn with considering the elements (Fig. 6). Average size of elements used is 4mm in analysis. While model size is limited, there are 65299 elements and 114979 nodes in it.

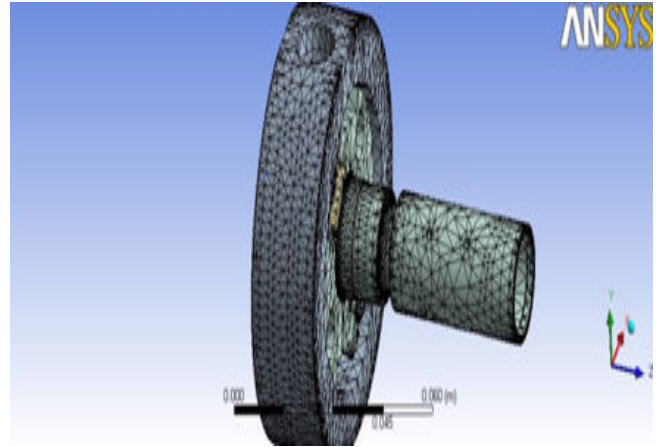


Fig. 6 Three dimension model of rotor, rollers and internal cam ring in ANSYS 11 software

III. RESULTS AND DISCUSSION

Where the maximum stress is applied, if piece be fragile, it will break. That is why designers are usually interested to know how much maximum yield strength is. Finally it will break, because after yield strength and the permanent deformation of piece toward failure. This theory is called distortion-energy. It was introduced by Von-Mises about flexible material in 1989 [13]. Von-Mises' stress is calculated by following equation:

$$\sigma' = \left[\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2}{2} \right]^{1/2} \quad (1)$$

In (1), σ_1 , σ_2 and σ_3 equal applied main stresses on three main axes.

According to distortion-energy, when allowable stress equals to yield stress, failure phenomenon will occur. So safety factor can be calculated by (2) via dividing yield limit stress on maximum Von-Mises' stress [13].

$$n_d = \frac{S}{\tau} \quad (2)$$

where, S= strength to fail, τ = allowable stress

Figs. 7 and 8 shows the earned results of analysis by ANSYS 11.

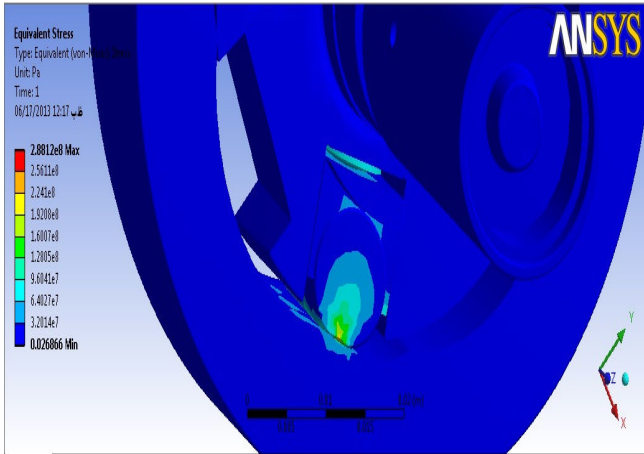


Fig. 7 Stress in contact surface of roller and internal cam ring

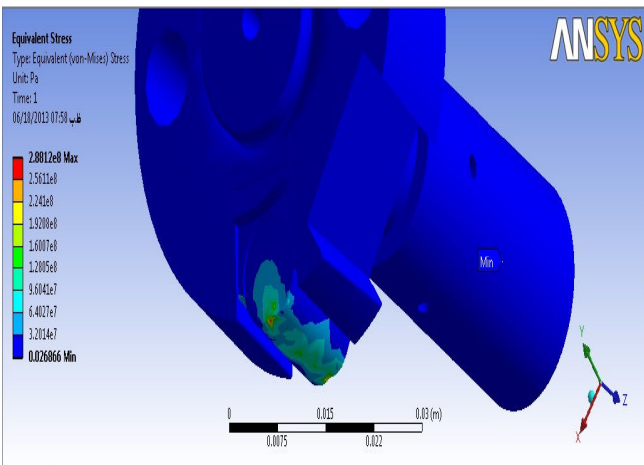


Fig. 8 Maximum stress in contact surface of roller

As can be seen from the figures, there is the maximum stress in contact surface of roller and internal cam ring and on roller surface. The maximum amount of this stress is 288.12 MPa. According to conducted analyses, the minimum value for safety factor is related to roller surface and it equals to 2.0477.

IV. CONCLUSION

In analyzing finite element method from mentioned internal parts in pump under static loading condition, it was found that the minimum value of safety factor is related to contact surface of roller and internal cam ring, especially on roller surface. According to experimental results in repair shops and service centers, the most abrasion and part replacement in injector pump of MF285 is related to rollers and internal cam ring. The earned results from analyzing by software confirm this problem. In fact, the maximum provided stress in these two parts cause to wear them. But according to very high price of internal cam ring than roller, it is recommended that roller is built from the alloy has lower resistance against abrasion than resistance against abrasion related to internal cam ring. Because this causes roller erodes more than internal cam ring that has more price than it. Consequently the life time of

expensive and incorrigible internal cam ring will increase. Of course, the rate of change in roller alloy should be to some extent to disrupt in fueling and its function. It also is recommended that pump and its internal parts are maintained continuously and regularly and its possible defects are removed in the first place to avoid spreading problem to other parts.

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