Influence of tightening screws process in high-pressure injection pump

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Abstract. The high-pressure pump is a component of the automotive common-rail system and has as main assemblies: housing, driveshaft, gaskets and front plate. Literature presents analyses of the threaded fastening assemblies, especially for those with the critical joints with screws, those involving torque and angle. The assembly process that we have studied performs the sealing of the components with the gasket through the screws, thus preventing the fuel from leaking from the pump. Our paper presents an analysis of the influence of the tightening process with screws of the housing, gasket and front plate. The experiment was conducted using the Zeiss measuring system and the screwdriver Janome. The tests analysis demonstrates that screwing process can influence the distortion.

1. Introduction
The development of the automotive industry in the last two decades evidences that the large automotive manufacturers using the direct injection have tried to offer and improve the advantages of the common-rail system in order not to lose „land” against electric cars and gasoline.

With the help of an experimental testing platform the actual dimensions and conditions of a motor-mounted pump are simulated. It has been observed that certain pumps cannot be mounted on the engine due to the distortion of the front plate nose. The distortion produced is a deviation from the original form of the component, a deformation performed only in certain conditions. As result, the sealing of the pump on the motor is impossible; it has a negative effect on the correct pump assembly.

The literature describes a series of analyses on the tightening process of assemblies using screws for threaded joints. The influence of the assembly process has been studied by different researchers from the literature. Therefore, investigations concerning mechanical, fastening, joining and assembly components using screws, the relaxation of high-strength screws on the sliding surfaces of bolt connections were developed [1-5].

Our paper presents a detailed analysis of the influence of the tightening process of the housing, gasket and front plate.

2. Constructive considerations
The high pressure pump components and the way are threaded the screws are depicted in figure 1. The connection between the front plate and the housing is a complex mechanical system, that is why the gasket of the pump must be selected and assembled in the most appropriate way to ensure the uniform
sealing. All components of this pump play a very important role for its proper operation. The design, manufacture and assembly of components play a very important role because the connections between the front plate and the housing influence the correct operation of the pump [6-9].

There are two categories of threaded assemblies, removable and not removable, and we can say that the removable ones are the most common nowadays. The advantages of the removable assemblies are given by the fact that, you can disassemble the parts without producing wear or damage to them [10].

![Figure 1. The components of an injection pump and the way are threaded the screws.](image)

The threaded assemblies shown in figure 2 are the most widespread removable assemblies. These normally have at least two pieces with thread and the third with or without thread. The fastener is marked with A (A1 is the bolt, A2 are the washers, A3 is the nut), then B is the flange and C is the gasket [3].

![Figure 2. The connections made by the flange-front plate.](image)

A major disadvantage of the pieces involved is that the surfaces are partial and without uniformity. Figure 3 suggests that the force applied to the screws is not evenly distributed over the entire surface. This is due to the fact that we do not have the same angle between the holes of the front plate, we do not have the same thickness of material on the entire surface of the front plate [11-12].
In the literature, the deforming of the gasket and the front plate is presented as the result of the uneven distribution of the bolt-screwing moment. We can say that the process of screwing influences the distortion occurring in the pumps and also the way in which the gasket is distorted [5]. Influence of the tightening process of the housing, gasket and front plate is the focus of our study.

![Image](image1.png)

**Figure 3.** Forces on the front plate and the gasket [5].

In the category of assembled organs are also screw parts that can be of different types. The most used are those with hex head and total thread, hex head screws and partial thread, round head screws and self-tapping screws [3],[13]. The thread represents the surface left by a profile (square, trapezoid, circular, triangular) on a cylinder or body for the axial displacement of this profile. Figure 4 presents information about the most stressed areas of the hex bolts involved in the front plate-gasket assembly process.

![Image](image2.png)

**Figure 4.** Highly stressed areas of screw [3].

From the concept phase each screw must have a high resistance and their functional role is to tighten, adjust, and transform the rotating motion into axial motion or vice versa.

The supplier for the screw provides different diagrams for inch and metric threads and table 1 shows that the M11 screw has a good size for load and stress [3],[14].
Table 1. Metric Series Screws (Preferred Pitch) [3].

| Nominal size | Stress area (mm²) | Pitch (mm) |
|--------------|------------------|------------|
| M5           | 14.20            | 0.8        |
| M8           | 36.60            | 1.25       |
| M10          | 58.00            | 1.50       |
| M12          | 84.30            | 1.75       |
| M16          | 157.00           | 2.0        |
| M20          | 245.00           | 2.5        |
| M24          | 353.00           | 3.0        |

3. Results and discussion
The tightening process was studied in two sequences, using a different order of tightening, as in figure 5. The experiment was carried out using the Janome screw drivers. Janome Electric screwdrivers are commonly used among all the tightening tools because are driven by an electric motor. With these screwdrivers we are able to record the values of the torque and angle for each screw. We can also put a maximum value to be reached by the screwdriver. Angle changes may affect the screw torque and ultimate preload. The screwdrivers have their applicability in industrial assemblies.

In order to have a wider visibility on the distortion created by the threading, we decided to plot all the screws values in terms of torque and angle within acceptable limits.

From the analysis of the recorded torque values we observe that a small population is below the limit accepted after the first variant of the tightening (figure 6). In this figure, the final torques for the first screwing variant from figure 5(a) is denoted with: Screw 1 NP, Screw 2 NP, and Screw 3 NP. The other notations from figure 6 (Screw 1 Test, Screw 2 Test and Screw 3 Test) represent the final torques for modified screwing sequence depicted in figure 5(b).

The torque values recorded by the screwdriver for the screw 3 are between and below the limits. The value of screw 3 is close and even in the acceptable limit while for the other two screws they fall outside the limit. It can be seen how the angle values for screw 3 are slightly higher than the other values.

From the analysis of the angle values we observe that a small amount of values are above the average values in the case of the second version of tightening. This is the conclusion analyzing the angle values depicted in figure 7. In this figure, Screw 1 NP, 2 NP, 3 NP represents the final angles for the first screw variant from figure 5(a) and Screw 1 Test, 2 Test, 3 Test represent the final angles for the modified screw sequence presented in figure 5(b).
Figure 6. Torque values for both threading variants.

Figure 7. Angle values for both threading variants.
The forces applied to screws are not uniformly distributed due to geometry of components and their dimensions. To demonstrate that screwing process can influence the distortion created measurements on two pumps with Zeiss measurements system are realized. Figure 8 presents the distortions created. The Section 3 max (denoted from this figure) is the most affected area because it has the smallest wall thickness.

Figure 8. Distortions created on two pumps.

4. Conclusions
Due to the fact that during assembly there is a series of distortions on the components we analyzed the impact of the tightening order with the screws. The tests were conducted on several injection pumps provided by different suppliers to identify if there are differences. Initial torque and angle values for section 3 (the thinnest) have shown that they are not centred in the middle, within the limits, as the values for the other sections are. Concerning the torque recorded for these screws, the value of screw 3 is in the acceptable limit while for the other two screws they fall outside the limit. From the analysis of the angle values it is resulting that a small population is above the average values for the second version of tightening. Considering the results obtained for the initial tightening sequence and the modified sequence, we can say that the current tightening variant remains more feasible because the modified variant has values outside the acceptable limits.

5. References
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