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Comparison of two sealing coupling geometries for a direct fuel injector

Francesca Di Puccio[a,*], Enrico Ciulli[a], Raffaele Squarcini[b]

[a]Department of Mechanical Nuclear and Production Engineering, University of Pisa, via Diotisalvi 2, 56126 Pisa, Italy
[b]Siemens Automotive VDO, Via Aurelia Sud, 56121 S. Piero a Grado (PI), Italy

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Abstract

The present paper describes some Finite Elements simulations carried out in order to investigate the contact problem in the sealing region of a direct fuel injector. In particular two different design solutions have been analyzed, both patent pending, one characterized by a conformal contact of two conic surfaces and the other one by a non-conformal contact between a cone and a sphere. Pressure distribution, contact width and von Mises equivalent stress have been calculated and employed as comparison parameters. Two different loading conditions have been considered: nominal loads and nominal loads plus undesired effects. Also deviations from the nominal geometry, obtained from profile detection of 40 samples, have been introduced for considering a real-like case. Numerical results stress the robustness of the non-conformal solution with respect to geometrical tolerances and real loading conditions.

Keywords: Automotive tribology; Finite element method; Sealing couping; Fuel injector

1. Introduction

Seal design is a very specific topic and is generally developed for each application, e.g. labyrinth seals in turbines, rubber seals in pressure vessels etc. Although there is a wide literature about seals in automotive applications [1–2], only a few papers can be referred to the case of seals for direct fuel injectors, which are metal on metal seals [3–4]. The peculiarity of this application is due to the extreme working condition that is high pressure and presence of an aggressive fluid such as gasoline. In addition, the sealing surface takes part to the generation of the spray, which is a fundamental feature for direct fuel injectors [5].

This study presents a comparison based on Finite Elements (FE) analyses of two different design solutions: one characterized by a conformal contact of two conic surfaces and a new model with a non-conformal contact between a cone and a sphere. Both geometries have been provided by Siemens VDO and are patent pending. No numerical data are shown since strictly confidential.

* Corresponding author. Tel.: +39 050 836676; fax: +30 050 836665.
E-mail address: dipuccio@ing.unipi.it (F. Di Puccio).

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2. Injector description

The direct fuel injector is a complex mechanical element, with a double function:

- *inlet phase*: to provide the combustion chamber with a definite quantity of gasoline (order of tenths of micrograms for each injection), in a proper spray shape and at the frequency required by the engine ($\sim 10^3$–10^4 s^{-1});
- *other phases of the engine cycle*: to keep the fuel, pressurized at 200 atm, separated from the combustion chamber.

The part of the injector under examination is the tip portion exposed to the combustion chamber, schematically drawn in Fig. 1a. Two elements act in this region: the cartridge and the needle inside, both made of AISI 440 steel, quenched and annealed; a special treatment makes the needle harder reaching HRC56 while the cartridge has HRC52.

In the inlet phase, a piezoelectric actuator moves the needle downwards and the fuel is sprayed in the combustion chamber; the stroke of the needle, about few tenths of microns, is calibrated to provide the required quantity of fuel, therefore, is a very important parameter for the performance of the injector. The needle is pulled back by a spring, that keeps it closed against the cartridge with

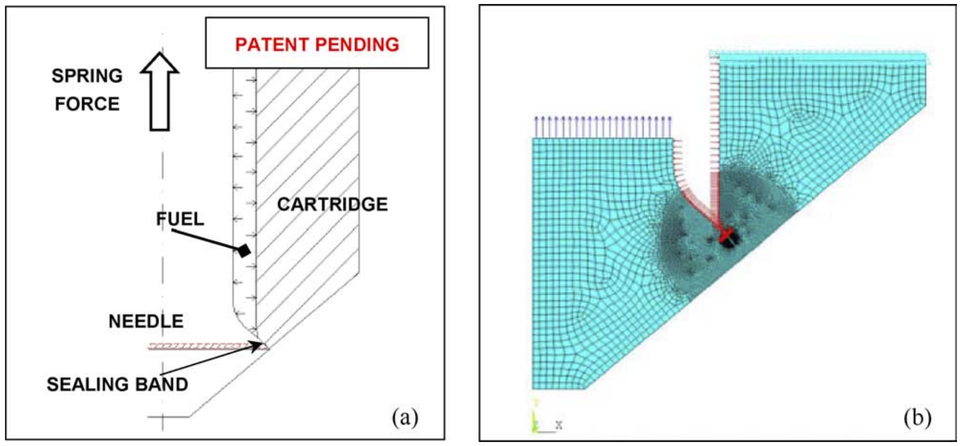

Fig. 1. Scheme of the injector tip (a) and FE model (b).

a force of several tenths of Newtons. The level of this force must be high enough for satisfying the sealing function, but on the other side it is limited by the fact that it causes a pre-elongation of the needle that, when recovered in the inlet phase, reduces its effective stroke. The area where the cartridge and the needle are in contact is denoted 'sealing band', approximately corresponding to an annulus with an inner radius of about 1 mm and a thickness of about 0.1 mm. It maybe worth noting that, in the two designs under examination, the cartridge inner surface has always a conical shape, while the needle outer surface can be conical or spherical.

3. Preliminary tribological investigation

As detailed in [6], in a previous study the sealing surfaces of the cone-cone design were observed by means of a Scanning Electron Microscope. The investigation was focused on the identification of leakage causes related to surfaces texture both at 0 h, as determined by the manufacturing process, and after tests, due to changes produced by the run-in or by wear effects. As an example, two cases are shown in Fig. 2: the first row corresponds to a needle-cartridge pair at 0 h while the second row refers to a pair examined after a 300 h run. It can be observed that

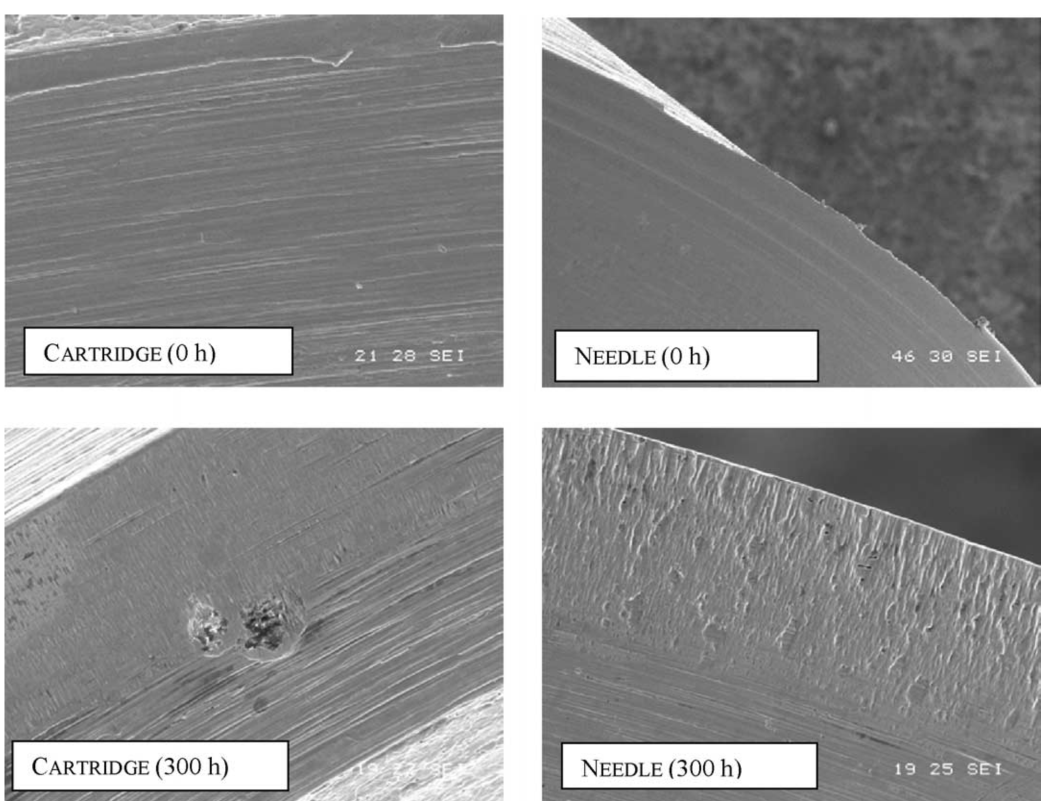

Fig. 2. SEM images of the sealing band surfaces.