Abstract— Ventricular assist devices are a technological solution for patients who suffer from cardiac insufficiency and await a transplant. In this work, a new design of an implantable pulsatile blood pump is analyzed in terms of blood damage, by means of finite elements on a simplified geometry. It is a double effect volumetric pump, which has a non-contact driven piston and four active valves. The analysis is done by means of blood flow simulation into the pump and the prediction of platelets activation. The last is a measure of the pump compatibility with human life.

The platelet activation state is evaluated by an equivalent or representative shear stress and compared with bibliographic data corresponding to other VAD kinds and cardiac prosthetic valves. The results show that, for the complementary blood flow rate supplied by the simulated VAD, the predicted platelet damage is in the same levels of current cardiac devices, particularly other VADs.

Keywords— Ventricular assist device, blood damage, platelet activation, pulsatile flow.

I. INTRODUCTION

Ventricular assist devices (VADs) are pumps that work in parallel with heart, pumping blood from the left ventricle to the aorta. They are used as a temporary solution for patients awaiting heart transplant, or as final therapy when heart replacement is not possible. The VAD’s function is to restore the physiologic flow helping the insufficient heart. Implantable VADs allow long term care with life quality improvement for patients, allowing them to do some normal activities.

Blood damage (BD) is one of the most significant aspects for the design and operation of VADs, the BD is caused mainly by shear stress acting on red blood cells (RBC) and platelets (PL). High shear stresses and the rate at which they are applied are the causes of platelet activation (PA) and hemolysis (H). These phenomena can trigger the coagulation cascade and produce a thrombogenic event that, in some cases, can produce death. Thus, it is necessary to limit PA and H, for wich VADs always require in vitro tests before in vivo use. Due to the cost of tests, computer simulations are a useful predictive tool before them.

The undesired effects of PA and H are also caused by prosthetic mechanical heart valves (MIV) and other devices. In this sense, two indexes are used to evaluate the performance of the VADs: the normalized index of hemolysis called NIH, which is standardized by the American Society for Testing and Materials (ASTM); and the rate of platelet activation called PAS, based on chemically modified prothrombinase test, proposed by Jesty and Bluestein (1999).

Hemolysis and platelet activation are complex processes because they depend on physical, chemical and physiological factors, but the shear stress is the main cause from the mechanical standpoint. Alemu and Bluestein (2007) described that while the RBCs resist 150 to 250 Pa for 100 seconds, the PLs resist 10 to 30 Pa in the same period of time. Since a decade ago computer simulations of blood flow into devices are used to predict the level of NIH and PAS based on the shear stresses (Alemu and Bluestein, 2007; Nobili et al., 2008).

In this work, PA of blood flowing into a VAD, designed as a pulsatile pump based on a double effect piston, was analysed. For this purpose and due to the high computational cost, blood flow was simulated in a simplified 2D configuration. As shown in a previous work (Di Paolo et al., 2014), this preliminary VAD geometry has many advantageous flow features, such as relative low velocities and very short-time vortices, that could preserve blood from both hemolisis and thrombosis. This assumption is reinforced here, because the results from cumulative damage model on platelets show that the device would produce flow conditions of low intensity interaction with blood, allowing long term use.

II. METHODS

A. VAD’s description

The simulated VAD is a double effect volumetric pump. It consists of a piston which is driven via electromagnetic way (not simulated here), a left (LC) and a right (RC) chamber, two inlet (IV) and two output (OV) active valves as depicted in Fig. 1. The piston moves in one direction (x) with sinusoidal displacements and each piston stroke is used to pump fluid in one chamber and fills the other in alternating way. Between the chamber walls and the piston there is a small gap of 100 μm, which is supposed constant, i.e. the piston is mantained in y position by a magnetic field without contact. At the same time, this magnetic field is supposed to be the driven force to move the piston along x axis. The opening and closing of the valves is