FAMU-FSU COLLEGE OF ENGINEERING

SENIOR DESIGN I – EML 4551

DELIVERABLE: MID-TERM REPORT

MECHANICAL DUMP VALVE – TEAM 3

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1.0 – Project Overview

1.1 Introduction

Cummins Inc Fuel Systems XPI (extreme pressure injection) department currently has an MDV (mechanical dump valve) operating in all their common rails as a mean of safely relieving the pressure in the rail in case of over pressurization. This valve is dormant while the rail pressure is within the limits desired for the engine and while the pressure sensor is able to regulate the fuel flow into the rail. In case of a failure of the pressure sensor the ECM (engine control module) has no way of telling the IMV (inlet metering valve) how much fuel it needs to allow to get pumped into the common rail, in which case over pressurization could happen. As a safety back up, a purely mechanical valve is installed on the common rail. The function of this valve is to allow the fuel out of the rail and therefore reduce the pressure within it, which ultimately avoids thermal events. The valve would then take over the system and act as a mechanical controller to regulate the amount of fuel in the common rail. The fuel the valve is relieving goes back into the fuel storage through a line to be reused. The common rail can be observed with the injectors in figure 1.

Figure 1. Common Rail

This MDV is durable, as well as reusable. The part is designed to reset once the engine is turned off. After the engine is turned back on, if the pressure sensor continues to fail the valve will once again begin to operate until the driver can get to a location where the sensor can be replaced. If the sensor is in working status the valve will be once again dormant until it is needed. The engineers at Cummins FS XPI wish to obtain a valve that continues to do these tasks but it is also more lightweight, more inexpensive, and with improved functions.

1.2 Problem Statement and Objective

There is a need for mechanically controlling the fuel pressure in a highly pressurized common rail diesel engine, as well as relieving the fuel in case of over pressurization. The means of achieving this should be inexpensive and the mechanical component should be lightweight and easy to install on an engine to allow for maintenance as well as easy replacement.

1.3 Non-Disclosure Agreement

A very important portion of this project is the Non-Disclosure Agreement (NDA). This NDA was created by Cummins Inc to prevent damages regarding intellectual property. If the product developed by the students meets the Technical Profile specifications and Cummins decides to manufacture it, the product will be patented. If the product is to be used by Cummins they will have to avoid competitors from using the new product as well. This creates the need for the project to be confidential and for the students to share no calculations results, data, dimensions, or prints with the public; for this reason any figures and data presented by this team are rough drawings and the data has been distorted to prevent confidential information share. Working around the NDA is one of the biggest challenges of this project.

1.4 Product Specification

As explained in the previous section, the exact values for the specifications of the product may not be disclosed in this document. Appendix A shows ranges of values that cover the specific constraints from the technical profile obtained. From these product specifications, the main constraints on the design are size and cost. The MDV will have to be installed in an existing location that has limited space. The cost of the existing valve that is used by Cummins Fuel Systems was given by the sponsors. In order for the new product to be considered it would have to be cheaper so this constraints the complexity and materials that can be used.

Another significant constraint is the way the MDV has to respond to the extreme pressures. As shown in Figure 2, the pressure inside the common rail should follow that behavior in case the pressure builds up. The MDV should start working when the pressure reaches P_1 which is in the range of 2400-2900 Bar. The MDV should regulate the pressure by bringing it down to P_2 which is defined as the Limp Home Pressure. The common rail should keep the P_2 pressure for an unlimited time, so that the engine can be taken to repair.

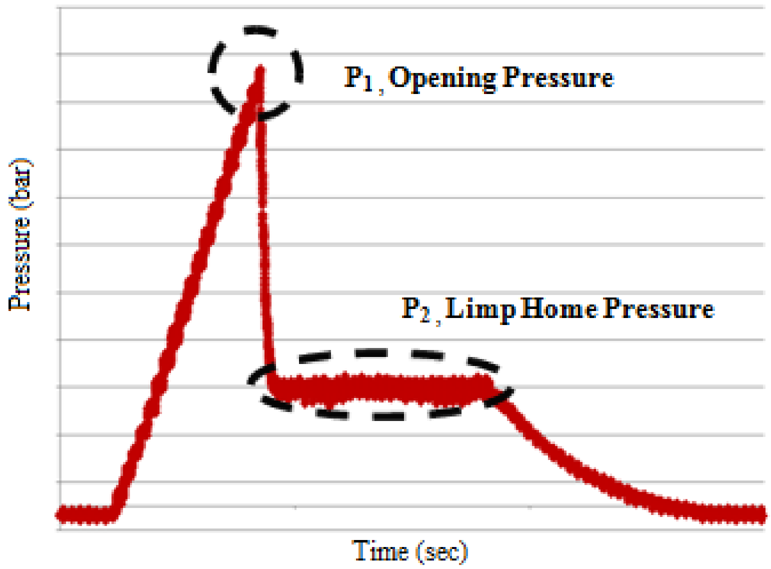


Figure 2. Desired Response of MDV

2.0 – Design Concepts

2.2 <u>Design Concept S</u>

The first design described in the project consists of two isolated spring systems. The lower spring system as shown in Figure 3 opens up (compresses) when the pressure in the common rail equals the Opening Pressure, as shown in Figure 2. As soon as the spring compresses, liquid will flow inside the lower compartment and the pressure will be acting on the entire surface area of the plunger, thus increasing the pressure force, as shown in Equation 1, where P equals pressure and A equals area. Since pressure force is much larger, the spring will remain compressed for the remaining time. The top spring is less stiff, however, the stiffness is to be calculated to match the force equivalent at the limp home pressure, so that it will uncompress as soon as pressure goes lower than limp home and then compress again as soon as the pressure increases. The design shows advantages in costs and simplicity. Both plungers would be the same material and the entire structure has no complicated shapes. The advantages and disadvantages compared to the other designs will be determined in order to decide the most appropriate design.

$F = P * A$ Equation 1

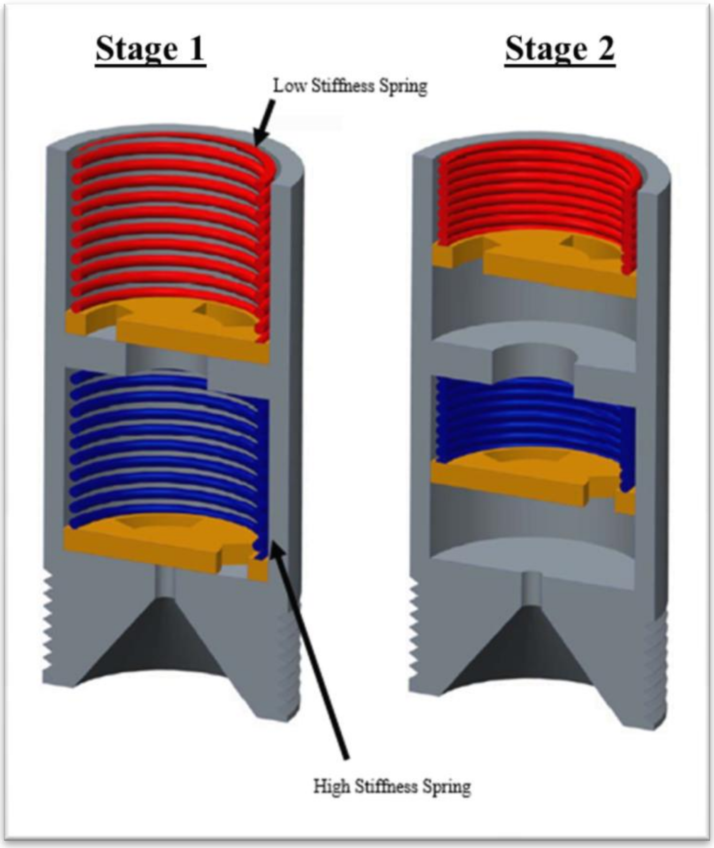


Figure 3. 2 Stages of Design Concept S

2.3 Design Concept D

This design is composed by a plunger and a spring inserted into the high-pressure seat casing. The smaller area A_1seats on the smaller cone (high-pressure seat) creating a seal as shown in Figure 4. The spring will be keeping the seal until the pressure buildup reaches P_1, which is the opening pressure. Once the opening pressure is reached the plunger will retract, compressing the spring. Once this first stage occurs the pressure will drop to P_2 which is the desired limp home pressure in stage 2 as shown in Figure 4. Also with this change, the area of interest has also changed to a larger A_2, the combination of the new pressure and area will maintain the valve open and in an oscillatory stage to meet and average desired limp home pressure. The flow will go around a small clearance around the cylindrical top area of the plunger. This design has some flaws, which include material restrictions due to high stresses, possible beating on the high-pressure seat due to impact could create a leak, and there could also be issues with the plunger not being centered correctly. Just as there are flaws there are various benefits to this design, since there are few components that are easy to machine and assemble the cost of production is decreased, also this design is relatively simple the mathematical/model analysis is not at difficult as with other designs.

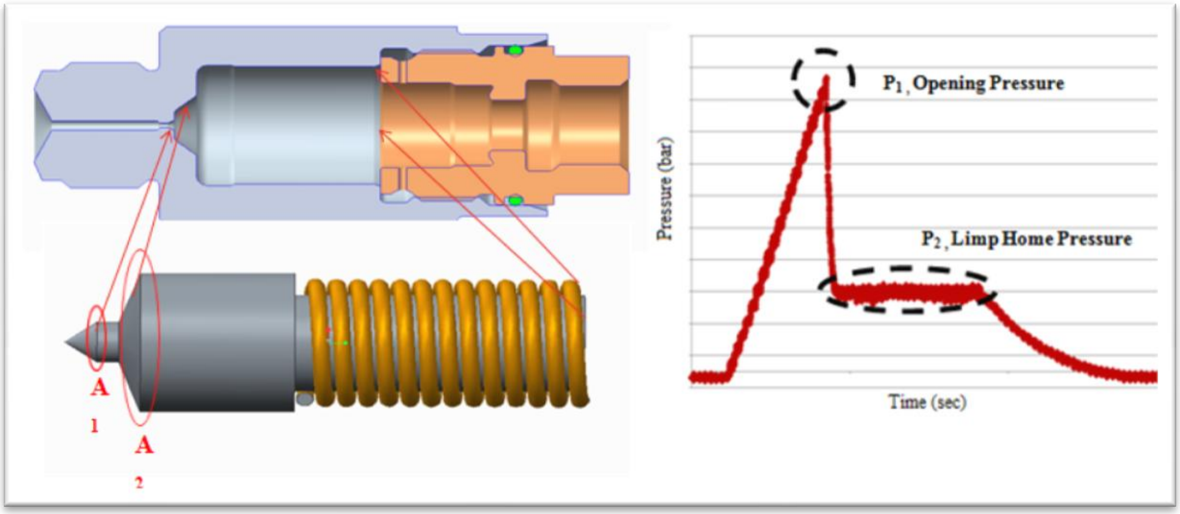


Figure 4. Design Concept D

2.4 Design Concept A

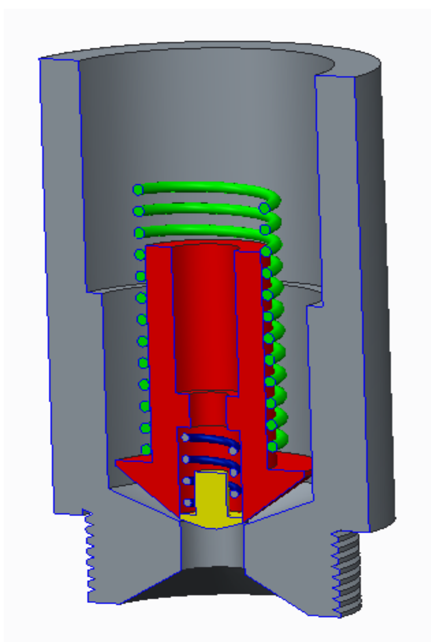


Figure 5. Design Concept A

Design concept A is a combination of both the previous designs. This design is composed by two plungers and two springs that work in conjunction to regulate the pressure within the common rail. The first plunger as shown in Figure 5 in yellow, has a spring that has a high enough spring constant to withstand the force of the fuel until it reaches the desired opening pressure P_1. Once the pressure has reached the desired value, the pressure will be released by the compression of the spring which will move the first plunger in the upward direction respectively. When this happens the force will decrease since the area has increased therefore decreasing the pressure to P_2 the limp home pressure. Next the second stage will be engaged. The first plunger will return into the second plunger, and this is going to regulate the limp home zone since the area has increased. With the second spring constant lower than the first will stay oscillating at this pressure and stay until the engine has turned off.

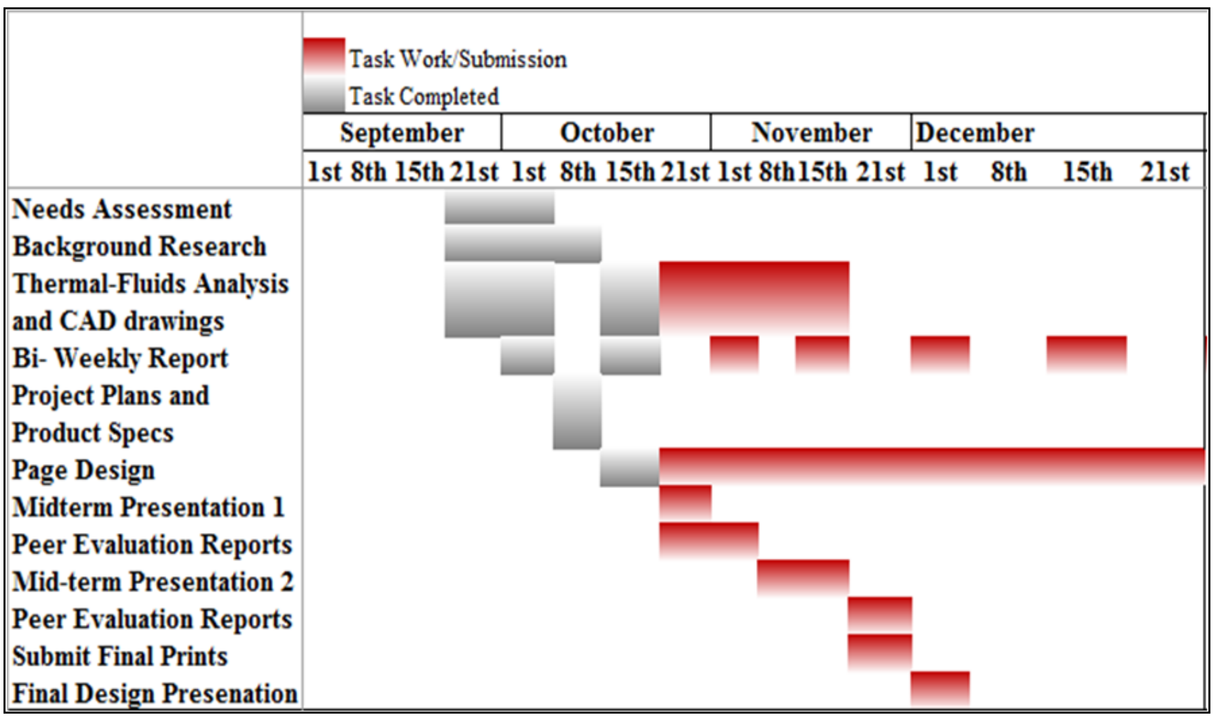
This design concept has it pros and cons. The good thing about this design is that it has two areas and two different spring constants that will make it easier for the mechanical dump valve to reach its desired valve. The spring constants and areas can be changed depending on what the calculations and the data simulation gives us. There are more cons than pros for this design. Since there are more parts it is one going to be more expensive to machine. Two there are going to be more modes of failures since there are more parts. Finally it's a complex design therefore repairs are going to be difficult, and if it is not perfectly machined it will not perform in the desired way it is supposed to.

3.0 – Future Work

3.1 <u>Gantt Chart</u>

The following Table shows the Gantt chart for the Fall semester. All the different tasks are up to date and the project is on track.

Table 1. Gantt Chart for Fall 2013



3.2 <u>Future Plans</u>

A complete full material, cost and patents analysis and other general background research has to be finalized. After the meeting with Cummins Fuel Systems in Columbus, IN, ideation and concept phase must be finalized. Also, a full design of a concept MDV that meets the specifications on the technical profile must be done. This includes thermal-fluids analysis and CAD drawings. Finally, prints must be submitted to Cummins so a prototype is machined. The testing of the MDV will occur on Spring 2014.

i. **References**

"Cummins Announces New Global Heavy-Duty Engine Platform." *Power Torque Magazine*. 20 Sept. 2013. 10 Oct. 2013. <http://www.motoringmatters.com.au/news/cummins-announces-new-global-heavy-duty-engine-platform>

"DieselNet: Diesel Engine Emissions Online." *DieselNet: Diesel Emissions Online*. N.p., n.d. Web. 10 Oct. 2013. <http://www.dieselnet.com/>.

Cummins Fuel Systems. <http://www.cummins.com/cmi/navigationAction.do?nodeId=7&siteId=1&menuId=1001>.

ii. **Appendix**

- Design Specifications
  - External Connection: M20 x 1.5-6g threads
  - Internal Drain Connection: M14 x 1.5-6g threads
  - Length: 30 – 60 mm
  - Sealing Pressure: 1.5 times operating pressure
  - Cost: <$26.00 per valve (Including man hours)
- Performance Specifications
  - Opening Pressure: 2400 – 2900 Bar
  - Limp Home Pressure Range: 200 – 1100 Bar between 0.15 L/min – 4.5 L/min flow rates
  - Minimum Limp Home Time: Unlimited.
  - Temperature Fluctuations: 100 – 200 °C