TRIBOLOGY PERSPECTIVE ON SEATBELT PRETENSIONING SYSTEM

Tribology perspective on seatbelt pretensioning mechanism

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Abstract: *This paper presents the factors and forces involved in the concept propulsion unit of a seatbelt pretensioning mechanism. The function and role of seatbelt pretensioning will be presented as an introduction, but the paper will focus on the propulsion from a tribology perspective focusing on the experiments and simulations performed to determine the factors of influence in this system.*

Keywords*: tribology, forces, lubricants, simulations, design of experiment*

1. Introduction

The pretensioning systems for seatbelts are designed to reduce the excess of webbing in the seatbelt system during and crash, this assures for a better fixing of the occupant in the seat, thus reducing the forward movement of the chest and the pelvis area. The system is presented in *figure 1*.

The evolution of pretensioning systems for the seatbelt has its roots in the need of automobile manufactures to constantly increase the performance, reduce the weight and overall size of the parts and also to avoid over engineering of all components used in the vehicle.

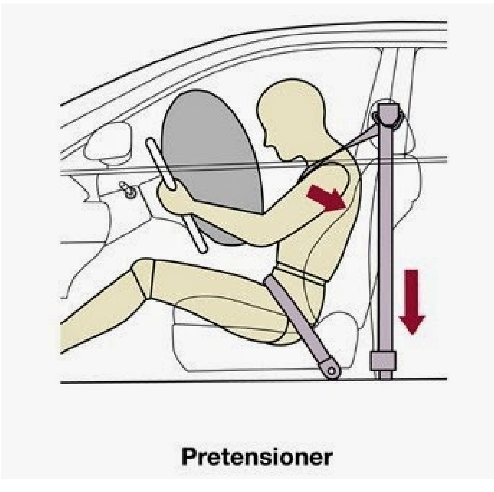

Fig.1. Pretensioning role during a car crash [3]

In the following chapters I will present a concept for the propulsion unit, this unit is activated by a gas generator which creates the necessary pressure on the surface of a piston in order to apply enough force on the seatbelt webbing to obtain the webbing excess reduction and improve the occupant positioning.

I will present the analysis performed on the mechanism using tests and simulations to be able to better understand the forces that are involved and improve the system.

2. Mechanism and function description

The pretensioning mechanism that will be discussed in this paper has two functions that can be investigated as individual entities, first we have the module that has to assure the restraint of the seatbelt webbing and it’s fixation to either the car body or the seat frame and secondly there is the part that assures the pretensioning function.

In *figure 2* the whole mechanism is presented and the two separate functions as shown above are shown. The focus in this paper will be on the forces and contacts that affect the pretensioning function in order to better understand the main causes for loosing energy in the system and to be able to further develop and improve the product.

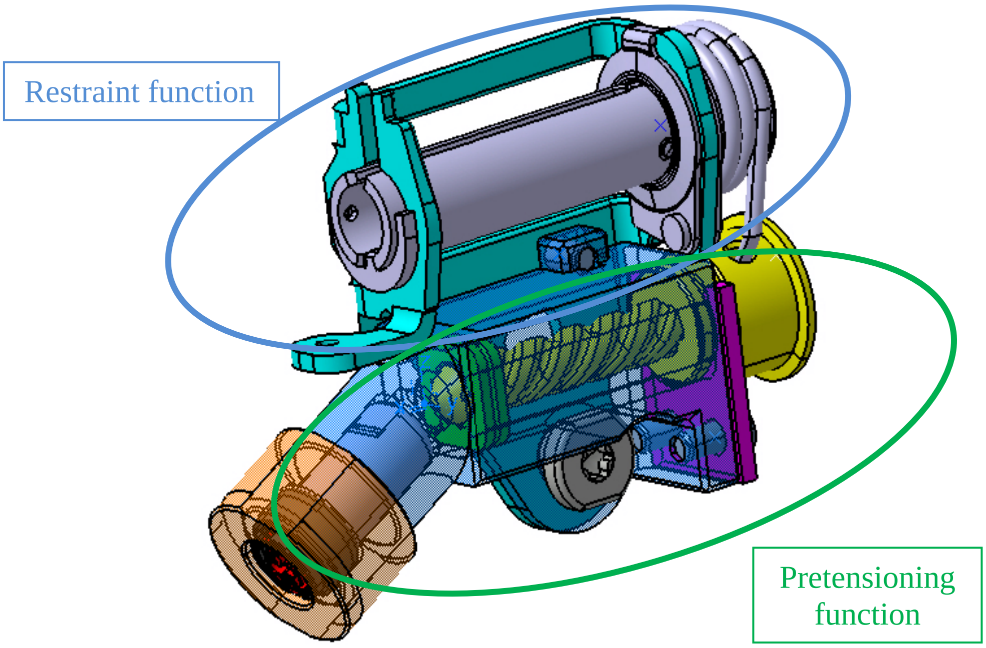

Fig.2. Pretensioning mechanism

The function of the mechanism as shown in *figure 3* is based on the pressure resulted from the gas generator is applied on the surface of the piston, this forces the piston to travel along the combustion chamber in a linear motion and using the thread on the inside acting like a nut and screw mechanism transforms the linear motion into revolutions of the spindle which in turn transmits this energy trough a cable to the webbing spindle.

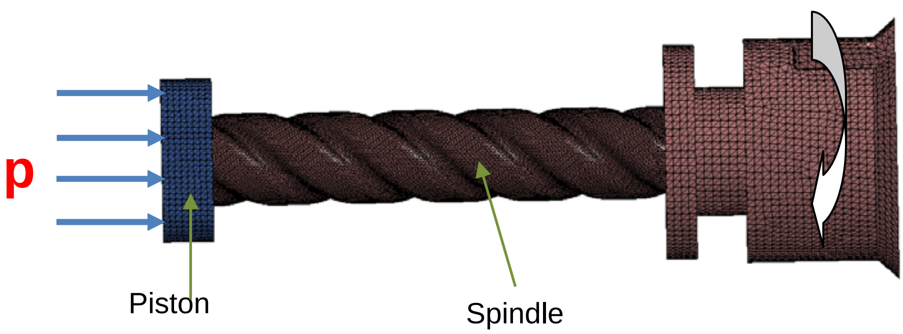

Fig.3. Function of system

3. Test description

The tests were performed on a machine as shown in *figure 4.* The purpose of the test was to measure the torque needed to rotate the spindle for 360º and move the piston.

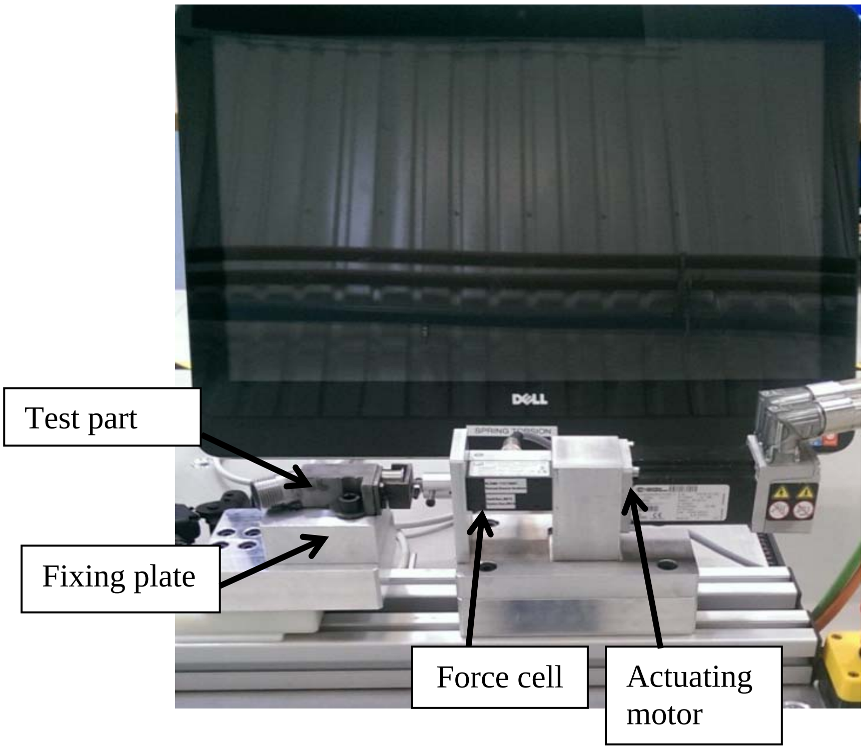

Fig.4. Test machine setup

To assure contact between all the parts I applied a force as shown in *figure 5.* The force applied was 50N and was limited by the recomanded maximum load on the force cell axis.

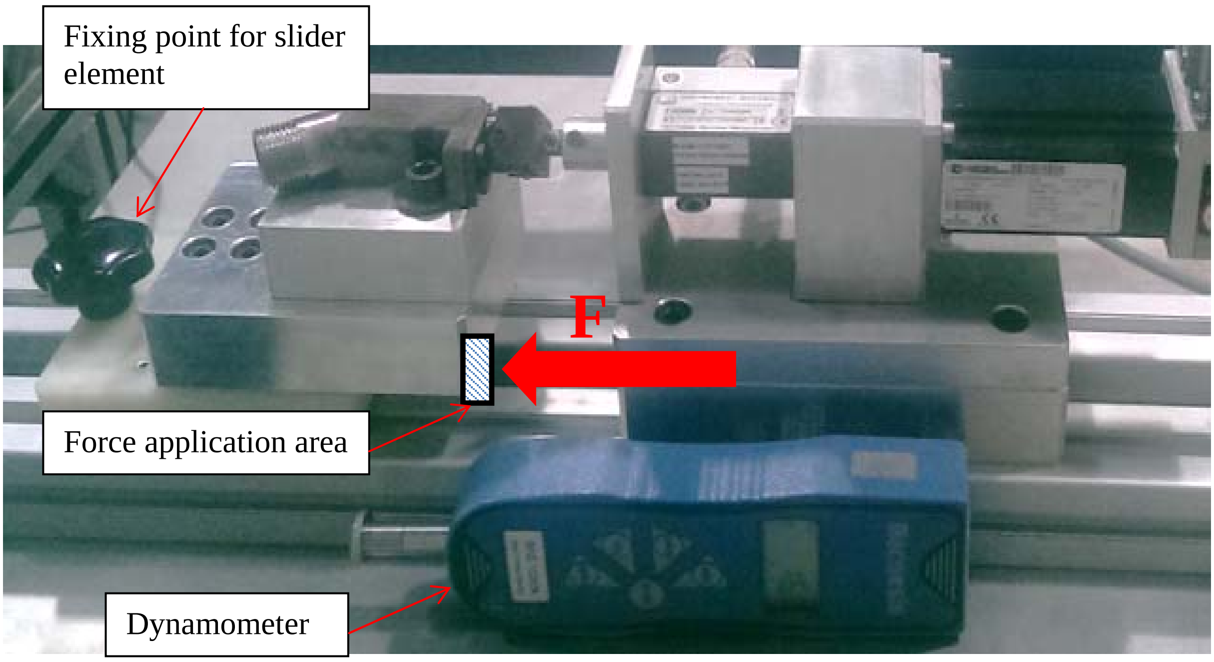

Fig.5. Force applied on the test part

For the test I used 4 different configurations as listed below and I did 10 trials with each variant.

1. Without any lubricant;
2. Lubricated using synthetic oil;
3. Lubricated with grease;
4. A version of the piston with different thread type and using grease as lubricant.

4. Test results and interpretation

Recorded data from the test is in the form of force overtime and I represented it in *graphic 6*, using NI DIAdem to create an overload of the data's obtained from all 4 tests.

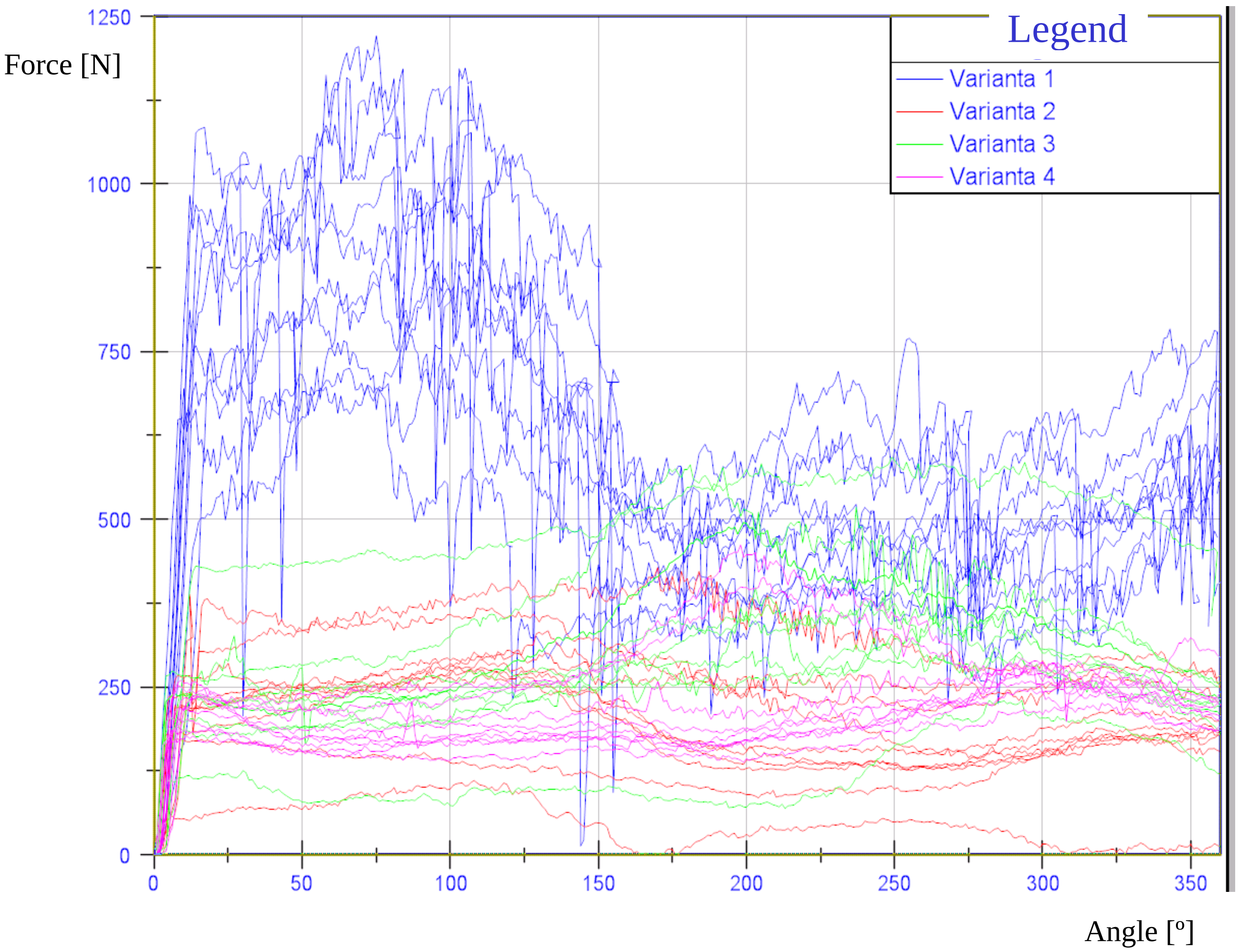

Fig.6. Overloaded graph of obtained data

For the statistical analysis I used the peek force obtained in each trial. The program used for this analysis was MiniTAB and I used it to create a boxplot of the forces to better observe the spread of the values, and a interval plot to be able to determine if there are any significant differences between the value sets, this two graphs are presented in *figures 7*.

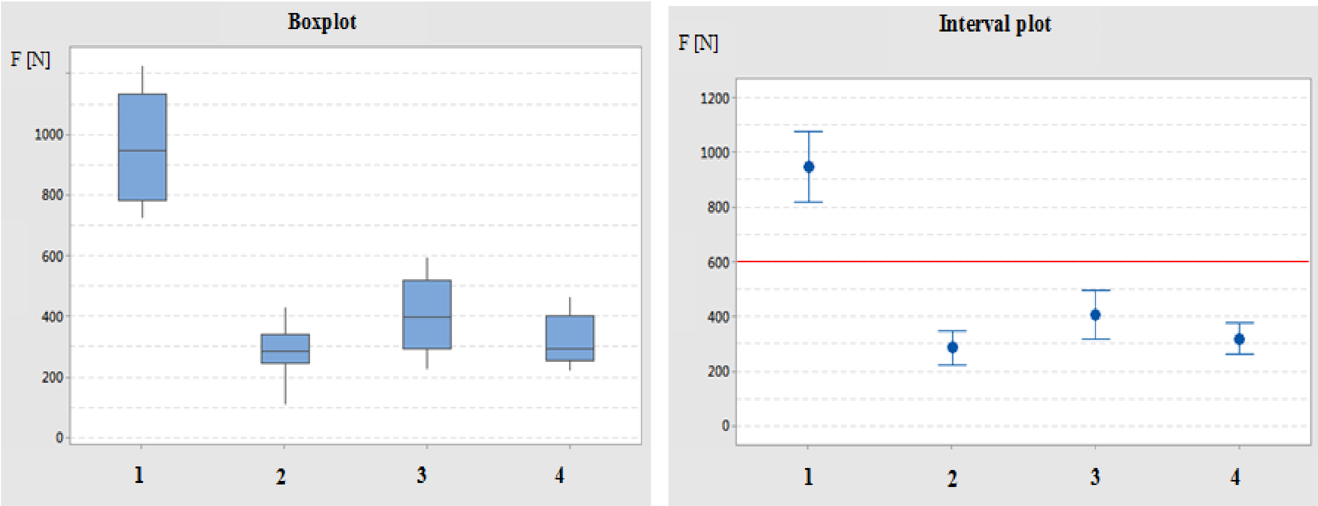

Fig.7. Boxplot and interval plot of maximum force obtained in each trial

The interval plot shows that there is a significant difference between variant 1 and the other 3 variants tested, so from this we can conclude that effect of using a lubricant in the system is a defining factor in order to reduce the forces needed to move the parts in the system.

In the interval plot no significant difference between the other 3 variants so a Two-sample T-test is need in order to see if there is a difference between the 3 sets of values. This test was also performed using MiniTAB. The test results re shown in *figure 8*.

This test is performed for two hypothesis H_0 and H_A. The H_0 (or null hypothesis) considers the data sets to no present any relations, be independent and the values are not different from each other. The H_A (alternative hypothesis) considers the data sets presenting relations, being dependent and the values are different from each other. If the resulting P value is below 0.05 there is a significant difference between the sets with a confidence interval of 95%. [2]

Two-Sample T-Test and CI: Varianta 3, Varianta 4

```
Two-sample T for Varianta 3 vs Varianta 4

                                 SE
              N   Mean  StDev  Mean
Varianta 3   10    406    125    40
Varianta 4   10  317.5   80.1    25


Difference = mu (Varianta 3) - mu (Varianta 4)
Estimate for difference:  88.5
95% CI for difference:  (-11.6, 188.6)
T-Test of difference = 0 (vs not =): T-Value = 1.88  P-Value = 0.079  DF = 15
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Two-Sample T-Test and CI: Varianta 2, Varianta 3

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Two-sample T for Varianta 2 vs Varianta 3

                                 SE
              N   Mean  StDev  Mean
Varianta 2   10  284.6   89.3    28
Varianta 3   10    406    125    40


Difference = mu (Varianta 2) - mu (Varianta 3)
Estimate for difference:  -121.4
95% CI for difference:  (-224.4, -18.4)
T-Test of difference = 0 (vs not =): T-Value = -2.50  P-Value = 0.024  DF = 16
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Fig.8. Two-sample T-test, variant 3 vs. 4 and variant 2 vs.3

The results of the Two-sample T-test shows that there is a significant difference between the two types of lubricant but there is no significant difference between the two types of piston.

5. Simulation of mechanism

A simulation can be performed on any system, the role of the simulations depends on the needs of the engineer, and they can vary from Finite Element Analysis to assembly and function check.

I this case I need a to prove that using a simulation I can reproduce the real live conditions and that the results are comparable to the tests results obtained and presented in chapter 4.

For the simulation I used the program MSC Adams View, i transferred the 3D CAD models from CATIA to the Adams platform, assembled the parts, set the connections between them and the forces the affected each component, the assembled model is shown in *figure 9.*

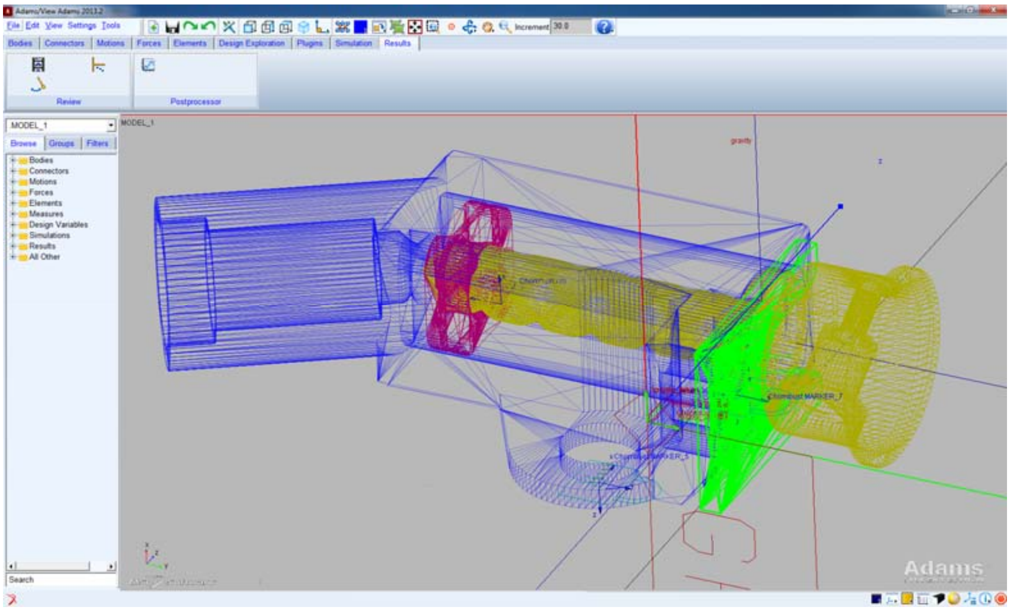

Fig.9. Model prepared for simulation in MSC AdamsView

After performing the simulation the maximum force obtained was 205 N and the graph is shown in *figure 10*. So the results are comparable to the test done in variant 2 and 3 as the friction coefficient used for the simulation was that of lubricated steel parts (0.2).

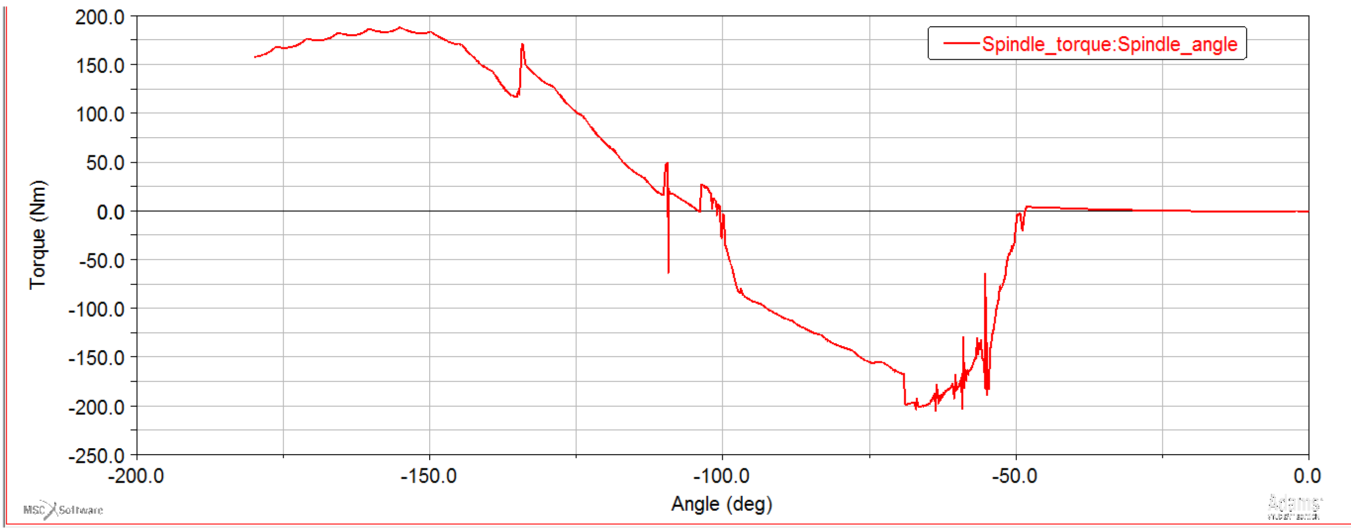

Fig.10. Force graph of the simulation

6. Design of experiment

Design of experiment (DoE), is a 6 sigma method used to be able to distinguish between factors that have an influence on the data obtained and factors that don't have a significant difference.

As presented in chapter 5 the simulation results are relevant and comparable to tests performed on prototypes, so this is used as a baseline for the DoE simulation.

To better understand the influence of 4 factors on the system presented in this paper I performed a DoE using four factors presented in *table 1*.

Table 1. Factors used for DoE

No.	Factor	lower limit	upper limit
1	Friction coefficient	0.2	0.8
2	Piston design	4 corners	8 corners
3	Pitch	0.5	2
4	Time to reach maximum pressure	2 ms	6 ms

The Pareto chart obtained for the factor influence is showed in figure 11. The factors that have a significant influence on the model are the Friction coefficient, the piston design, and a combination between the friction coefficient and piston design.

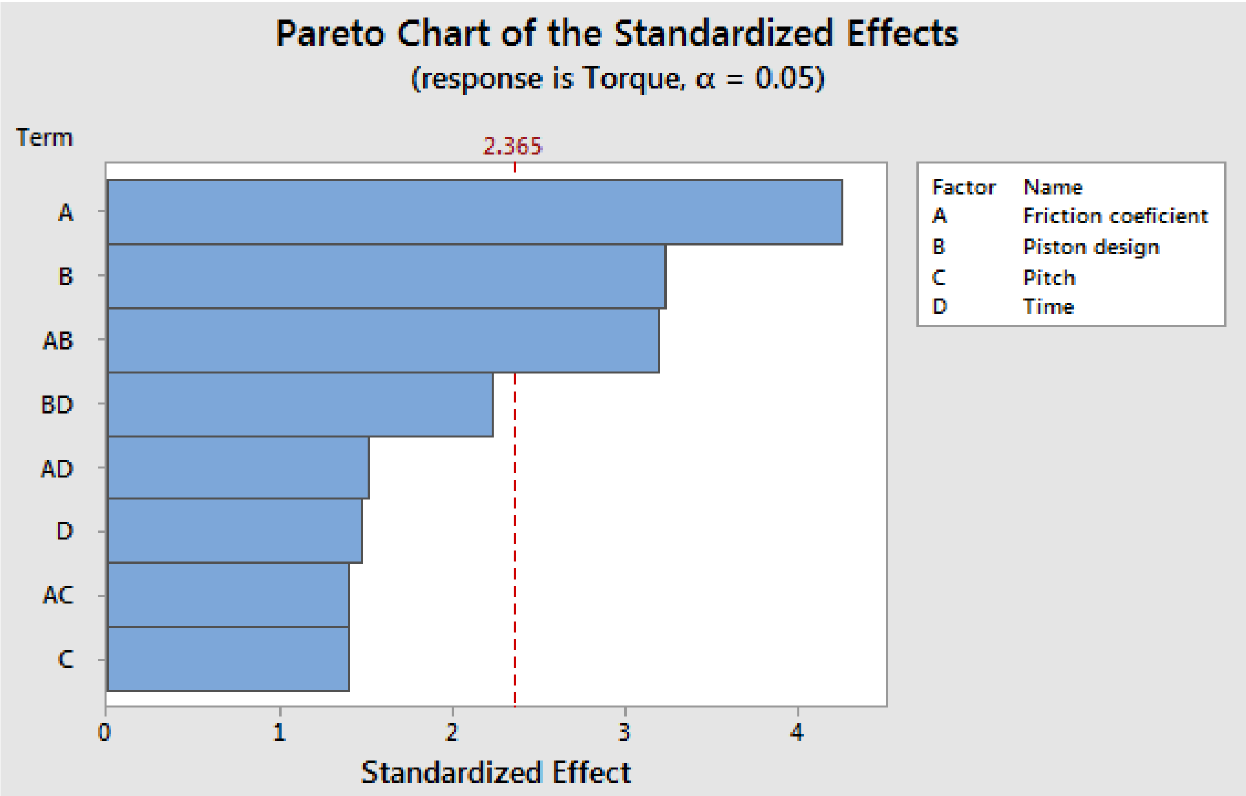

Fig.11. Pareto chart of the standardized effect

7. Conclusions

The tests performed showed the current state of the product and the importance of using a lubricant to reduce the fiction forces between the pats. Also by analysing the result a significant difference was observed between the two different types of lubricant.

The simulations performed showed that the simulation model is comparable to real life experiment bought in setup and results, allowing me to perform a DoE using different factors in the simulation program, as a result saving time and reducing cost for the prototypes and the tests.

The results of the DoE showed me the direction of focus needed to further improve the product with minimal cost and effort.

This paper presents how you can achieve results faster and with a better confidence interval using all the available tools for an engineer, like building prototypes, performing tests, analysing the results using 6 sigma statistical analyses and DoE's and using simulation programs to reduce effort needed for investigating different factors.

REFERENCES

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