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DESIGN OPTIMIZATION AND ANALYSIS OF PISTON, DRILL BIT FOR ROCK DRILL

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Abstract: *Rock drilling is an essential part of several important industrial activities: mining, oil and water well drilling and engineering, the latter concept covering a large variety of different contract work applications. Since our focus is on design, we will choose to work with tetrahedral – this allows us to focus on the design aspects without getting tied down meshing complications on Drill bit and Piston of the Rock Drill. This project involves Catia for modeling and Ansys for Analysis; it does mechanics for stress analysis, and rigid body dynamics for calculation of displacements. The modeling focus is on creation of joints and bodies. And requires that the two grids be used to define revolute and translational joints – one grid on each of the bodies. The grids that define the joints need to be on the axis of rotation, for a revolute joint. Since there may not be elements at the desired location, we make liberal use of "rigid" elements. The use of "ground" bodies means we do not need any restraints on the FEA model. Unlike an FEA solution, the time integration scheme used by the Ansys solver embedded in analysis calculates the step-size for time-integration internally.*

I- INTRODUCTION

Rock drilling is an essential part of several important industrial activities: mining, oil and water well drilling and civil engineering, the latter concept covering a large variety of different contract work applications. Two main rock drilling methods are available:

- Rotary drilling of large diameter holes from above ground in all kind of rocks.
- Percussive drilling of small to medium diameter holes in all kind of rocks, both under and from above ground.

Fig 1.1: Atlas Copco Rocket Boomer WL4 C30

Figure1.1. Shows a drill rig Rocket Boomer WL4C30. It is used for tunnel drifting underground. The rocket boomer has four rock drills, which all can be operated at the same time. Percussive method of rock drilling differs from the other in one fundamental aspect: the drilling equipment is comparatively light and accordingly easily maneuverable. The percussive rock drilling system may be regarded as a force amplifier, which transforms a constant low thrust force to a periodic force on the bit, alternating between almost zero for most of the time and the same

high force as for the rotary bit for only a few percent of the blow period.

1.1Background and Purpose

Since our focus is on design, we will choose to work with tetrahedral- this allows us to focus on the design aspects without getting tied down meshing complications. Since solid elements have 3 degrees-of-freedom per node, a 19,041 node model has 57,123 DOF's. This is reasonable for static analysis.

This project involves mechanics for stress analysis, and rigid body dynamics for calculation of displacements. The modeling focus is on creation of joints and bodies. RADIOSS requires that the two grids be used to define revolute and translational joints – one grid on each of the bodies. The grids that define the joints need to be on the axis of rotation, for a revolute joint. Since there may not be elements at the desired location, we make liberal use of "rigid" elements. This approach allows us to define the grids for the joints at locations that are correct from the view of the multi-body solver.

Drill Bit

The drill bit, shown in figure 1.2.3, is mounted at the end of the drill steel .It has several hard carbide steel buttons, which crush the rock. The force needed for flushing the rock is increased with the number of bit buttons, the bit button diameter and how worn the buttons are. With the right choice of drill bit, the cuttings are relatively coarse, whereas a drill bit with too many, and/or too worn bit buttons, produces very fine cuttings. There are mainly two types of bit buttons, ballistic, and spherical, shown in figure 1.2.3. Ballistic bit buttons generally give a higher drilling rate, but they are more difficult to regrind .The drilling capacity of drill bit is 8000-12000 ft's.

II - LITERATURE REVIEW

Background

In June 1997 a drilling company (AB Norrfjärdens Brunnsborrningar) was contracted by the Swedish telephone company TELIA to drill a BTES cooling plant for an underground telephone switching station. TELIA are gradually replacing all their old cooling (CFC) machines by more environmentally friendly systems.

Performed pre-design of the BTES system showed that 72 boreholes (160 m) would be sufficient. Because of limited space for the drilling it was suggested to drill deeper holes and the after re-designing the plant it was found that 60 boreholes at 200 m would also fulfill the cooling requirements.

Previous drilling in the area showed that the rock was water rich and fractured, which means that it would be difficult if not impossible to perform the drilling with pneumatic DTH equipment. So, the drill rig was re-constructed for water driven DTH drilling.

Advantages

- High penetration rate, 0.5 to 1.0 m/min. The average penetration rate after 57 boreholes was 0.6 m/min.
- The penetration rate changes very little by increasing depth. It would be possible to drill too much greater depths.
- Only clean water is injected into the boreholes (no oils or other additives).
- The diesel oil consumption was reduced to 1/3 of conventional pneumatic DTH drilling.
- Very good working environment. No dust, no oil mist, no spill.
- Drill bit wearing comparable with pneumatic DTH drilling.

- Almost no wearing (blasting) on hammer and drill pipes.
- Rapid breaking of drill string because of immediate pressure drop when the hydraulic pump is switched off.
- The water driven drilling system is insensitive to water rich rock.

Disadvantages

- Minimum water is high 200 l/min (when the hammer is new) and 300 l/min (when old).
- High requirements on the purity of water. Maximum grain size of 50 micron, desirable grain size 10 micron. Maximum 50 mg/l of water.
- High investment cost for re-circulation of water.
- Big stress wave rebound from the hammer resulting on heavy loads on the rotation unit, Feed cylinders and drill pipes.
- Frequent and long standstills because of necessary maintenance and reparation of the Drilling equipment due to the big stress wave rebound from the hammer.
- High hammer cost. The hammer is expensive in spite of its simple construction. In Addition the life time is short and the spare parts are expensive, the total hammer cost is about 6 SEK/m. The total drilling cost is approximately US$15.

The drilling company’s conclusion is that if the drill cost is reduced to a more reasonable level and the re-circulation of water would be achieved at a lower investment cost the Wassara hammer will become very competitive for drilling of single wells for both water and energy extraction. When it comes to larger projects with many wells on a limited area it will be outstanding.

III- PROBLEM DESCRIPTION

3.1 Valve less Rock drills

In a valve less rock drill the piston is the only moving part. The term "valve less" is however not quite adequate since the piston it is used as a valve. In this kind of drill, compressibility of the fluid plays an important role in the operation of the drill machine. The basic aim to design rock drills without any valves is to increase their overall efficiency.

3.1.1 Working Mechanism

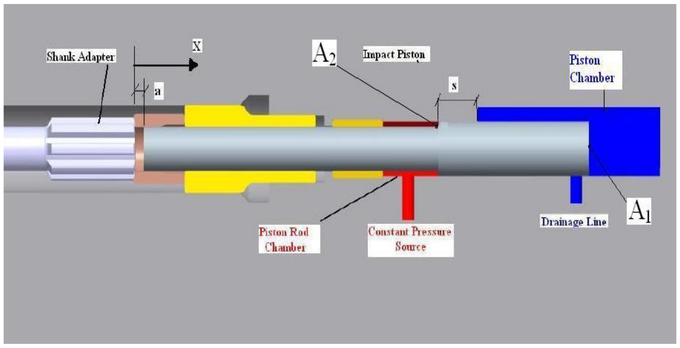


Fig 3.1: Valve less Rock Drill

Rock drill mechanism consists of an impact piston, two chambers, piston chamber(rear side) area A1 and piston rod chamber(front side area A2), which are connected periodically with each other. Furthermore, piston rod chamber is permanently connected with the inlet constant pressure source p, whereas the piston chamber is connected with the drainage line periodically. After a blow, the piston is first accelerated by force F = p_A2 to the position X = a. Next it continues to compress the fluid in the piston chamber. It is assumed that the pressure in the piston chamber increases linearly with the piston displacement X - a.

IV - WORKING OPERATION OF ROCK DRILL

4.1 Operation

The main difference from pneumatic DTH equipment is that the power from above ground to the hammer is transferred by water. The drilling system runs on filtered water at pressures up to 18 MPa (180 bars, 2500 psi) from a conventional high-pressure plunger pump. Low velocity flushing water causes little wear to drill pipe and hammer case, allowing for tight stabilizing and straight holes. After flushing the cuttings from the hole, water can be filtered and recycled to minimize loss. Although it was developed for use in underground mining, it has features which can provide many economical and technical benefits in surface drilling. The main problem in UTES drilling is the filtering and recirculation of water.

4.1.1 Drilling Equipment

The drilling equipment is water driven, hydraulic, down-the-hole (DTH) percussive drilling system for hard rock. It was developed by G-Drill, a company owned by Sandvik Rock Tools and LKAB, a large Swedish mining company.

4.2 Environment

When comparing drilling between Wassara and a conventional pneumatic DTH drilling system, the most obvious difference is a cleaner environment. Dust is virtually eliminated and because lubricating oil is not used in the hammer the atmosphere is oil free. Transmitting energy by means of water hydraulics is extremely energy efficient. By comparison, pneumatic equipment uses four to six times more energy for every meter drilled.

4.3 Drilling Accuracy

As a result of using water for flushing, erosion is greatly reduced on the outside of the hammer and drill string. This makes the use of close fitting stabilizers more practical. Consequently, the hole straightness can be improved even further over conventional DTH drilling.

4.4 Performance

Tests performed in LKAB's Malmberget mine show that Wassara is giving two and a half times the penetration rate of a typical four inch air hammer operating at 2 MPa (20 bars, 300 psi). When compared to modern hydraulic top hammer drilling, the difference at the hole beginning is less pronounced, but at greater depths Wassara's penetration rate is far superior. * Varies with hole size, percussion pressure, bit button shape and rock hardness.

V - MODELING OF HAMMER ASSEMBLY

Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

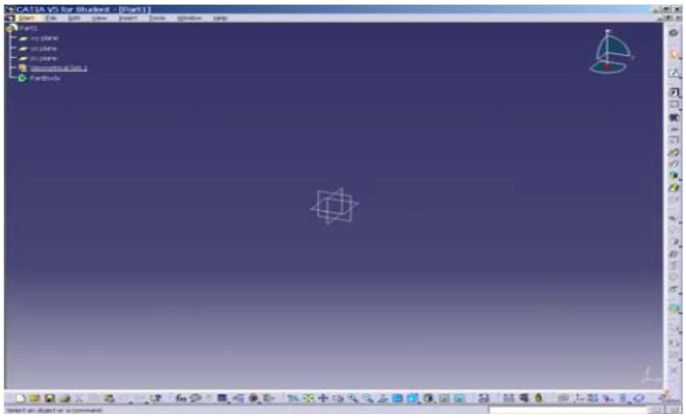


Fig: 5.1: Home Page of Catia

User's preferences. Therefore Dassault Systems offers three different software installation versions. The platform P1 contains the basic features and is used for training courses or when reduced functionality is needed. For process orientated work the platform P2 is the appropriate one. It enables, apart from the basic design features, analysis tools and production related functions. P3 comprises specific advanced scopes such as the implementation of external software packages.

Modeling of Master Hammer Assembly

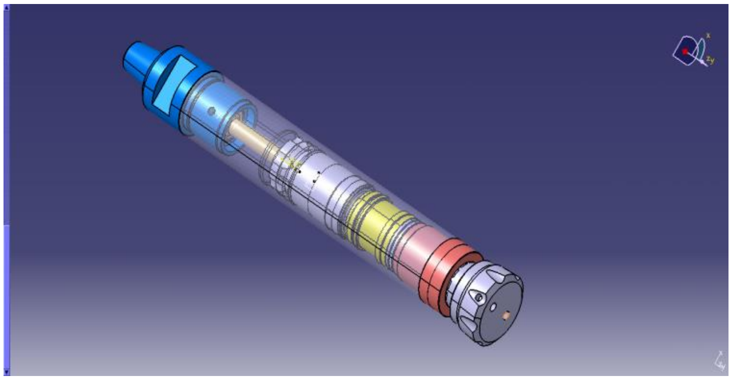


Fig: 5.2 Master Hammer Assembly

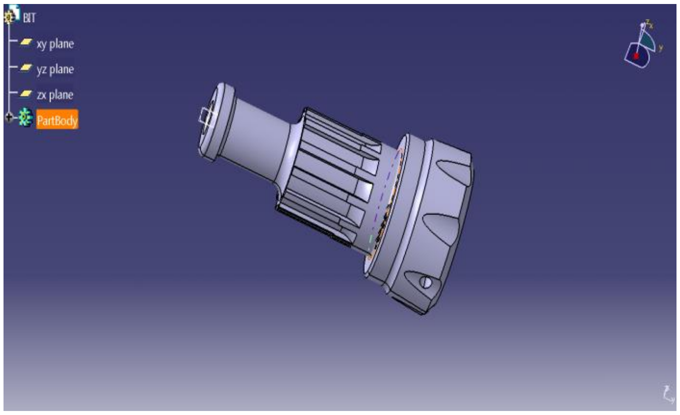


Fig: 5.3 Drill Bit

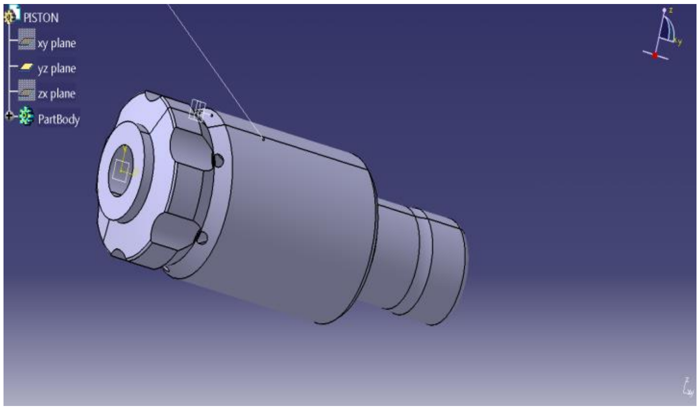


Fig: 5.9 Piston

VI - METHODOLOGY OF THE PREPROCESSING

Altair Ansys is a high-performance finite element pre-processor to prepare even the largest models, starting from import of CAD geometry to exporting an analysis run for various disciplines. Importing the Cad model in the Preprocessing Software and meshing is done for the model and property and material is assigned to the model and Strength analysis for Piston and Rotational force analysis is carried out for Bit.

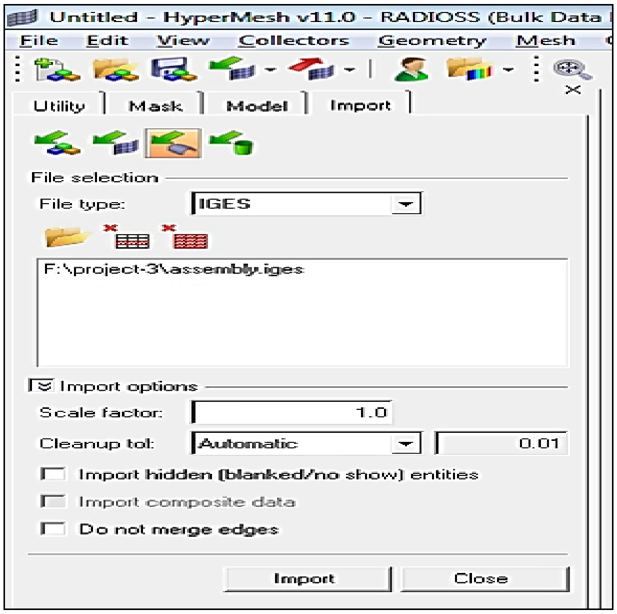
6.1 Type of Analysis

Simulation of complete assembly of Rock drill machine using Motion View

1. Stress Analysis of Reference Piston & Modified Piston
2. Rotational Force Analysis of Reference Drill Bit & Modified Drill Bit

Rock Drill Assembly

Complete Rock Drill Assembly is opened using Import Geometry option. This is IGES format which was saved in Pro-e. The same file opened in Ansys.



File type: IGES

F:\project-3\assembly.iges

Scale factor: 1.0

Cleanup tol: Automatic 0.01

☐ Import hidden (blanked/no show) entities

☐ Import composite data

☐ Do not merge edges

Fig 6.5 IMPORTING ROCK DRILL ASSEMBLY MODEL IN MOTIONVIEW

The modeling focus is on creation of joints and bodies. Optistruct / Analysis require that the two grids be used to define revolute and translational joints - one grid on each of the bodies. The grids that define the joints need to be on the axis of rotation, for a revolute joint. Since there may not be elements at the desired location, we make liberal use of "rigid" elements. These are equations that tell the solver that all "slave" nodes must move exactly as the "master" does. This approach allows us to define the grids for the joints at locations that are correct from the point of view of the multi-body solver.

Also, to ease visualization, we choose to create the joints with the grids in physically different locations. This way we can see the joint-definitions clearly. Once we have completed defining the joints, we move the grids and the associated bodies so that the "coincident grids" requirement is satisfied.

Loads and Restraints

This step is different from that of a "usual" Finite Element Analysis. The use of "ground" bodies means we do not need any restraints on the FEA model. That is, we do not need any SPCs. Since this is a dynamic analysis, we will provide an initial velocity to the piston, to simulate the effect of a "kick-start" .Further, we define the interval for which we want to solve the problem. Note that unlike an FEA solution, the time-integration scheme used by the MBD solver embedded in Optistruct / Analysis calculates the step-size for time-integration internally. Here, we specify the time-steps at which we want results reported. This data is all that is required to generate the results.

VII - RESULTS & DISCUSSION

This study and analysis helped in analyzing the performance of valve less rock drill when it is allowed to operate with and without gas accumulators. In this thesis work the following tasks are performed:

The design running drill bit and piston is considered for the finite element analysis using Altair Hyper works software. Here we need to do show the best and perfect design of drill bit and piston with application of high pressure load and low pressure load.

Aim of this project is to smoothen the work flow while drilling the ground. The drill bit should withstand the applied pressure load of high and low. A piston and drill bit has been modeled in CATIA and its characteristic behavior has been studied. In this modeling, all the important factors which have effect on the piston have been taken into account, such as mass and hence inertia of piston, friction in sliding contact between piston and cylinder and effective bulk modulus for oil, gas and mixture of oil and gas. As the piston is designed to work over high pressure loading.

Firstly, the results of base design of Drill bit and Piston are not satisfied. Based on the results the design has been changed for both the components which are very important in rock drill machine.

Using Catia software design has been changed and analysis is carried by the given loading conditions. Results are discussed in above chapter. Finally by seeing the results of modified designs and base designs what design perfectly suit the requirement of strength of the design.

Analysis is carried out the results are also compared in above chapter finally will conclude that displacement is reduced for modified piston design. For high accumulator pressure value and low pressure value the piston was analyzed and it is having more strength than the base design. So modified design of piston is suitable for industry requirements.

7.1. Results of Kinematics of Rock Drill

Fig: 7.1: Starting Movement showing in shaded view and transparency view

The above figure explains about the multi body dynamics of complete assembly of rock drill machine. Multi body dynamics is nothing but seeing the simulation using the applied joints using Motion View software.

7.2 Results of Reference Piston & Modified Piston Strength Analysis

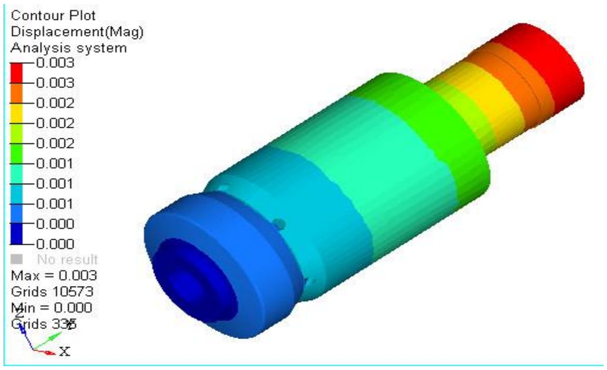


Fig: 7.6 Displacement is minor which 0.003mm for applied 2.4Mpa is (Low Pressure)

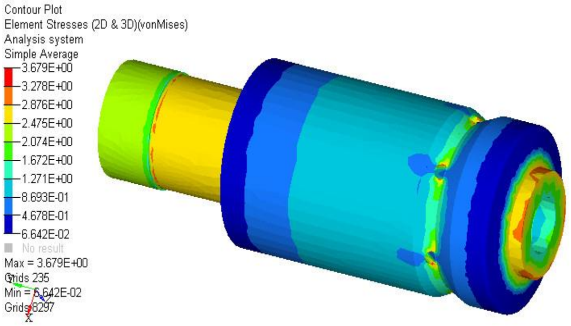


Fig: 7.7 Stress is 3.6Mpa for Base design for applied 2.4Mpa (Low Pressure)

Design satisfies the above results and the design modification is required to reduce the stress and displacement, using experience knowledge on manufacturing requirement, the Piston Design is changed and rerun the strength analysis is carried and check the results comparison.

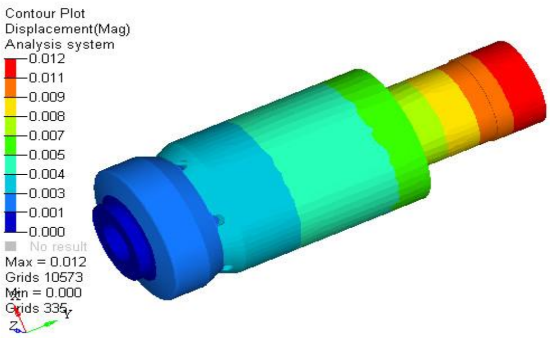


Fig: 7.8 Displacements for High Pressure Analysis of Piston.

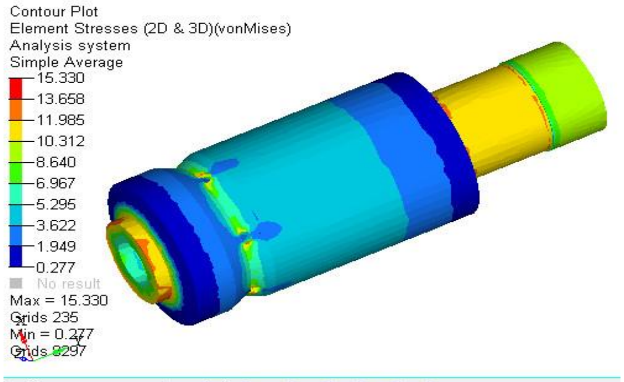


Fig: 7.9 Showing Stress of a piston

Stress is very less which beyond the yield value of Piston under small accumulator pressure and high pressure accumulator pressure.

7.3 Modified Piston Results at high pressure

Redesign Model

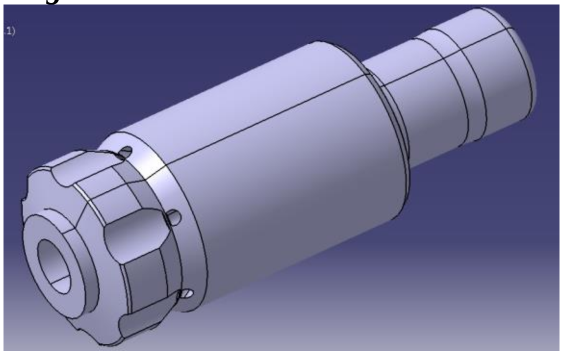


Fig: 7.10 Modified piston

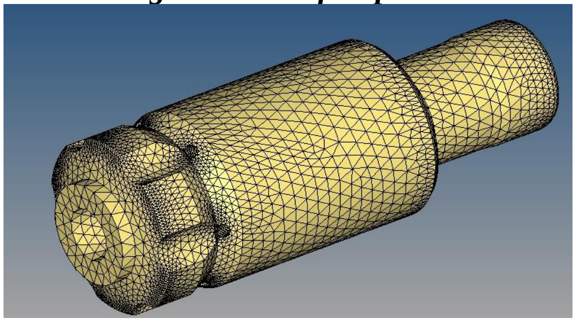


Fig: 7.11 Meshed Model of Piston

7.3.1 Results for Modified Piston are shown below

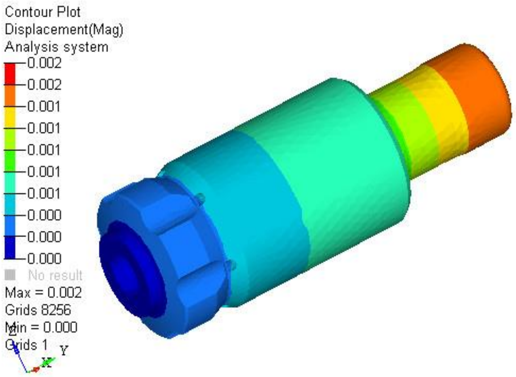


Fig: 7.12 Displacement is 0.002mm

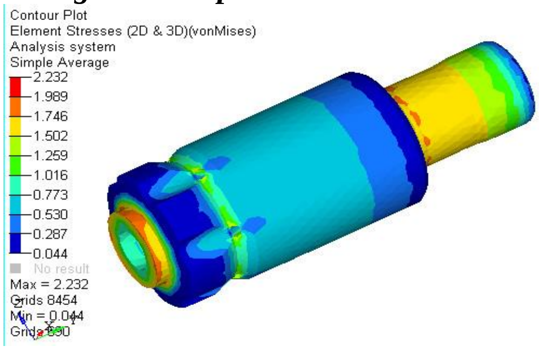


Fig: 7.13 Stress of piston is 2.232Mpa

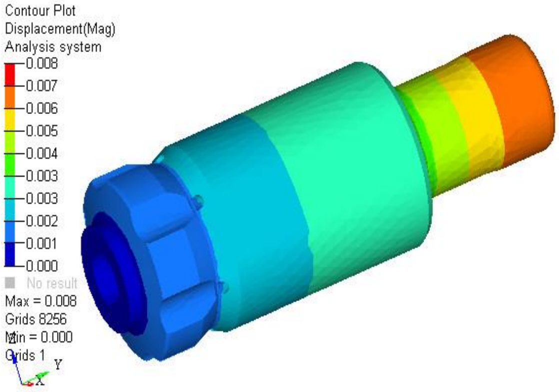


Fig: 7.14 Displacement is 0.008mm for high pressure

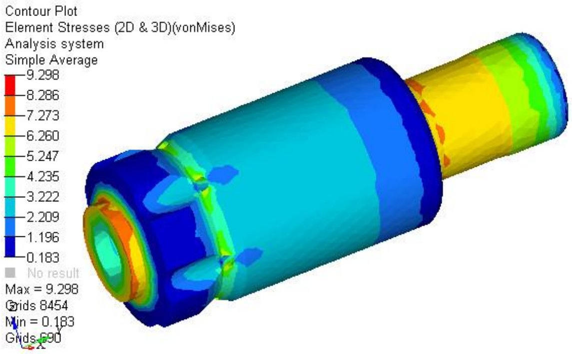
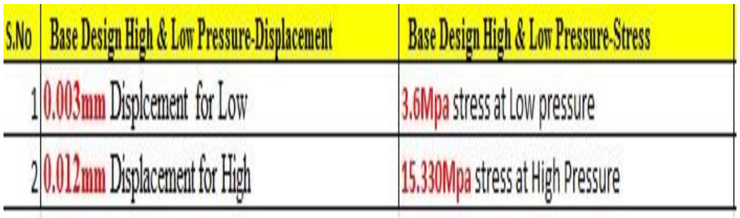


Fig: 7.15 Stress is 9.298Mpa for High pressure accumulator

7.4 Comparison of Low Pressure and High Pressure Results



S.No	Base Design High & Low Pressure-Displacement	Base Design High & Low Pressure-Stress
1	0.003mm Displcement for Low	3.6Mpa stress at Low pressure
2	0.012mm Displacement for High	15.330Mpa stress at High Pressure

Fig: 7.16 comparison of base component pressure

Modified Design High & Low Pressure-Displacement	Modified Design High & Low Pressure-Stress
0.002mm Displcement for Low	2.232Mpa stress at Low pressure
0.008mm Displacement for High	9.298Mpa stress at High Pressure

Fig: 7.17 comparison of base component pressure

By observing above results the second Piston results are better than the first base design, finally will conclude that modified design of Piston satisfies the stress and displacement values because which are less than base results. For all the results the modified piston is sustaining the load which is not failing. The modified design is having less stress and less displacement.

7.5 Results of Drill Bit Base Design and Modified Design Rotational Force Analysis

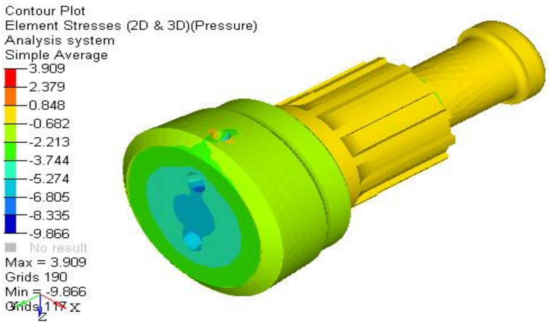


Fig: 7.18 showing base piston stresses Base Design Pressure is 3.909N/M2 is maximum Minimum is -9.866N/M2

Rotation force is applied to the base drill bit and finding out rotational stress, rotational pressure while in motion. Pressure value for base design is 3.909N/M2 and minimum stress is -9.866 N/M2.

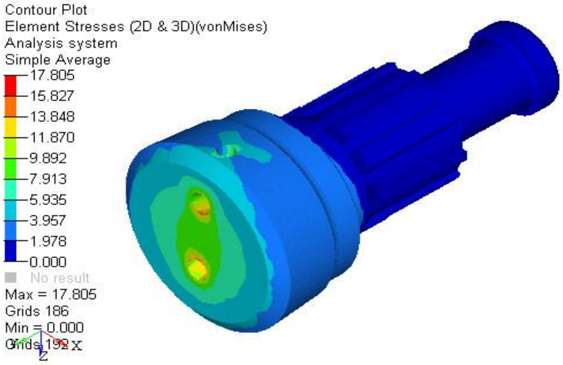


Fig: 7.19 Base Design Stress is 17.805

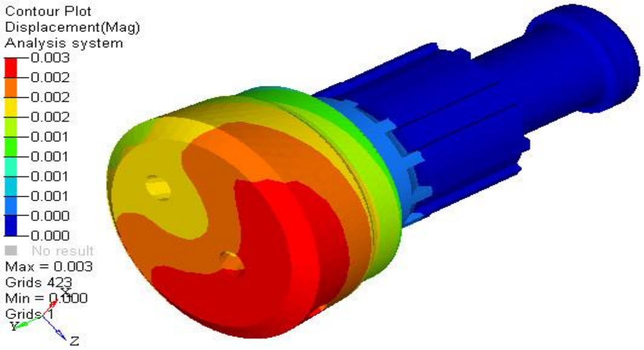


Fig: 7.20 Displacement 0.003mm for base design of Drill bit

Displacement and stress is less compare to the yield point of base drill bit.

7.6 Modified Results of Drill Bit

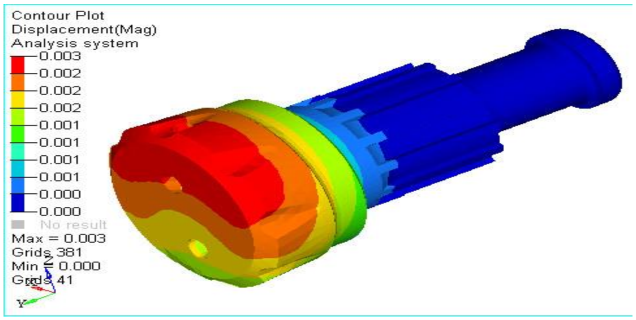


Fig: 7.21 Displacement 0.003mm for Modified design of Drill bit

Modification is done to drill bit for smoother drilling, when it is drilling the ground the sand should come outside smoothly which should not create any damage to the drill bit. For that purpose the design has been changed from base to new design which is shown above. The results are also changing for both designs, comparing the stress, displacement; rotational pressure to the surface is very less compare to the base design.

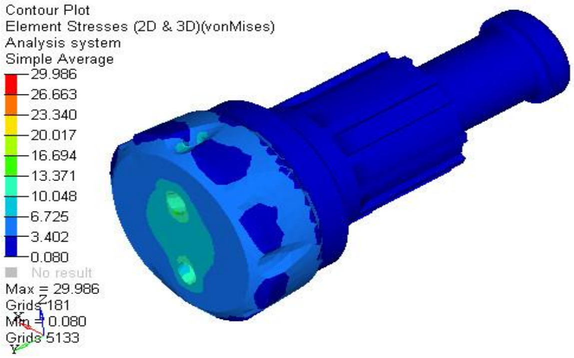


Fig: 7.22Stress for modified Drill bit is 29.986 MPa

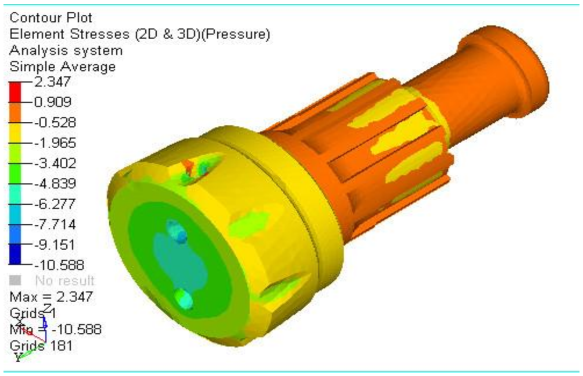


Fig: 7.23 Pressure for Modified design of drill bit is 2.347N/M2

Rotation force is applied to the base drill bit and finding out rotational stress, rotational pressure while in motion. Pressure value for base design is 2.347 N/M2 and minimum stress is -10.588 N/M2.

VIII - CONCLUSION

This study and analysis helped in analyzing the performance of valve less rock drill when it is allowed to operate with and without gas accumulators. In this thesis work the following tasks are performed:

A piston has been modeled in CATIA and its characteristic behavior has been studied. In this modeling, all the important factors which have effect on the piston have been taken into account, such as mass and hence inertia of piston, friction in sliding contact between piston and cylinder and effective bulk modulus for oil, gas and mixture of oil and gas. As the piston is designed to work over high pressure loading. Firstly, the results of base design of Drill bit and Piston are not satisfied. Based on the results the design has been changed for both the components which are very important in rock drill machine.

Using Catia software design has been changed and analysis is carried by the given loading conditions. Results are discussed in above chapter. Finally by seeing the results of modified designs and base designs what design perfectly suit the requirement of strength of the design. Analysis is carried out the results are also compared in above chapter finally will conclude that displacement is reduced for modified piston design. For high accumulator pressure value and low pressure value the piston was analyzed and it is having more strength than the base design. So modified design of piston is suitable for industry requirements. Drill bit analysis is carried out for base design and new modified design using rotation force analysis is carried out finally in that analysis air pressure outlet is very less for modified design of drill bit, Pressure are shown in above chapter. Results shown clearly that yield point value for both the components are very less which is below the yield value. So material is so strong which is proven by solver, design changes are needed for getting good results now a days. Design changes are given good results for both the components.

REFERENCES

[1] Gunnar Wijk, Percussive Rock Drilling
[2] Atlas Copco Photo Archive, http://atlascopco.com/Standard/index.jsp
[3] Gunnar (1996) Wijk, Total Rock Drilling Technology, • Orebro, Atlas Copco Rock Drills
[4] Johan Aleberg, Andreas Wiberg (2007), Designing a Hydraulic Energy Absorber for Endurance Tests of Percussive Rock Drills
[5] Anthony Esposito, Fluid Power with Applications, Sixth Edition
[6] Karl-Erik Rydberg, Gas Charged Accumulators as Energy Storage Devices in Hydrostatic Drives
[7] HYDAC International Accumulators Catalogue
[8] Karl-Erik Rydberg (2003), Modeling level for S
[8] Karl-Erik Rydberg (2003), Modeling level for Simulation and Design of Fluid
Power Systems
[9] Krus, Peter (1994), an introduction to Modeling of Transmission Lines, Link opings Universities, Link oping, IKP-R-732
[10] Larsson, Jonas (2002), User's guide to HOPSAN, Link• opingsUniversitet, Link oping

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