Design Evaluation of the head gasket on a 6.0 liter diesel engine

You will work in teams of 2-3 for this assignment. You will have to figure out how to model the block and cylinder on your own. I will answer questions, but I will not guide you through the process. This is your chance to apply critical thinking skills to a problem that has NO easily available answer.

This assignment involves evaluating the failure of the head gaskets in the Ford 6.0l diesel engine. This set-up used 4 bolts per cylinder. Internal pressures are roughly 2700 psi [18.6-20 MPa]. Basic cylinder dimensions are in table1 below, while an image of the head bolt pattern and installation torque sequence is shown in figure 1. Our task is to understand the pressure that will be exerted on the gasket between the head and the cylinder when the bolts are fully torqued, especially, the variation in the contact pressure with location around the cylinder. Also, what is the factor of safety against bolt fatigue. Given this info, does it make sense that this particular engine was so prone to head gasket failure.

To accomplish this, you will use a head gasket as a sketch template to model one of the cylinder banks of the engine, then scale the template to achieve the proper cylinder bore diameter. We are not concerned about cylinder wall failure or head failure, just gasket pressure. You do not need to worry too much about the geometry of the head above the cylinder, though some hemispherical cut-out is actually specified for the head. To function properly, the gasket pressure must exceed the peak internal pressure in the cylinder by 10%. We will design a cylinder with a cap using 4 bolts spaced at 90 degree intervals around the cylinder. The bolts are torqued to 175ft-lbs or 237N-m and are specified as M14x2.0 grade 10.9. You will have to find head torque specs and determine the proper bolt pre-load from those specs. Your job is to build a CAD model, bolt the head to the block, including the cam carrier, add internal pressure to one of the cylinders and run an FEA. You will use the FEA results to probe the stresses at the clamped interface and evaluate the factor of safety against opening and fatigue for this representation.

Use the Bolted Connectors feature in Fusion 360 to create the bolts. The bolts are specified as Torque-to-Yield M14x2.0 grade 10.9 bolts with a length of 238 mm and a threaded length of 133 mm. The resulting preload is based upon results from Chapman, Newnham, and Wallace's[1] research asserting that (after being torqued to yield) torque to yield fasteners carry a preload such that the bolt experiences a stress that is 80% of its yield strength.

[1] Ian Chapman, John Newnham, and Paul Wallace, 1986: **The Tightening of Bolts to Yield and Their Performance Under Load**, Journal of Vibration and Acoustics, pg. 215

Tasks:

1. Validate the internal pressures that occur during the power stroke. Use that to calculate loads on the ‘head’.

2. Validate bolt sizes and torques to achieve the given loads.

3. Calculate the bolt and member loads, as well as the bolt and average member stresses across the gasket. For simplicity, you can treat this as s cylinder with a flat cap and look at a cross section of the simple system. Studs are threaded into the block, then nuts are used to compress the head (cap) onto the head (cylinder).

4. What is the grip length?

5. Why is the grip length so long? Does this influence gasket clamping pressure?

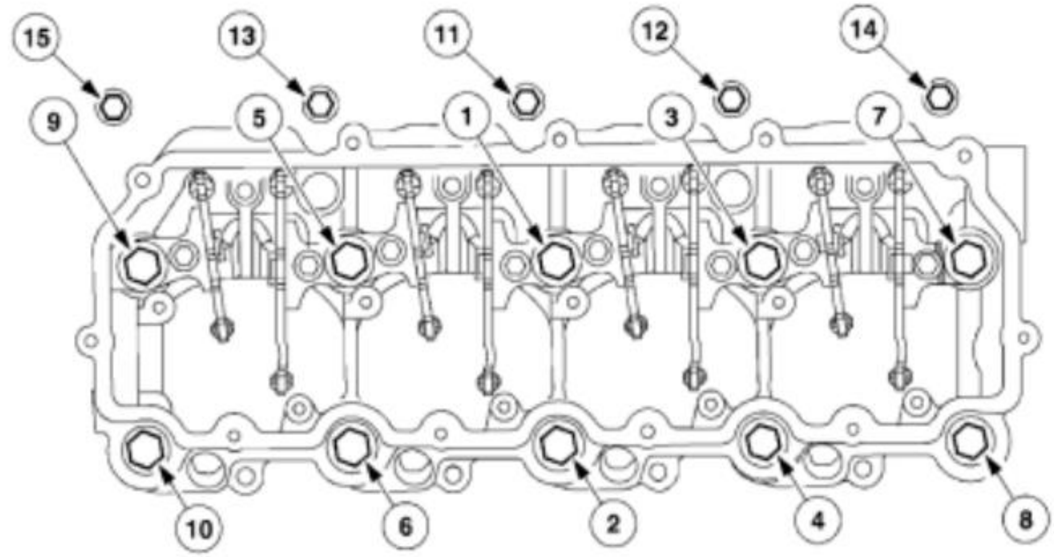
6. Use your spreadsheets to find all the factors of safety for a bolted connection.

7. Why did the next generation engine increase the bolt diameter to 16mm?

6.0L Powerstroke Specifications

Engine:	6.0L Powerstroke
Engine Design:	Turbocharged V-8 Diesel
Transmissions:	5-Speed 5R110W Torqshift Automatic ZF6 6-Speed Manual
Displacement:	6.0 Liters or 365 Cubic Inches
Bore:	3.74 inches or 95 mm
Stroke:	4.134 inches or 105 mm
Block Material:	Cast Iron Block
Cylinder Head Material:	Cast Iron Cylinder Heads 4 valves per cylinder head
Intake Manifold:	Aluminum
Compression Ratio:	18.0:1
Firing Order:	1-2-7-3-4-5-6-8
Turbocharger/Air:	Garrett VGT GT3782 TurboCharger
Fuel Injection:	HEUI, Hydraulic Actuated electronic unit injectors
Valvetrain:	Single Cam 32 Valve
Engine Oil Capacity:	15 Quarts including filter
Def Fluid Capacity:	0 – DEF Not Used
Cooling System Capacity:	27.5 Quarts or 8.75 Gallons.
Fuel:	Diesel
Fuel Tank Size:	29 Gallon or 38 Gallon Options
Horsepower:	325 horsepower @ 3,300 rpms
Torque:	2003-2004: 560 lb/ft @ 2000 rpms 2005-2007: 570 lb/ft @ 2000 rpms

Torque Sequence



6.0L powerstroke diesel engine: 2003-2007 (NAVISTAR)

6.4L powerstroke: 2007-2010 (NAVISTAR)

6.7L powerstroke: built in-house by Ford 2011-present

The 6.0 L head bolts are ISO Grade 10.9 M14x2 bolts

S_y=940MPa

Bolt length = 238mm

Threaded Length = 133mm

Threaded cross sectional area A_t= 115mm^2

I attach a picture of the original head bolts that are are used by Ford when assembling the 6.0L turbo diesel. These are M14-2 x 238mm. They are NOT standard bolts…the threaded length of the bolts is 133mm, the unthreaded length is 105mm. The bolts pass through an aluminum rocker carrier which is 51mm thick, though a cast-iron head, which is 95mm thick, and through a hole into the threaded cast iron block, for the sake of simplicity, assume the threads in the block begin roughly 10mm down from the top of the block (base of the head. Decide upon the overall grip length for a bolt threading into the block with the threads beginning 10mm down in the hole. That puts us 10+d/2 down in the block as a grip length in the bottom block. There is no washer under the bolt head…just the aluminum rocker carrier, the cast iron head and the cast iron block into which the bolts thread. Assume there is sufficient depth of thread for the bolt to not bottom out.