The problem deals with a static force balance between fluid pressure inside a pressure vessel (the engine cylinder) and the structural tension holding it together (the stud bolts).

When reviewing this for a board examination, note that it assumes standard nominal bolt dimensions where the tensile stress area equals the gross area $\left(\frac{\pi}{4}d^2\right)$. In precise field design, engineers utilize the smaller *tensile stress area* (A_s) of threaded fasteners rather than the nominal shank diameter to account for the material carved out by thread roots. However, for standard board tracking, using the nominal diameter provides the clean, exact analytical solution.

A 20 mm stud bolts are used to fasten a 280 mm diameter cylinder head of a diesel engine. If there are 12 stud bolts, determine the pressure inside the cylinder if the bolt stress is 60 MPa.n expected by the examiners.

<u>Step 1:</u> Formulation of the Total Resisting Bolt Force (F_{bolts})

When the combustion stroke occurs in a diesel engine, high-pressure gas pushes upward against the circular cylinder head. This separation force is directly countered by the cumulative tensile strength of the pre-tensioned fasteners.

The total tension force developed by all bolts combined (F_{bolts}) is the product of the number of bolts (n), the allowable normal stress (S_b), and the cross-sectional area of a single bolt (A_b):

$$S_b = \frac{F_{bolts}}{n\,A_b}$$

$$F_{bolts} = (n)\left(S_b\right)\left(\frac{\pi}{4}d^2\right)$$

Substituting the given values (n = 12, S_b = 60 MPa = 60 $\frac{N}{mm^2}$, d = 20 mm):

$$F_{bolts} = (12)\left(60\ \frac{N}{mm^2}\right)\left(\frac{\pi}{4}\right)(20\ mm)^2$$

$$F_{bolts} = 226,194.67\ N$$

<u>Step 2:</u> Formulation of the Internal Gas Explosion Force (F_{gas})

The fluid pressure (P) acts uniformly across the exposed circular face of the engine's upper cylinder head. The total upward thrust (F_{gas}) generated by the combustion pressure is equal to the pressure multiplied by the internal cylinder bore area ($A_{cylinder}$):

$$F_{gas} = P\left(\frac{\pi}{4}D^2\right)$$

<u>Step 3:</u> Establishing Equilibrium to Solve for Pressure (P)

For the cylinder head to remain perfectly static without blowing off the engine block, Newton's first law dictates that the downward fastening force must equal the upward pressure force ($F_{gas} = F_{bolts}$):

$$P\left(\frac{\pi}{4}D^2\right) = 226,194.67\ N$$

Given the cylinder diameter D = 280 mm

$$P\left[\frac{\pi}{4}(280mm)^2\right] = 226,194.67\ N$$

P = 3.67347 MPa = 3,673.47 kPa

By using 12 smaller bolts rather than 4 massive ones, the designer ensures uniform pressure distribution along the perimeter of the head sealing ring. This distribution prevents localized warping of the engine block and provides safety redundancy—if a single bolt develops a manufacturing defect and relaxes, the remaining fasteners can temporarily carry the structural load without catastrophic engine failure.