A Short Discussion About Fasteners and Gaskets

Things you should know about all mechanical joints.

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Two Rules that are Inviolate

1- Everything Leaks

It is just a matter of degree.

2- Everything Bends

That deformation just may not matter **Today.**

Why are these two together?

Gaskets and Bolts are very different things.

This is very true, but the vast majority of sealing failures of mechanical joints has been shown to be caused by fact the that the required fastener tension was never effectively established.

If the screws aren’t tight, it is going to leak.

A Bolt

Any piece of material can qualify as a bolt.

If it is threaded and has a head shaped such that it can be turned by that head,
- it is a screw.

This is why I will refer to all of these as fasteners because that is what they are and as I so often wrote for legal depositions, that is what I will probably always call them.

How bolts (aka HHCS) are made

These processes are very fast and effective.

- Machines are fed wire stock
- Stock is cut to length
- Wire is clamped and cold headed
- Threads are rolled on the shank

They may go on to further treatment

I watched a line spit out the long side Chevy SB head bolts at a rate of ~120 per minute. Bins that were about half a yard were filled while I watched.

Fasteners come in grades

SAE Grades are commonly 2, 5 and 8
SAE Grades 10 and 12 also exist but are rare

Din Grades of 8.8 and 10.8 are close equivalents to SAE 5 and 8, but the .8 specifies a thread tolerance.

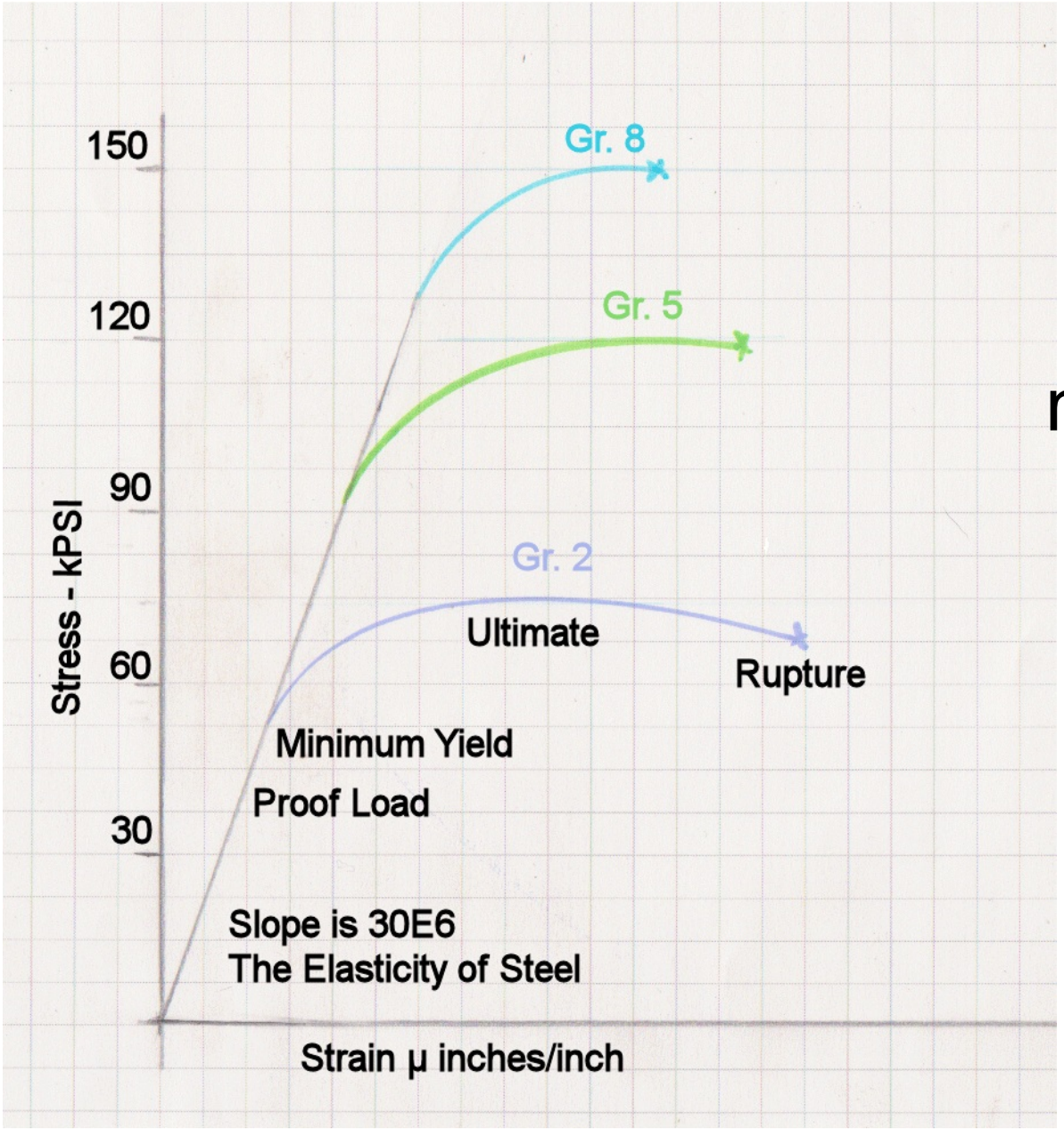
Aircraft grades are another story I will ignore them completely in this summary.

What do the grades mean?

SAE Grade	Proof Load	Minimum Yield	Minimum Tensile
2	33,000 psi	36,000 psi	60,000 psi
5	74,000 psi	81,000psi	105,000 psi
8	120,000 psi	130,000 psi	150,000 psi

And??

What does that mean in practical terms??



This is what this means to you when you are trying to build something.

US Bolts

Head Marking	Grade and Material	Nominal Size Range (inches)	Mechanical Properties		
			Proof Load (psi)	Min. Yield Strength (psi)	Min. Tensile Strength (psi)
 No Markings	**Grade 2** Low or medium carbon steel	1/4" thru 3/4"	55,000	57,000	74,000
		Over 3/4" thru 1-1/2"	33,000	36,000	60,000
 3 Radial Lines	**Grade 5** Medium carbon steel, quenched and tempered	1/4" thru 1"	85,000	92,000	120,000
		Over 1" thru 1-1/2"	74,000	81,000	105,000
 6 Radial Lines	**Grade 8** Medium carbon alloy steel, quenched and tempered	1/4" thru 1-1/2"	120,000	130,000	150,000
	**Grade A325** Carbon or Alloy Steel with or without Boron	1/2" thru 1-1/2"	85,000	92,000	120,000
Stainless markings vary. Most stainless is non-magnetic	**18-8 Stainless** Steel alloy with 17-19% Chromium and 8-13% Nickel	All Sizes thru 1"		20,000 Min. 65,000 Typical	65,000 Min. 100,000 – 150,000 Typical

Why Choose one and not the other?

Advantages of higher grade fasteners are:

1 - Better dimensional controls
2 - More consistent alloy controls
3 - Higher yield strength

Disadvantages of higher grade fasteners are:

1 - COST !!
2 - Propensity to Gall
3 - The temper required to make a high strength fastener can get “blown out” by exposure to high temperatures

Type of loads on fasteners

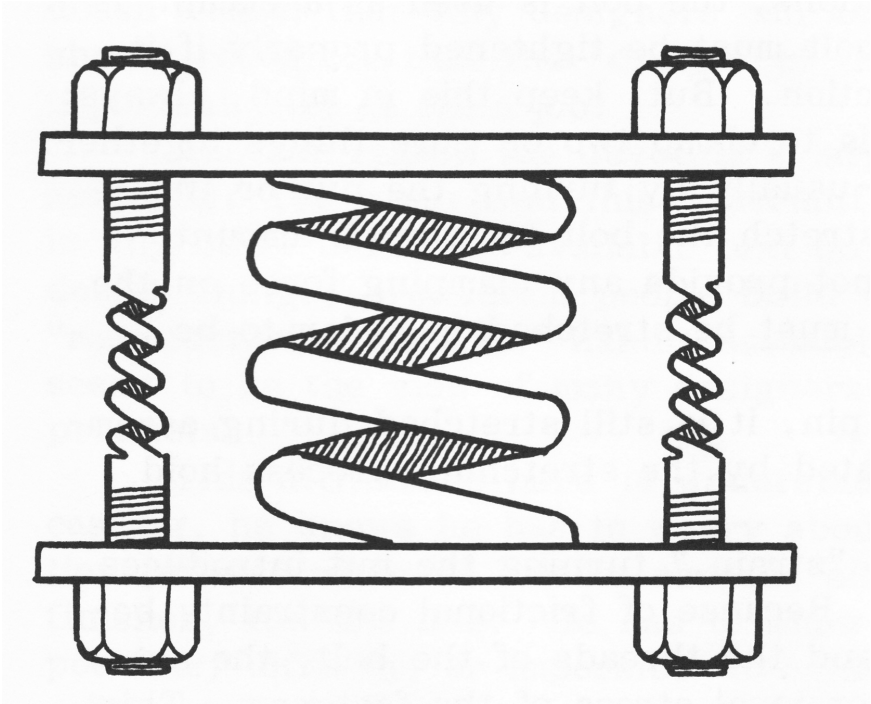
Tensile: The fastener is important to the integrity of the final assembly

Examples: Bearing caps and cylinder heads

Shear: The fastener is important to the structure of the assembly. The structure may use the inter-element friction as added joint stabilizer.

Examples: Flywheels, Cam gears, GMC Drive axles

How fasteners really work.



When you torque a fastener,
you are imbuing it with tension.

You are, in fact, cocking a spring.

Why do you want stretch?

A very valid question.

Stretch in any fastener is a response to the load on said fastener. In the case of steel, the elastic modulus is about 30,000,000.

If you do the math, that means that a 4" grip length Gr.8 fastener at proof load (~120kpsi) can be expected to stretch 0.012" without any permanent yield.

This elongation allows the fastener to accommodate both thermal movement and relaxation in the joint.

Relaxation (creep) can be expected in all assembled joints whether hard (like main journals) or soft (like a composite gasket.

A fastener for a Special Place?

It has two very special features

The thick washer is to extend the grip length to allow more stretch in the assembly.

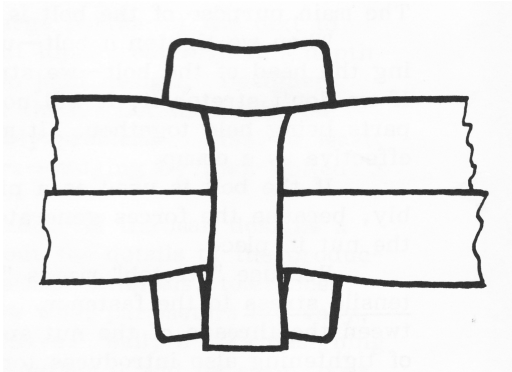
The nut is a prevailing torque lock nut.

A Dozen of these hold the front clip frame to the rest of the main frame of a TZE.

Creating Proper Tension in Fasteners

How do we stretch them the right amount?

- Pull and Guess
- Torque only
- Torque and Turn
- Torque to Yield
- Measured Elongation



Establishing Fastener Tension without any calibrated instrument

An experienced mechanic may be as reliable and as accurate as the situation requires in very many cases

Wrenches are shorter and longer for a reason.

Pay attention to what you are doing.
(Listen to the little voice.)

Tensioning Fasteners by Measured Torque Only

According to an ASTM study,
there are 54 variables that significantly affect the torque/tension relationship.

Calibration of the instrument is critical.

Condition of the components is critcal.

Final tension can still be target +/- 30%.

This is a short list of those variables that affect the torque/tension relationship:

- Dimensional control of all components x12
- Material quality control of all components x6
- Thread profile of the fastening components x2
- Thread finish of the fastening components x2
- Surface finish of the related components x4
- Quality of provided lubricant x 3
- Quantity of provided (or not) lubricant x 2
- Component temperature at assembly x4

** The x numbers can vary by joint type.

Torque and Turn Method

Much more consistent than torque only
Have a friend help you to keep track

- An initial load compresses the crushable elements of the structure

- A second operation hopefully causes a known fastener elongation

Torque to Yield

Always starts as Torque and Turn.
Fasteners are good for a single assembly only.

- An initial load compresses the crushable portion of the assembly
- A second operation causes a known fastener elongation into the yield area of the fastener's known properties
- Requires fasteners have known properties

Measured Elongation

Requires very specific instruments

- The length of a prepared fastener is recorded
- The fastener is then installed and tensioned until the desired length increase is reached.

The change in length can be determined by actual measurement or by the rotation of the thread engagement.

Anybody here ever install Carillo rods?

Ultrasonic Extensometer

The elongation type on technological steroids

- A fastener is prepared and its length is measured from one end with an ultrasonic device while being tensioned in an instrumented system
- The fastener is then installed and tensioned until the required extension is reached

This process is restricted to critical assemblies and laboratory testing.

Assembling Mechanical Joints

A successful joint assembly requires many different issues to be accommodated effectively.

We can put it together, but now to keep it leak free.

Remember, eveything leaks!

- Leakage is essentially an ongoing condition
- We attempt to mitigate this with a number of different methods that are:

1 - Surface finish
2 - Compliant sealing element *
3 - Appropriate connection strength and load

*May be omitted if some super finish parts are capable.

Just what is meant by Leak Free ?

Leak Free simply means that what is supposed to be contained by the final assembly will not permeate the mechanical joint at a rate that causes any maintenance or aesthetic issue.

Translation:
If it doesn't look ugly or drip where it matters - Who Cares??

Sealing Methods

Perfect surface match

Formed in place gasket

Elastomeric element

Deformable matrix

Perfect Surface match

- Requires an incredibily fine surface finish and parts with an absolute dimensional match
  - Think of the glass stopper in a chemical bottle
  - This is only common in diesel injection parts

Sealing Elements

Any part added to the joint to faciltate a seal

All Sealing Elements must have some compliance to make allowance for the mating surface's imperfections.

Any joint that includes a Sealing Element should have some capability for recovery from expected variations.

An elastomeric element will have a lot,
and an embossed shim will have very little.

These are features that I refer to as
"Sense of Humor".

Formed in place gaskets

This includes all sealing products
that are liquid when used

There are four general categories
and it is important that you know
what you are using

- Solvent carrier
- Anaerobic cure (air is excluded)
- Presence of Oxygen (or other)
- Presence of Moisture

Elastomeric Element

Good for sealing where leakage is critical

- May be good for sealing low to moderate pressures when low clamping available.
- Higher pressures require very careful dimensional control.
- Always temperature limited

Types of

Deformable Matrix Materials

- Specialty Paper
- Deformable solid shim
- Laminated Systems
- Multi-Layer Steel
- Metal Filler Metal - This is an obsolete construction used for some cylinder head and exhaust flanges. It is a metal -usually copper -formed around a soft core that most often contained an asbestos filler.

Specialty Paper

Hardly “Paper”

While it is processed as a paper, it is usually much thicker to enhance comformability.

Most have an elastomeric binder and may contain reenforcing fibers like glass or kevlar.

Deformable Solid Shim

What the Olds engines had for head and intake

Embossed metal like soft steel or copper that will get flattened during assembly but will retain some possible recovery.

These gaskets always require coating to have any chance at micro-seal.

This type of gasket requires that the mating parts be extremely ridgid.

Laminated Systems

How most of the replacement important gaskets are made

Typically a steel core with facing paper adheared to or mechanically bonded to one or both surfaces.

The facing “Paper” may be flexible graphite sheets or other unfamiliar material.

These may include combustion seal armor and other load balancing features.

Multi-layer Steel

Might look like an embossed shim

Multiple layers of embossed spring tempered stainless steel with an elastomeric coating and assembled to form a single unit.

This type of sealing element has very low relaxation and so is often the choice with torque to yield assemblies.

These have become very common in spite of the cost. They survive well in multi-metal engine.

Surfaces

Three Classes of surface conditon:

- Flatness
- Waviness
- Surface finish

These are actually all the same thing, but the length of measurement varies.

“If you can’t measure it, it is an opinion.”
Dave Lenzi

Flatness

A simple feature that can be critical

This is a relatively simple measurement.

Using a certified straight bar, place it on a surface and try to rock it.

If you cannot feel it rock, then place a piece of gauge stock or shim on the center of the surface and try to rock the bar.

Heads always curl toward the fire deck, the amount of warp the manfacturer believes is acceptable should be in the rebuild specifications.

Waviness

A feature that many are not familiar with

This can best be evaluated with light under a ground straight edge or plastigage and clamps.

Again, the specification should be in the rebuild data. This is a VERY common problem with resurfaced cylinder heads on newer engines.

The instrument that can actually measure this is expensive and rare.

This is a very important issue to MLS gaskets because if any more than minimum exists, the joint may very well fail.

Surface finish

- Is a record surface smooth??

Best to learn to work with a comparator plate. If you have no fingernails left, learn to use a guitar pick. Save that pick.

When you break into an engine, make a note of the deck and head finish that you find. If you have to have the castings resurfaced, be certain the shop knows the requirements.

Using a Comparitor Plate

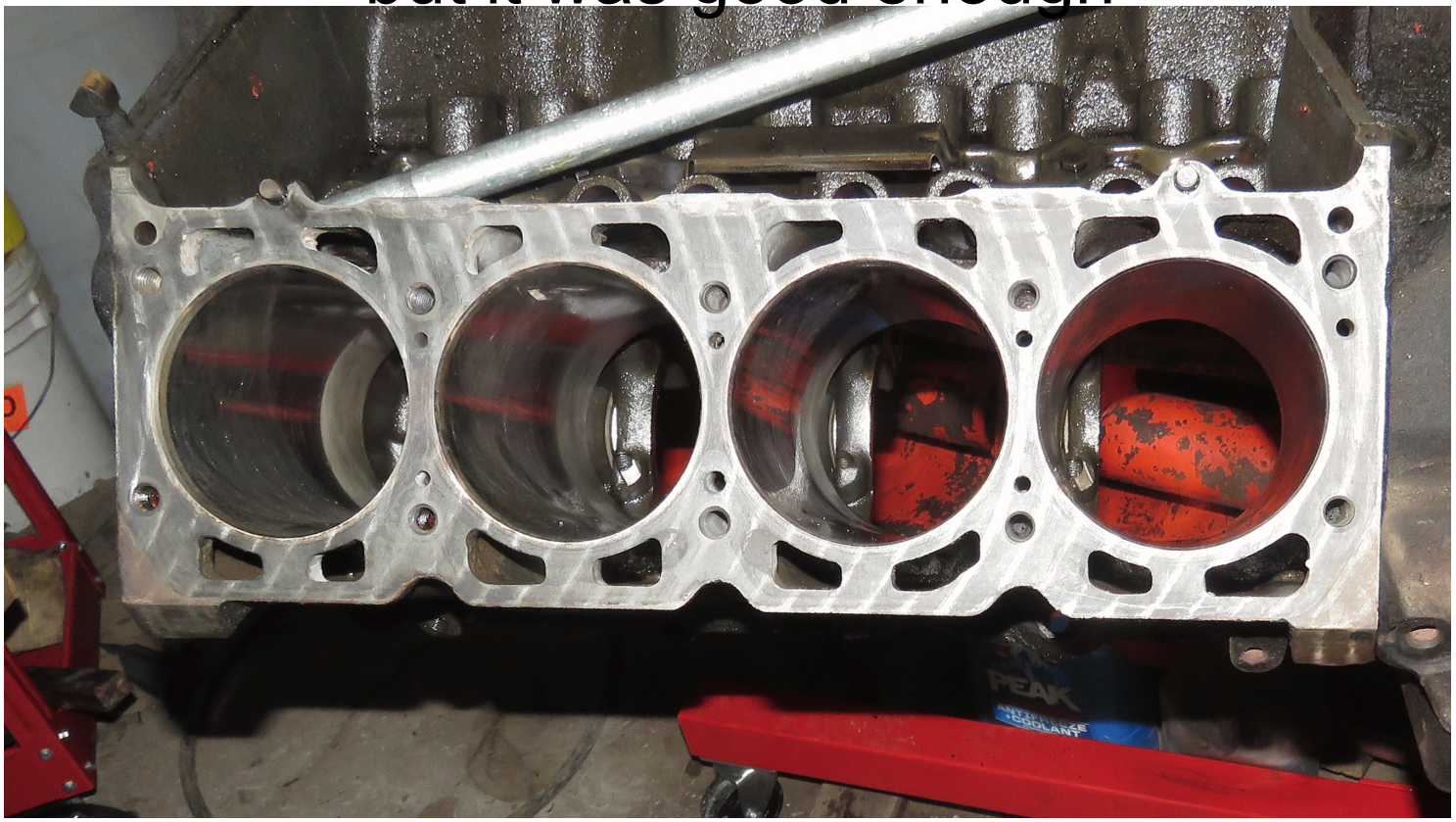
The cheap ones are really cheap

These will provide a solid basis for evaluating final finishes.

If you are dealing with any competent machining source, do not be afraid to quote the numbers you have found and state an expected final for this.

A Terrific Example

Of a case of poor finish,
but it was good enough



This is after working it with a hand stone for a while.

Assembly issues

Preparation is the key

- Clean the mating surfaces
- Level surfaces with an oil stone
  (a stone can remove only high spots)
- Threads should be chased and then the bottom cleaned
- Fasteners should be inspected for distress and then lightly oiled

Care at assembly

- Do not drop the parts together.
- Use guide pins when you can.
- Inspect and clean all fasteners
- Chase and solvent wash all tapped holes
- Inspect and clean all mating surfaces

A Word of Caution

This is specific to those reading the Oldsmobile manual

The manual recommends that important fasteners be dipped in engine oil before installing.

If there is too much oil in the assembly of a fastener in a blind tapped hole, the fastener can “Hydrolock” on that oil and thus create a torque load where little or no actual fastener tension exists.

In the engine assembly shops, it was found to be best to oil the fasteners and then place them on a rag to let the excess oil run off.

The tapped holes were lubricated with a single drop that was allowed to run down the threads.

Also be certain that there is some oil under the fastener head and washer as well.

Torque sequence

Try to use the manufacturer's recommended pattern for tensioning.

Cylinder head sequences may have been developed to minimize bore distorion caused by bolt loading and gasket issues

Intake manifolds often require special care

If you are dealing with a cylinder block that has been bored and honed with a honing plate in place, then the final tensioning of the cylinder head fasteners should dupicate the installation of the plate.

All tensioniong has to be from the center out
If you are on your own use a circle or cross
Same Same

Things that are not true.

I don’t care where you heard it.

- Some surface roughness will keep a gasket from sliding out of a joint.
- Full size ground thread studs are better
- You have to use new gaskets
- You have to put something on most gaskets
- If castings are the same material - they will expand and contract together
- Retorque is a waste of time
- Torque sequence has to be like the book

Surface Finish

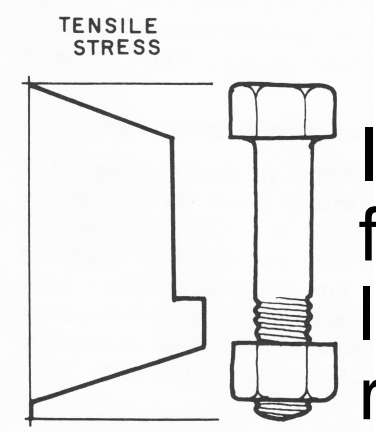
"There has never been a documented sealing failure attributed to too smooth a surface finish."
(Richard Russel - Chief Engineer at McCord Gasket)

Surface finish roughness is more likely to cause a gasket to "crawl" out of a joint than it is to hold it in place.

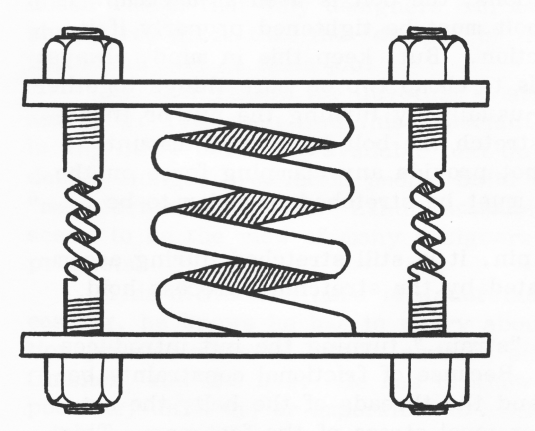
It can also be a preformed path for future leakage at that joint.

Full size ground thread studs

Memory Test: Look at slide 11



In this full size shank fastener, the maximum load is still limited by the root area of the thread.



But now the fastener stretch is reduced because of the larger body diameter and this will make the joint less compliant. (Less sense of humor.)

Any gasket that is removed undamaged can be reused

- It does have to go back the same way between the same two parts.
- It has already accommodated the irregularities of the mated parts.
- The fasteners do have to be tensioned as originally required.
- You were told the other story by the people that want to sell new gaskets.

Many new gaskets have a microseal coating.

Many modern gaskets are suppied with a very thin coating to enhance the surface microseal. This coating may not be very visible, and applying anything to the coated surface could at least be a waste of effort and it could possibly make the provided coating ineffectve.

If a gasket is coated on one side only, it may be intended to allow the parts to slide without damaging the integrity of the joint.

Head and Block Expand at the same time if the same material

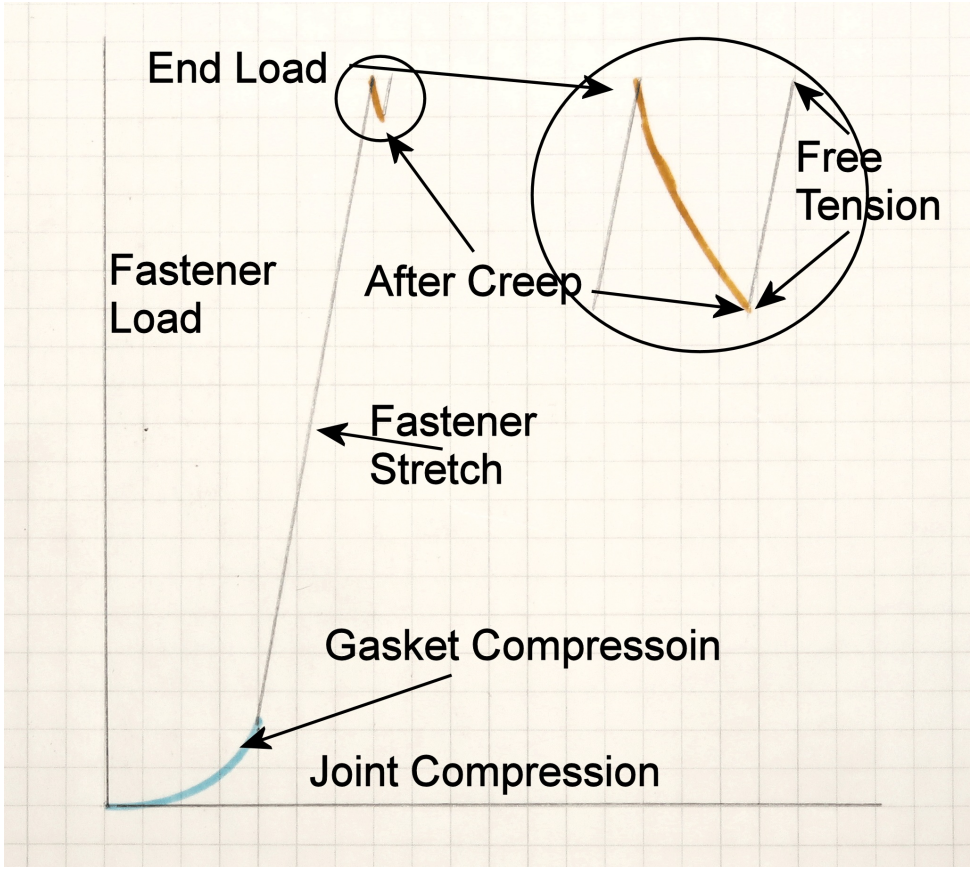
Not Happening in a running engine

The head always runs hotter than the block/crankcase

In a set of engineering lab experiments, I measured .015" joint movement on a Ford 4 cylinder tractor engine for each thermal cycle.

Retorque Always Helps

Clamp load is essential to a sound joint.
Joint relaxation reduces the final clamp load.
Would you like to get that back for Free?**



The name of the game with cylinder head gaskets is the ratio of bolt load to fire pressure

**It does require that you do a little more work.

If you can't do a hot retorque, let it sit a day.

Types of torque wrenches

- Flexible beam with floating pointer
- Deflecting Beam
- Dial face with pointer
- Preset click type
- Computer controlled with strain beam and angle sensor

Each of these have some advantages and disadvantages and some specific value

Flexible Beam

With a floating pointer

Advantages: The all time price leader
Calibration is inherent
Easy to use
Can be used to measure installed torque

Disadvantages: Requires that user can see the scale
No tactile indicator

Deflecting Beam

A Flexible Beam with a visual and tacticle indicator

Advantages: Operator does not have to see the scale
Calibration is inherent

Disadvantages: Sensor element can become inconsistent
No direct calibration
Does not self reset

Dial Face with Pointer

A flexible beam with clock gears in a case

Advantages: Clean appearance
Can be used to measure installed torque
Can be preset to end value

Disadvantages: The indicator mechanism is fragile
Operator has to be able to see the indicator

Preset Click Type

Very good for repetitive tensioning

Advantages: Presets to a precise value
Can produce highly consistent torque
Tactile indication
Most include a ratchet head

Disadvantages: Calibration is not inherent
Require more care and maintenance
No current value display

Computer Controlled

With Strain Bridge and Angle Sensor

Advantages: Presets to a precise value
Can produce highly consistent torque
Can have Audio and Tactile indication
Can display current value
Most include a ratchet head

Disadvantages: Calibration is not inherent
Require more care and maintenance
Require a battery or power supply

Measuring installed torque

This can be an effective diagnostic

There are Three Common Methods

- Break Away Torque
- Torque to Tighten
- Torque to Align (Mark)

That last is best and it will be outlined on the next two slides.

Torque to Align (Marks)

The best way to evaluate retained tension

Approved Method

1 - Put the socket on the fastener head and turn to tighten to very near design load.

2 - Make a reference mark on the socket while it is loaded.

3 - Back the fastener off until load is relieved.

4 - With a torque wrench, return the socket to align the marks.

5 - Record that torque value.

Torque to Align

This works just as well

Faster & Simpler Method

Uses a flexible beam torque wrench

1 - Put the socket on and pull at near final torque

2 - Make a clear mental note of the location in space of the end of the wrench pointer.

3 - Loosen the fastener until the load is relieved.

4 - Pull the wrench until the end of the pointer is where it was in step 2.

5 - Record that torque value.

Summary

Things I hope you didn't miss as it rolled by

- Everything leaks, bends and stretches
- Fastener grades are not interchangable either way
- Thinking of fasteners as springs is pretty close
- There are lots of ways to get to the right tension
- Nothing always works in the gasket world
- Surface finish almost always matters
- Care and Cleanliness both matter a lot
- Gaskets that are not damaged can be reused
- Torque wrenches are not the same, shop carefully