**ME 481/581**

***Unconstraint Fits***

What is an unconstraint fit?

What applications are usually unconstrained fits?

**Fit Application #1** – fit of a shaft to a thin sheet hole. Requires that: At each cross-section, the shaft must be smaller than the hole. Fit is guaranteed by limits of size only.

Terminology (memorize)

* What does “nominal size” mean?
* Hole Limits of size: Hmin and Hmax
* Shaft Limits of Size: Fmin and Fmax
* The difference between the size limits is the tolerance of size designated by lower case t
* Specify the tolerances of size in terms of size limits:
	+ tF =
	+ tH =
* Minimum play in a fit: Pmin
* Maximum play in a fit: Pmax
* What is the formula for calculating Pmin Pmin =
* What is the formula for calculating Pmax Pmax =
* Here to solve a fit problem we have to come up for the values of the 4 size limits. One is to be selected arbitrarily, so 3 unknows remain. We also specify the required fit performance (that is the minimum Pmin and maximum plays Pmax values).
* We still need another relationship to solve for all the size limits. A common approach is to set tF = tH.
* When solving tolerancing problems we have to select one of the limits of size arbitrarily. Usually the hole minimum size (Hmin) is selected to be equal to the nominal size. For example, if the nominal size is 20 mm, we select Hmin=20. This is because fixed tools such as drills or reamers create holes a little larger than their nominal size creating an acceptable hole quickly at least cost.
1. A round shaft is to fit a hole in a sheet metal. The nominal size is 20 mm.
2. Determine the size limits on both features for fit. Determine the size limits such that minimum possible play in the fit is 1 mm and maximum possible play is 2 mm.

**Solution**

1. In Prob-1 determine:
2. The MMC sizes of the shaft \_\_\_\_\_\_. The symbol for MMC size of shaft \_\_\_\_\_
3. The LMC sizes of the shaft \_\_\_\_\_\_. The symbol for LMC size of shaft \_\_\_\_\_
4. The MMC sizes of the hole \_\_\_\_\_\_. The symbol for MMC size of hole \_\_\_\_\_
5. The LMC sizes of the hole \_\_\_\_\_\_. The symbol for MMC size of hole \_\_\_\_\_
* An alternate and often better approach is not to solve for tolerance values – **since we know the intended processes, we know what size tolerance they can hold**. If we do that, we end up with 4 unknows and 5 equations! The common practice is to insist on the value of Pmin and set up an upper limit for Pmax. For example, Pmin = 1 and Pmax <= 2.

Go ahead and solve the problem again. But, instead of tH=tF, select tolerance values consistent with the intended processes. For example, the hole size tolerance tH=0.5 and the shaft size tolerance tF = 0.3

**Solution:**

1. In Prob-1, theoretical meaning of size tolerances. Practical inspection methods are based on these meanings but we will not go into inspection details.
	1. Draw the gage necessary to inspect the shaft. (on the paper for a 2D gage)
	2. Draw the gage necessary to inspect the hole. (on the paper for a 2D gage)
	3. Describe the theoretical inspection method.

Fit Application #1 is the only situation where is assured by using correct sizes and size tolerances. This type of fit almost never comes up in application. Fit applications always require control of other geometric aspects of the features in addition to the size limits.

The following case is a case of unconstrained fit between two features in which both features have significant length.

* What is the meaning of a fit being unconstrained?

**Fit Application #2** – fit of a shaft to a hole (no longer thin). In this case, the size limits on the shaft alone does not assure fit. Instead, we need to control the bending of the shaft (and the hole) as well. In fact, we need to control the combination of size and bending. For cylindrical features bending is controlled through straightness of axis tolerance. The combined size and bending for the shaft (or hole) are called fit boundaries (FB).

Draw the fit boundary for a 19-20 mm shaft that is also controlled by a straightness tolerance of 1 mm. For shafts the combined size (size of FBF) is the sum of the largest size shaft plus the straightness tolerance.

* Draw a schematic to show the FB of a shaft with size limits of 19-20 and straightness tolerance of 1 mm.
* Draw a schematic to show the FB of a hole with size limits of 22-23 and straightness of 1 mm.
* Write the formula for FBF (use the drawing above): FBF =
* Write the formula for FBH (use the drawing above): FBH =

Fit boundary sizes are also the sizes of the GO gages.

* What is a GO gage for a shaft with the above shaft fit boundary?
* What is a GO gage for a hole with the above hole fit boundary?
* Draw the two gages together
* Show (on the above) a shaft that fits the GO gage (but barely)
* Show (on the above) a hole that fits the GO gage (but barely)
* Based on what you see in the drawing above, write the formula for the minimum assures play Pmin.

 Pmin =

* Do the appropriate substitutions and write Pmin in terms of sizes and geometric tolerances (straightness tolerances).

Pmin =

* Draw a condition (sizes and bending) that results in maximum play happening in the fit.
* Based on what you drew, what is the formula for the maximum possible play?

Pmax =

* Alternate formula for Pmax by substitutions (follow class instructions):

Pmax =

1. A round shaft is to fit a hole. Both shaft and hole have significant length (not a sheet metal anymore). The general size (nominal size) is 20 mm. We know the following:

Hmin = 20 (selection)

tH = tF = 0.5 (size tolerances the intended processes can hold)

TH = TF = 0.25 (Straightness tolerances the intended processes can hold)

Pmin = 1 (design choice)

Pmax <= 3 (design choice)

1. **Determine:** The other 3 size limits such that Pmin and Pmax requirements are met. If Pmax exceeds the limit, adjust the tolerance values.
2. Place the required tolerances on the shaft and hole features.
3. What is the size of the FB of the shaft
4. What is the size of the FB of the hole
5. The MMC sizes of the shaft
6. The LMC sizes of the shaft
7. The MMC sizes of the hole
8. The LMC sizes of the hole \_
9. The formula for minimum play:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
10. The formula for maximum play: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
11. The alternate formula for maximum play in terms of tolerance values
12. Theoretical meaning of GD&T statement (straightness) for the shaft and the hole.
	1. Draw the gage necessary to inspect the shaft. (this is a 3D gage)
	2. Draw the gage necessary to inspect the hole. (this is a 3D gage)

**Some deductions:**

1. If a shaft is made to be closer to its minimum size, the shaft can bend more than when it is made closer to its maximum size [T F]
2. If a shaft has size limits of 20-22 and a straightness tolerance of 1 mm (all at **m**), then it can bend 3 mm when it is made at 20 mm [T F].
3. If a hole has size limits of 18-20 and a straightness tolerance of 1 mm, then it can bend as much as 2 mm when it is made at 20 mm. [T F]
4. Suppose a shaft size limits are 20-22 and its straightness is 1 mm (total tolerance 3 mm)
	1. What is the size of the fit boundary?
	2. A shaft made at 20.5 with 1 mm bending is acceptable [T F]
	3. A shaft made at 20.5 with 2.2 mm bending is acceptable [T F]
	4. A shaft made at 22.5 with 0.2 mm bending is acceptable [T F]
5. Suppose the shaft size limits are 20-23 and its straightness is 0 mm (total tolerance 3 mm)
	1. What is the size of the fit boundary?
	2. A shaft made at 20.5 with 1 mm bending is acceptable [T F]
	3. A shaft made at 20.5 with 2.2 mm bending is acceptable [T F]
	4. A shaft made at 22.5 with 0.2 mm bending is acceptable [T F]

Questions 9 and 10 are two versions of specifying tolerances (combined tolerances of 3 mm). Both have the same fit boundary (same Pmin performance) and both have the same Fmin (same Pmax performance). Which one is better and why?

Default form control

* If the size limits of a feature of size are specified with no straightness control specification, then by default it has a zero-straightness tolerance at MMC. This is known as Rule#1

This default rule is there because a lot of untrained design engineers think that if the minimum size of the hole is equal to or larger than the maximum size of the shaft, then the fit is assured – which is not true as size tolerance only controls the cross-sections. Show this graphically.