# MATERIALS MATTER

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## DIN 5481 type spline serrations can be manufactured by milling cutter, hob, broach, and rolling.

**THIS MONTH, WE WILL FOCUS ON CALCULATING AND SIZING** DIN 5481 type spline serrations for any application. The latest document is a 2009 update to the original 1956 standard. However, the document is not available in the U.S. due to publishing restrictions. As far as I know, it is only printed in German. Nevertheless, the procedure for designing with these straight-sided serrations is straightforward. The splines themselves make for connections that are simple, elegant, easily calculated, and strong. They can be manufactured by milling cutter, hob, broach, and rolling. Net shape molding is easily done with tooling readily made by many suppliers.

The DIN standard fixes spline serrations both internal and external with a constant space angle of 60° for numbers of teeth between, 28 to 42 and pitch diameters from 7.0 mm up to 60.0 mm. For larger splines,, a constant space angle of 55° is specified for numbers of teeth between, 41 to 81 and pitch diameters of 60.0 to 120.0 mm.

DIN 5481 includes standard tables for internal and external spline fits. This design data is tried and true. However, the document is in German and equations for the table data are not provided. For net shape gearing, this type of serration can be applied to any custom application requirements. Unique spline sizes and fits that are not found in the tabled data can be developed just by using the same geometric logic. Custom sizes are easily calculated by understanding the underlying basic geometry.

The spline geometry, illustrated in Figure 1, is as follows:
The choice of the inclusive angle is arbitrary but the DIN standard uses only 60° and 55°

### DEFINITIONS:

- (L) = chord subtended by tangent points intersecting the pin diameter and the serration space width
- (MOW) = measure over wires, pins or balls for external Splines
- (MBW) = measure between wires, pins or balls for internal Splines (not shown)
- (rpin) = radius of the pin,
- (Dpin) = pin diameter
- (h) = distance from the chord to the pin center
- (H/2) = distance from center of spline axis to chord

### ABOUT THE AUTHOR:

Fred Eberle is a technical specialist in the development of gearing, drive motors, and power closure devices in the automotive industry. He currently serves on the AGMA Plastic and PM Gearing Committees. Eberle has authored several papers on gearing, measurement system analysis and process statistics. He can be reached at Fred_Eberle@hci.Hi-Lex.com.

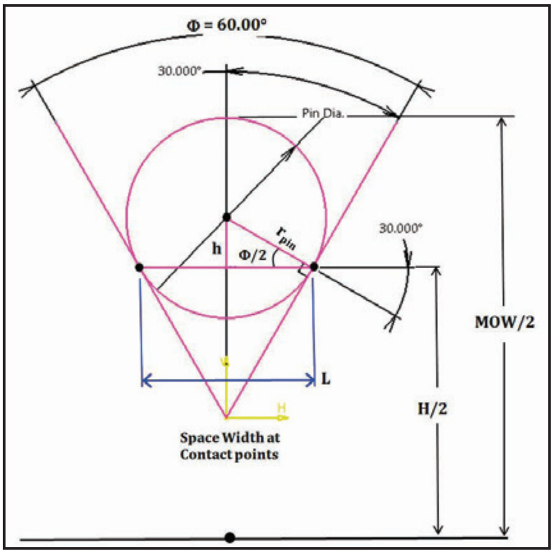

Figure 1: Spline Space Width at Contact Points

### RELATIONS:

- Sin (/2) = h/rpin,
- h = rpin*Sin(/2)
- Cos(/2) = (L/2) / rpin = L / Dpin
- L = Dpin*Cos(/2)
- H/2 = [MOW/2 - rpin – h]

The key to serration tolerances: Space width clearance per side as shown is equal to:

- Minimum, [0.5*(Min Internal MBW/2 - Max External MOW/2)]
- Maximum, [0.5*(Max Internal MBW/2 - Min External MOW/2)]

Clearance fits between major and minor diameters are set by the designer by specifying internal/external diameters and root radii (see Figure 2). Some examples of useful serations are as follows:

For ease of assembly, a net shape molded tapered spline, as illustrated in Figure 3, can be designed. These are more complicated to execute and measure, but they are developed exactly the same way as single straight splines. Pick two locations along the spline length, determine the taper angle desired, and then determine the measure over wires or pins to suit your taper. Design of

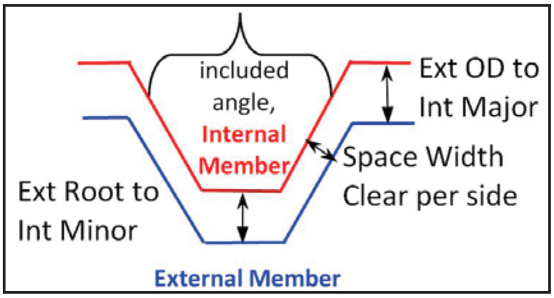

Figure 2: Mating Spline clearances.

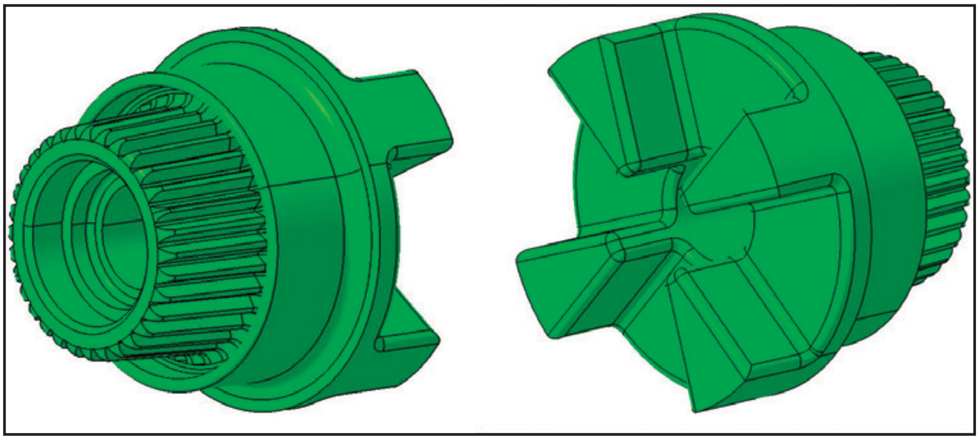

Figure 3: Example of a tapered Spline.

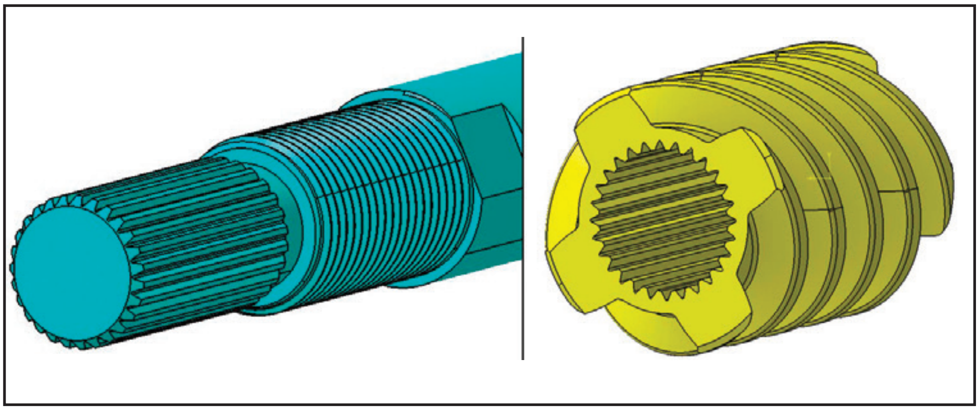

Figure 4: Example Int/Ext Spline connection.

the internal member is done by off-setting the external member (via an increase in the distance between pins), then rotating it one tooth space. Once done, the model is ready for virtual assembly.

## AN IMPORTANT OBSERVATION

The difference between the measure to the center of the (external) pin and the measure to the center of the (internal) pin will result in a total space clearance between two mating splines (an example of which is seen in Figure 4) of the same amount or one-half the amount per side when assembled. For example: if the center to the external pin is 10 mm and the center to the internal pin is 11 mm; then the total clearance will be 1 mm or 0.5 mm on the side of each spline. This can be readily verified by modeling.

Determining the strength of the spline connections is reasonably easy with finite element programs. The geometry is symmetrical. Therefore, a small portion of the component and number of the teeth are only needed for the analysis. The strength will be determined by the number of teeth and portions of teeth in contact (see Figure 5). The load sharing is predicated on the physical tooth alignments. Plastics tend to deliver surprisingly good results especially in unfilled materials. The compliance of the teeth may result in complete load sharing, whereas in hardened steel splines compliant load sharing can be significantly limited. In these cases, the precision of the analysis will be predicated on accuracy of the components and assembly alignments in addition to experience and good engineering judgment regarding loaded tooth contacts within the application. The key to load sharing is deflection. FEA will give a theoretical result. But if axis alignments, pitch and lead variations can be discerned and modeled, virtual contact can be evaluated to derate the theoretical result accordingly and lead to a more accurate analysis.

## INSPECTION MEASUREMENTS OF INTERNAL SPLINES

A drawback to measuring internal splines is verifying the between-pin distance. This can be especially difficult when the component is non-metallic. As long as the pins are firmly held in place without causing deflection of the teeth, a particular concern with plastics, a CMM can take measurements between the exposed wires. A cylindrical wedge can be helpful to hold the pins in place, as illustrated in Figure 6. However, with smaller modules even this technique becomes more difficult. In these cases and for high volume components GO / NOGO gages are recommended. For modules of 0.7 and smaller, the gage may be the only reasonable choice.

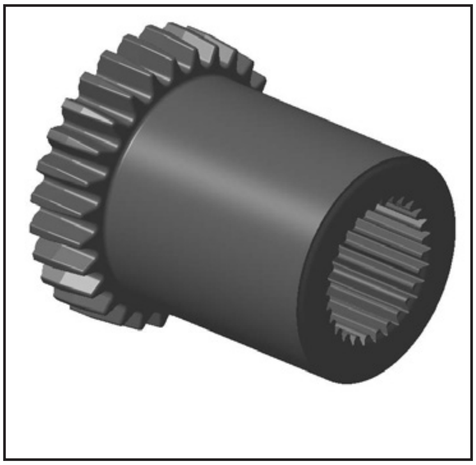

Figure 5: Example of a Int Spline with an Ext spline for over-molding into a plastic connection.

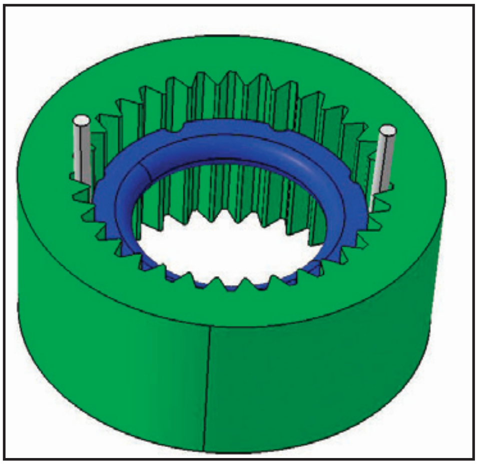

Figure 6: Measurement of an Internal non-metallic Spline.

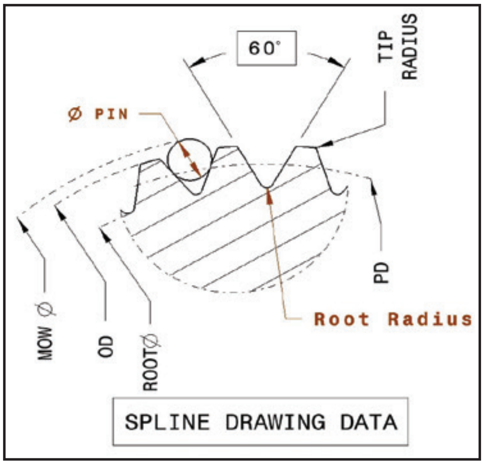

Figure 7: Example of Spline drawing data