Published at http://gtrebaol.free.fr/doc/catia/spur_gear.html Written by <u>Gildas Tr é baol</u> on June 10, 2005. Zipped part: <u>spur_gear.zip</u> (256 KB). Zipped demo: <u>spur_gears.zip</u> (1.25 MB). VRML97 model: <u>spur_gear.wrl</u> (44 KB).



Since the geometry of a spur gear is controlled by a few parameters, we can design a generic gear controlled by the following parameters:

The pressure angle a. The modulus m. The number of teeth Z.

This tutorial shows how to make a basic gear that you can freely re-use in your assemblies.

1 Sources, credits and links

Most of my tutorial is based on a nice tutorial on helical gears in English at <u>http://ggajic.sbb.co.yu/pub/catia/</u>. I improved it a little for making an exactly symmetric tooth. The mathematic description of the involute curve is visually explained in French at <u>http://serge.mehl.free.fr/courbes/developC.html</u>. The gear technology is explained in French at <u>http://casm.insa-lyon.fr/engrenag/</u>. The conventional formulas and their names in French come from the pocket catalog <u>Engrenages H.P.C</u>, June 1999 edition.

2 Table of gear parameters and formulas

Here is a table containing the parameters and formulas used later in this tutorial. The table is given first so that you can use it for further copy/paste operations. All the units are defined in the metric system.

#	Parameter	Type or unit	Formula	Description	Name in French
1	а	angular degree	20deg	Pressure angle: technologic constant (10deg a 20deg)	Angle de pression.
2	m	millimeter	—	Modulus.	Module.
3	Z	integer	_	Number of teeth (5 Z 200).	Nombre de dents.
4	р	millimeter	m *	Pitch of the teeth on a straight generative rack.	Pas de la denture sur une cr é maill è re g é n é ratrice rectiligne.

5	e 🧭	millimeter	p / 2	Circular tooth thickness, measured on the pitch circle.	Epaisseur d'une dent mesur é e sur le cercle primitif.
6	ha 🗭	millimeter	m	Addendum = height of a tooth above the pitch circle.	Saillie d'une dent.
7	hf	millimeter	if m > 1.25 hf = m * 1.25 else hf = m * 1.4	Dedendum = depth of a tooth below the pitch circle. Proportionnally greater for a small modulus (1.25 mm).	Creux d'une dent. Plus grand en proportion pour un petit module (1.25 mm).
8	rp 🧭	millimeter	m * Z / 2	Radius of the pitch circle.	Rayon du cercle primitif.
9	ra 🥽	millimeter	rp + ha	Radius of the outer circle.	Rayon du cercle de t ê te.
10	rf 🗭	millimeter	rp - hf	Radius of the root circle.	Rayon du cercle de fond.
11	rb 🥽	millimeter	rp * cos(a)	Radius of the base circle.	Rayon du cercle de base.
12	rr	millimeter	m * 0.38	Radius of the root concave corner. (m * 0.38) is a normative formula.	Cong é de raccordement à la racine d'une dent. (m * 0.38) vient de la norme.
13	t	floating point number	0 t 1	Sweep parameter of the involute curve.	Param è tre de balayage de la courbe en d é veloppante.
14	xd	millimeter	rb * (cos(t *) + sin(t *) * t *)	X coordinate of the involute tooth profile, generated by the t parameter.	Coordonn é e X du profil de dent en d é veloppante de cercle, g é n é r é par le param è tre t.
15	yd	millimeter	rb * (sin(t *) - cos(t *) * t *)	Y coordinate of the involute tooth profile.	Coordonn é e Y du profil de dent en d é veloppante de cercle.

Draft showing the parameters: a, ra, rb, rf, rp:



2.1 Notes about the formulas (in French)

Formule N ° 11: explication de l' é quation rb = d * cos(a) / 2:

La cr é maill è re de taillage est tangente au cercle primitif. Au point de contact, a d é finit l'angle de pression de la ligne d'action. La ligne d'action est tangente au cerce de base. On a donc un triangle rectangle à r é soudre.

Formule N ° 12:

Entre le cercle de pied et les flancs des dents, pr é voir un petit cong é de raccordement pour att é nuer l'usure en fatigue.

Formule N ° 14: explication de x = rb * cos(t) + rb * t * sin(t):

Le premier terme correspond à une rotation suivant le cercle de base. Le second correspond au d é roulement de la d é veloppante.

3 Enable the display of the parameters and formulas

We first need to configure Catia: set the 2 highlighted check boxes:

```
Designing parametric spur gears with Catia V5
```

Options Général Général Affichage Document Part Affichage dans l'arbre Compatibilité Paramètres et mesure Périphériques et Réalité Périphériques et Réalité Product Structure Product Structure Poto Studio Pos de vérification au renommage Pas de vérification Sous le même noeud Dans l'objet principal Forme	Options	2 🔀 🕤
Analyse & Simulation Rétablir	Options Général Matfichage Paramètres et mesure Périphériques et Réalité Product Structure Product Structure Material Library Editeur de catalogue Photo Studio Photo Studio Photo Studio Photo Studio Paramètre Infrastructure DELMIA Infrastructure 3D Anno Conception Mécanique Forme Analyse & Simulation Rétabir	thage Document Part rbre es externes es es es géométrie t le solide courant opéré res de composants et contraintes ification au renommage érification nême noeud jet principal

Now the tree of your part should look like this:



4 Define the generation parameters

Switch to the Generative Shape Design workshop and click on the f(x) button:

Omm	
	≈_
Avec Simple Valeur	
Supprimer formule	N
OK Appliquer S Annuler	*
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Then you can create the gear generation parameters:

- 1. Select the unit (integer, real, length, angle, ...).
- 2. Press the create parameter button.

- 3. Enter the parameter's name.
- 4. Set the initial value, used only if the parameter has a fixed value.

F	ormules: gear				? 🛛
	Incrémental Filtre sur gear Filtre par Nom : Filtre par Type : Tous Double cliquer dans la liste pour modifier un paramètre				Importer
	Paramètre	Valeur	Formule		Active
	m	2mm			
	gear\Reference gear\Nomenclature gear\Revision gear\Description_produit gear\Definition	gear			
I	Editer le nom ou la valeur du paramètre sélectionné				
	m		2mm	-	
	Créer paramètre de type Longueur 💌 Avec S	imple Valeur	▼ 2mm		Ajouter formule
	Supprimer paramètre				Supprimer formule
			🙆 ок	Applique	uer 🧕 🔪 Annuler

Now your tree should look like this:



5 Define the computed parameters

Most of the geometric parameters are related to \underline{a} , \underline{m} , and \underline{Z} . You don't need to assign them a value, because Catia can compute them for you. So, instead of filling the initial value, you can press the add formula button:

F	ormules: gear				?	P X
	Incrémental Filtre sur gear Filtre par Nom : Filtre par Type : Tous				Importe	r
1	Double cliquer dans la liste pour modifier un paramètre	1	- (
	Paramètre	Valeur	Formule		Active	^
	a	20deg				
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e.	gear)Nomenclature					
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	ju Editer le pom ou la valeur du paramètre célectioppé	omm				
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	Créer paramètre de type Longueur 🗸 Avec S	5imple Valeur	•		uter formu	
	Supprimer paramètre			Supp	rimer form	ule
			🙆 ОК	Appliquer	🤪 Annu	ler

Then you can edit the formula:

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```

Editeur de formules : d					
Incrémental d m * Z		=	2		
Dictionnaire Paramètres Table de paramétrage Opérateurs Points Constructeurs Loi Droites Constructeurs Cercles Constructeurs Chaîne	Membres de Paramètres Tous Paramètres renommés Longueur Entier Angle String Plan Solide	Membres de Tous Membre			
		🗳 ок	Annuler		

6 Check the fixed and computed parameters

Set the following option in order to display the values and formulas of each parameter:

```
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```



Now your tree should display the following parameters and their formulas:



7 Define the parametric laws

Up to now, we have defined formulas for computing parameters. Now we need to define the formulas defining the $\{X,Y\}$ position of the points on the involute curve of a tooth.

We could as well define a set of parameters x0, y0, x1, y1, ... for the coordinates of the involute's points. However, Catia provides a more convenient tool for doing that: the parametric laws.

In order to create a law, press the fog button and enter the law name as follows:



Then edit the formula of the 2 laws used for the X and Y coordinates of the involute curve:

xd = rb * (cos(t * PI * 1rad) + sin(t * PI * 1rad) * t * PI) yd = rb * (sin(t * PI * 1rad) - cos(t * PI * 1rad) * t * PI)

```
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Editeur de loi : x Active	
	0
<pre>/* x pour la developpante */ xd = rb * (cos(t * PI * 1rad) + sin(t * PI * 1rad) * t * PI)</pre>	Paramètres formels Type xd Longueur t Réel
	t Créer paramètre de type Réel 💌
Dictionnaire	Supprimer
Paramètres Tous Relations\Formule.1\Activité` Mots clés Paramètres renommés Relations\Formule.2\Activité` Table de paramétrage Booléen Relations\Formule.3\Activité` Opérateurs Entier Relations\Formule.4\Activité`	
Points Constructeurs Longueur `Relations\Formule.5\Activité` Loi Angle Z Droites Constructeurs String m Cercles Constructeurs Plan a	<u>~</u>
	OK Appliquer OK

Notes about the formula editor of Catia:

The trigonometric functions expect angles, not numbers, so we must use angular constants like 1rad or 1deg. PI stands for the number.

8 Make the geometric profile of a single tooth

The whole gear is a circular repetition of the tooth pattern. The following steps explain how to design a single tooth:

- 1. Define the parameters, constants and formulas (already done).
- 2. Insert a set of 5 constructive points, having a position defined by the xd(t) and yd(t) laws:
 - $_{\odot}~$ Define 5 points anywhere on the XY plane:



• Edit the H and V coordinates of the points for t = 0 to t = 0.4 (most gears do not use the involute spiral beyond 0.4)

🏻 👇 r 🛛 poir	it 2	
	H=24,36mm=Relations\xd.Evaluate(0.2)	
	Editer paramètre	? 🗙
	Corps surfacique.1\point 2\Point 2\Point	⊟ f ∞
← - poir	С ок	Annuler

- o Compute the H and V coordinates of each point with a different value of the sweep parameter t.
- \circ For example, for the V coordinate of the involute's point corresponding to t = 0.2:

Editeur de formules	*Corps surfacique.1\point 2\Point sur plan.1\V	?×
Incrémental Corps surfacique.1\point	2\Point sur plan.1\V =	Ø
Relations\yd.Evaluate((2)	
Dictionnaire Paramètres Table de paramétrage Opérateurs Points Constructeurs Loi Droites Constructeurs Cercles Constructeurs Chaîne	Membres de Paramètres Membres de Tous Tous Corps_principal\Esquisse.1\Activity Paramètres renommés Corps_principal\Esquisse.1\Repere\A Boolean Corps_principal\Esquisse.1\Contact.1 Corps_principal\Esquisse.1\Contact.1 Corps_principal\Esquisse.1\Contact.1 Corps_principal\Esquisse.1\Parallelism Corps_principal\Esquisse.1\Parallelism Angle Corps_principal\Esquisse.1\Parallelism Booléen Corps_principal\Esquisse.1\Parallelism Corps_principal\Esquisse.1\Parallelism Corps_principal\Esquisse.1\Parallelism	ctivil 9\A 9\m 1e.21 1e.21
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3. Make a spline curve connecting the 5 constructive points:

D	Définition de la courbe 🛛 ? 🔀								
	Points	Dir Tangentes	Tensions	Dir Rayons	Rayons Co	irbure			
	point 0	Diri Tangoneos	TOTISIONS	Dirritayons	- Rayons Co.				
	point 1								
e.	point 2								
	point 4								
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	Ajoute	er après 🔿 Ajou	ter avant (O Remplacer					
	🗌 Géome	etrie sur support	Pas de sé	lection					
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	Plus de F	^p aram >>							
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4. Extrapolate the spline toward the center of the gear:

• The involute curve ends on the base circle of radius rb = rp * cos(20) rp * 0.94.

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- When Z < 42, the root circle is smaller than the base circle. For example, when Z = 25: rf = rp - hf = rp - 1.25 * m = rp * (1 - 2.5 / Z) = rp * 0.9.
- So the involute curve must be extrapolated for joining the root circle (the length to extrapolate is empirically defined by the formula f(x) = 2 * m):

Définition de l'extrapolation ? 🔀					
Extrémité:	point 0				
Extrapolé:	Spline.1				
Limite —					
Type:	Longueur 🗾				
Longueur:	4mm \Xi f (x)				
Júsqu'à:	Pas de sélection				
Continuité:	Tangence 🗾				
Support:	Défaut (Aucun)				
ок	Annuler Aperçu				

5. Check the extrapolation near the point zero of the involute spline:

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6. Define the contact point, at the intersection between the involute curve and the pitch circle:

- $_{\odot}\,$ By principle, on that point the polar angle equals the pressure angle.
- $_{\odot}\,$ At the contact point we have the sweep parameter t = a / 180deg
- $_{\odot}$ So we can compute it like the previous constructive points p0 ... p3:



7. Define a contact plane that contains the gear axis and the contact point:

Définition du plan	? 🗙
Type de plan : Par un point et ur	ne droit 💌
Point: point contact	
Droite: Axe Z	
OK OK	Aperçu

- 8. Define the median plane of a tooth:
 - $_{\odot}$ On a symmetric gear, the angular width of each tooth is 180deg / Z.
 - So the angle between the median plane and the contact plane is twice smaller: 90deg / Z.
 - The median plane is defined as a plane containing the rotation axis,

with and angle of 90deg / Z relative to the contact plane:

Définition du plan	×			
Type de plan : Angle/Normal à un plan	•			
Axe de rotation : Axe Z				
Référence: plan ligne contact				
Angle: 4,091deg 🗄	x)			
Normal au plan Répéter l'objet après OK				
OK Annuler Aperçu				

- 9. Define the start plane of a tooth:
 - We are designing a single tooth.
 - $_{\odot}~$ The profile of each tooth starts on the root circle,
 - at the midpoint between two consecutive teeth.

- The start plane is defined as a plane containing the rotation axis, with and angle of -90deg / Z relative to the contact plane.
- As you can see, it is symmetric to the median plane, relative to the contact plane.
- 10. Draw the root circle:
 - o On the start plane, define the start point of the root circle :

V = 0

H = -rf = -(rp - hf) = -rp + 1.25 * m

(or the opposite, depending on the normal direction on that plane)

o Define the root circle with the "Center-Point" dialog box:

Center = 0,0,0

Point = the start point defined above.

Sweep angle = 0 to 90deg.

deg

11. Insert a round corner between the root circle and the extrapolated spline:

 Set the cut and assemble check boxes, so that the resulting shape is a single curve that contains the root circle, the round corner and the extrapolated spline:

Définition du coin		
Type de coin: Coin Sur Support 🗾		
Coin sur sommet		
Elément 1: cercle fond		
📁 Découpe et assemblage de l'élément 1 🔵		
Elément 2: Extrapolation.1		
🕞 Découpe et assemblage de l'élément 2		
Support: Défaut (Plan)		
Rayon: 0,5mm 🗄 f(x)		
Solution suivante		
OK Annuler Aperçu		

- 12. Draw the outer circle with the Center-Radius dialog box:
 - Center = 0,0,0

0

- \circ Support = XY plane
- Radius = ra = rp + ha = rp + m
- \circ Sweep angle = 0deg to 90deg.
- 13. Build the other side of the tooth with a symmetry of the corner curve:

Définition	de la symétrie	?×
Elément:	conge fond	
Référence:	plan median	
Cac	her/Montrer l'élément initia	l le
OK	Annuler A	perçu

14. Glue both symmetric profiles and the outer circle with 2 successive cut and assemble operations:

Définition du découpage assemblé	?×		
Elément 1: conge fond			
Elément 2: Symétrie.2			
Support: Défaut (Aucun)			
Eléments à retirer: Défaut (Aucun)			
Eléments à garder: Défaut (Aucun)			
Autre partie de l'élément 1			
Autre partie de l'élément 2			
Simplification du résultat			
Calcul de l'intersection			
OK Annuler 4	Aperçu		

15. Check the resulting tooth profile:



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9 Build the whole gear profile

The gear profile is just a circular repetition of the tooth:

```
Repetition mode: whole circle or whole crown.
Rotation axis : Z.
Number of instances: f(x) = Z.
```

Then you can merge together the repeated profile and the tooth base profile. The following tree shows the completed geometry, ready for the extrusion:

```
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```



10 Build the gear part body

Switch to the Part Design workshop.

Build the main body with a revolving sketch that gives the primary part to be machined on a lathe:



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Insert a second part body that gives the extruded profile of the teeth:



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Intersect both part bodies to obtain the final gear:



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Now you can play with the Z and m parameters and generate any spur gear:



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Luiter le parametre

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