Rolling of external threads

Generality

One of the most efficient systems for the generation of external threads is precisely the thread rolling, this consists of a cold lamination, which exploits the properties of certain materials to deform plastically.

The machines that perform these processes are specifically designed to make high production in a short time and, consequently, are almost always completely automated.

The thread rolling can be performed with circular or flat dies. In any case, the piece to be threaded, with a diameter slightly more than the medium diameter of the thread to be generated, is forced to roll between two dies properly threaded or grooved , which, under pressure , penetrate in the piece and gradually impressing the bottom of the profile and forcing the material to swell and move radically outward generating the crest of the tread. Therefore, there is not removal of chips contrary to what happens with other cutting tools.

Advantages and disadvantages of thread rolling

This type of processing has advantages and disadvantages, so that its adoption should be carefully considered. The advantages can be briefly listed as:

- *Speed and efficiency*. The thread rolling process is undoubtedly the fastest to execute threads in a wide range, and in fact, in some cases you can get to production of over a thousand pieces per minute. The appropriate use of autoloaders also allows a single operator to control multiple machines with a considerable saving of manpower.
- *Material savings*. Since there is no generation of chips, you get a slight economy of material: lower in smaller sizes, greater in larger diameters. They are also not ecological problems related to disposal of oil soaked chips.
- *Improvement of technological properties*. Since the fibers of the material are not cut as in conventional methods, but plastically deformed and forced to follow the contours of the thread, there is a general improvement of all the technological characteristics. The tensile strength, in rolled products in general, is about 10% higher than the normal . The resistance to torsion is significantly increased, and finally the resistance to stress, given the greater smoothness of the surfaces of the threads, which ensures a better grip, increase of about 75%.
- *Accuracy*. With the rolling of threads you can get high precision thread, suitable for every application, but only if that the roller dies are carefully constructed and that the blanks are properly prepared.
- *Uniformity of production*. The rolling dies (or the rolling racks) are not reground and retain their original profile until the entire band is not seriously damaged (almost always with more or less extensive chipping). So the threads are produced by thread rolling have an very uniform size if the blanks have constant diameters and that the material always has the same characteristics. Consequently, the dimensional control of parts produced may be limited to a small percentage.
- *Smoothness*. Browning due to compression and friction of the dies on the parts, cause slight surface hardening and a remarkable improvement of the roughness of the surface of the thread generated, improving its strength.

Besides these advantages, however, there are a number of disadvantages that can be as listed:

- *High cost of the rolling dies:* This factor makes it uneconomic rolling of a limited number of pieces.
- *Parts with cavities*. They are easily deformable under the pressure of the dies and thus can not be rolled.
- Materials with low ductility. Can not be rolled material having a coefficient of less than 8% elongation.

- *Hard materials*. Materials with a hardness exceeding 35 HRC are extremely difficult to roll.
- Depth-diameter ratio of the thread. When the depth of the thread is over 15% of the diameter, the roll is very difficult because the pieces after rolling, are distorted.
- Preparation of the blanks. Since this procedure is based on a movement of a definite amount of material, the accuracy of the various diameters of the thread, depends largely on the precision with which he prepared the diameter of pre-rolling. It is therefore necessary that the diameter of the workpiece to be rolled is contained in the tolerances at least equal to those required by the finished part. So operations are required to prepare a little more complex than those required for other methods of generation of the threads.

Circular rolling dies

A series of circular dies can be made up of two or three pieces depending on the machine on which must be used.

Set of two pieces. It's a very popular and is mounted on machines Pee Wee, Grob, Magnaghi, Escofier, Ort Rollwalztechnik, Seny, Wagner, Reed Rolled, Fette, Tornos,, etc. . The workpiece is supported by a holder, coming then compressed between two rolling dies mounted on parallel and horizontal shafts rotating in the same direction, see Fig. N° 1 and Figure N°2.

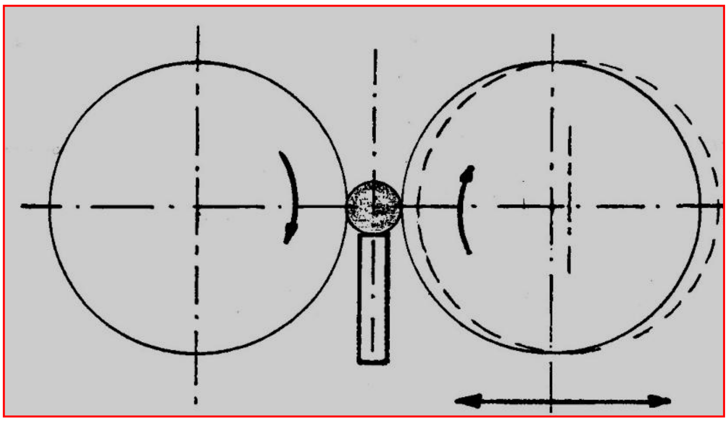

Fig. N°1

Fig. N°2

Normally in these machines a rolling dies olders is mounted on a fixed head, while the second is on a moving head , so as to allow, through a hydraulic control device, the approach, the penetration and the 'distancing rolling dies from the piece. This is not the only way, in fact, the feed can also be in tangential direction or the two rollers can move both in radial direction, as shown schematically in figures N°3 a) and N°3 b).

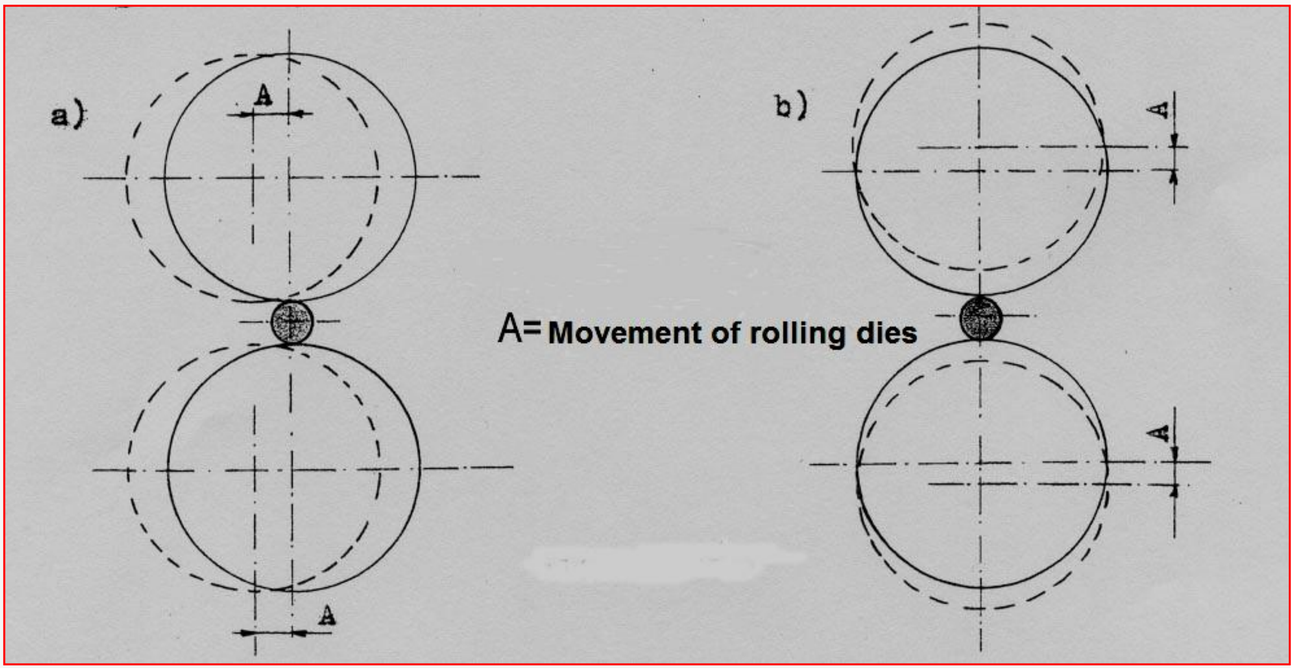

Fig.N°3 a) , b)

<u>Set of three pieces</u>. Are mounted on machines such as Wagner, Fette, Landis, Alco, etc.. where the three rollers rotate simultaneously at a determined speed parallel shafts driven by a system of "cammes" that determine the alternate approach and simultaneous removal. In this case the piece to be threaded does not need any support, because it is kept between the rollers that approach radially and rotated into a fluctuating position between them. See figures N°4, N°5 and N°6.

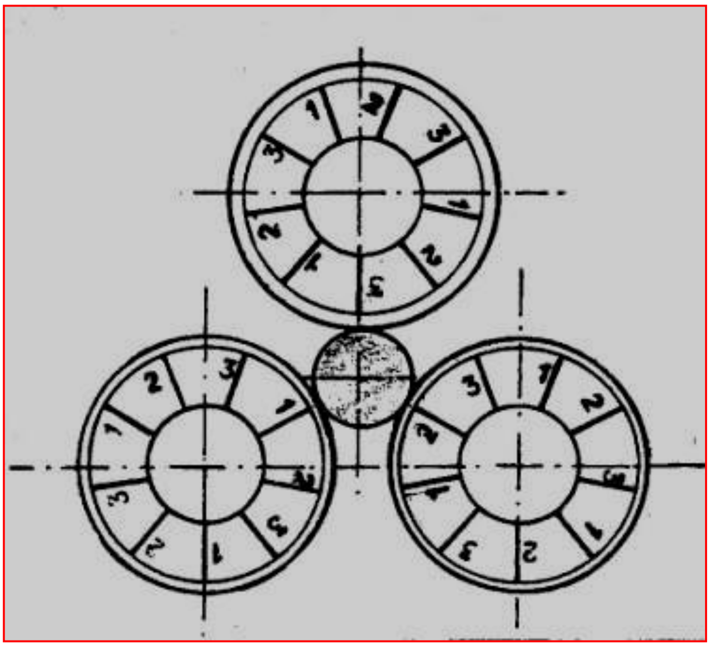

Fig.N°4

Fig. N°5

Fig. N°6

<u>Sizing of the threads rollers</u>

The most important elements to be determined during the design of the roller are the diameter and thickness.

For the calculation of the medium diameter of the roller is necessary to determine how many revolutions to do the piece to get the complete thread. In this regard, it may refer to table N°1, which for the most common materials, and for each pitch, gives the approximate number of revolutions required to get the thread.

Using this value and considering that the thread is finished in a revolution of the roller and that the thread helix angle on the roller must coincide with the helix angle of the thread to make, it is easy to calculate the diameter of the roller and the other elements.

Fig. N°6

You can apply the following formulas:

D_r = medium diameter of the roller

D_m = medium diameter of the thread to be executed

N = number of revolutions of the part for each revolution of the roller

$$D_r = D_m \cdot N$$

The helix angle of the part is:

$$tg\alpha = \frac{P}{D_m \cdot \Pi}$$

and since this angle must match the helix of the thread of the roller, we have:

$$tg\alpha = \frac{P \cdot N}{D_r \cdot \Pi}$$

which means that the roller should have a thread with N starts.
It is clear therefore that a set of rollers can perform only one type of thread and you can not roll with the same set of rollers, threads having the same pitch and different diameters.
It 'should be noted, however, that the one just described is just one of many systems of design and construction of the rollers. It 'clear that it is not obligatory that at in a single revolution of the roller you end up the thread.
Many manufacturers of rolling machines adopt much smaller rolles dies and they turn them several times on the piece in order to complete progressively the thread.
Ultimately, it could make a series of rollers equal to the thread to make and turn it N times on the piece.
The small diameter rollers have the obvious advantage of costing less, but they also have a shorter life.
The thickness of the roller is good if it is at least 10 to 15% greater than the length of the thread , of course, with rollers of a given thickness can roll all the threads with a length less than the thickness itself.

Tab. N°1- Approximate number of revolutions of the piece to form the thread

Thread per inch	*Pitch in mm*	*Brass, Alluminum*	*Steel with C or alloyed HRc=15*	*Steel with C or Cr or stainless. HRc=20*
32	0,75	10 – 15	11 – 18	14 – 23
24	1,00	11 –17	13 – 20	16 – 25
18	1,50	12 – 19	15 – 22	18 – 28
14	2,00	14 – 21	17 – 25	20 – 31
10	2,50	17 – 24	21 – 28	25 – 34
8	3,00	21 - 27	25 - 31	29 - 37

Generation of the threads with rollers, can also occur with some systems' less dedicated, ie using conventional equipment and machinery.
For example, the thread can be performed on a standard lathe, or even simple threading machines, using a single roller. It is pressed against the workpiece to be threaded up that has penetrated to the desired depth. You can roll with this method, pieces with diameters up to about 100 mm with a rolling speed of 16 - 20 m / min.
Lubricating properly you can get smooth surfaces, but the accuracy is lower than that obtained with other systems. This method can be used for production of small series.
This system is also poorly suited to small diameter pieces that have a tendency to flex.
See Figure N°7.

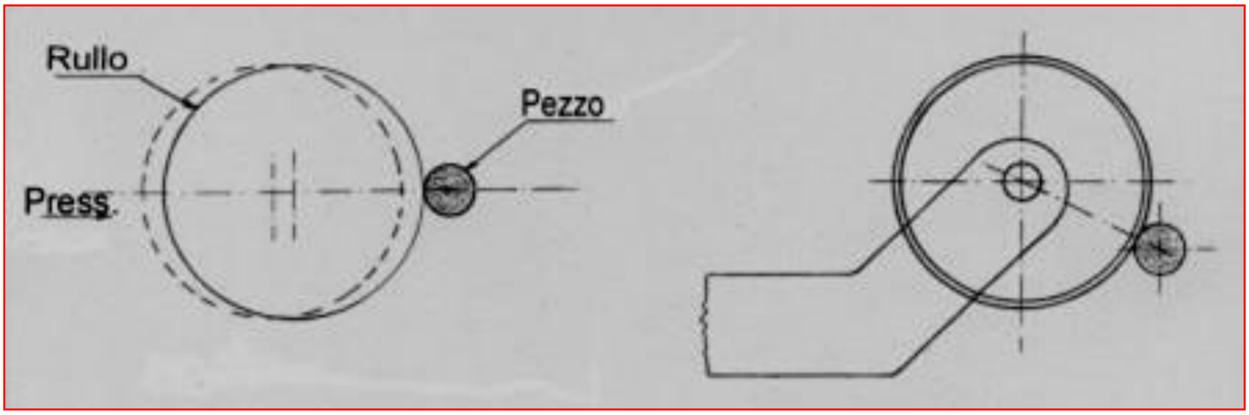

Fig. N°7

Some notes about the tangential feed of rolling dies

The feed of roller of the type shown in Figure N° 2 a) is generated by a circular cam whose development is shown in figure N°5.
Let's talk about cams, but in modern machines the same movement can be offered by a CNC which manages the progression of the feed more or less with the same law.
To determine the succession of feed is necessary to fix the feed of the roller per revolution of the workpiece.
Since:
F = feed of the slide for each revolution of the piece;
A = working stroke of the roller (from initial contact to the coincidence of the axis of the roller with the axis of the piece);
R = number of revolutions of the workpiece.

It's valid the following relationship $F = \frac{A}{R}$ and the working stroke is found with:

$A = \sqrt{P \cdot D_s \cdot (N+1)}$ where:

P = total depth of penetration of the roller in the blanks;
D_S = diameter of the blanks;
N = number of starts of the thread of the roller

The choice of the feed of the rollers is very important: in general, the ideal movement is what moves the center of roller until the center line of the piece with a predetermined and constant feed per revolution and after an eventual short stop in this position, returns the rollers to the starting position with a rapid stroke. This scheme is shown in figure N° 8.

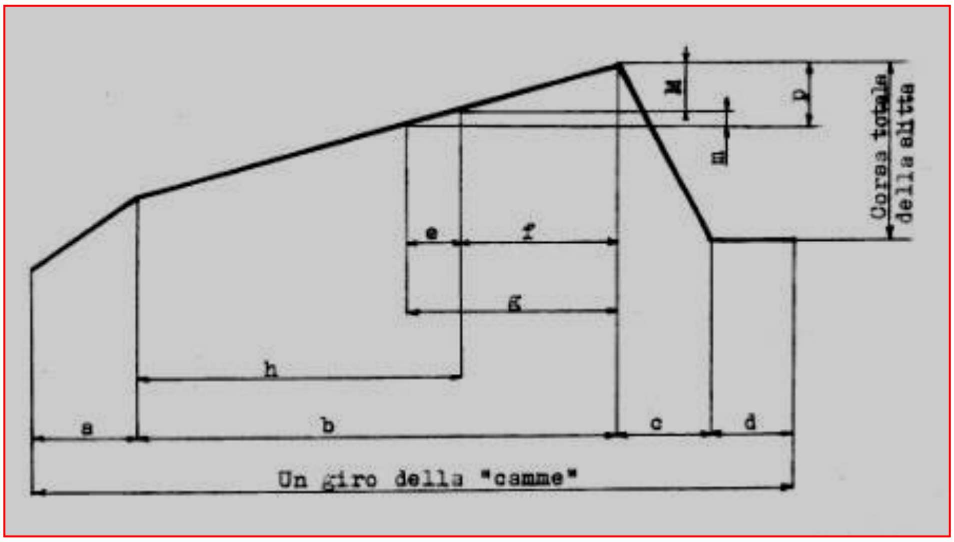

Fig. N°8

a)- Approach with a fast feed
b)- Stroke of approaching of the roller
c)- Return rapid stroke
d)- Stop of the slide in the back position
e)- m)- 25% of approach for positioning the roller
f)-M)- Approach of the roller to a final position
g)-p)- Sector required for the rolling cycle
h)- Stroke before contact of the roller with the blanks

Thread racks
Figure N°9 shows a scheme of the rolling operation with a set of thread racks.
There are two racks: normally, the lower is fix and the other, the upper, is movable.
With a stroke of the upper rack you get the full thread.
In some rolling machines racks are both mobile in opposite direction.

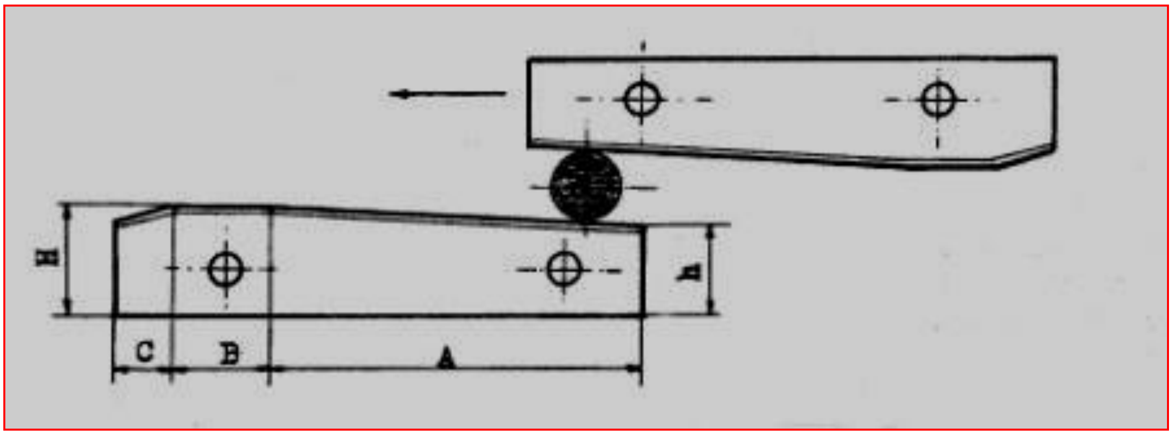

Fig. N°9

As can be seen in Figure N°9, the total length of the rack is divided into three parts: the first section A, named roughing has the function to penetrate into the workpiece and create the thread and, for this purpose, it is incremented. The second section B, named finisher, has the function to finish the thread by correcting any imperfections and make at least one full turn to the part about the final size. Finally, the third section, slightly decreased, gradually discharge the pressure from the workpiece.
The difference between height H and h must be at least equal to the half of difference between the diameter of the blank and root diameter of the thread. In practice, however, this difference has more to prevent you start working at the edge of the rack.
The determination of the various sections should be done keeping in mind the following points.

- *The number of revolutions of the piece needed to perform the thread. Are shown in table N°2.*
- *The section of finishing must allow at least one complete revolution of the workpiece.*
- *The length of the discharge may be about two-thirds of that finish.*

The speed of the racks, that is, the peripheral speed of the workpiece, it depends very much on the material being processed, on the type of thread , on the accuracy desired, on the type of machine, on the type of cooling oil, etc.. It is therefore not easy to give an absolute value of the rolling speed.
If you consider a soft steel, with R = 500 to 600 N/mm^2, rolling speed can be between 30 and 60 m/min. In table N°2 is shown what could be the rolling speed, in % of the above speed, for other materials.

Tab. N°2 – Number of devolution of the workpiece in the rack

Material	*N° of devolution of the part*		*Hardness*	*% of the speed given for C10 steel*
	Min	Preferable		
Aluminum	4	5 - 6	soft	80 %
Brass	4	5 - 6	soft	100 %
Steel C10 – C30	4	5 - 6	soft	100 %
Steel C30 – C50 or alloyed	5	6 – 7	15 – 25 HRc	70 %
	6	7 – 8	26 – 32 HRc	50 %
	7	8 - 10	33 – 40 HRc	25 %
Stainless steel	6	7 – 8	with Ni-Cr	50 %
	5	6 - 7	with Cr	60 %

In order to prevent that at the point where the workpiece detaches from the racks, may generate a longitudinal imperfection which would compromise the good efficiency of the thread, the exit edge must have a radius of 2 to 3 mm (figure N°10a).
The longitudinal thread obtained on the active surface of the racks, must have the same helix angle of the thread to be generated.
For example, in a set of racks for rolling a thread of 14x1,5 MB (medium diameter D_m=13.026), the inclination of the thread in the racks will be:

$$tg\alpha = \frac{P}{D_m \Pi} = \frac{1,5}{13,026 \cdot 3,14} = 0,03667 \Rightarrow \alpha = 2°6'$$

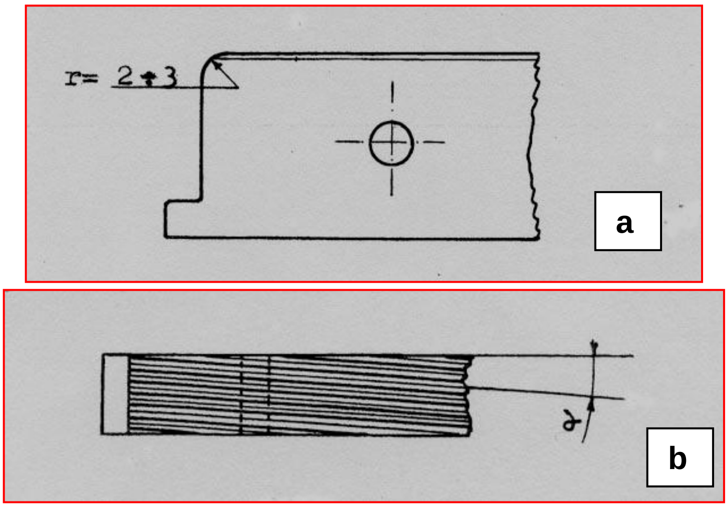

Fig. N°10 a) and b)

The teeth, having the profile of the thread to be executed, must be offset between a rack and the other, just half a pitch.
And should be therefore that the racks are positioned correctly on the machine both in the longitudinal direction (axial) and in the direction of the width (transverse).
For this purpose one end and the lateral surface of the racks are carefully ground to ensure perfect positioning against surfaces of the racks holder (see figure N°11).

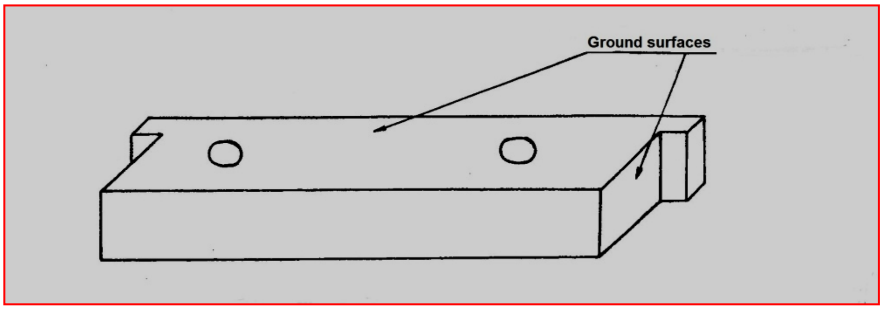

Fig. N°11

Rotary Planetary Thread Rolling
Is widely used for high production and for thread less than diameter of 12 mm, a system that includes a rotating roller and a fixed segment, both threaded with the characteristics of the thread to be generated.
The method, illustrated schematically in Figure 12, allows to obtain very high productions , up to 1600 parts per minute, because are eliminated all passive time in fact, during every revolution of the roller many thread are executed.

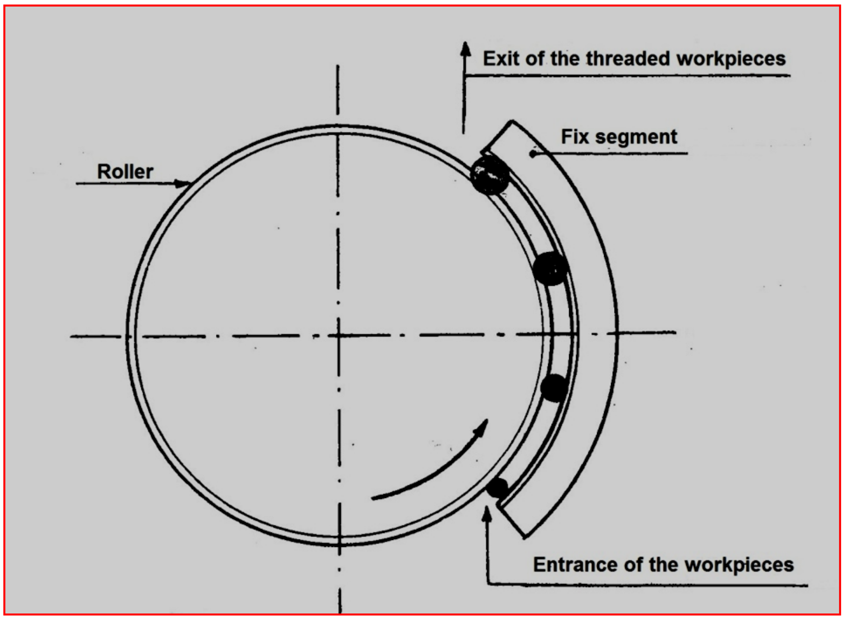

Fig. N°12

The table N°3 shows the possible productions executable with the various systems that we have talked just above.

Thread diameter (inch)	*Rotary Planetary*	*Racks*	*Roller*
1/8	400 - 1600	60 - 250	20 – 100
3/16		60 - 250	20 – 100
1/4		60 - 150	20 – 100
3/8	150	60 - 100	20 – 90
1/2	150	60 - 80	20 – 90
5/8	--	50 - 70	20 - 80
3/4	--	40 - 60	20 – 60
1	--	30 - 50	15 – 40
1 1/2	--	--	10 – 20
2	--	--	6 – 20
2 1/2	--	--	6 – 15
3	--	--	4 – 6
4	--	--	4 - 6

Preparation of blanks

In the rolling of the threads, the result depends largely on the precision with which the blanks are prepared. It 'should therefore be turning, and in some cases to grind the blanks. To get a good thread have to keep in mind the following points:
The diameter of the blank to be uniform over the entire length to be threaded.
The pieces must be free from excessive ovality because in this case would tend to jump out of the rolling position, causing the breakage of the racks.
The extremities of the pieces must have a chamfer of 30 ° to avoid chipping the threads of the racks
The undercuts adjacent to the shoulder, usually necessary in the threads machined or ground, are superfluous in rolled threads. When the grooves are necessary for specific work requirements, they should have a chamfer of 30 °.
Figure N° 13 shows some examples of pieces prepared for rolling.

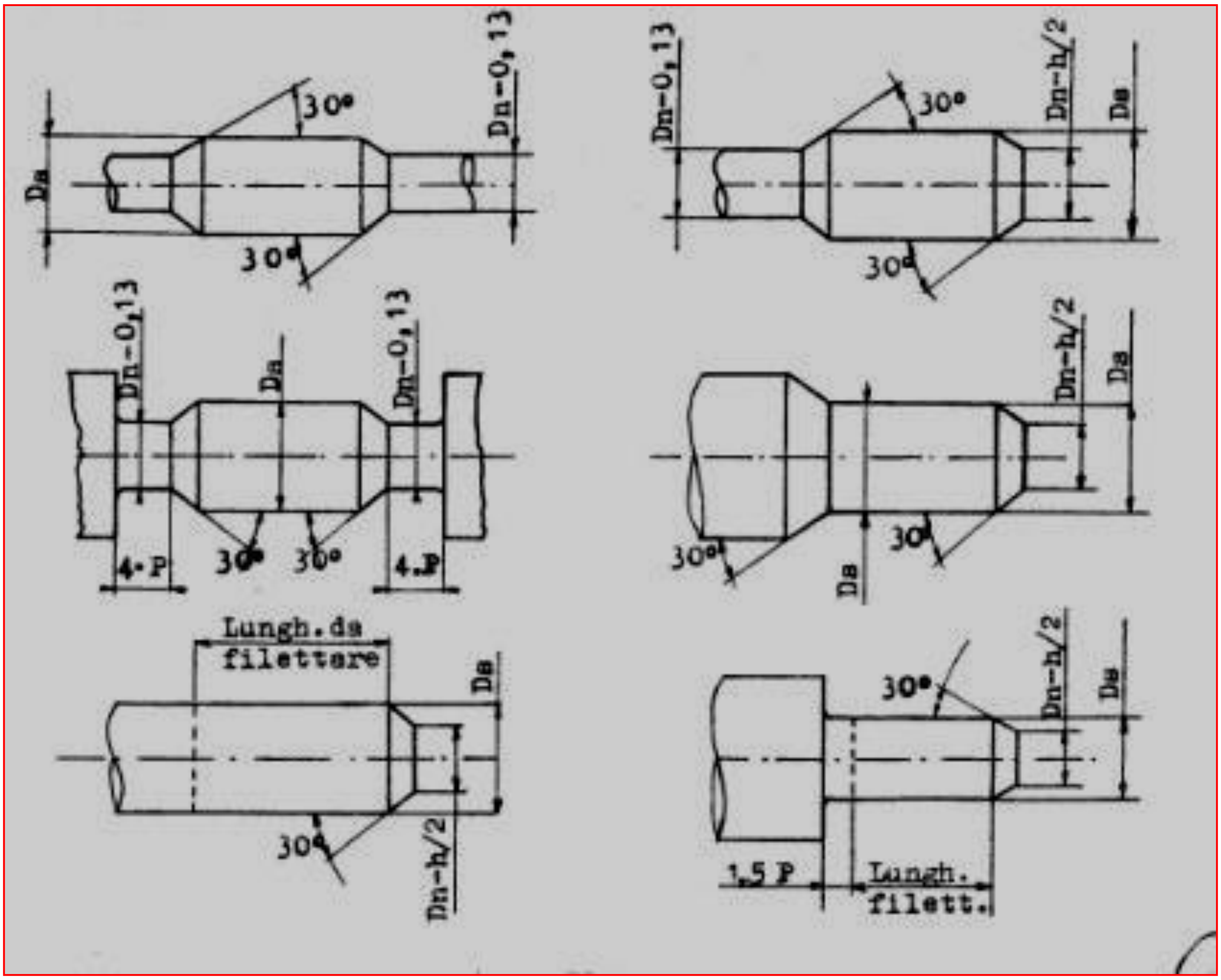

Fig. N°13

D_n = Root diameter of the thread
D_s = Diameter of the blank
h = Height of the teeth of the thread
P = Pitch of the thread

Diameter of the blank
The diameter of the pre-roll has, as has been said, the utmost importance not only for the accuracy of the finished piece, but also for the life of the racks .
The exact preventive determination of the diameter is difficult because depends largely on the characteristics of the material to roll.

Others secondary factors are the type of thread and the approaching speed.
For the calculation of the diameter of pre-rolling it's possible to use the tables N°4 and N°5 which refer to normal threads, where the height of the tooth profile is twice of the addendum.
The minimum pre-rolling diameter in the absence of secondary effects, should be the minimum of medium diameter of the thread. However this value is necessary to make slight adjustments depending on the type of material being processed.
The table N°4 shows the percentages of the tolerance of the medium diameter to be added to the minimum medium diameter of the thread to get the minimum diameter of rolling.
The pre-rolling diameter depends on the tolerance of the medium diameter of the thread and the diameter of the thread itself.
According to these elements have values that add to the minimum pre-rolling diameter in order to obtain the maximum diameter. See table N° 5.

Tab. N°4 – Data for calculation of pre-rolling diameter in according to the material

Material	*Hardness*	*% of tolerance of medium diameter of the thread*
Aluminum alloy	soft	20 – 50
Brass - Bronze	soft	20 – 40
Steel with 0,10 – 0,15% of C	Hard	0 – 20
Steel with 0,30 – 0,50% of C	HRc 12 - 25	20 – 40
Steel with 0,30 – 0,50% of C or alloy	HRc 26 - 32	30 – 50
Steel with 0,30 – 0,50% of C or alloy	HRc 33 - 40	40 – 60
Stainless steel- Alloy with Cr-Ni	--	60 – 80
Stainless steel- Alloy with Cr	--	40 - 60

The values shown in table N°5 are valid for threads having a length at least equal to the diameter (for threads up to diameter 25 mm) and a length of at least 25 mm for threads with larger diameter.
In case of short threads, the pre-rolling diameter shall be increased by higher percentages than those indicated in the table, to compensate the stretching that occurs during the rolling at the end of the blank. The more the threaded part is short and the greater the pitch, the more the pre-rolling diameter must be increased.

Tab. N°5- Values in microns to add to minimum diameter of pre-rollingin order to obtain the max diameter

Tolerance of medium diam. of thread (microns)	*Nominal diameter of thread (mm)*				
	Up to 12	12 - 25	25 - 38	30 – 50	50 – 80
28	8	6	5	--	--
40	13	10	8	--	--
50	18	18	15	13	--
56	18	18	18	15	13
63	20	20	20	15	13
71	25	25	25	18	15
80	25	25	25	20	15
90	30	30	30	20	20
100	33	33	33	25	20
112	35	38	38	30	30
125	38	43	43	38	38
140	43	52	52	43	43
160	52	52	52	52	52
180	57	57	57	57	57
200	63	63	63	63	63
224	--	63	75	75	75
250	--	75	75	90	90
280	--	75	90	90	100
355	--	--	--	100	100

Life of the racks

The life of the rollers and racks, as well as general factors, such as the characteristics of the rolling machine, the lubrication system, the accuracy of the assembly of the rollers and racks, also depends, and in a decisive way, on the type of material worked and, as has been said several times , on the precision of the diameter of the blanks.
If the diameter of the blanks exceeds the maximum obtained from table N° 5, the life decreases dramatically and this loss of efficiency is the more pronounced the higher the hardness of the material being processed.
Figure N°14 schematically shown the above said.

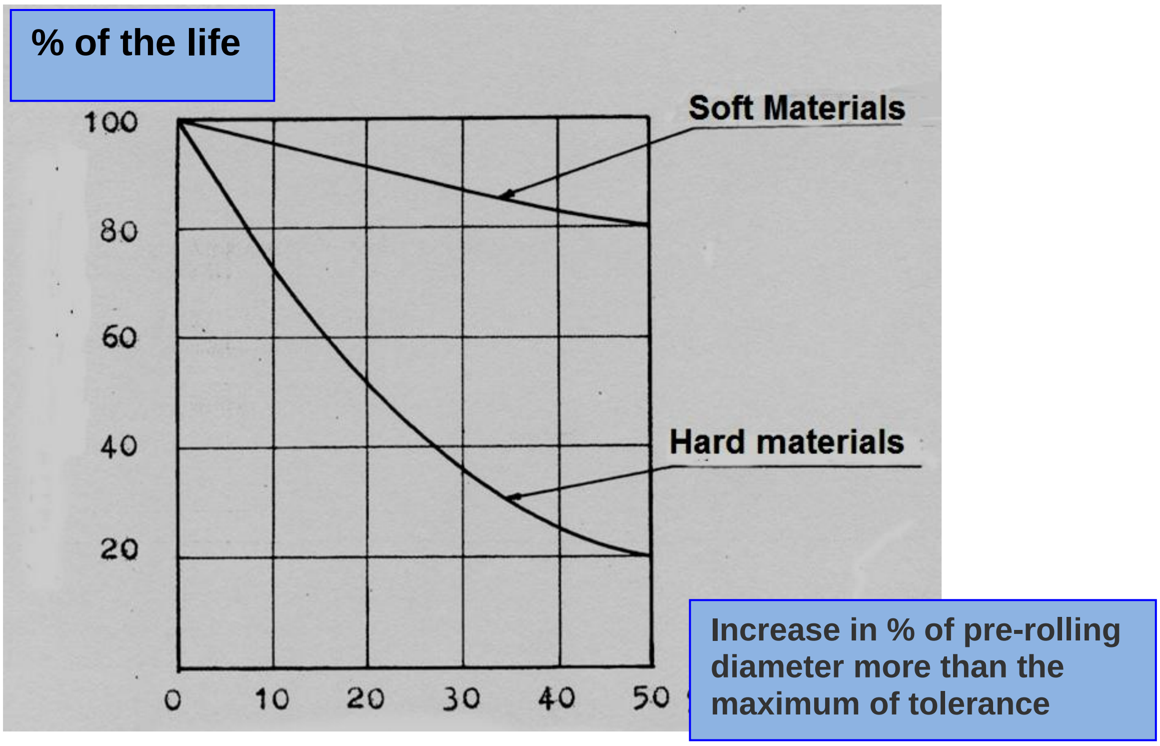

Fig. N°14

Ultimately, the most important factors that affect the life of the rollers are:

- *the quality and type of rollers;*
- *the nature of the material to be cut;*
- *the care with which the rollers are used;*
- *the use of rollers suitable for the work to be performed;*
- *proper lubrication;*
- *correct preparation of the blanks*

The quality of the rollers includes the accuracy of finish, accuracy of dimensions, the metallurgical properties of steel used to manufacture.
The nature of the material to roll is, in general, an invariant characteristic of the finished product, but keep in mind, as already mentioned, that rolling hard materials such as stainless steel, it is to have an efficiency much lower than what could be rolling on soft materials and that mistakes in preparation of the blanks sometimes can have catastrophic effects on life of rollers or racks.
The care with which the rollers are used is also a very important factor and in particular care must be taken so that the rollers are correctly paired. A error of setup causes lateral and radial movement of the rollers on the tool-holder, generating abnormal pressures which impact significantly on the life of the rollers.

Where allowed, it is very useful to perform a large chamfer on the edge of the rollers in this way will reduce the load on the ends of the rollers extending the duration and reducing the possibility of chipping.
Many times a longer life of the rollers is provided if we roll an incomplete profile of the thread, that is, leaving unfinished the top of the teeth. Where you satisfied with this, you can reduce the load on the rollers and you can have, moreover, a margin of safety against overload caused by too large diameter blanks.

Rolling defects and their causes

Very irregular thread with deformation of teeth

- Rollers are not synchronized
- Feeding is inclined respect to the axis of the rollers
- Material not suitable for cold rolling
- Rollers overload
- Blanks surface with excessive rough

Irregular helix of thread

- Rollers are not synchronized
- Feeding is inclined respect to the axis of the rollers
- Rollers imperfect

Threads with wrong size

Outside and medium diameters both oversized	Diameter of blank oversized
Oversized medium diameter and exact outside diameter	Diameter of blank oversized. If the thread of the piece is complete, the thread of the roller is not deep enough
Medium diameter oversized and undersized outside diameter	Insufficient pressure of the rollers. If the thread executed is complete, the thread of the roller is not deep enough
Exact medium diameter and oversized outside diameter	Oversized diameter of blank. Thread of the roller deeper than necessary
Exact medium diameter and undersized outside diameter	Undersized diameter of blank. If the thread executed is complete, the thread of the roller is not deep enough
Undersized medium diameter and oversized outside diameter	Excessive pressure of the rollers. Thread of the roller deeper than necessary
Undersized medium diameter and exact outside diameter	Undersized diameter of blank. Thread of the roller deeper than necessary
Outside and medium diameters both undersized	Undersized diameter of blank.

Runout of the piece

- Runout of the blank
- Feeding is inclined respect to the axis of the rollers
- Penetration and retraction of the rollers at speeds too high
- Material is not sufficiently ductile for cold lamination

Conical part

Cylindrical medium diameter and conical outside diameter and thread not complete in the top in smaller side of the cone	Conical blank.
Medium and outside diameter tapered in the same direction	Conical blank and rollers mounted with the same taper of the blank
Medium and outside diameter tapered in the opposite direction and thread not complete in the top in smaller side of the cone	Rollers with poor pressure on the side where the medium diameter is oversized and the outer diameter undersized.

Thread with oversized pitch

- Rollers with oversized pitch

Thread with undersized pitch

- Rollers with undersized pitch
- Material with hardness higher than normal (HRC = 18 and over): shrink slightly after rolling, it is necessary for precision work using rolls with pitch appropriately increased.

Thread profile incorrect

- Rollers with incorrect thread profile
- Set up of the rollers not correct
- Feeding inclined to the axis of the roller

Threads complete at the center and incomplete at the end or vice versa

- Rollers with diameter not constant throughout the width
- Blank with not constant diameter at the section threaded

Final teeth incomplete

- Surface of the blank with too high roughness
- Excessive rolling pressure

Thread with poor surface finish

- Rollers with poorly finished surfaces of the threads
- Rollers worn or chipped
- Rollers mounted poorly
- Material is not sufficiently ductile for cold roll

Top of the thread incomplete

- Undersized diameter of the blank
- Thread of rollers too deep. The defect can be reduced with a cycle of slower penetration

Ribbed top of the thread (only in case of machining with 2 rolls)

- The guide blade not well smoothed
- Insufficient hardness of the guide blade
- inadequate lubrication

Piece with cavity - (the hole shrinks)

- It 'necessary to support by a spindle
- Excessive penetration speed

Piece with cavity - (the hole is expanded)

- Spindle support too exact
- Excessive penetration speed
- Outside diameter of the blank too large

Piece with cavity - (eccentricity of the piece)

- Excessive penetration speed
- Too little time spent with rollers completely matched
- Excessive speed of removal of the rollers

Piece with cavity - Tapered thread

- Inadequate support spindle that does not provide proper support where needed
- Excessive penetration speed
- Taper of the rollers is not enough to offset the tendency of the part to become conical.
- Wall thickness is too low.