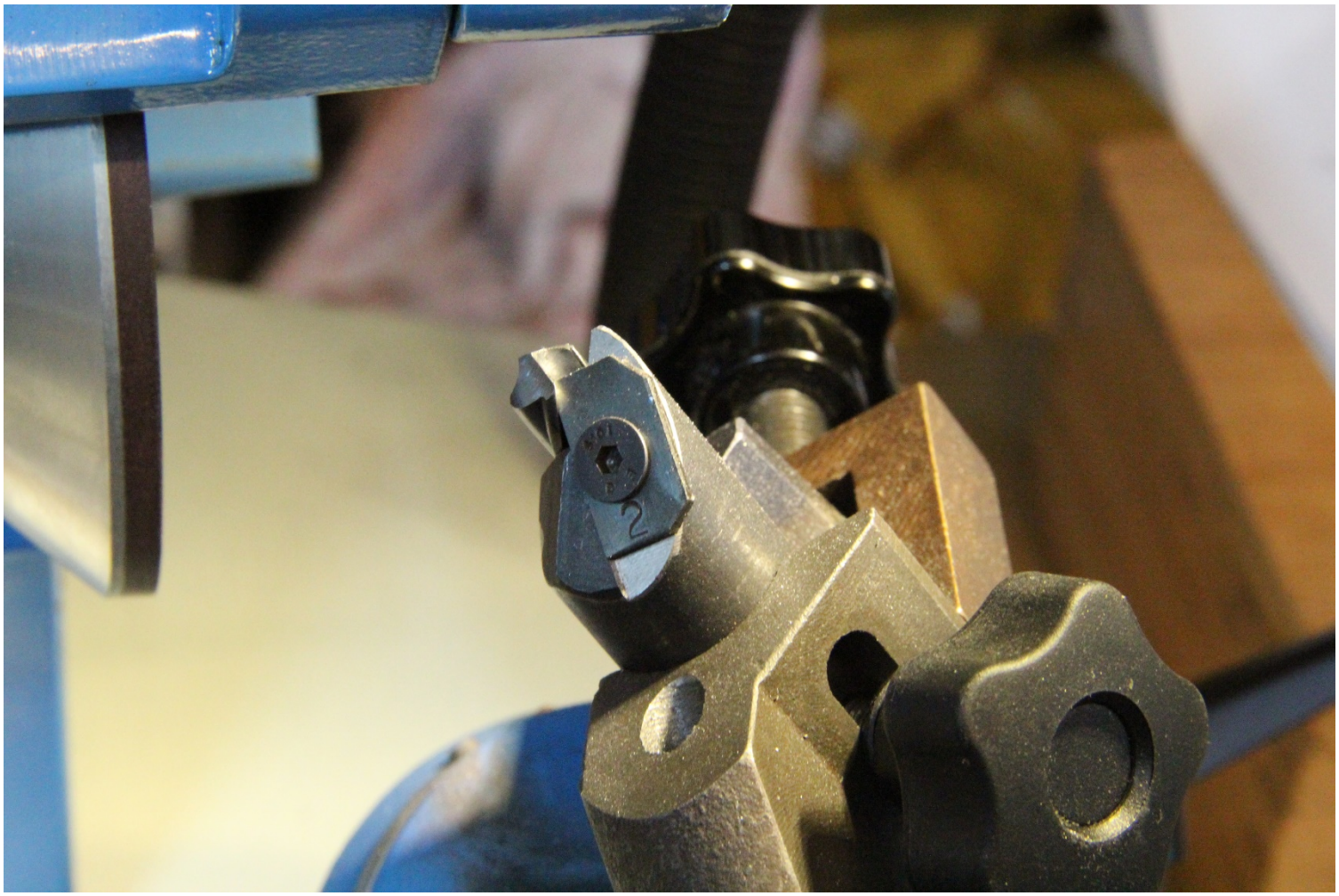
Drill grinding with the PP-U3 grinder; copy of the Deckel SO grinder

By: Luc Wybo

Video instructions for HSS: https://www.youtube.com/watch?v=1egAPzOGVDw

Video instructions for HSS-Co: https://www.youtube.com/watch?v=BU8r43QoMms&t=9s

Last update:26/10/2018



Introduction:

The Chinese copy of the Deckel tool grinder S0 has a very poor documentation, and the most important thing is not copied of the drill grinder attachment. I has bought this machine two years ago for grinding lathe tools and end-mills. For this you will find a lot documentation via You-tube. I has a lot expensive cobalt drills who are where-out and they must regrind. I has two solutions; grind the drills by hand as I did usually, or using the tool grinder PP-U3. Because I had some time to do this investigation this winter, I will use the PP-U3 grinder. After the reverse engineering of this drill attachment and also done some calculations is was able to grind drill of diameter 9.98mm who gives a hole diameter 10,05. With hand grinding I never comes so close to the expected diameter and it was always a 0.1 to 0.3mm (4- to 12 thou) greater than the diameter of the drill. This means that the tool is very useful because it is similar to the POTS drill jig who is existing form 1930. The clever engineer Michael Deckel has adapted on his single lip grinder in a clever way. The missing thing in the Chinese copy is a scale on the v-grove part where you has place the tool. With the use of two tables is the missing thing not necessary. But there are also more things where we must keep attention. The main disadvantage of the PP-U3 drill grinding jig the drill holding and his orientation in the tool. Change over form one cutting edge to the other must be done carefully and close to the drill top we has no sense where the important cone-shape axes is positioned regarding the drill. In this document I will described the necessary hardware changes to make it more usefully and accurate.

During the search of others drill grinding jig's there are two persons takes my attention;

- Prof. Joerg Hugel

- Joseph Mazoff

Both persons has done a lot of research about drill top geometric, and leave us with a lot of useful documentation about drill relief geometric on the internet.

Of course today I suppose that there exist more accurate drill grinding tools, some are good others are terrible bad. For my hobby workshop is the PP-U3 exceptional good and always better than hand grinding, so I don't spend money and effort to make one drill jig. But as you know with all the Chinese machine there is a lot room to do some improvements. Practice about drill grinding shows always for a nice and precise results. Both cutting edges take away the same amount of material and the down-feed speed has a linear function in order to the turning speed of the drill. Pulling harder to speed-up the drilling process has no sense and it will invoke more friction on the first facet of the relief angle. Even a grinded drill on PP-U3 cut's munch better than a new drill.

For factories they has mostly an own tool-grinding department with very expensive grinding machines and if not they give the tools grinding job to an external and specialized company.

Modifications to the drill jig attachment.

1): V-bar end.

With this jig one of the major problem is the orientation of the drill in the V-bar, and to change over to the other cutting edge, by turning the drill 180 degrees exactly. A little error of 5 degrees will caused an asymmetrical grinded drill where only one cutting edge will cut, but these error will become worse if you aligned the first cutting edge to the cone-axes. To avoid this problem we need a fixed reference to the cone-axes on the V-bar. To obtain this reference is done by cutting 1mm away, where the top of the end-mill is positioned 9.80mm of the top-side from V-bar (see setup on the video). After removal of the drill-clamping tool the setup is done as following; the V-bar is sitting in 2 small V-blocs under 45 degrees on the milling table and the 12mm jig holder axes must be held parallel to the milling table, with an error less 0.005mm on both ends of the 12mm axes. To complete this modifications 3 new stop-plates must be make, see fig 3.

2): Drill quick-release clamping.

With one lever and one setting screw is it possible to clamp the drill in the v-bar. It has nothing to do with the drill grinding, but it will make this easier. For this reason I will make a separate project for this improvement.

HSS Drill grinding with PP-U3.

Setup the tool:

Once the setup is done for one drill nothing has to be changed until both cutting edges are finished.

1.) Machine setup:
- Put the grinder-stone to the left side completely.
- Set the relief angle setting on zero degrees and lock position. This is the bottom swivelling of the tool-post.
- Set the Twist position regarding the stone side on 14 degrees (= cone angle) and lock the position.
- Cross-slide adjustment in both directions at the middle and locked in both sides
- Swivel the whole tool-post backwards is order to setup the drill jig.
- Use 12mm 5C collect to hold the drill jig. Assemble the drill jig on his place and lock the 5C collect, release the indent-pin so that the tool can swivel.

2.) Drill jig setup:
- Select the correct stop-plate according the diameter of the drill.
- Measure the half pitch length of the spiral, this is not always the same for the same diameter of the drill.
- On table one you will find the stick-out length of the drill called Xd. Here you must set drill-end stop. For the good practices use always the 20 degrees setting, if the amount that grinding of the drill is shorter 0.5mm, otherwise if greater you have to add this grinding amount to figures from the table.

- On table two you will find the stick-out length of the V-Bar called Xt, to the flat face of the swivel part. When it is possible use always the max value. The effect of the position of the cone summit result in greater relief angle when the cone-high is smaller.
- Swivel the whole tool post close to the stone and lock the position.
- Start to grind the first cutting edge by bringing the grinding-stone closer to drill, meanwhile swivelling the drill jig tool-holder. Keep always in mind the end travelling position on the dial-scale of the stone displacement. If first looks good, retract the stone after notice the position.
- When the first edge is completed, swivel away the whole tool holder from the grinding-stone.
- Twist the drill 180 degrees to grind the other cutting edge.
- Grind the second cutting edge by bringing the grinding stone closer to drill, until you reach the same dial position as before. Lock now the position of the stone and swivel the drill jig a few times.
- Twist the drill again 180 degrees to the first grinded edge and swivel the drill jig again a few times. After this the grinding is complete when you has checked the visually if everything is done.

Explanation on the figures:

On fig 1, I has drawing several sizes of cones on the same axes but the only good range between 2.4 and 3 times the diameter of the drill. The table 2 is only valid for a drill top angle of (14+45)*2 = 118 degrees. This top angle is common for the most applications of HSS drills. Fig 2 gives an enlargement of view on the top of drill. The cone axes on this drawing is always above drill axes and will meet the cutting edge of the drill when the latter is positioned on zero degrees of twist, meaning that this becomes inline with stop-side the new adjusters plates. Due to the inclination of the V-grove all the cutting edges of the drills form several diameter lying more or less against to the cone axes. When you put the cutting edge on the cone axes before starting of grinding, then you will grind only a two facet of the drill. The result is that the hart line is straight line and orthogonal with the drill axes, and this will cause walking around of the drill point on a flat surface. In order to get a four facet grinded drill the drill must be twisted and put in such position that the finishing of grinding the cutting edge must be at least more than ten degrees twisted.

Results:

Beyond all expectations, the results are excellent if you follow the settings of the tables. Both cutting edges remove roughly the same amount of material during drilling. Sometimes the grinding work is too good because the bore diameter comes too close to the drill diameter, which causes increased friction when drilling deep holes of at least 50mm.

Remarks:

For small drills below 5mm the setting position of the whole tool-post has an influence on the initial relief angle, because the tool-post tilted more to the stone. This initial relief angle is important for the first facet and practice shows that an extra relief angle is needed, when the drill don't want to enter the workpiece. With the PP-U3 you can easy increase the relief angle to max 3 degrees with the relief angle setting.

For large drills above the 15mm the jig swivelling radius is always increasing and it is possible you will come to the limits of the machine when you using 3*D column. In this case you can 2,4*D or the minimum radius in the table. This give as result a little greater relief angle due to the smaller cone but the initial relief angle of the flat surface remains the same.

HSS-Co and Carbide drill grinding with PP-U3

The basic grinding method is completely the same as by HSS drills only the top angle is increased. I has done the calculations for a top angle of 134° and 138° degrees. The 134° is more recommended for HSS-Co with soft stainless steel while 138° is useful HSS-Co and carbide drills hard stainless steel and other hard tool steel. The cone corner is then set to 22° or 24° instead of 14° by HSS. Thus for the cobalt drills the settings of table 1 remains valid while the setting of Xt is different and for this you need to use table 3 or table 4. To make a hole in hard stainless steel, has the top of drill, I main the heart line, problems to push away material out of the centre of the drill, the temperature will increase on the heart. The stainless steel becomes harder by increase the temperature and this will lead us to broken or burned drill. To avoid this problem we need to reduce the heart line on the top of the drill by adding two small cutting edges to the centre of the drill. Remark; by increasing the cone corner the swing radius becomes greater. Larger range of diameters are not feasible with the tool grinder PP-U3.

Additional grindings:

Reduction of the heart-line or creating a tertiary facet and centre cutting edge:

For the cobalt drills is this work strongly recommended. After grinding the first two cutting edge , we have to change the machine setup. Al settings of the drill-jig remains the same. Now we must bring the drill axes line orthogonal with the stone axes. It is better to set it for positive rake-angle of 5 degrees so that the little new cutting edge at centre takes material away instead of displace it. This little cutting edge start very close to the centre and may not pass over the centre. Take a lot care while you are grind this, because it must also repeated for the other cutting edge. The stone corner may not pass over the cuttings edges and also not pass the chisel-edge. The smallest part of the corner becomes the new additional little cutting edge close to the drill centre(line between green and blue face in the drawing below). For both sides they must lie on one straight line. Be carefull it is precision grinding, stone corner must reach the centre, but when it goes over you must restart form the beginning.

The setting steps for grinding is as follows:

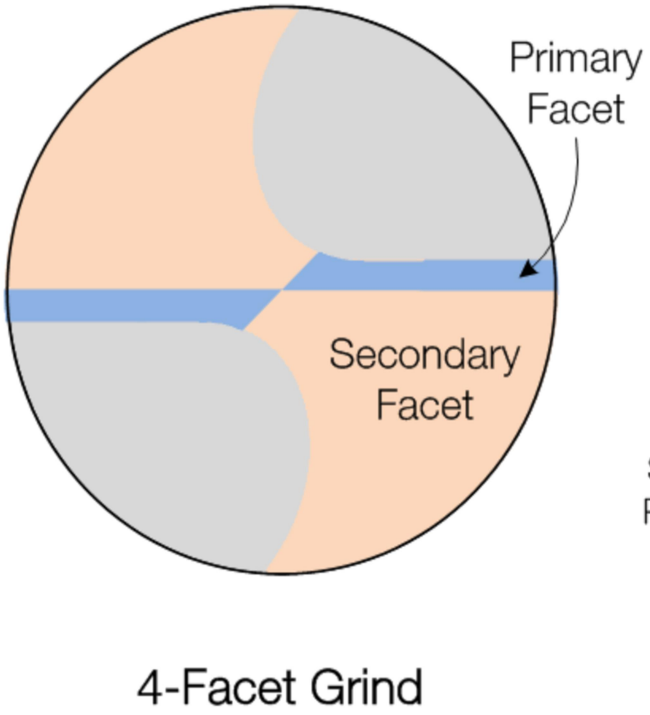
- Set the drill tool close to the stone but the drill-centre is not reachable by the stone.
- Adjust the swivelling until it starts grinding, and fix this movement.
- Move the grinding stone sideways until the side plane of the stone is in line with the drill centre. Notice the distance from the dial, and retract the stone.
- Swivel the drill tool backwards and turn the drill itself over 180° for the second edge.
- Swivel the drill tool carefully and slow to the detent.
- Start grinding by moving the stone forward to same setting as before.

Remove side points or create secondary point angle:

Regarding the documents of Joseph Mazoff he has proven that the outer sharp corner points of the cutting edge are not needed, because it is the first thing that will be wear off. By adding an extra cutting edge on these two corners the tool life can be extended by 30 to 50 percent. Of course this is means an additional machine setup for grinding but on the U3 tool grinder is it impossible to execute this successfully.

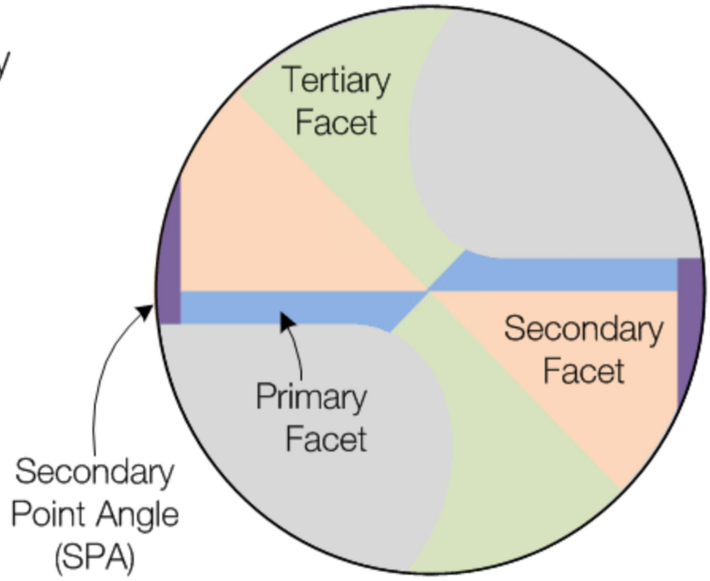
For more information about drill grinding go to website of Joseph:
http://www.newmantools.com/machines/drillpoint.html

HSS-drill 4-facet



4-Facet Grind

HSS-Co drills 6-facet



Grind with
Additional Facets

Drill speeds

I has some comments on drill speeds, because I saw a lot hobby-shop where they are using the wrong speed. At the end of this document I has make table with de recommend speed for drilling. Experienced technicians immediately feel the speed needed to drill into various materials.

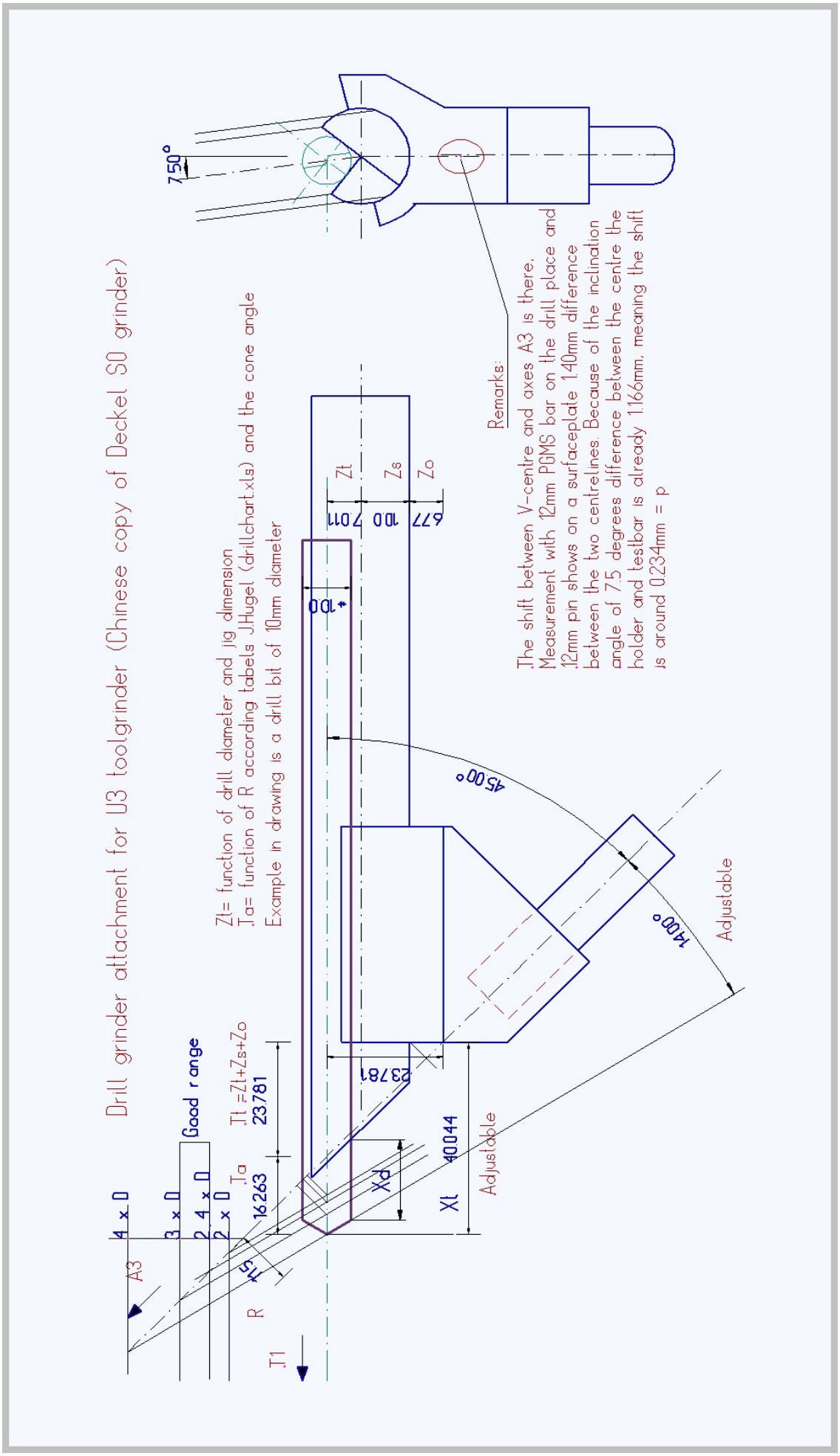

Drill grinder attachment for U3 toolgrinder (Chinese copy of Deckel S0 grinder)
Zt= function of drill diameter and jig dimension
Ta= function of R according tabels JHugel (drillchart.xls) and the cone angle
Example in drawing is a drill bit of 10mm diameter
Remarks:
The shift between V-centre and axes A3 is there.
Measurement with 12mm PGMS bar on the drill place and
12mm pin shows on a surfaceplate 1.40mm difference
between the two centrelines. Because of the inclination
angle of 7.5 degrees difference between the centre the
holder and testbar is already 1.166mm, meaning the shift
is around 0.234mm = p
7.50°
Zt
Zs
Zo
6.77
10.70
10.00
45.00°
14.00°
Adjustable
Adjustable
23.781
Tl =Zt+Zs+Zo
23.781
Ta
16.263
Xd
Xl
40.044
Good range
4 x D
3 x D
2.4 x D
2 x D
A3
R
T1

Fig 1

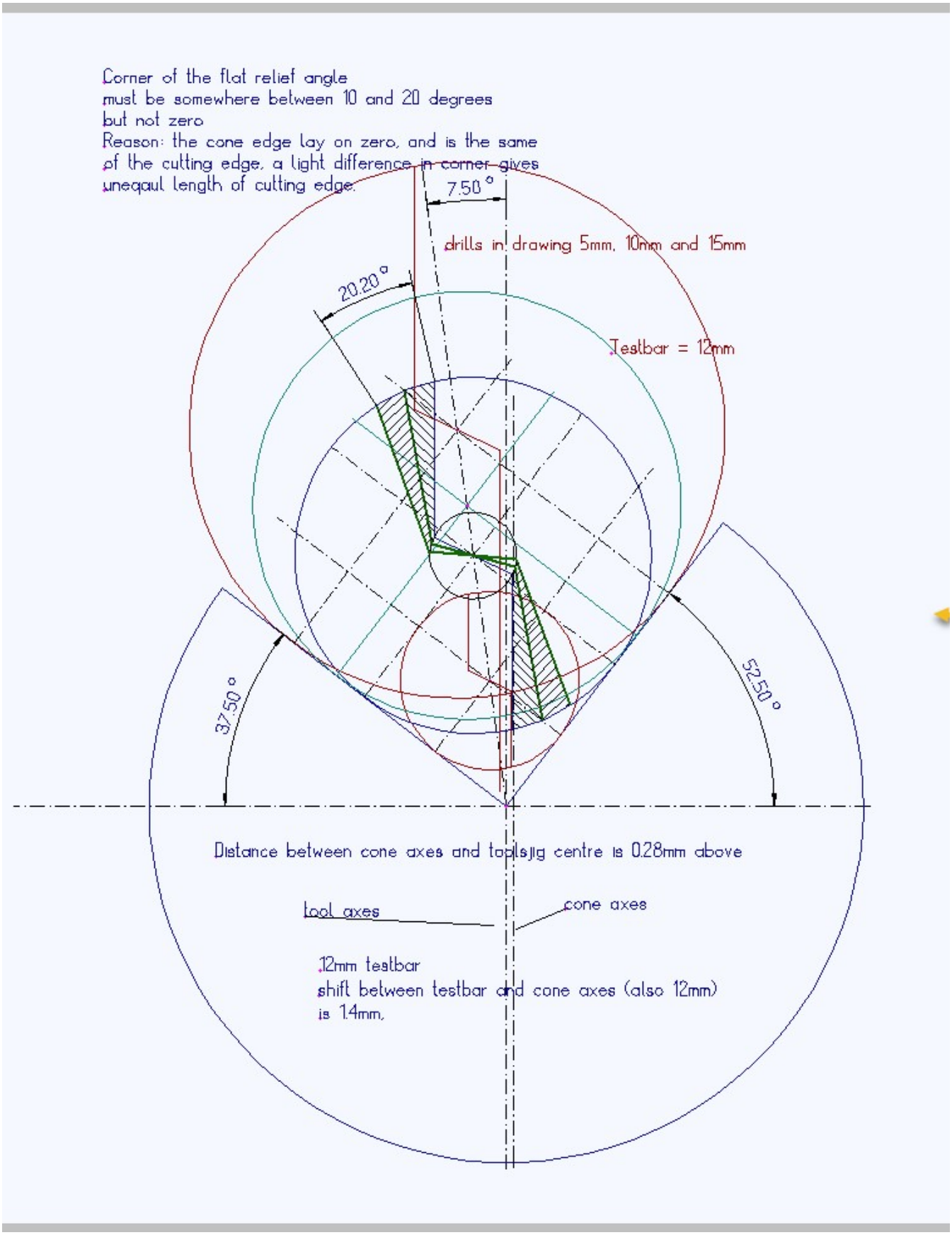

Corner of the flat relief angle
must be somewhere between 10 and 20 degrees
but not zero
Reason: the cone edge lay on zero, and is the same
of the cutting edge, a light difference in corner gives
uneqaul length of cutting edge.
7.50 °
drills in drawing 5mm, 10mm and 15mm
20.20 °
Testbar = 12mm
37.50 °
52.50 °
Distance between cone axes and tool/jig centre is 0.28mm above
tool axes
cone axes
12mm testbar
shift between testbar and cone axes (also 12mm)
is 1.4mm.

Fig 2

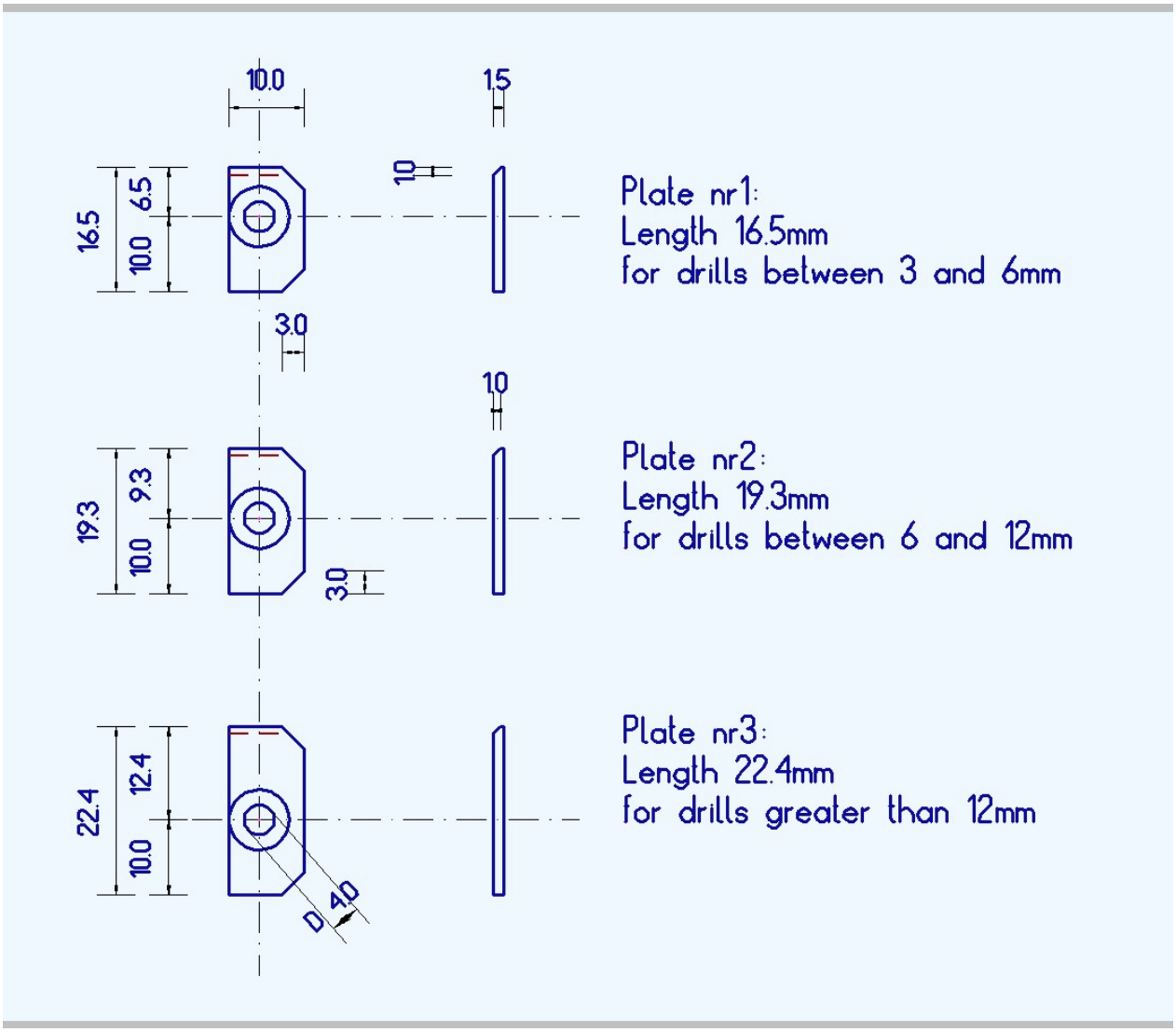


Fig 3

On fig 3 there is one dimension is forgotten: centre of 4mm hole from the straight side is 3.8mm

The left side of the plate must be a straight edge without chamfers while the top side has a large chamfer a the backside of 45 degrees. The thickness for all plates must be between 1.5mm and 2.0mm.

Remarks on all the tabels: linear interpolation is possible, calculations in metric and inches

Table 2 valid for HSS drills cone corner 14° results in a top angle 118°

Table 3 for HSS-Co drills cone corner 22° results in a top angle 134°

Table 4 for HSS-Co drills cone corner 24° results in a top angle 138°

Table 1: Drill distance to the tool-stop Xd

Distance between corner of drill and the tool holder

Twist angle of the drill in the jig

pitch/2	0,055556	0,111111
	min	max
mm	10°	20°
10	**0,56**	**1,11**
11	**0,61**	**1,22**
12	**0,67**	**1,33**
13	**0,72**	**1,44**
14	**0,78**	**1,56**
15	**0,83**	**1,67**
16	**0,89**	**1,78**
17	**0,94**	**1,89**
18	**1,00**	**2,00**
19	**1,06**	**2,11**
20	**1,11**	**2,22**
22	**1,22**	**2,44**
24	**1,33**	**2,67**
26	**1,44**	**2,89**
28	**1,56**	**3,11**
30	**1,67**	**3,33**
32	**1,78**	**3,56**
34	**1,89**	**3,78**
36	**2,00**	**4,00**
38	**2,11**	**4,22**
40	**2,22**	**4,44**
42	**2,33**	**4,67**
44	**2,44**	**4,89**
46	**2,56**	**5,11**
48	**2,67**	**5,33**
50	**2,78**	**5,56**
52	**2,89**	**5,78**
54	**3,00**	**6,00**
56	**3,11**	**6,22**
58	**3,22**	**6,44**
60	**3,33**	**6,67**

pitch/2	0,055556	0,111111
	min	max
inch	10°	20°
0,394	**0,022**	**0,044**
0,433	**0,024**	**0,048**
0,472	**0,026**	**0,052**
0,512	**0,028**	**0,057**
0,551	**0,031**	**0,061**
0,591	**0,033**	**0,066**
0,630	**0,035**	**0,070**
0,669	**0,037**	**0,074**
0,709	**0,039**	**0,079**
0,748	**0,042**	**0,083**
0,787	**0,044**	**0,087**
0,866	**0,048**	**0,096**
0,945	**0,052**	**0,105**
1,024	**0,057**	**0,114**
1,102	**0,061**	**0,122**
1,181	**0,066**	**0,131**
1,260	**0,070**	**0,140**
1,339	**0,074**	**0,149**
1,417	**0,079**	**0,157**
1,496	**0,083**	**0,166**
1,575	**0,087**	**0,175**
1,654	**0,092**	**0,184**
1,732	**0,096**	**0,192**
1,811	**0,101**	**0,201**
1,890	**0,105**	**0,210**
1,969	**0,109**	**0,219**
2,047	**0,114**	**0,227**
2,126	**0,118**	**0,236**
2,205	**0,122**	**0,245**
2,283	**0,127**	**0,254**
2,362	**0,131**	**0,262**

Table 2: Distance Xt for HSS drills, top angle 118° cone angle 14°

r=	1,35	1,72		2,4 * D	3 * D
Drill diameter	**Distance Ta**		**Distance Tt**	**Total distance Ta+Tt**	
All dimensions in **mm**					
	min	max		min	max
3	2,9	3,6	18,9	**21,7**	**22,5**
3,5	3,3	4,3	19,2	**22,5**	**23,5**
4	3,8	4,9	19,6	**23,4**	**24,4**
4,5	4,3	5,5	19,9	**24,2**	**25,4**
5	4,8	6,1	20,3	**25,0**	**26,3**
5,5	5,2	6,7	20,6	**25,9**	**27,3**
6	5,7	7,3	21,0	**26,7**	**28,3**
6,5	6,2	7,9	21,3	**27,5**	**29,2**
7	6,7	8,5	21,7	**28,3**	**30,2**
7,5	7,2	9,1	22,0	**29,2**	**31,1**
8	7,6	9,7	22,4	**30,0**	**32,1**
8,5	8,1	10,3	22,7	**30,8**	**33,0**
9	8,6	10,9	23,1	**31,7**	**34,0**
9,5	9,1	11,6	23,4	**32,5**	**35,0**
10	9,5	12,2	23,8	**33,3**	**35,9**
10,5	10,0	12,8	24,1	**34,1**	**36,9**
11	10,5	13,4	24,5	**35,0**	**37,8**
11,5	11,0	14,0	24,8	**35,8**	**38,8**
12	11,5	14,6	25,2	**36,6**	**39,8**
12,5	11,9	15,2	25,5	**37,4**	**40,7**
13	12,4	15,8	25,9	**38,3**	**41,7**
13,5	12,9	16,4	26,2	**39,1**	**42,6**
14	13,4	17,0	26,6	**39,9**	**43,6**
14,5	13,8	17,6	26,9	**40,8**	**44,6**
15	14,3	18,2	27,3	**41,6**	**45,5**
15,5	14,8	18,9	27,6	**42,4**	**46,5**
16	15,3	19,5	28,0	**43,2**	**47,4**
16,5	15,8	20,1	28,3	**44,1**	**48,4**
17	16,2	20,7	28,7	**44,9**	**49,3**
17,5	16,7	21,3	29,0	**45,7**	**50,3**
18	17,2	21,9	29,4	**46,6**	**51,3**

r=	1,35	1,72		2,4 * D	3 * D
Drill diameter	**Distance Ta**		**Distance Tt**	**Total distance Ta+Tt**	
All dimensions in **inch**					
	min	max		min	max
0,118	0,113	0,144	0,742	**0,855**	**0,886**
0,138	0,131	0,168	0,756	**0,887**	**0,924**
0,157	0,150	0,192	0,770	**0,920**	**0,961**
0,177	0,169	0,215	0,784	**0,953**	**0,999**
0,197	0,188	0,239	0,797	**0,986**	**1,037**
0,217	0,207	0,263	0,811	**1,018**	**1,075**
0,236	0,225	0,287	0,825	**1,051**	**1,112**
0,256	0,244	0,311	0,839	**1,083**	**1,150**
0,276	0,263	0,335	0,853	**1,116**	**1,188**
0,295	0,282	0,359	0,866	**1,148**	**1,226**
0,315	0,301	0,383	0,880	**1,181**	**1,263**
0,335	0,320	0,407	0,894	**1,214**	**1,301**
0,354	0,339	0,431	0,908	**1,246**	**1,339**
0,374	0,357	0,455	0,922	**1,279**	**1,377**
0,394	0,376	0,479	0,935	**1,311**	**1,414**
0,413	0,395	0,503	0,949	**1,344**	**1,452**
0,433	0,414	0,527	0,963	**1,377**	**1,490**
0,453	0,432	0,551	0,977	**1,409**	**1,528**
0,472	0,451	0,575	0,991	**1,442**	**1,565**
0,492	0,470	0,599	1,004	**1,474**	**1,603**
0,512	0,489	0,622	1,018	**1,507**	**1,641**
0,531	0,507	0,646	1,032	**1,539**	**1,678**
0,551	0,526	0,670	1,046	**1,572**	**1,716**
0,571	0,545	0,694	1,060	**1,605**	**1,754**
0,591	0,564	0,718	1,073	**1,637**	**1,792**
0,610	0,582	0,742	1,087	**1,670**	**1,829**
0,630	0,601	0,766	1,101	**1,702**	**1,867**
0,650	0,620	0,790	1,115	**1,735**	**1,905**
0,669	0,639	0,814	1,129	**1,768**	**1,943**
0,689	0,658	0,838	1,142	**1,800**	**1,980**
0,709	0,676	0,862	1,156	**1,833**	**2,018**

Table 3: Distance Xt for HSS-Co drills, top angle 134° cone angle 22°

r=	1,35	1,72		2,4 * D	3 * D
Drill diameter	**Distance Ta**		**Distance Tt**	**Total distance Ta+Tt**	
All dimensions in **mm**					
	min	max		min	max
3	4,1	5,2	18,9	**23,0**	**24,0**
3,5	4,8	6,0	19,2	**24,0**	**25,2**
4	5,5	6,9	19,6	**25,1**	**26,5**
4,5	6,2	7,8	19,9	**26,1**	**27,7**
5	6,9	8,6	20,3	**27,2**	**28,9**
5,5	7,6	9,5	20,6	**28,2**	**30,1**
6	8,3	10,4	21,0	**29,2**	**31,3**
6,5	9,0	11,2	21,3	**30,3**	**32,5**
7	9,7	12,1	21,7	**31,3**	**33,7**
7,5	10,4	12,9	22,0	**32,4**	**35,0**
8	11,1	13,8	22,4	**33,4**	**36,2**
8,5	11,7	14,7	22,7	**34,4**	**37,4**
9	12,4	15,5	23,1	**35,5**	**38,6**
9,5	13,1	16,4	23,4	**36,5**	**39,8**
10	13,8	17,3	23,8	**37,6**	**41,0**
10,5	14,5	18,1	24,1	**38,6**	**42,2**
11	15,2	19,0	24,5	**39,7**	**43,5**
11,5	15,9	19,9	24,8	**40,7**	**44,7**
12	16,6	20,7	25,2	**41,7**	**45,9**
12,5	17,3	21,6	25,5	**42,8**	**47,1**
13	18,0	22,4	25,9	**43,8**	**48,3**
13,5	18,6	23,3	26,2	**44,9**	**49,5**
14	19,3	24,2	26,6	**45,9**	**50,7**
14,5	20,0	25,0	26,9	**46,9**	**52,0**
15	20,7	25,9	27,3	**48,0**	**53,2**
15,5	21,4	26,8	27,6	**49,0**	**54,4**
16	22,1	27,6	28,0	**50,1**	**55,6**
16,5	22,8	28,5	28,3	**51,1**	**56,8**
17	23,5	29,4	28,7	**52,1**	**58,0**
17,5	24,2	30,2	29,0	**53,2**	**59,2**
18	24,9	31,1	29,4	**54,2**	**60,4**

r=	1,35	1,72		2,4 * D	3 * D
Drill diameter	**Distance Ta**		**Distance Tt**	**Total distance Ta+Tt**	
All dimensions in **inch**					
	min	max		min	max
0,118	0,163	0,204	0,742	**0,905**	**0,946**
0,138	0,190	0,238	0,756	**0,946**	**0,994**
0,157	0,218	0,272	0,770	**0,987**	**1,042**
0,177	0,245	0,306	0,784	**1,028**	**1,090**
0,197	0,272	0,340	0,797	**1,069**	**1,137**
0,217	0,299	0,374	0,811	**1,110**	**1,185**
0,236	0,326	0,408	0,825	**1,151**	**1,233**
0,256	0,353	0,442	0,839	**1,192**	**1,281**
0,276	0,381	0,476	0,853	**1,233**	**1,328**
0,295	0,408	0,510	0,866	**1,274**	**1,376**
0,315	0,435	0,544	0,880	**1,315**	**1,424**
0,335	0,462	0,578	0,894	**1,356**	**1,472**
0,354	0,489	0,612	0,908	**1,397**	**1,520**
0,374	0,517	0,646	0,922	**1,438**	**1,567**
0,394	0,544	0,680	0,935	**1,479**	**1,615**
0,413	0,571	0,714	0,949	**1,520**	**1,663**
0,433	0,598	0,748	0,963	**1,561**	**1,711**
0,453	0,625	0,782	0,977	**1,602**	**1,759**
0,472	0,653	0,816	0,991	**1,643**	**1,806**
0,492	0,680	0,850	1,004	**1,684**	**1,854**
0,512	0,707	0,884	1,018	**1,725**	**1,902**
0,531	0,734	0,918	1,032	**1,766**	**1,950**
0,551	0,761	0,952	1,046	**1,807**	**1,998**
0,571	0,789	0,986	1,060	**1,848**	**2,045**
0,591	0,816	1,020	1,073	**1,889**	**2,093**
0,610	0,843	1,054	1,087	**1,930**	**2,141**
0,630	0,870	1,088	1,101	**1,971**	**2,189**
0,650	0,897	1,122	1,115	**2,012**	**2,236**
0,669	0,924	1,156	1,129	**2,053**	**2,284**
0,689	0,952	1,190	1,142	**2,094**	**2,332**
0,709	0,979	1,224	1,156	**2,135**	**2,380**

Table 4: Distance Xt for HSS-Co drills, top angle 138° cone angle 24°

r=	1,35	1,72		2,4 * D	3 * D
Drill diameter	**Distance Ta**		**Distance Tt**	**Total distance Ta+Tt**	
All dimensions in **mm**					
	min	max		min	max
3	4,4	5,5	18,9	**23,3**	**24,4**
3,5	5,2	6,5	19,2	**24,4**	**25,7**
4	5,9	7,4	19,6	**25,5**	**26,9**
4,5	6,7	8,3	19,9	**26,6**	**28,2**
5	7,4	9,2	20,3	**27,6**	**29,5**
5,5	8,1	10,2	20,6	**28,7**	**30,8**
6	8,9	11,1	21,0	**29,8**	**32,0**
6,5	9,6	12,0	21,3	**30,9**	**33,3**
7	10,4	12,9	21,7	**32,0**	**34,6**
7,5	11,1	13,9	22,0	**33,1**	**35,9**
8	11,8	14,8	22,4	**34,2**	**37,1**
8,5	12,6	15,7	22,7	**35,3**	**38,4**
9	13,3	16,6	23,1	**36,4**	**39,7**
9,5	14,0	17,6	23,4	**37,5**	**41,0**
10	14,8	18,5	23,8	**38,5**	**42,2**
10,5	15,5	19,4	24,1	**39,6**	**43,5**
11	16,3	20,3	24,5	**40,7**	**44,8**
11,5	17,0	21,3	24,8	**41,8**	**46,1**
12	17,7	22,2	25,2	**42,9**	**47,3**
12,5	18,5	23,1	25,5	**44,0**	**48,6**
13	19,2	24,0	25,9	**45,1**	**49,9**
13,5	20,0	25,0	26,2	**46,2**	**51,2**
14	20,7	25,9	26,6	**47,3**	**52,4**
14,5	21,4	26,8	26,9	**48,4**	**53,7**
15	22,2	27,7	27,3	**49,4**	**55,0**
15,5	22,9	28,7	27,6	**50,5**	**56,3**
16	23,7	29,6	28,0	**51,6**	**57,5**
16,5	24,4	30,5	28,3	**52,7**	**58,8**
17	25,1	31,4	28,7	**53,8**	**60,1**
17,5	25,9	32,3	29,0	**54,9**	**61,4**
18	26,6	33,3	29,4	**56,0**	**62,6**

r=	1,35	1,72		2,4 * D	3 * D
Drill diameter	**Distance Ta**		**Distance Tt**	**Total distance Ta+Tt**	
All dimensions in **inch**					
	min	max		min	max
0,118	0,175	0,218	0,742	**0,917**	**0,961**
0,138	0,204	0,255	0,756	**0,960**	**1,011**
0,157	0,233	0,291	0,770	**1,003**	**1,061**
0,177	0,262	0,327	0,784	**1,046**	**1,111**
0,197	0,291	0,364	0,797	**1,089**	**1,161**
0,217	0,320	0,400	0,811	**1,131**	**1,211**
0,236	0,349	0,437	0,825	**1,174**	**1,262**
0,256	0,378	0,473	0,839	**1,217**	**1,312**
0,276	0,408	0,509	0,853	**1,260**	**1,362**
0,295	0,437	0,546	0,866	**1,303**	**1,412**
0,315	0,466	0,582	0,880	**1,346**	**1,462**
0,335	0,495	0,619	0,894	**1,389**	**1,513**
0,354	0,524	0,655	0,908	**1,432**	**1,563**
0,374	0,553	0,691	0,922	**1,475**	**1,613**
0,394	0,582	0,728	0,935	**1,518**	**1,663**
0,413	0,611	0,764	0,949	**1,561**	**1,713**
0,433	0,640	0,800	0,963	**1,603**	**1,764**
0,453	0,670	0,837	0,977	**1,646**	**1,814**
0,472	0,699	0,873	0,991	**1,689**	**1,864**
0,492	0,728	0,910	1,004	**1,732**	**1,914**
0,512	0,757	0,946	1,018	**1,775**	**1,964**
0,531	0,786	0,982	1,032	**1,818**	**2,014**
0,551	0,815	1,019	1,046	**1,861**	**2,065**
0,571	0,844	1,055	1,060	**1,904**	**2,115**
0,591	0,873	1,092	1,073	**1,947**	**2,165**
0,610	0,902	1,128	1,087	**1,990**	**2,215**
0,630	0,931	1,164	1,101	**2,033**	**2,265**
0,650	0,961	1,201	1,115	**2,075**	**2,316**
0,669	0,990	1,237	1,129	**2,118**	**2,366**
0,689	1,019	1,274	1,142	**2,161**	**2,416**
0,709	1,048	1,310	1,156	**2,204**	**2,466**

Table 5:Recommended drill speed rpm

The drill-speed must be lower than the lathe cutting speed.
This should arround 2/3 of the lathe cutting speed.
This speed are good for HSS and HSS-Co drills.
For carbide drills it recommended to incraese the rpm by a factor 2

Cutting speed in M/min

Material	min	max	avg	drill-cutting speed
Steel	25	35	30	20
aluminium	50	70	60	40
bronze	50	70	60	40
inox	8	12	10	6,67

Drill diameter		Steel	Aluminium Bronze	Inox
mm	**inch**	**rpm**	**rpm**	**rpm**
2	0,079	**3183**	**6366**	**1061**
3	0,118	**2122**	**4244**	**707**
4	0,157	**1592**	**3183**	**531**
5	0,197	**1273**	**2546**	**424**
6	0,236	**1061**	**2122**	**354**
7	0,276	**909**	**1819**	**303**
8	0,315	**796**	**1592**	**265**
9	0,354	**707**	**1415**	**236**
10	0,394	**637**	**1273**	**212**
11	0,433	**579**	**1157**	**193**
12	0,472	**531**	**1061**	**177**
13	0,512	**490**	**979**	**163**
14	0,551	**455**	**909**	**152**
15	0,591	**424**	**849**	**141**
16	0,630	**398**	**796**	**133**
17	0,669	**374**	**749**	**125**
18	0,709	**354**	**707**	**118**
19	0,748	**335**	**670**	**112**
20	0,787	**318**	**637**	**106**