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Mounting accuracy key issue in gear system design

Understanding how mounting accuracy affects gearing performance.

Some assembly required. These dreaded words are frequently found on the packaging of many weekend projects. Whether it is assembling a desk for that new pandemic home office or building the new BBQ grill you received as a Father's Day gift, we always hope that all of the parts are included and that they fit together as expected.

When it comes to gearing, there is a misnomer that in order to design the best gear system you must use the most precise gears. However, even if the gear is produced with high accuracy, if the gear is not mounted properly, it is not possible to avoid the problems of bad tooth contact: noise, wear, and breakage.

Unit: μm

Center Distance (mm)		Accuracy Grade of Gears			
More than	Less than	N3,N4	N5,N6	N7,N8	N9,N10
5	20	6	10	16	26
20	50	8	12	20	31
50	125	12	20	32	50
125	280	16	26	40	65
280	560	22	35	55	88

Table 1: Center distance tolerance of spur and helical gears ± f_a

One of the errors that can occur in assembly of gear pairs occurs with the center distance. Errors occurring with the center distance of two gears directly influence the backlash of the gear mesh. If the center distance value is increased, then the backlash value is increased. As a result of this increased center distance, the gear teeth cannot mesh deeply enough into each other, and the contact ratio decreases. If the center distance value is decreased, then the backlash value also decreases. If the backlash decreases too much, the gears' ability to rotate is inhibited. Table 1 shows the center distance tolerances for spur and helical gears. The tolerance values in this table are quoted from JGMA 1101-01 (2000) and are applicable for involute spur and helical gears that are made from steel.

Another error that can occur in assembly of gear systems occurs with the axial parallelism of the pair. The accuracy of two parallel axis gears is composed of the parallelism error and shaft offset error. These errors influence the tooth contact in the tooth trace direction. They may also result in bad tooth contact occurring at the tip of tooth width. Any increase of these errors results in the decreasing the backlash and will cause both noise and tooth breakage. Tables 2 and 3 detail the shaft parallelism error tolerances and the offset error tolerances for spur and helical gears, as detailed in JGMA 1102-01 (2000). Figure 1 details the location of these tolerances.

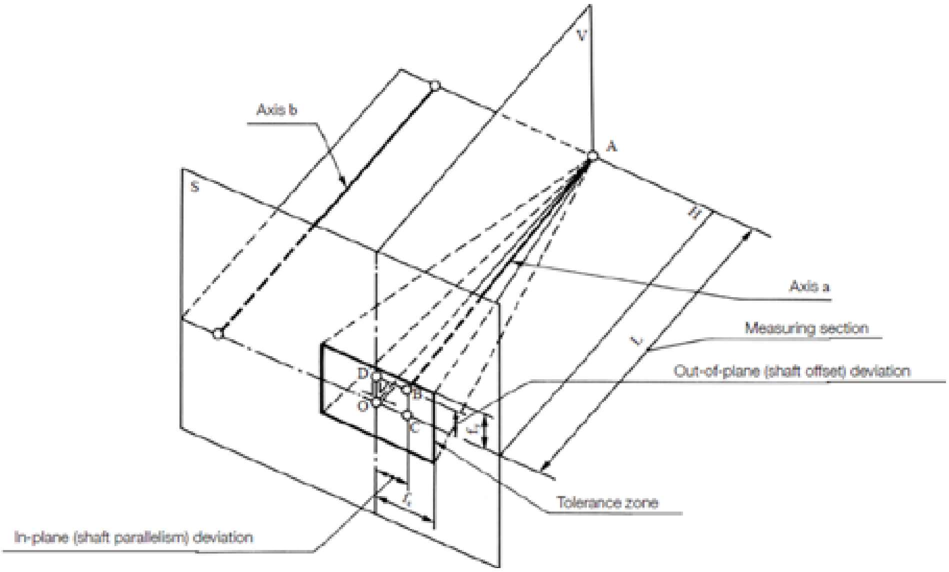

Figure 1: Shaft parallelism error and shaft offset error.

Being aware of the different tolerances during assembly is necessary and will allow the gears to perform as designed. Setting the gears at the proper center distance and axial alignment will help to maintain the proper backlash and the desired tooth contact. With these two factors in check, the gear system will exhibit minimal noise and will achieve the designed gear life.

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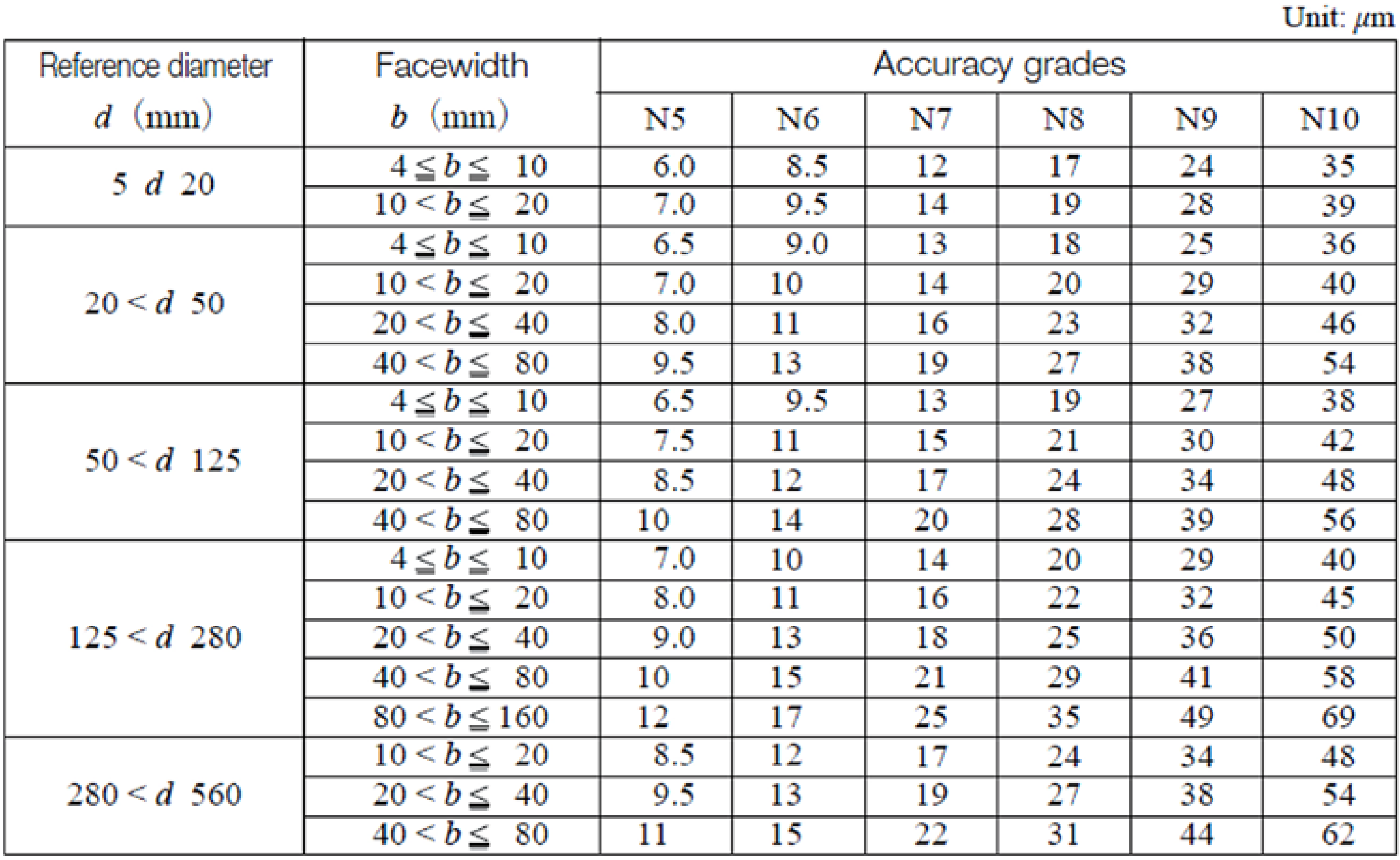
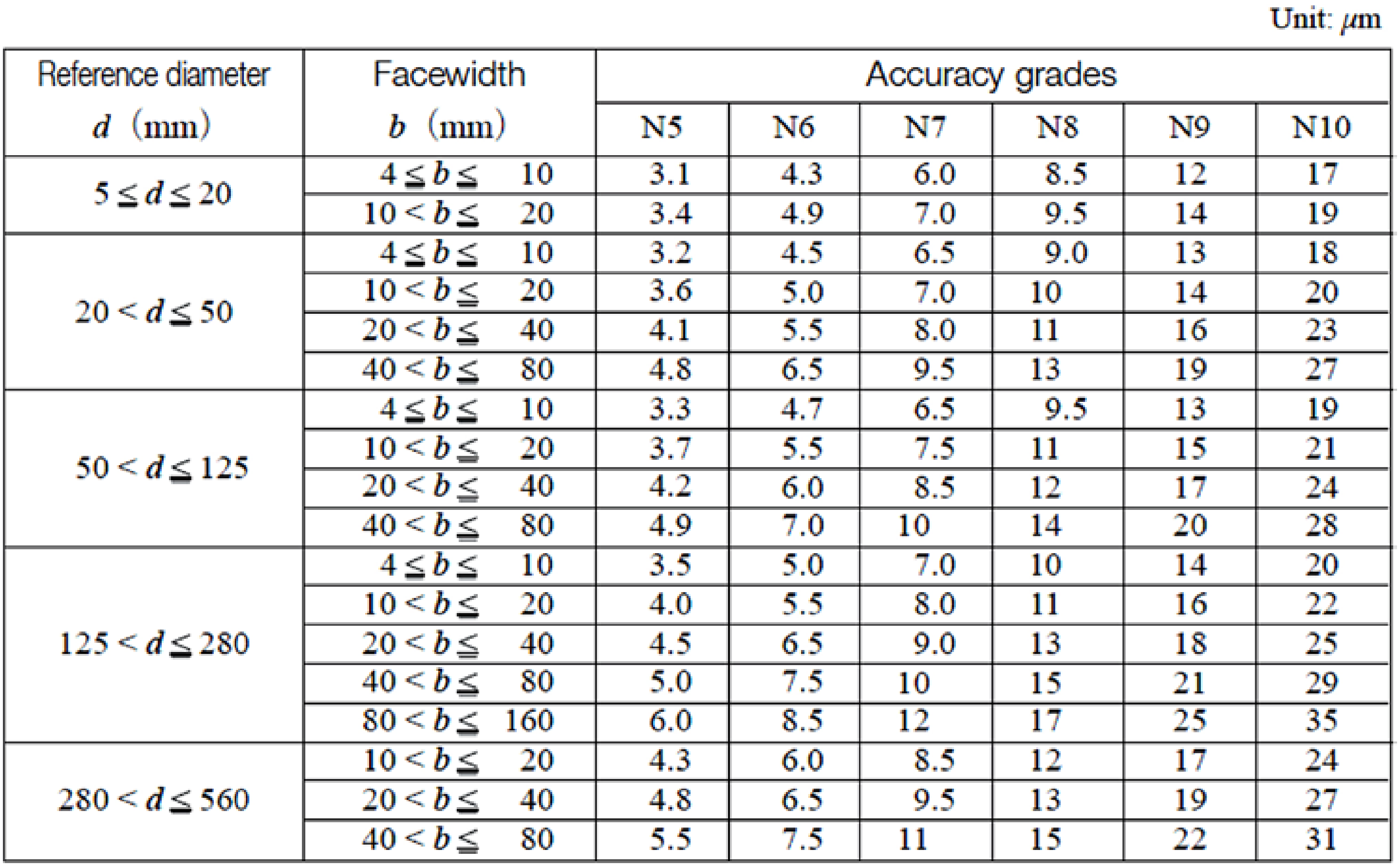


Unit: μm

Reference diameter d (mm)	Facewidth b (mm)	Accuracy grades					
		N5	N6	N7	N8	N9	N10
$5\ d\ 20$	$4 \le b \le 10$	6.0	8.5	12	17	24	35
	$10 < b \le 20$	7.0	9.5	14	19	28	39
$20 < d\ 50$	$4 \le b \le 10$	6.5	9.0	13	18	25	36
	$10 < b \le 20$	7.0	10	14	20	29	40
	$20 < b \le 40$	8.0	11	16	23	32	46
	$40 < b \le 80$	9.5	13	19	27	38	54
$50 < d\ 125$	$4 \le b \le 10$	6.5	9.5	13	19	27	38
	$10 < b \le 20$	7.5	11	15	21	30	42
	$20 < b \le 40$	8.5	12	17	24	34	48
	$40 < b \le 80$	10	14	20	28	39	56
$125 < d\ 280$	$4 \le b \le 10$	7.0	10	14	20	29	40
	$10 < b \le 20$	8.0	11	16	22	32	45
	$20 < b \le 40$	9.0	13	18	25	36	50
	$40 < b \le 80$	10	15	21	29	41	58
	$80 < b \le 160$	12	17	25	35	49	69
$280 < d\ 560$	$10 < b \le 20$	8.5	12	17	24	34	48
	$20 < b \le 40$	9.5	13	19	27	38	54
	$40 < b \le 80$	11	15	22	31	44	62

Table 2: Allowable in-plane deviation with respect to parallelism of axes per facewidth f_x



Unit: μm

Reference diameter d (mm)	Facewidth b (mm)	Accuracy grades					
		N5	N6	N7	N8	N9	N10
$5 \le d \le 20$	$4 \le b \le 10$	3.1	4.3	6.0	8.5	12	17
	$10 < b \le 20$	3.4	4.9	7.0	9.5	14	19
$20 < d \le 50$	$4 \le b \le 10$	3.2	4.5	6.5	9.0	13	18
	$10 < b \le 20$	3.6	5.0	7.0	10	14	20
	$20 < b \le 40$	4.1	5.5	8.0	11	16	23
	$40 < b \le 80$	4.8	6.5	9.5	13	19	27
$50 < d \le 125$	$4 \le b \le 10$	3.3	4.7	6.5	9.5	13	19
	$10 < b \le 20$	3.7	5.5	7.5	11	15	21
	$20 < b \le 40$	4.2	6.0	8.5	12	17	24
	$40 < b \le 80$	4.9	7.0	10	14	20	28
$125 < d \le 280$	$4 \le b \le 10$	3.5	5.0	7.0	10	14	20
	$10 < b \le 20$	4.0	5.5	8.0	11	16	22
	$20 < b \le 40$	4.5	6.5	9.0	13	18	25
	$40 < b \le 80$	5.0	7.5	10	15	21	29
	$80 < b \le 160$	6.0	8.5	12	17	25	35
$280 < d \le 560$	$10 < b \le 20$	4.3	6.0	8.5	12	17	24
	$20 < b \le 40$	4.8	6.5	9.5	13	19	27
	$40 < b \le 80$	5.5	7.5	11	15	22	31

Table 3: Allowable out-of-plane deviation with respect to parallelism of axes per facewidth f_y