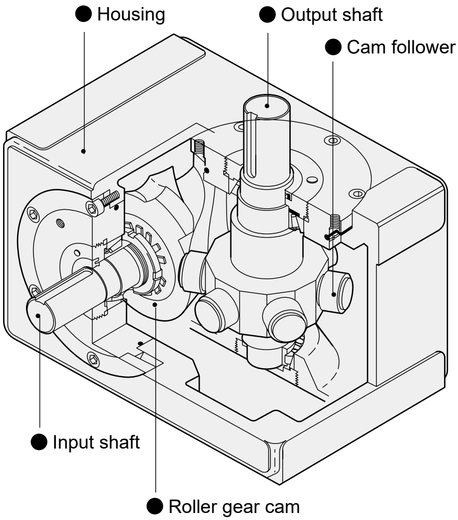
Technical Explanation B

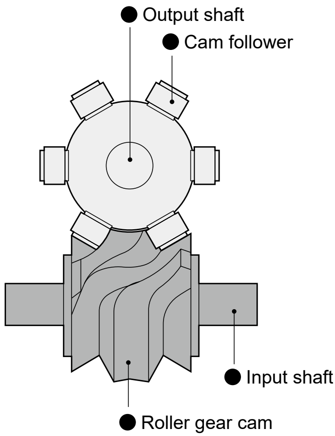
Explanation of operation

1. Name of parts and motion

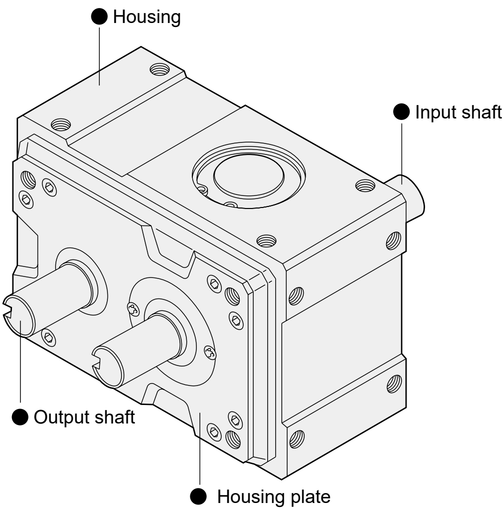
Name of parts

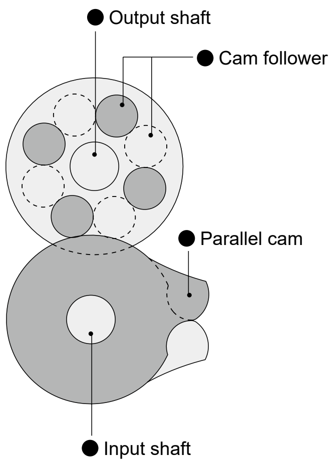
● Roller gear cam mechanism





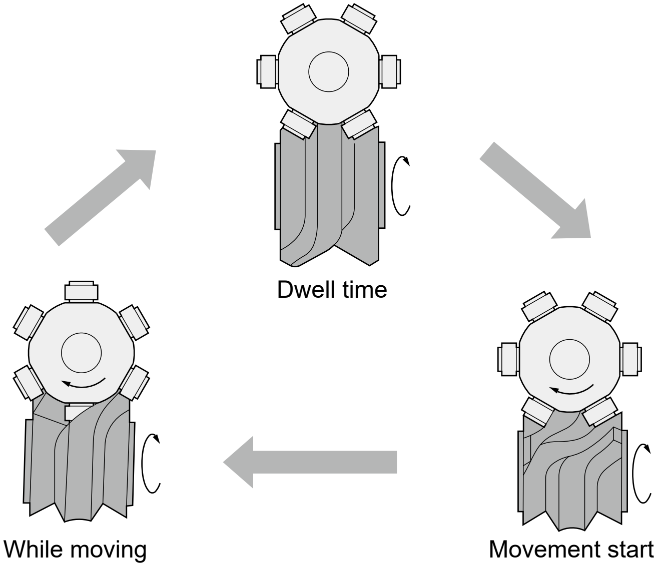
● Parallel cam mechanism



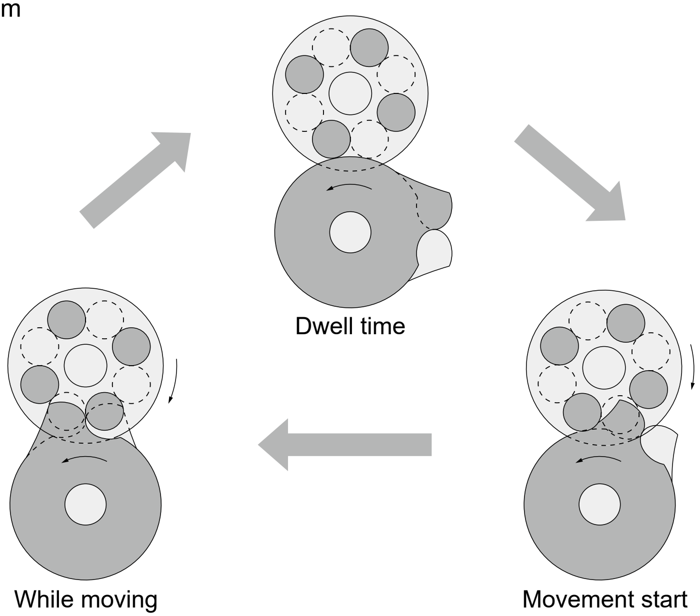


Motion

● Roller gear cam



● Parallel cam



Explanation of operation

2. Index number and index angle

2-1. Index number (n)

The output shaft of index drive repeats the cycle of moving and stopping. How many times the output shaft stops for 1 full turn is called the "index number." For instance, when the output shaft stops at equal intervals 4 times for 1 full 360 turn, it turns by 90 degrees. This 90 degree angle is called the oscillating angle (ψ). The index number and the oscillating angle have the following relationship.

$$n = \frac{360}{\psi}$$

Since the output shaft of the Oscillator oscillates by a certain angle, the oscillating angle is used instead of the index number.

2-2. Index angle (θh)

The index angle represents the rotational angle of the input shaft required to move the output shaft for 1 index position.
The section of the index angle is called the index section, and the rest is called the dwell section.
In the dwell section, the output shaft stays stopped even if the input shaft rotates. You can choose the index angle freely within a certain range depending on the specifications. In this case, choose one generally based on 2 criteria depending on the operation of the input shaft.

(1) When the input shaft rotates continuously
The ratio of moving and stopping of the output shaft is equal to the ratio of the index angle and the dwell angle. For instance, when you choose the index angle to be 120 degrees, the dwell angle will be 240 degrees, and the ratio of moving and stopping will be 1:2.

(2) When the input shaft stops at every index position
Since the ratio of moving and stopping can be adjustable while the input shaft is stopped, a larger index angle among the standard values, such as 270 degrees and 300 degrees, is generally selected as this is more beneficial in terms of capacity.

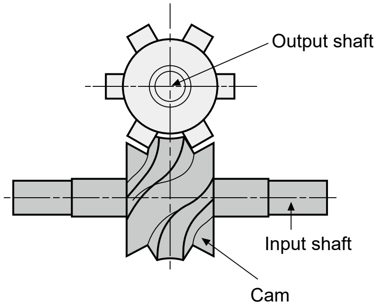
t_0: Unit cycle time (s)

t_1: Index time (s)

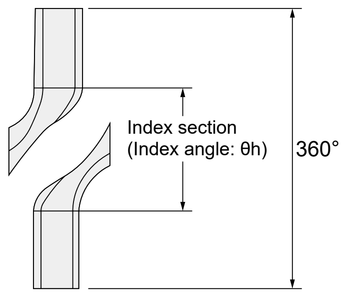
z: Dwell No.

$$\theta h = \frac{360 \cdot t_1}{z \cdot t_0}$$

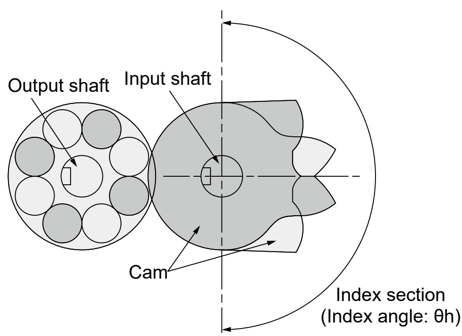
● Index angle of the roller gear cam



Cam development diagram



● Index angle of the parallel cam



2-3. Dwell No. (z)

The dwell No. represents the number of indexing done by the output shaft for 1 full turn of the input shaft.
For instance, when a single indexing is done for 1 full turn of the input shaft, the dwell No. will be 1, and this is called a "1 dwell system.". The system with 2 or more dwell intervals is called the multi-dwell interval system.
For index drive, a single-dwell interval system is the standard, but a multi-dwell interval system is used for a greater index number.
(Note 1)
The 2 dwell interval system is the standard for Oscillators.
In some cases, systems have an identical index number but with different dwell interval numbers. In these cases, the greater the dwell interval number, the more beneficial in terms of capacity.

Model No.	RGIS		
Size	80	Material of housing:	FC
Index number	16	Shaft type	S shaft
Index angle:	120 degrees	Unit cycle time:	2 s
Cam curve	MS		

(N·m)

Dwell No.	Dynamic rated output torque
1	30.0(30rpm)
2	133.0(15rpm)

Table. Comparison of output torque for identical specifications

2-4. Total index angle (θt)

The total index angle is the total of index angles present within 1 full turn of the input shaft.
For a single-dwell interval system, the index angle and the total index angle are identical. In this catalog, the total index angle is used in the specifications for the model number and a torque table.

$$\theta t = \theta h \times z$$ (for the standard specification)

3. Cycle time

Unit cycle time (t_0)

Time required for 1 full cycle of the machine is called the cycle time.
All machines have a cycle time. The cycle time for the entire machinery is called the machine cycle time, while the cycle time for a unit composing the machine is called the unit cycle time. Henceforth, unless otherwise specified, "cycle time" refers to the unit cycle time.
When the input shaft of index drive is rotated continuously, the machine cycle time and the unit cycle time are identical. However, if the input shaft of index drive is stopped at every indexing, the machine cycle time and the unit cycle time are different. In this case, you should consider them separately.
When you select a size for index drive, the unit cycle time is used.

t_1: Index time (s)
t_2: Dwell time (s)
N: Input shaft rotational speed (rpm)
Suppose,

$$t_0=t_1+t_2=\frac{60}{N \times z}$$

and
tm: Machine cycle time (s)
ts: Input shaft stop time (s)
to be suppose,
the calculation will be:
$tm = t_0+ts$

Explanation of operation

4. Timing chart and keyway location

4-1. Timing chart

The chart which represents the movements of the output shaft of the index drive is called the timing chart.
This chart may not be important for the standard drive, but for an output shaft with special specifications making complicated movements, the timing chart is used to describe the motion.
The timing chart is drawn with the rotational angle (position) of the input shaft (Note 2) on the horizontal axis and the rotational angle (position) of the output shaft on the vertical axis to indicate the output shaft position relative to the input shaft position.
When you draw the chart, first plot the starting and ending points of the index section and then connect these with a straight line. (Note 3)

The line of the timing chart is drawn as below.

- ● Index section
  Since both the input shaft and the output shaft move, the line will be either upward-sloping or downward-sloping. Whether it becomes upward-sloping or downward-sloping, it will correspond to the direction of the twist of the cam. Depending on how to choose the reference point, the direction of the twist cannot be determined for the upward-sloping line.
- ● Dwell section
  Since the output shaft is stopped although the input shaft is rotating, the line becomes horizontal.

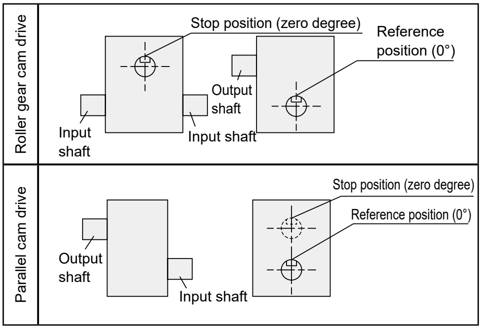
By default, the point of origin (the starting point of the input/output shaft, 0°position) for drawing the timing chart is the keyway location indicated in this catalog.
(For Oscillators, the output shaft is drawn at the middle of the movement for the purpose of convenience.) If you request a special movement of the index and specify its specifications with the timing chart, you can follow this convention.
In the case of special timing, if the input shaft rotation is reversed, you cannot obtain the expected movements. Hence, it is necessary to specify the rotational direction of the input/output shaft in the timing chart.

Note 2: To be precise, the horizontal axis represents time. Since the input shaft of the index drive rotates at a constant speed, the position of the input shaft and time are synonymous.

Note 3: The timing chart refers to the starting and ending points of the index section of the cam. Although the index section has a smooth curve, the line is represented with a straight line on the timing chart.

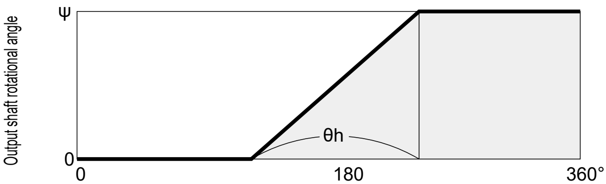
4-2. Standard Index

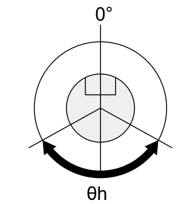
The standard index is located at the center of the cam dwell section when the input shaft keyway is at the "reference position." The output shaft is moved by the set angle referring to the "stop position" as the input shaft rotates.
The relationship between the standard timing chart and the input shaft keyway position is shown below with index angles. Refer to this when designing a system.



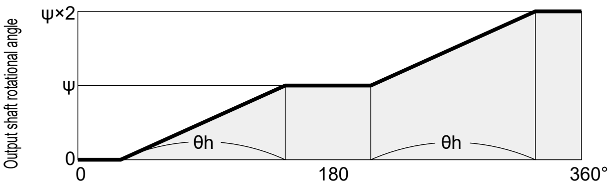
● Input shaft keyway position and index angle (θh)

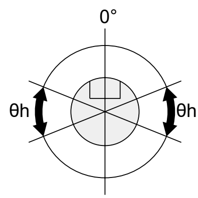
1 dwell



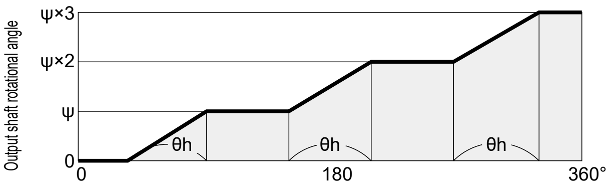


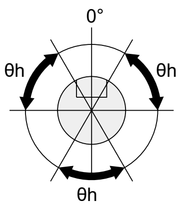
2 dwell



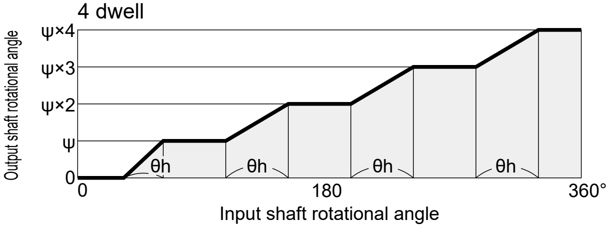


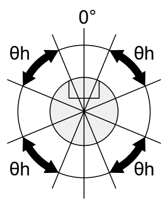
3 dwell





4 dwell





Explanation of operation

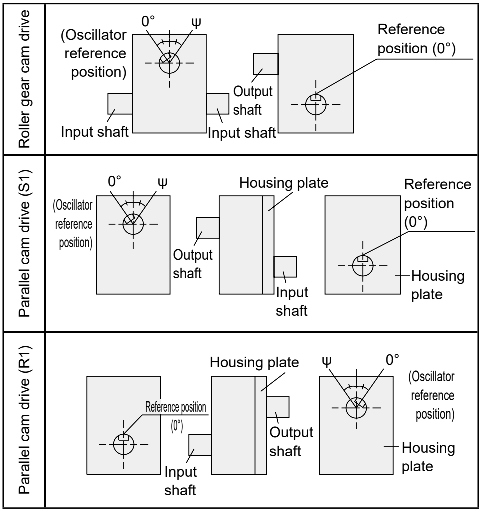
4. Timing chart and keyway location

4-3. Standard oscillator

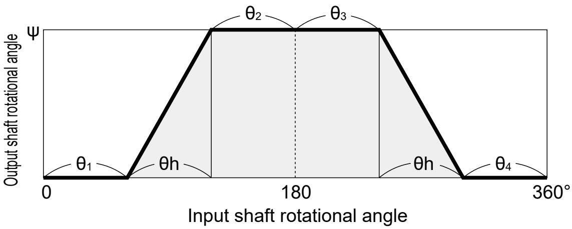
The standard oscillator is located at the center of either of the 2 cam dwell sections when the input shaft keyway is at the "reference position."
At this time, the output shaft stops at the "oscillator reference position." The oscillator is conducted by the set angle from this spot as the input shaft rotates.

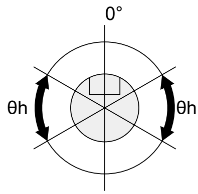
Note 1: In the outline dimensional diagram of the Product specifications D, the output shaft keyway is drawn at the center of the oscillating angle.
For the input/output shaft, the reference point in the right figure and the oscillator reference point are taken to be the reference (zero degrees). Refer to this when designing a system.

Note 2: When the output shaft is the flange, the mounting hole locations on the flange face will have the same positional relationship as the keyway.



● Input shaft keyway position and index angle (θh)

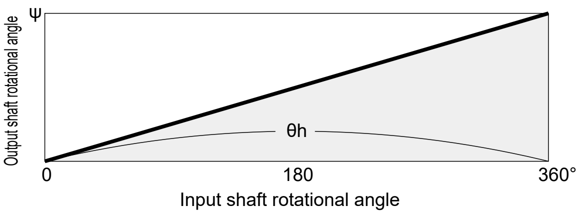


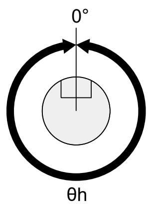


4-4. Standard reducer

This reducer has extremely small backlash from the cam and cam follower. During the full turn (360°) of the input shaft, there is no dwell section and while the rotational speed is constant, it is reduced and outputted.

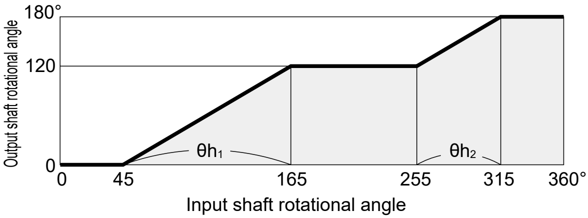
● Input shaft keyway position and index angle (θh)

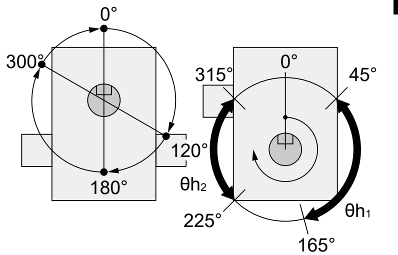




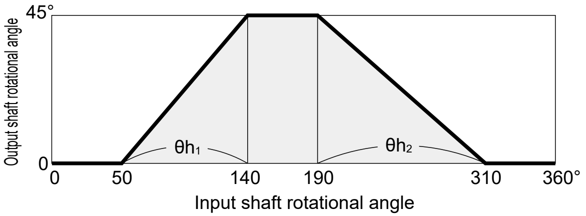
4-5. Sample of special timing chart

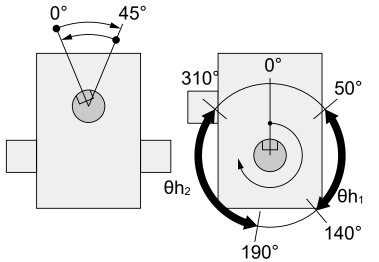
● Special index (unequal division)





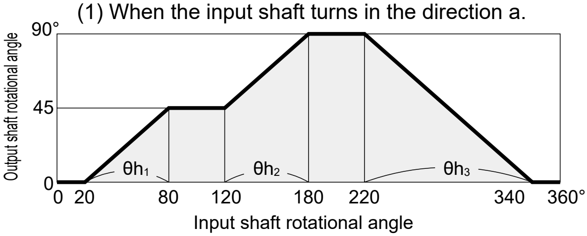
● Special oscillator

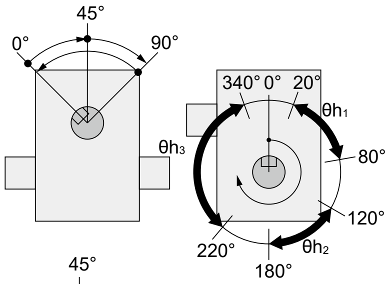




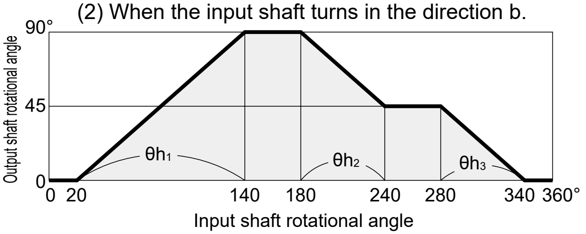
● Special oscillator

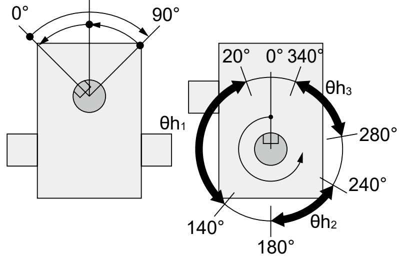
(1) When the input shaft turns in the direction a.





(2) When the input shaft turns in the direction b.





When you order an index drive with special timing, create a timing chart verifying the following points.

(1) Keyway of the input/output shaft and the position of the reference point (0 degrees) for the mounting holes.

(2) Rotational direction of the input/output shaft

(3) Shaft layout in the case of the parallel cam drive

Explanation of operation

5. Cam curve

Overview

The cam curve represents the movement curve of the output shaft driven by the cam. The index drive converts the continuous rotation of the input shaft into intermittent operation of the output shaft. Generally in this case, only the starting and the ending points are taken into consideration, but in order to move the workpiece smoothly at high speeds, how the movement occurs becomes important. To discuss how the workpiece moves throughout the movement, the movement is represented with the movement curve and this is called the cam curve. Characteristics of the movement curve include displacement (S), speed (V), acceleration (A) and jump (J).

Standard curve

There are various cam curves, but the MS curve is the most commonly used today. When we think of a curve to be used with the general purpose index drive, the primary requirement is that the cam curve should be balanced since the index drive is used for various applications. Hence, the MS curve, which has excellent balance, is adopted as the standard curve for various index drive products. When you select a cam curve, we consider it appropriate to select the standard MS curve for most cases.

The cam has existed as a mechanical element for ages, and there are numerous variations. On the contrary, the cam curve is relatively a new notion. This becomes important as the machining accuracy of the cam is increased and flexible cam forms can be created.
In the early days, the cam was manufactured by defining the contour of the cam, and the motion characteristics were not particularly taken into consideration. However, the current cam design defines the motion characteristics of the output shaft first and then creates the cam contour which achieves these characteristics. Hence, it becomes possible to balance high precision and high frequency, which are contradictory at a higher dimension.

Characteristics of the cam curve

Characteristics of the movement curve include displacement (S), speed (V), acceleration (A) and jump (J). These are obtained by differentiating the displacement (S) with time (T) in sequence. The formulae are given as:

$$V=\frac{dS}{Td}$$

$$A=\frac{d^2S}{dT^2}$$

$$J=\frac{d^3S}{dT^3}$$

The subscript "m" is added to the max. values as "Vm", "Am", etc.
When you actually design the curve, values with units are used, but to represent the cam curve, non-dimensional values are used.
The following relationship holds between the non-dimensional values and the actual values with dimensions. Suppose the values with dimensions to be displacement (s), speed (v), acceleration (a) and jump (j).

$$s= h\cdot S$$

$$v=\frac{h}{th}\cdot V$$

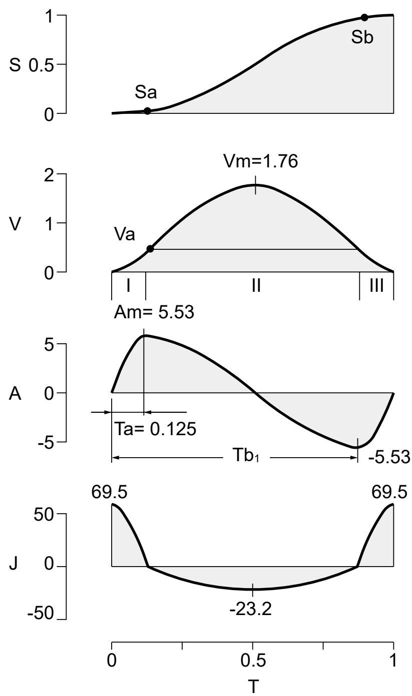
$$a=\frac{h}{th^2}\cdot A$$

$$j=\frac{h}{th^3}\cdot J$$

Here, "h" represents the actual size of displacement and "th" represents the time from the start of the displacement to its end.

MS: Modified sine curve

The modified sine curve is similar to a curve with the acceleration peak of the cycloid curve horizontally moved (displaced). The motion characteristics are relatively compact and well balanced, which is why this is commonly used. We use this curve as the standard curve as well.



Constant formula

$$Ta=\frac{1}{8}$$

$$Am=\frac{1}{\frac{2Ta}{\pi}+\frac{2-8Ta}{\pi^2}}$$

$$Va=\frac{2TaAm}{\pi}$$

$$Sa=\frac{2Ta^2Am}{\pi}-\frac{4Ta^2Am}{\pi^2}$$

$$Sb=1-Sa$$

Displacement formula

Section I ($0 \le T \le Ta$)

$$S=\frac{2TaAm}{\pi}T-\frac{4Ta^2Am}{\pi^2}\sin\frac{\pi T}{2Ta}$$

Section II ($Ta < T \le 1-Ta$)

$$S=\frac{(1-2Ta)^2Am}{\pi^2}\left(1-\cos\frac{\pi(T-Ta)}{1-2Ta}\right)+Va(T-Ta)+Sa$$

Section III ($1-Ta < T \le 1$)

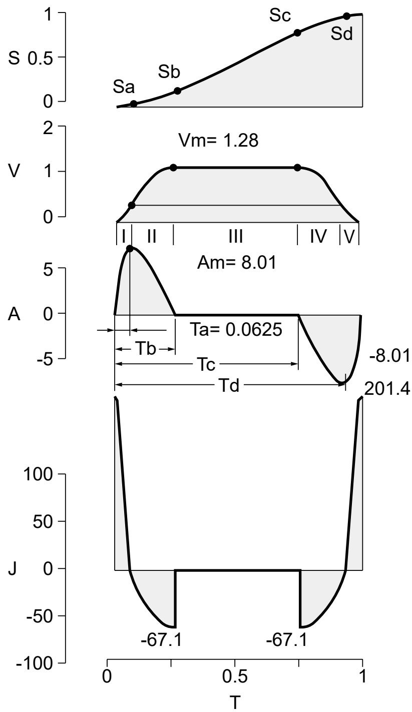
$$S=\frac{4Ta^2Am}{\pi^2}\left(\cos\frac{\pi(T-1+Ta)}{2Ta}-1\right)+Va(T-1+Ta)+Sb$$

Explanation of operation

5. Cam curve

MC: Modified constant velocity curve

The modified constant velocity curve has a constant speed section in the middle of the movement. Although this curve is inferior to MS in terms of motion characteristics, it is used when the workpiece is transferred in the middle of the movement or when the workpiece should be moved at a constant velocity.
Generally, this is called the MCV50 curve, but we abbreviate it as the MC curve. The figure "50" in "MCV50" represents the ratio of the time the output shaft moves at a constant speed. Therefore, MCV50 means the output shaft moves at a constant speed for 50% of the movement time. MCV25 is also used.



Constant formula

$$Ta=\frac{1}{16}$$

$$Tb=\frac{1}{4}$$

$$Am=\frac{1}{\frac{2}{\pi}\left(\left(2-\frac{8}{\pi}\right)TaTb+\left(\frac{4}{\pi}-2\right)Tb^2+Tb\right)}$$

$$Va=\frac{2TaAm}{\pi}$$

$$Sa=\frac{2Ta^2Am}{\pi}-\frac{4Ta^2Am}{\pi^2}$$

$$Vm=\frac{2TbAm}{\pi}$$

$$Sb=\frac{4(Tb-Ta)^2Am}{\pi^2}+Va(Tb-Ta)+Sa$$

$$Sc=1-Sb$$

$$Sd=1-Sa$$

Displacement formula

Section I ($0 \leq T \leq Ta$)

$$S=\frac{2TaAm}{\pi}T-\frac{4Ta^2Am}{\pi^2}\sin\frac{\pi T}{2Ta}$$

Section II ($Ta < T \leq Tb$)

$$S=\frac{4(Tb-Ta)^2Am}{\pi^2}\left(1-\cos\frac{\pi(T-Ta)}{2(Tb-Ta)}\right)+Va(T-Ta)+Sa$$

Section III ($Tb < T \leq 1-Tb$)

$$S=Vm(T-Tb)+Sb$$

Section IV ($1-Tb < T \leq 1-Ta$)

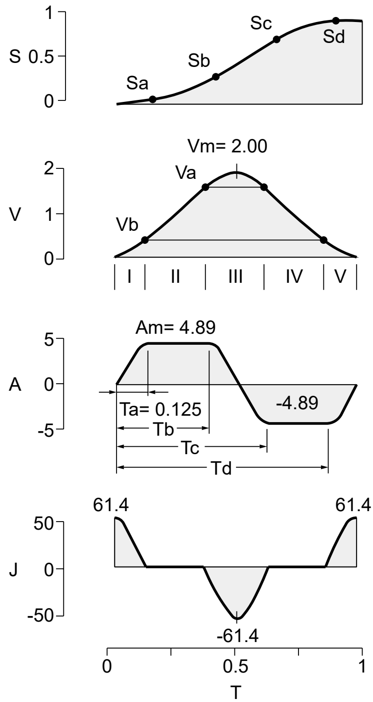
$$S=\frac{4(Tb-Ta)^2Am}{\pi^2}\sin\frac{\pi(T-1+Tb)}{2(Tb-Ta)}-\frac{2(Tb-Ta)Am}{\pi}\times(T-1+Tb)+Vm(T-1+Tb)+Sc$$

Section V ($1-Ta < T \leq 1$)

$$S=\frac{4Ta^2Am}{\pi^2}\left(\cos\frac{\pi(T-1+Ta)}{2Ta}-1\right)+Va(T-1+Ta)+Sd$$

MT: Modified trapezoidal curve

The modified trapezoidal curve has a compact value for the max. acceleration and is suitable for high speeds. Yet, this is not very good except for the acceleration. It is not well balanced compared to the MS from a comprehensive perspective, and the MT is not often used except for special applications.



Constant formula

$$Ta=\frac{1}{8}$$

$$Am=\frac{1}{\frac{1}{4}-Ta+\frac{2}{\pi}Ta}$$

$$Va=\frac{2TaAm}{\pi}$$

$$Sa=\frac{2Ta^2Am}{\pi}-\frac{4Ta^2Am}{\pi^2}$$

$$Vb=Am(0.5-2Ta)+Va$$

$$Sb=\frac{Am}{2}(0.5-2Ta)^2+Va(0.5-2Ta)+Sa$$

$$Sc=1-Sb$$

$$Sd=1-Sa$$

Displacement formula

Section I ($0 \le T \le Ta$)

$$S=\frac{2TaAm}{\pi}T-\frac{4Ta^2Am}{\pi^2}\sin\frac{\pi T}{2Ta}$$

Section II ($Ta < T \le 0.5-Ta$)

$$S=\frac{Am}{2}(T-Ta)^2+Va(T-Ta)+Sa$$

Section III ($0.5-Ta < T \le 0.5+Ta$)

$$S=\frac{4Ta^2Am}{\pi^2}\left(1-\cos\frac{\pi(T-0.5+Ta)}{2Ta}\right)+Vb(T-0.5+Ta)+Sb$$

Section IV ($0.5+Ta < T \le 1-Ta$)

$$S=-\frac{Am}{2}(T-0.5-Ta)^2+Vb(T-0.5-Ta)+Sc$$

Section V ($1-Ta < T \le 1$)

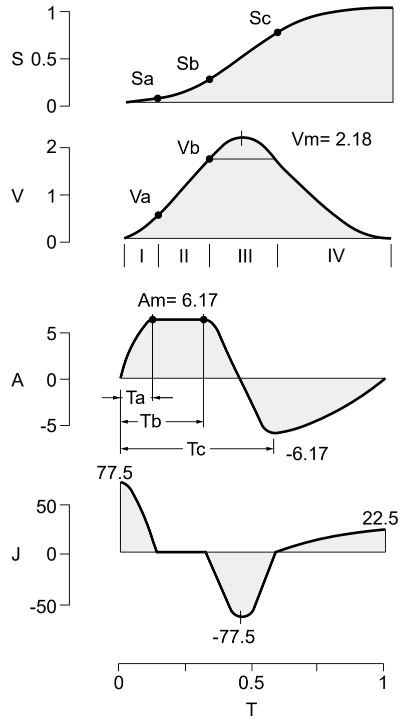
$$S=\frac{4Ta^2Am}{\pi^2}\left(\cos\frac{\pi(T-1+Ta)}{2Ta}-1\right)+Va(T-1+Ta)+Sd$$

Explanation of operation

5. Cam curve

TR: Trapecloid curve (Asymmetrical cam curve)

This curve is used when you want to minimize the residual vibration at dwell intervals.
This does not hold in every case, but if the residual vibration at high speeds becomes an issue with a system of sufficient rigidity, this curve can mitigate residual vibration more than other curves. The vibration issue, however, is closely related to the rigidity of the machinery or the backlash load rather than the cam curve, and adopting this curve does not guarantee the complete elimination of residual vibrations.
In addition, since this curve is an asymmetrical cam curve, the system does not work properly if the input shaft rotation is reversed. Hence, the rotational direction of the input/output shaft will have to be determined beforehand.



Constant formula

$$Ta=\frac{1}{8}$$

$$Tb=\frac{2-6Ta+\pi Ta}{2+\pi}$$

$$Tc=\frac{2-2Ta+3\pi Ta}{2+\pi}$$

$$Am=1\Big/\left(\left(-\frac{3}{2}+\frac{4}{\pi}+\frac{4}{\pi^2}\right)Ta^2+\left(1+\frac{2}{\pi}\right)TaTb+\frac{1}{2}Tb^2+\left(\frac{2}{\pi}-\frac{4}{\pi^2}\right)(1-Tc)^2\right)$$

$$Va=\frac{2TaAm}{\pi} \qquad Sa=\frac{2Ta^2Am}{\pi}-\frac{4Ta^2Am}{\pi^2}$$

$$Vb=Am(Tb-Ta)+Va$$

$$Sb=\frac{Am}{2}(Tb-Ta)^2+Va(Tb-Ta)+Sa$$

$$Sc=\frac{8Ta^2Am}{\pi^2}+2VbTa+Sb$$

Displacement formula

Section I ($0 \le T \le Ta$)

$$S=\frac{2TaAm}{\pi}T-\frac{4Ta^2Am}{\pi^2}\sin\frac{\pi T}{2Ta}$$

Section II ($Ta < T \le Tb$)

$$S=\frac{Am}{2}(T-Ta)^2+Va(T-Ta)+Sa$$

Section III ($Tb < T \le Tc$)

$$S=\frac{4Ta^2Am}{\pi^2}\left(1-\cos\frac{\pi(T-Tb)}{2Ta}\right)+Vb(T-Tb)+Sb$$

Section IV ($Tc < T \le 1$)

$$S=\frac{4(1-Tc)^2Am}{\pi^2}\left(\cos\frac{\pi(T-Tc)}{2(1-Tc)}-1\right)+Vb(T-Tc)+Sc$$

Cam curve characteristics table and how to use it

The cam curve characteristics table is shown below. All these values do not have dimensions, and to convert them into values with units a simple calculation is required.

(Sample)

Index number = 6 Index angle = 270°

Cam curve = MS Input shaft rotational speed = 60 rpm

For an index with the above specifications, let us try to calculate the position of the input shaft and the output shaft angular speed when the output shaft moves 11 degrees.

Since the index number is 6, the size of displacement (h) (in this case, the oscillating angle of the output shaft) is

$$h=\frac{360}{6}=60°$$

and the time (th) required to move 60 degrees is

$$th=\frac{\theta h}{360}\times\frac{60}{N}$$

θh: Index angle (degrees)

N: Input shaft rotational speed (rpm)

$$th=\frac{270}{360}\times\frac{60}{60}=0.75\text{ (sec)}$$

First, when the output shaft position of 11 degrees is represented with a non-dimensional value, the calculation will be:

$$S=\frac{11}{60}=0.1833$$

When we search this value in the non-dimensional displacement (S) in the cam curve characteristics table, we can obtain close values of 0.17789 and 0.19132. The non-dimensional time (T) at this time is 0.30 and 0.31 respectively. From these values, when you obtain the non-dimensional time when S is 0.1833, with the proportional interpolation, the calculation will be:

$$T=0.3+(0.31-0.3)\times\frac{(0.1833-0.17789)}{(0.19132-0.17789)}=0.304$$

In the same manner, non-dimensional speed (V) is

$$V=1.32295+(1.36325-1.32295)\times\frac{(0.1833-0.17789)}{(0.19132-0.17789)}$$

$$=1.339$$

Since the input shaft rotates at a constant speed, Non-dimensional time = Non-dimensional input shaft position, which does not pose any problems. That is, the input shaft position (θ) is

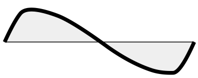
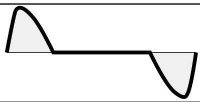
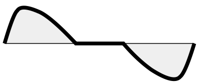
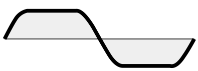
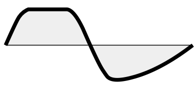
$\theta = \theta h \times T = 270 \times 0.304 = 82.08°$

Then, the speed (v) at this time is

$$v=\frac{h}{th}\times V\times\frac{\pi}{180}=\frac{60}{0.75}\times1.339\times\frac{\pi}{180}$$

$$=107.12\times\frac{\pi}{180}=1.8696\text{(rad/s)}$$

List of characteristics of the cam curve

Name	Acceleration curve	Vm	Am	Jm	Qm
MS Modified sine curve		1.76	±5.53	+69.5 -23.2	±0.99
MC Modified constant velocity curve (MCV50)		1.28	±8.01	+201.4 -67.1	±0.72
Modified constant velocity curve (MCV25)		1.48	±6.19	+103.8 -34.6	±0.83
MT Modified trapezoidal curve		2.00	±4.89	±61.4	±1.65
TR Trapecloid curve		2.18	±6.17	±77.5	±1.76

Explanation of operation MS

5. Cam curve characteristics table

● MS Modified sine curve

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.00000	0.00000	0.00000	0.00000	69.46636	0.00000
0.01000	0.00001	0.00347	0.69284	68.91859	0.00043
0.02000	0.00009	0.01382	1.37475	67.28394	0.00344
0.03000	0.00031	0.03089	2.03498	64.58819	0.01137
0.04000	0.00073	0.05441	2.66311	60.87383	0.02621
0.05000	0.00142	0.08401	3.24925	56.19946	0.04938
0.06000	0.00243	0.11923	3.78415	50.63880	0.08162
0.07000	0.00382	0.15950	4.25936	44.27952	0.12289
0.08000	0.00564	0.20419	4.66741	37.22194	0.17240
0.09000	0.00792	0.25260	5.00185	29.57734	0.22856
0.10000	0.01070	0.30396	5.25740	21.46628	0.28909
0.11000	0.01400	0.35747	5.43004	13.01670	0.35114
0.12000	0.01785	0.41228	5.51705	4.36183	0.41147
0.13000	0.02225	0.46754	5.52674	-0.48493	0.46744
0.14000	0.02720	0.52277	5.51705	-1.45394	0.52173
0.15000	0.03270	0.57785	5.49767	-2.42040	0.57468
0.16000	0.03876	0.63269	5.46865	-3.38262	0.62590
0.17000	0.04536	0.68719	5.43004	-4.33890	0.67502
0.18000	0.05250	0.74126	5.38190	-5.28757	0.72167
0.19000	0.06018	0.79480	5.32432	-6.22696	0.76552
0.20000	0.06839	0.84771	5.25740	-7.15543	0.80622
0.21000	0.07713	0.89991	5.18125	-8.07134	0.84347
0.22000	0.08639	0.95131	5.09602	-8.97310	0.87697
0.23000	0.09616	1.00180	5.00185	-9.85911	0.90646
0.24000	0.10642	1.05131	4.89890	-10.72783	0.93168
0.25000	0.11718	1.09975	4.78735	-11.57773	0.95241
0.26000	0.12841	1.14703	4.66741	-12.40731	0.96847
0.27000	0.14012	1.19307	4.53928	-13.21513	0.97969
0.28000	0.15227	1.23779	4.40318	-13.99977	0.98594
0.29000	0.16487	1.28111	4.25936	-14.75984	0.98711
0.30000	0.17789	1.32295	4.10807	-15.49402	0.98315
0.31000	0.19132	1.36325	3.94957	-16.20102	0.97400
0.32000	0.20515	1.40192	3.78415	-16.87960	0.95968
0.33000	0.21935	1.43891	3.61208	-17.52856	0.94021
0.34000	0.23392	1.47414	3.43368	-18.14678	0.91566
0.35000	0.24883	1.50756	3.24925	-18.73315	0.88612
0.36000	0.26406	1.53911	3.05912	-19.28667	0.85173
0.37000	0.27961	1.56873	2.86363	-19.80635	0.81264
0.38000	0.29543	1.59636	2.66311	-20.29128	0.76905
0.39000	0.31153	1.62197	2.45792	-20.74061	0.72119
0.40000	0.32787	1.64551	2.24842	-21.15356	0.66929
0.41000	0.34443	1.66693	2.03498	-21.52940	0.61364
0.42000	0.36120	1.68620	1.81796	-21.86746	0.55453
0.43000	0.37815	1.70328	1.59776	-22.16717	0.49230
0.44000	0.39525	1.71814	1.37475	-22.42798	0.42728
0.45000	0.41250	1.73076	1.14933	-22.64945	0.35985
0.46000	0.42986	1.74112	0.92189	-22.83118	0.29036
0.47000	0.44732	1.74920	0.69284	-22.97286	0.21923
0.48000	0.46484	1.75498	0.46257	-23.07424	0.14685
0.49000	0.48241	1.75845	0.23149	-23.13514	0.07364
0.50000	0.50000	1.75960	0.00000	-23.15545	0.00000

MS Modified sine curve

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.50000	0.50000	1.75960	0.00000	-23.15545	0.00000
0.51000	0.51759	1.75845	-0.23149	-23.13514	-0.07364
0.52000	0.53516	1.75498	-0.46257	-23.07424	-0.14685
0.53000	0.55268	1.74920	-0.69284	-22.97286	-0.21923
0.54000	0.57014	1.74112	-0.92189	-22.83118	-0.29036
0.55000	0.58750	1.73076	-1.14933	-22.64945	-0.35985
0.56000	0.60475	1.71814	-1.37475	-22.42798	-0.42728
0.57000	0.62185	1.70328	-1.59776	-22.16717	-0.49230
0.58000	0.63880	1.68620	-1.81796	-21.86746	-0.55453
0.59000	0.65557	1.66693	-2.03498	-21.52940	-0.61364
0.60000	0.67213	1.64551	-2.24842	-21.15356	-0.66929
0.61000	0.68847	1.62197	-2.45792	-20.74061	-0.72119
0.62000	0.70457	1.59636	-2.66311	-20.29128	-0.76905
0.63000	0.72039	1.56873	-2.86363	-19.80635	-0.81264
0.64000	0.73594	1.53911	-3.05912	-19.28667	-0.85173
0.65000	0.75117	1.50756	-3.24925	-18.73315	-0.88612
0.66000	0.76608	1.47414	-3.43368	-18.14678	-0.91566
0.67000	0.78065	1.43891	-3.61208	-17.52856	-0.94021
0.68000	0.79485	1.40192	-3.78415	-16.87960	-0.95968
0.69000	0.80868	1.36325	-3.94957	-16.20102	-0.97400
0.70000	0.82211	1.32295	-4.10807	-15.49402	-0.98315
0.71000	0.83513	1.28111	-4.25936	-14.75984	-0.98711
0.72000	0.84773	1.23779	-4.40318	-13.99977	-0.98594
0.73000	0.85988	1.19307	-4.53928	-13.21513	-0.97969
0.74000	0.87159	1.14703	-4.66741	-12.40731	-0.96847
0.75000	0.88282	1.09975	-4.78735	-11.57773	-0.95241
0.76000	0.89358	1.05131	-4.89890	-10.72783	-0.93168
0.77000	0.90384	1.00180	-5.00185	-9.85911	-0.90646
0.78000	0.91361	0.95131	-5.09602	-8.97310	-0.87697
0.79000	0.92287	0.89991	-5.18125	-8.07134	-0.84347
0.80000	0.93161	0.84771	-5.25740	-7.15543	-0.80622
0.81000	0.93982	0.79480	-5.32432	-6.22696	-0.76552
0.82000	0.94750	0.74126	-5.38190	-5.28757	-0.72167
0.83000	0.95464	0.68719	-5.43004	-4.33890	-0.67502
0.84000	0.96124	0.63269	-5.46865	-3.38262	-0.62590
0.85000	0.96730	0.57785	-5.49767	-2.42040	-0.57468
0.86000	0.97280	0.52277	-5.51705	-1.45394	-0.52173
0.87000	0.97775	0.46754	-5.52674	-0.48493	-0.46744
0.88000	0.98215	0.41228	-5.51705	4.36183	-0.41147
0.89000	0.98600	0.35747	-5.43004	13.01670	-0.35114
0.90000	0.98930	0.30396	-5.25740	21.46628	-0.28909
0.91000	0.99208	0.25260	-5.00185	29.57734	-0.22856
0.92000	0.99436	0.20419	-4.66741	37.22194	-0.17240
0.93000	0.99618	0.15950	-4.25936	44.27952	-0.12289
0.94000	0.99757	0.11923	-3.78415	50.63880	-0.08162
0.95000	0.99858	0.08401	-3.24925	56.19946	-0.04938
0.96000	0.99927	0.05541	-2.66311	60.87383	-0.02621
0.97000	0.99969	0.03089	-2.03498	64.58819	-0.01137
0.98000	0.99991	0.01382	-1.37475	67.28394	-0.00344
0.99000	0.99999	0.00347	-0.69284	68.91859	-0.00043
1.00000	1.00000	0.00000	0.00000	69.46636	0.00000

Explanation of operation MCV50

5. Cam curve characteristics table

● MC Modified constant velocity curve (MCV50)

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.00000	0.00000	0.00000	0.00000	201.38070	0.00000
0.01000	0.00003	0.01002	1.99267	195.05395	0.00249
0.02000	0.00027	0.03944	3.86014	176.47125	0.01900
0.03000	0.00088	0.08641	5.48506	146.80021	0.05915
0.04000	0.00204	0.14799	6.76533	107.90517	0.12495
0.05000	0.00388	0.22030	7.62051	62.23006	0.20951
0.06000	0.00647	0.29880	7.99687	12.64480	0.29821
0.07000	0.00986	0.37887	7.99687	-4.21493	0.37812
0.08000	0.01404	0.45853	7.92673	-9.80610	0.45362
0.09000	0.01902	0.53722	7.80098	-15.32849	0.52303
0.10000	0.02478	0.61437	7.62051	-20.74335	0.58430
0.11000	0.03131	0.68945	7.38660	-26.01272	0.63558
0.12000	0.03856	0.76193	7.10087	-31.09963	0.67523
0.13000	0.04653	0.83130	6.76533	-35.96839	0.70189
0.14000	0.05518	0.89708	6.38234	-40.58486	0.71455
0.15000	0.06446	0.95880	5.95458	-44.91666	0.71253
0.16000	0.07434	1.01603	5.48506	-48.93340	0.69552
0.17000	0.08477	1.06837	4.97706	-52.60691	0.66362
0.18000	0.09569	1.11546	4.43415	-55.91142	0.61728
0.19000	0.10706	1.15695	3.86014	-58.82375	0.55737
0.20000	0.11881	1.19257	3.25905	-61.32347	0.48506
0.21000	0.13089	1.22206	2.63510	-63.39306	0.40189
0.22000	0.14323	1.24521	1.99267	-65.01798	0.30967
0.23000	0.15577	1.26186	1.33627	-66.18686	0.21044
0.24000	0.16844	1.27190	0.67048	-66.89148	0.10643
0.25000	0.18119	1.27526	0.00000	0.00000	0.00000
0.26000	0.19394	1.27526	0.00000	0.00000	0.00000
0.27000	0.20669	1.27526	0.00000	0.00000	0.00000
0.28000	0.21944	1.27526	0.00000	0.00000	0.00000
0.29000	0.23220	1.27526	0.00000	0.00000	0.00000
0.30000	0.24495	1.27526	0.00000	0.00000	0.00000
0.31000	0.25770	1.27526	0.00000	0.00000	0.00000
0.32000	0.27045	1.27526	0.00000	0.00000	0.00000
0.33000	0.28321	1.27526	0.00000	0.00000	0.00000
0.34000	0.29596	1.27526	0.00000	0.00000	0.00000
0.35000	0.30871	1.27526	0.00000	0.00000	0.00000
0.36000	0.32146	1.27526	0.00000	0.00000	0.00000
0.37000	0.33422	1.27526	0.00000	0.00000	0.00000
0.38000	0.34697	1.27526	0.00000	0.00000	0.00000
0.39000	0.35972	1.27526	0.00000	0.00000	0.00000
0.40000	0.37247	1.27526	0.00000	0.00000	0.00000
0.41000	0.38523	1.27526	0.00000	0.00000	0.00000
0.42000	0.39798	1.27526	0.00000	0.00000	0.00000
0.43000	0.41073	1.27526	0.00000	0.00000	0.00000
0.44000	0.42348	1.27526	0.00000	0.00000	0.00000
0.45000	0.43624	1.27526	0.00000	0.00000	0.00000
0.46000	0.44899	1.27526	0.00000	0.00000	0.00000
0.47000	0.46174	1.27526	0.00000	0.00000	0.00000
0.48000	0.47449	1.27526	0.00000	0.00000	0.00000
0.49000	0.48725	1.27526	0.00000	0.00000	0.00000
0.50000	0.50000	1.27526	0.00000	0.00000	0.00000

● MC Modified constant velocity curve (MCV50)

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.50000	0.50000	1.27526	0.00000	0.00000	0.00000
0.51000	0.51275	1.27526	0.00000	0.00000	0.00000
0.52000	0.52551	1.27526	0.00000	0.00000	0.00000
0.53000	0.53826	1.27526	0.00000	0.00000	0.00000
0.54000	0.55101	1.27526	0.00000	0.00000	0.00000
0.55000	0.56376	1.27526	0.00000	0.00000	0.00000
0.56000	0.57652	1.27526	0.00000	0.00000	0.00000
0.57000	0.58927	1.27526	0.00000	0.00000	0.00000
0.58000	0.60202	1.27526	0.00000	0.00000	0.00000
0.59000	0.61477	1.27526	0.00000	0.00000	0.00000
0.60000	0.62753	1.27526	0.00000	0.00000	0.00000
0.61000	0.64028	1.27526	0.00000	0.00000	0.00000
0.62000	0.65303	1.27526	0.00000	0.00000	0.00000
0.63000	0.66578	1.27526	0.00000	0.00000	0.00000
0.64000	0.67854	1.27526	0.00000	0.00000	0.00000
0.65000	0.69129	1.27526	0.00000	0.00000	0.00000
0.66000	0.70404	1.27526	0.00000	0.00000	0.00000
0.67000	0.71679	1.27526	0.00000	0.00000	0.00000
0.68000	0.72955	1.27526	0.00000	0.00000	0.00000
0.69000	0.74230	1.27526	0.00000	0.00000	0.00000
0.70000	0.75505	1.27526	0.00000	0.00000	0.00000
0.71000	0.76780	1.27526	0.00000	0.00000	0.00000
0.72000	0.78056	1.27526	0.00000	0.00000	0.00000
0.73000	0.79331	1.27526	0.00000	0.00000	0.00000
0.74000	0.80606	1.27526	0.00000	0.00000	0.00000
0.75000	0.81881	1.27526	0.00000	-67.12690	0.00000
0.76000	0.83156	1.27190	-0.67048	-66.89148	-0.10643
0.77000	0.84423	1.26186	-1.33627	-66.18686	-0.21044
0.78000	0.85677	1.24521	-1.99267	-65.01798	-0.30967
0.79000	0.86911	1.22206	-2.63510	-63.39306	-0.40189
0.80000	0.88119	1.19257	-3.25905	-61.32347	-0.48506
0.81000	0.89294	1.15695	-3.86014	-58.82375	-0.55737
0.82000	0.90431	1.11546	-4.43415	-55.91142	-0.61728
0.83000	0.91523	1.06837	-4.97706	-52.60691	-0.66362
0.84000	0.92566	1.01603	-5.48506	-48.93340	-0.69552
0.85000	0.93554	0.95880	-5.95458	-44.91666	-0.71253
0.86000	0.94482	0.89708	-6.38234	-40.58486	-0.71455
0.87000	0.95347	0.83130	-6.76533	-35.96839	-0.70189
0.88000	0.96144	0.76193	-7.10087	-31.09963	-0.67523
0.89000	0.96869	0.68945	-7.38660	-26.01272	-0.63558
0.90000	0.97522	0.61437	-7.62051	-20.74335	-0.58430
0.91000	0.98098	0.53722	-7.80098	-15.32849	-0.52303
0.92000	0.98596	0.45853	-7.92673	-9.80610	-0.45362
0.93000	0.99014	0.37887	-7.99687	-4.21493	-0.37812
0.94000	0.99353	0.29880	-7.99687	12.64480	-0.29821
0.95000	0.99612	0.22030	-7.62051	62.23006	-0.20951
0.96000	0.99796	0.14799	-6.76533	107.90517	-0.12495
0.97000	0.99912	0.08641	-5.48506	146.80021	-0.05915
0.98000	0.99973	0.03944	-3.86014	176.47125	-0.01900
0.99000	0.99997	0.01002	-1.99267	195.05395	-0.00249
1.00000	1.00000	0.00000	0.00000	201.38070	0.00000

Explanation of operation MCV25

5. Cam curve characteristics table

● Modified constant velocity curve (MCV25)

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.00000	0.00000	0.00000	0.00000	103.78659	0.00000
0.01000	0.00002	0.00518	1.03302	102.33316	0.00086
0.02000	0.00014	0.02056	2.03710	98.01360	0.00676
0.03000	0.00046	0.04573	2.98413	90.94888	0.02203
0.04000	0.00108	0.07997	3.84758	81.33687	0.04967
0.05000	0.00209	0.12232	4.60327	69.44678	0.09090
0.06000	0.00355	0.17160	5.23003	55.61163	0.14489
0.07000	0.00554	0.22643	5.71030	40.21892	0.20874
0.08000	0.00809	0.28528	6.03065	23.69976	0.27774
0.09000	0.01125	0.34648	6.18208	6.51681	0.34580
0.10000	0.01503	0.40840	6.19053	-1.20737	0.40815
0.11000	0.01942	0.47021	6.16881	-3.13548	0.46828
0.12000	0.02443	0.53171	6.12786	-5.05382	0.52601
0.13000	0.03005	0.59271	6.06779	-6.95640	0.58060
0.14000	0.03628	0.65301	5.98880	-8.83728	0.63134
0.15000	0.04311	0.71242	5.89113	-10.69061	0.67755
0.16000	0.05053	0.77077	5.77510	-12.51059	0.71861
0.17000	0.05852	0.82786	5.64105	-14.29157	0.75392
0.18000	0.06708	0.88353	5.48942	-16.02797	0.78299
0.19000	0.07619	0.93760	5.32066	-17.71439	0.80536
0.20000	0.08582	0.98989	5.13531	-19.34557	0.82065
0.21000	0.09598	1.04025	4.93395	-20.91643	0.82859
0.22000	0.10662	1.08852	4.71720	-22.42205	0.82895
0.23000	0.11774	1.13454	4.48574	-23.85775	0.82160
0.24000	0.12931	1.17818	4.24029	-25.21905	0.80652
0.25000	0.14129	1.21930	3.98162	-26.50171	0.78375
0.26000	0.15368	1.25778	3.71054	-27.70173	0.75344
0.27000	0.16644	1.29348	3.42788	-28.81535	0.71580
0.28000	0.17954	1.32630	3.13453	-29.83912	0.67115
0.29000	0.19296	1.35613	2.83140	-30.76983	0.61989
0.30000	0.20665	1.38290	2.51945	-31.60459	0.56247
0.31000	0.22060	1.40650	2.19964	-32.34079	0.49946
0.32000	0.23477	1.42687	1.87297	-32.97614	0.43144
0.33000	0.24913	1.44394	1.54046	-33.50865	0.35909
0.34000	0.26364	1.45766	1.20315	-33.93666	0.28313
0.35000	0.27827	1.46799	0.86208	-34.25885	0.20430
0.36000	0.29299	1.47489	0.51833	-34.47420	0.12342
0.37000	0.30776	1.47835	0.17296	-34.58204	0.04128
0.38000	0.32255	1.47878	0.00000	0.00000	0.00000
0.39000	0.33733	1.47878	0.00000	0.00000	0.00000
0.40000	0.35212	1.47878	0.00000	0.00000	0.00000
0.41000	0.36691	1.47878	0.00000	0.00000	0.00000
0.42000	0.38170	1.47878	0.00000	0.00000	0.00000
0.43000	0.39649	1.47878	0.00000	0.00000	0.00000
0.44000	0.41127	1.47878	0.00000	0.00000	0.00000
0.45000	0.42606	1.47878	0.00000	0.00000	0.00000
0.46000	0.44085	1.47878	0.00000	0.00000	0.00000
0.47000	0.45564	1.47878	0.00000	0.00000	0.00000
0.48000	0.47042	1.47878	0.00000	0.00000	0.00000
0.49000	0.48521	1.47878	0.00000	0.00000	0.00000
0.50000	0.50000	1.47878	0.00000	0.00000	0.00000

● Modified constant velocity curve (MCV25)

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.50000	0.50000	1.47878	0.00000	0.00000	0.00000
0.51000	0.51479	1.47878	0.00000	0.00000	0.00000
0.52000	0.52958	1.47878	0.00000	0.00000	0.00000
0.53000	0.54436	1.47878	0.00000	0.00000	0.00000
0.54000	0.55915	1.47878	0.00000	0.00000	0.00000
0.55000	0.57394	1.47878	0.00000	0.00000	0.00000
0.56000	0.58873	1.47878	0.00000	0.00000	0.00000
0.57000	0.60351	1.47878	0.00000	0.00000	0.00000
0.58000	0.61830	1.47878	0.00000	0.00000	0.00000
0.59000	0.63309	1.47878	0.00000	0.00000	0.00000
0.60000	0.64788	1.47878	0.00000	0.00000	0.00000
0.61000	0.66267	1.47878	0.00000	0.00000	0.00000
0.62000	0.67745	1.47878	0.00000	0.00000	0.00000
0.63000	0.69224	1.47835	-0.17296	-34.58204	-0.04128
0.64000	0.70701	1.47489	-0.51833	-34.47420	-0.12342
0.65000	0.72173	1.46799	-0.86208	-34.25885	-0.20430
0.66000	0.73636	1.45766	-1.20315	-33.93666	-0.28313
0.67000	0.75087	1.44394	-1.54046	-33.50865	-0.35909
0.68000	0.76523	1.42687	-1.87297	-32.97614	-0.43144
0.69000	0.77940	1.40650	-2.19964	-32.34079	-0.49946
0.70000	0.79335	1.38290	-2.51945	-31.60459	-0.56247
0.71000	0.80704	1.35613	-2.83140	-30.76983	-0.61989
0.72000	0.82046	1.32630	-3.13453	-29.83912	-0.67115
0.73000	0.83356	1.29348	-3.42788	-28.81535	-0.71580
0.74000	0.84632	1.25778	-3.71054	-27.70173	-0.75344
0.75000	0.85871	1.21930	-3.98162	-26.50171	-0.78375
0.76000	0.87069	1.17818	-4.24029	-25.21905	-0.80652
0.77000	0.88226	1.13454	-4.48574	-23.85775	-0.82160
0.78000	0.89338	1.08852	-4.71720	-22.42205	-0.82895
0.79000	0.90402	1.04025	-4.93395	-20.91643	-0.82859
0.80000	0.91418	0.98989	-5.13531	-19.34557	-0.82065
0.81000	0.92381	0.93760	-5.32066	-17.71439	-0.80536
0.82000	0.93292	0.88353	-5.48942	-16.02797	-0.78299
0.83000	0.94148	0.82786	-5.64105	-14.29157	-0.75392
0.84000	0.94947	0.77077	-5.77510	-12.51059	-0.71861
0.85000	0.95689	0.71242	-5.89113	-10.69061	-0.67755
0.86000	0.96372	0.65301	-5.98880	-8.83728	-0.63134
0.87000	0.96995	0.59271	-6.06779	-6.95640	-0.58060
0.88000	0.97557	0.53171	-6.12786	-5.05382	-0.52601
0.89000	0.98058	0.47021	-6.16881	-3.13548	-0.46828
0.90000	0.98497	0.40840	-6.19053	-1.20737	-0.40815
0.91000	0.98875	0.34648	-6.18208	6.51681	-0.34580
0.92000	0.99191	0.28528	-6.03065	23.69976	-0.27774
0.93000	0.99446	0.22643	-5.71030	40.21892	-0.20874
0.94000	0.99645	0.17160	-5.23003	55.61163	-0.14489
0.95000	0.99791	0.12232	-4.60327	69.44678	-0.09090
0.96000	0.99892	0.07997	-3.84758	81.33687	-0.04967
0.97000	0.99954	0.04573	-2.98413	90.94888	-0.02203
0.98000	0.99986	0.02056	-2.03710	98.01360	-0.00676
0.99000	0.99998	0.00518	-1.03302	102.33316	-0.00086
1.00000	1.00000	0.00000	0.00000	103.78659	0.00000

Explanation of operation MT

5. Cam curve characteristics table

● MT Modified trapezoidal curve

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.00000	0.00000	0.00000	0.00000	61.42597	0.00000
0.01000	0.00001	0.00307	0.61264	60.94161	0.00038
0.02000	0.00008	0.01222	1.21563	59.49616	0.00304
0.03000	0.00027	0.02732	1.79944	57.11243	0.01006
0.04000	0.00065	0.04811	2.35487	53.82799	0.02318
0.05000	0.00125	0.07429	2.87317	49.69466	0.04367
0.06000	0.00215	0.10543	3.34615	44.77761	0.07217
0.07000	0.00338	0.14104	3.76636	39.15439	0.10867
0.08000	0.00498	0.18056	4.12718	32.91368	0.15245
0.09000	0.00700	0.22336	4.42291	26.15391	0.20210
0.10000	0.00946	0.26878	4.64888	18.98167	0.25563
0.11000	0.01238	0.31610	4.80154	11.51008	0.31050
0.12000	0.01578	0.36456	4.87848	3.85697	0.36384
0.13000	0.01967	0.41343	4.88812	0.00000	0.41343
0.14000	0.02405	0.46231	4.88812	0.00000	0.46231
0.15000	0.02892	0.51119	4.88812	0.00000	0.51119
0.16000	0.03428	0.56007	4.88812	0.00000	0.56007
0.17000	0.04012	0.60895	4.88812	0.00000	0.60895
0.18000	0.04646	0.65783	4.88812	0.00000	0.65783
0.19000	0.05328	0.70671	4.88812	0.00000	0.70671
0.20000	0.06059	0.75559	4.88812	0.00000	0.75559
0.21000	0.06839	0.80448	4.88812	0.00000	0.80448
0.22000	0.07668	0.85336	4.88812	0.00000	0.85336
0.23000	0.08546	0.90224	4.88812	0.00000	0.90224
0.24000	0.09472	0.95112	4.88812	0.00000	0.95112
0.25000	0.10448	1.00000	4.88812	0.00000	1.00000
0.26000	0.11472	1.04888	4.88812	0.00000	1.04888
0.27000	0.12546	1.09776	4.88812	0.00000	1.09776
0.28000	0.13668	1.14664	4.88812	0.00000	1.14664
0.29000	0.14839	1.19552	4.88812	0.00000	1.19552
0.30000	0.16059	1.24441	4.88812	0.00000	1.24441
0.31000	0.17328	1.29329	4.88812	0.00000	1.29329
0.32000	0.18646	1.34217	4.88812	0.00000	1.34217
0.33000	0.20012	1.39105	4.88812	0.00000	1.39105
0.34000	0.21428	1.43993	4.88812	0.00000	1.43993
0.35000	0.22892	1.48881	4.88812	0.00000	1.48881
0.36000	0.24405	1.53769	4.88812	0.00000	1.53769
0.37000	0.25967	1.58657	4.88812	0.00000	1.58657
0.38000	0.27578	1.63544	4.87848	-3.85697	1.63221
0.39000	0.29238	1.68390	4.80154	-11.51008	1.65408
0.40000	0.30946	1.73122	4.64888	-18.98167	1.64649
0.41000	0.32700	1.77664	4.42291	-26.15391	1.60755
0.42000	0.34498	1.81944	4.12718	-32.91368	1.53621
0.43000	0.36338	1.85896	3.76636	-39.15439	1.43236
0.44000	0.38215	1.89457	3.34615	-44.77761	1.29692
0.45000	0.40125	1.92571	2.87317	-49.69466	1.13190
0.46000	0.42065	1.95189	2.35487	-53.82799	0.94033
0.47000	0.44027	1.97268	1.79944	-57.11243	0.72619
0.48000	0.46008	1.98778	1.21563	-59.49616	0.49434
0.49000	0.48001	1.99693	0.61264	-60.94161	0.25028
0.50000	0.50000	2.00000	0.00000	-61.42597	0.00000

● MT Modified trapezoidal curve

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.50000	0.50000	2.00000	0.00000	-61.42597	0.00000
0.51000	0.51999	1.99693	-0.61264	-60.94161	-0.25028
0.52000	0.53992	1.98778	-1.21563	-59.49616	-0.49434
0.53000	0.55973	1.97268	-1.79944	-57.11243	-0.72619
0.54000	0.57935	1.95189	-2.35487	-53.82799	-0.94033
0.55000	0.59875	1.92571	-2.87317	-49.69466	-1.13190
0.56000	0.61785	1.89457	-3.34615	-44.77761	-1.29692
0.57000	0.63662	1.85896	-3.76636	-39.15439	-1.43236
0.58000	0.65502	1.81944	-4.12718	-32.91368	-1.53621
0.59000	0.67300	1.77664	-4.42291	-26.15391	-1.60755
0.60000	0.69054	1.73122	-4.64888	-18.98167	-1.64649
0.61000	0.70762	1.68390	-4.80154	-11.51008	-1.65408
0.62000	0.72422	1.63544	-4.87848	-3.85697	-1.63221
0.63000	0.74033	1.58657	-4.88812	0.00000	-1.58657
0.64000	0.75595	1.53769	-4.88812	0.00000	-1.53769
0.65000	0.77108	1.48881	-4.88812	0.00000	-1.48881
0.66000	0.78572	1.43993	-4.88812	0.00000	-1.43993
0.67000	0.79988	1.39105	-4.88812	0.00000	-1.39105
0.68000	0.81354	1.34217	-4.88812	0.00000	-1.34217
0.69000	0.82672	1.29329	-4.88812	0.00000	-1.29329
0.70000	0.83941	1.24441	-4.88812	0.00000	-1.24441
0.71000	0.85161	1.19552	-4.88812	0.00000	-1.19552
0.72000	0.86332	1.14664	-4.88812	0.00000	-1.14664
0.73000	0.87454	1.09776	-4.88812	0.00000	-1.09776
0.74000	0.88528	1.04888	-4.88812	0.00000	-1.04888
0.75000	0.89552	1.00000	-4.88812	0.00000	-1.00000
0.76000	0.90528	0.95112	-4.88812	0.00000	-0.95112
0.77000	0.91454	0.90224	-4.88812	0.00000	-0.90224
0.78000	0.92332	0.85336	-4.88812	0.00000	-0.85336
0.79000	0.93161	0.80448	-4.88812	0.00000	-0.80448
0.80000	0.93941	0.75559	-4.88812	0.00000	-0.75559
0.81000	0.94672	0.70671	-4.88812	0.00000	-0.70671
0.82000	0.95354	0.65783	-4.88812	0.00000	-0.65783
0.83000	0.95988	0.60895	-4.88812	0.00000	-0.60895
0.84000	0.96572	0.56007	-4.88812	0.00000	-0.56007
0.85000	0.97108	0.51119	-4.88812	0.00000	-0.51119
0.86000	0.97595	0.46231	-4.88812	0.00000	-0.46231
0.87000	0.98033	0.41343	-4.88812	0.00000	-0.41343
0.88000	0.98422	0.36456	-4.87848	3.85697	-0.36384
0.89000	0.98762	0.31610	-4.80154	11.51008	-0.31050
0.90000	0.99054	0.26878	-4.64888	18.98167	-0.25563
0.91000	0.99300	0.22336	-4.42291	26.15391	-0.20210
0.92000	0.99502	0.18056	-4.12718	32.91368	-0.15245
0.93000	0.99662	0.14104	-3.76636	39.15439	-0.10867
0.94000	0.99785	0.10543	-3.34615	44.77761	-0.07217
0.95000	0.99875	0.07429	-2.87317	49.69466	-0.04367
0.96000	0.99935	0.04811	-2.35487	53.82799	-0.02318
0.97000	0.99973	0.02732	-1.79944	57.11243	-0.01006
0.98000	0.99992	0.01222	-1.21563	59.49616	-0.00304
0.99000	0.99999	0.00307	-0.61264	60.94161	-0.00038
1.00000	1.00000	0.00000	0.00000	61.42597	0.00000

Explanation of operation TR

5. Cam curve characteristics table

● TR Trapecloid (Asymmetrical cam)

Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.00000	0.00000	0.00000	0.00000	77.54006	0.00000
0.01000	0.00001	0.00387	0.77336	76.92864	0.00049
0.02000	0.00010	0.01543	1.53453	75.10400	0.00384
0.03000	0.00035	0.03448	2.27149	72.09493	0.01269
0.04000	0.00082	0.06074	2.97263	67.94888	0.02926
0.05000	0.00158	0.09378	3.62689	62.73123	0.05512
0.06000	0.00271	0.13308	4.22396	56.52427	0.09110
0.07000	0.00426	0.17804	4.75441	49.42590	0.13718
0.08000	0.00629	0.22792	5.20988	41.54804	0.19244
0.09000	0.00884	0.28196	5.58318	33.01495	0.25512
0.10000	0.01194	0.33929	5.86844	23.96120	0.32269
0.11000	0.01563	0.39902	6.06115	14.52956	0.39195
0.12000	0.01993	0.46020	6.15827	4.86878	0.45929
0.13000	0.02484	0.52188	6.17044	0.00000	0.52188
0.14000	0.03036	0.58358	6.17044	0.00000	0.58358
0.15000	0.03651	0.64529	6.17044	0.00000	0.64529
0.16000	0.04327	0.70699	6.17044	0.00000	0.70699
0.17000	0.05065	0.76870	6.17044	0.00000	0.76870
0.18000	0.05864	0.83040	6.17044	0.00000	0.83040
0.19000	0.06726	0.89211	6.17044	0.00000	0.89211
0.20000	0.07649	0.95381	6.17044	0.00000	0.95381
0.21000	0.08633	1.01552	6.17044	0.00000	1.01552
0.22000	0.09680	1.07722	6.17044	0.00000	1.07722
0.23000	0.10788	1.13892	6.17044	0.00000	1.13892
0.24000	0.11957	1.20063	6.17044	0.00000	1.20063
0.25000	0.13189	1.26233	6.17044	0.00000	1.26233
0.26000	0.14482	1.32404	6.17044	0.00000	1.32404
0.27000	0.15837	1.38574	6.17044	0.00000	1.38574
0.28000	0.17254	1.44745	6.17044	0.00000	1.44745
0.29000	0.18732	1.50915	6.17044	0.00000	1.50915
0.30000	0.20272	1.57086	6.17044	0.00000	1.57086
0.31000	0.21874	1.63256	0.20000	0.00000	1.63256
0.32000	0.23537	1.69426	6.17032	-0.49473	1.69423
0.33000	0.25262	1.75578	6.11673	-10.20898	1.74050
0.34000	0.27048	1.81628	5.96667	-19.76223	1.75630
0.35000	0.28894	1.87480	5.72252	-29.00381	1.73871
0.36000	0.30797	1.93043	5.38812	-37.78799	1.68568
0.37000	0.32754	1.98228	4.96875	-45.97623	1.59623
0.38000	0.34760	2.02954	4.47102	-53.43939	1.47058
0.39000	0.36811	2.07146	3.90277	-60.05979	1.31019
0.40000	0.38901	2.10739	3.27298	-65.73300	1.11782
0.41000	0.41023	2.13675	2.59157	-70.36957	0.89743
0.42000	0.43172	2.15909	1.86929	-73.89636	0.65408
0.43000	0.45339	2.17404	1.11753	-76.25777	0.39374
0.44000	0.47517	2.18138	0.34815	-77.41655	0.12308
0.45000	0.49699	2.18098	-0.42673	-77.35442	-0.15083
0.46000	0.51877	2.17287	-1.19487	-76.07236	-0.42076
0.47000	0.54043	2.15715	-1.94418	-73.59060	-0.67967
0.48000	0.56189	2.13408	-2.66282	-69.94827	-0.92095
0.49000	0.58308	2.10403	-3.33946	-65.20282	-1.13871
0.50000	0.60395	2.06747	-3.96344	-59.42908	-1.32799

● TR trapecloid

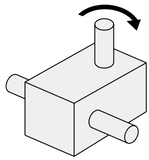
Non-dimensional time T	Non-dimensional displacement S	Non-dimensional speed V	Non-dimensional acceleration A	Non-dimensional saltation J	Torque coefficient Q=(A·V)/Am
0.50000	0.60395	2.06747	-3.96344	-59.42908	-1.32799
0.51000	0.62441	2.02497	-4.52492	-52.71810	-1.48496
0.52000	0.64443	1.97721	-5.01503	-45.17573	-1.60698
0.53000	0.66394	1.92494	-5.42606	-36.92091	-1.69272
0.54000	0.68291	1.86897	-5.75151	-28.08383	-1.74208
0.55000	0.70131	1.81021	-5.98626	-18.80385	-1.75617
0.56000	0.71911	1.74956	-6.12660	-9.22732	-1.73713
0.57000	0.73630	1.68800	-6.17043	0.04171	-1.68800
0.58000	0.75287	1.62631	-6.16591	0.86297	-1.62511
0.59000	0.76883	1.56471	-6.15318	1.68309	-1.56033
0.60000	0.78417	1.50327	-6.13225	2.50096	-1.49397
0.61000	0.79889	1.44209	-6.10317	3.31551	-1.42637
0.62000	0.81301	1.38124	-6.06596	4.12564	-1.35785
0.63000	0.82652	1.32080	-6.02067	4.93028	-1.28874
0.64000	0.83943	1.26085	-5.96737	5.72835	-1.21936
0.65000	0.85174	1.20148	-5.90613	6.51880	-1.15001
0.66000	0.86346	1.14275	-5.83703	7.30058	-1.08101
0.67000	0.87460	1.08476	-5.76015	8.07263	-1.01263
0.68000	0.88516	1.02758	-5.67561	8.83394	-0.94517
0.69000	0.89515	0.97127	-5.58351	9.58349	-0.87889
0.70000	0.90459	0.91593	-5.48398	10.32028	-0.81403
0.71000	0.91347	0.86162	-5.37715	11.04334	-0.75085
0.72000	0.92182	0.80841	-5.26317	11.75169	-0.68955
0.73000	0.92964	0.75638	-5.14217	12.44441	-0.63033
0.74000	0.93695	0.70559	-5.01433	13.12055	-0.57339
0.75000	0.94376	0.65612	-4.87982	13.77923	-0.51888
0.76000	0.95008	0.60802	-4.73881	14.41957	-0.46695
0.77000	0.95593	0.56136	-4.59149	15.04071	-0.41771
0.78000	0.96131	0.51621	-4.43806	15.64183	-0.37128
0.79000	0.96626	0.47262	-4.27872	16.22213	-0.32772
0.80000	0.97077	0.43065	-4.11369	16.78084	-0.28711
0.81000	0.97487	0.39036	-3.94318	17.31721	-0.24946
0.82000	0.97858	0.35181	-3.76742	17.83052	-0.21480
0.83000	0.98192	0.31503	-3.58665	18.32010	-0.18312
0.84000	0.98489	0.28009	-3.40110	18.78530	-0.15438
0.85000	0.98752	0.24702	-3.21103	19.22548	-0.12855
0.86000	0.98984	0.21588	-3.01668	19.64008	-0.10554
0.87000	0.99185	0.18670	-2.81831	20.02853	-0.08528
0.88000	0.99358	0.15953	-2.61620	20.39032	-0.06764
0.89000	0.99505	0.13439	-2.41060	20.72497	-0.05250
0.90000	0.99627	0.11133	-2.20179	21.03203	-0.03972
0.91000	0.99728	0.09037	-1.99005	21.31109	-0.02914
0.92000	0.99809	0.07154	-1.77566	21.56178	-0.02059
0.93000	0.99872	0.05486	-1.55891	21.78377	-0.01386
0.94000	0.99919	0.04036	-1.34008	21.97677	-0.00877
0.95000	0.99953	0.02806	-1.11947	22.14051	-0.00509
0.96000	0.99976	0.01798	-0.89737	22.27477	-0.00261
0.97000	0.99990	0.01012	-0.67408	22.37939	-0.00111
0.98000	0.99997	0.00450	-0.44988	22.45421	-0.00033
0.99000	1.00000	0.00113	-0.22509	22.49915	-0.00004
1.00000	1.00000	0.00000	0.00000	22.51413	0.00000

Explanation of characteristics

Explanation of allowable values and characteristics

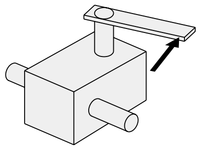
● Dynamic rated output torque

The dynamic rated output torque represents the max. torque that can be applied to the output shaft while it is moving.
When you select the size of index drive, obtain the load torque that ultimately applies to the output shaft taking the weight of the workpiece, movement speed, index number, index angle, etc. into consideration. Based on this value, the appropriate size should be selected. The output torque table contains the allowable rated torque values for each speed of the various models and specifications.



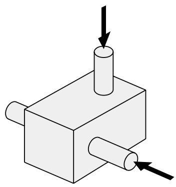
● Static rated output torque

The static rated output torque represents the max. torque that can be applied to the output shaft within the index angle when the input shaft is stopped.
As in the case of the dynamic rated output torque, the static rated output torque varies depending on the specifications including index number and index angle, even if the size is the same. If a torque greater than this is applied to the output shaft, the internal components may be damaged.



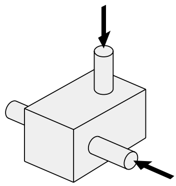
● Input/Output shaft tolerance Thrust force

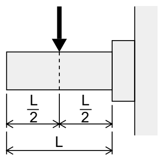
The allowable thrust force indicates the max. force that can be applied in the direction parallel to the axis (thrust). This is not an issue for the input shaft, but this restricts the load value of the table for the output shaft.



● Input/Output shaft tolerance Radial force

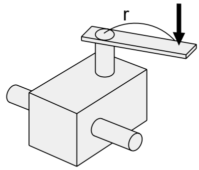
The allowable radial force indicates the max. force that can be applied in the direction perpendicular to the axis (radial). This restricts the tension of the pulley attached to the input shaft and the table load when the output shaft is installed horizontally such as in Position #5. The value indicates the force that can be applied to the center of the shaft.
When you want to know the value if the force is applied to the end or to the shaft extension, please contact us.





● Allowable bending moment for the output shaft

The allowable bending moment for the output shaft indicates the max. load that can be applied to the spot offset from the center of the output shaft. The unit is "N·m" and the moment will be the position of the point of action (r) multiplied by load.



● Moment of inertia of the input shaft

This indicates the total moment of inertia of the input shaft and the cam. This is required to select a clutch brake. Generally, when the clutch brake is activated to start or stop the motion, it is performed at the cam dwell section. Hence, there is no need to consider the moment of inertia of the output shaft as a load.

● Moment of inertia of the output shaft

This represents the moment of inertia of the output shaft itself. In most cases, this value is not often used, but when a motor is selected for high speed operation, the value of the moment of inertia of the output shaft should be added to the moment of inertia of the load. This is because the moment of inertia of the output shaft at low speeds is negligible compared to the moment of inertia of the load although it becomes relatively greater at high speeds. That is, the output shaft itself becomes a load at high speeds. If a motor is selected disregarding the moment of inertia of the output shaft, the system may not work properly at high speeds due to insufficient capacity.

● Internal frictional torque

This indicates that a torque is required to rotate the input shaft of the index drive itself. The index drive has a preload to maintain accuracy, and so even without a load, a certain amount of torque is required to rotate it. This value is required when you select a reducer or a motor.

Explanation of accuracy

Indexing accuracy

We can think of 2 types of indexing accuracy for the index drive. One is the dynamic indexing accuracy when a load is applied to the system, and the other is the static indexing accuracy when the system is stopped or no load is applied. Generally, when we mention "indexing accuracy," we refer to the static indexing accuracy.
The factors that affect accuracy include the machining accuracy of the output shaft, the accuracy of the cam follower, the accuracy of the journals and bearings, and the accuracy of assembly and adjustment. Taking all these factors into consideration, we try to achieve the optimum result with a 1-piece design of the output shaft and turret and high precision cam follower.

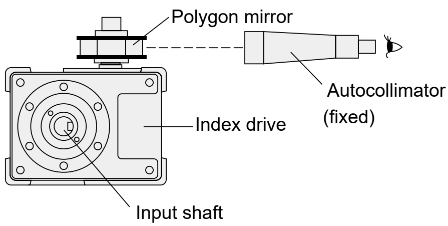
Static indexing accuracy

The static indexing accuracy is the statically measured accuracy of the index drive itself. Factors closely related to the indexing accuracy are repeatability and dwell accuracy.

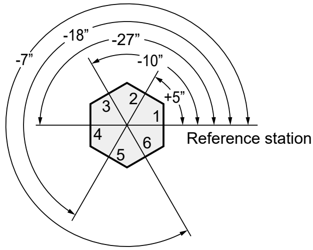
Indexing accuracy

The indexing accuracy of the index drive indicates the difference between the target position and the actual position where the output shaft moves. The target position is defined with the angle from the reference station, and for each station, the target value is defined. Based on the max. and min. values obtained for each station, the indexing accuracy is calculated. Incidentally, the reference station is the position indicated in the dimensions of this catalog.
To measure the angle, an autocollimator or high precision angle encoder is used.
When an autocollimator is used, a polygon mirror (when index number is 6, hexagon mirror) which has a number of faces corresponding to the index number is mounted on the output shaft of the index drive. The autocollimator emits light towards the mirror and receives its reflection, and the angular misalignment is displayed. If the polygon is created with sufficient accuracy, the value will be the indexing accuracy of the index drive.

Measuring indexing accuracy using the autocollimator



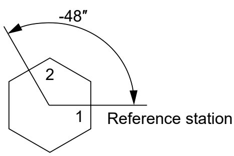
An example of the indexing accuracy measurement of the index drive



Measurement position	Measured values
1	0
2	+5”
3	-10”
4	-27”
5	-18”
6	-7”

Indexing accuracy ±16

An example of the indexing accuracy measurement of the Oscillator



Measurement position	Measured values
1	0
2	-48

Indexing accuracy ±24″

Repeatability

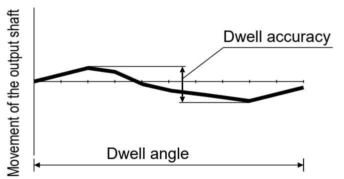
Repeatability is the amount of variation that occurs in the results when measured repeatedly under the same conditions. The max. value of the variations is indicated in seconds (").

- Swing direction
  This accuracy represents repeatability of the positioning of each index. This is one of the typical features why the cam mechanism is evaluated to be highly reliable. Depending on the accuracy requirements of the machinery, you should choose either repeatability or indexing accuracy.
  For oscillators, indexing accuracy is not critical in most cases, while repeatability becomes critical.
- Lift direction
  This accuracy represents the repeatability of positioning at the upper and the lower ends. This is one of the typical features why the cam mechanism is evaluated to be highly reliable.

Dwell accuracy

Dwell accuracy represents the movement of the output shaft when the input shaft is turned within the dwell section of the cam.
As its name indicates, the dwell section is where the output shaft is stopped, but to be precise, it is not completely stopped. Due to errors of the components, it moves very slightly. The max. difference in movement is represented in secs.

Dwell accuracy example



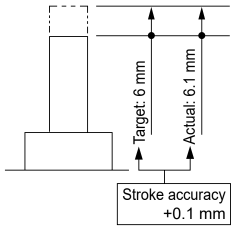
Dynamic indexing accuracy

Dynamic indexing accuracy represents the indexing accuracy when the machinery to which the installed index drive is operating. Therefore, for the automated machinery, the dynamic indexing accuracy determines the accuracy of the entire machinery.
Factors that affect the dynamic indexing accuracy of the index drive include the load to be used, rigidity, cam curve, the driving system of the input/output shaft, service life, static indexing accuracy, etc. When a system is designed, it is important to select the model, calculate the load and design the driving system while taking important factors from various perspectives into consideration.

Stroke accuracy

The stroke accuracy in the P&P drive represents the difference between the target stroke and the actual stroke.
As in Figure d, by measuring the stroke from the bottom end to the top end or from the top end to the bottom end, the stroke accuracy is obtained.

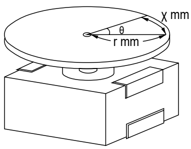
Stroke accuracy example



Accuracy of torque saver and torque guard

- Return accuracy
  This represents the displacement when reset after a release (trip).
- Variations of release (trip) torque
  This represents the range of variations of release torque.
  (For TGX, this represents the difference of neighboring trip torque variations when the trip is repeated.)
- Lost motion (torque saver)
  This represents the displacement from the original position when torque (T) is applied and is then released.
  Torque (T) = 1/2 of set torque

Calculating indexing accuracy



$$(\pm)\chi = 2\pi r \frac{(\pm)\theta}{360\times60\times60}$$
$$=0.00000485 \times r \times \theta$$

Angle θ / Radius r	10"	20"	30"	60"	90"
100 mm	0.005	0.010	0.015	0.029	0.044
200 mm	0.010	0.019	0.029	0.058	0.087
300 mm	0.015	0.029	0.044	0.087	0.131

● References

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Mechanical Engineering Handbook. 1986. Japan Society of Mechanical Engineers
JIS Z8203 International Unit System (SI) and how to use. 1985. Japan Standards Association.