

Kinematics report

Sample document with complete example values. It shows the report the purchased export produces for YOUR input - it is not itself a report for any part.

Project: Sample project

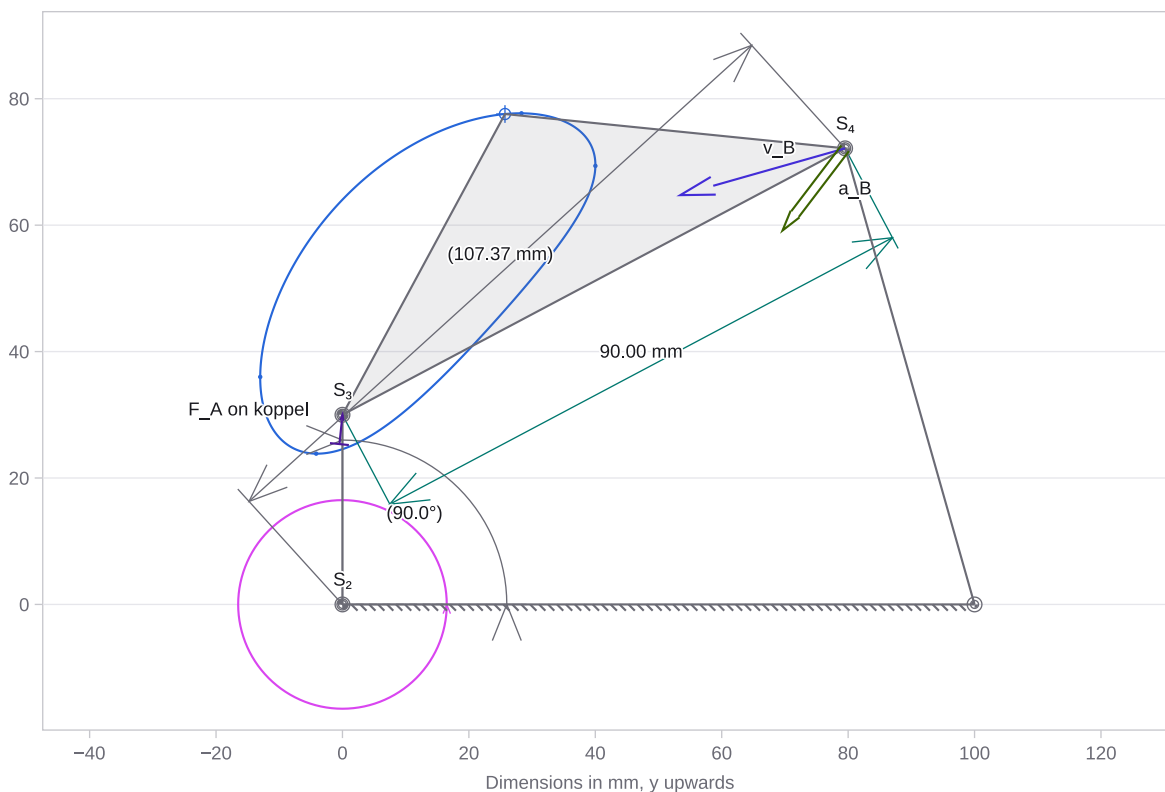
Part/Position: no real part

Prepared by: Sample, not released

Overall assessment: OK — every checked condition is met. Only the rows of the verification table were assessed; everything else is stated as a characteristic value without rating.

This document certifies the MOTION of the linkage described below: its structure, its traverse, the angles, torques and joint forces computed from it, and the accuracy of that computation. It expressly certifies NO strength, no service life, no natural frequency and no manufacturing tolerance. Of freedom from collision it certifies exactly what was checked: the position of the link centre lines relative to the drawn keep-out areas — not the links against each other, not their actual width, and nothing where no keep-out area is given.

System sketch in position 90 of 360



Drawn is the same scene as on screen: frame, links and joints in the neutral tone.

The path of the marked point is drawn in the curve colour; its crosshair and its reversal marks carry the same tone.

The drive stands out by the circle around its bearing. The arrowheads on it show which way it turns — one for a full revolution, two for a drive that swings between two limits. The horizontal line from the pivot to the circle is the zero direction the arc is read against: the drive angles count from it, anticlockwise, and not from the link line that starts there.

At individual points there are vector arrows whose LENGTH states the magnitude: it is the value divided by the scale printed below this paragraph. All kinds carry the same colour in this document; they are told apart by their shape and by the label at each single arrow. Velocity and acceleration place their tail on the point and point away from it, the joint force places its head on it. The acceleration carries two thin parallels instead of one line; on screen it also has a colour of its own, which does not exist here. Every arrow is labelled; the magnitudes also appear as numbers further below.

The force arrow shows the joint force on the grounded link when exactly one of the two links is held — otherwise the one on the second side. Which link is meant is stated in the label at the arrow. It is the constraint force of the joint and not the applied load, which may stand next to it as a symbol of fixed size. At its free end it carries a short stroke across the shaft: it states where this

arrow ends. That is needed as soon as the force and the velocity of the same joint lie on one line — they do so in every position in which they point against each other, and without that cross stroke you would see a single arrow with two heads there. The stroke also tells it apart from the symbol of an applied load, which carries none.

(Velocity scale: $m_v = 12.57$ (mm/s) per mm of drawing)

(Acceleration scale: $m_a = m_v^2 = 157.9$ (mm/s²) per mm of drawing)

(Force scale: $m_F = 0.2317$ N per mm of drawing)

The thin lines with a number in round brackets are the measured dimensions: a dimension line or arc with a terminator at each end, plus the extension lines to the measured locations. The value stands in brackets because it is read off — it prescribes nothing and does not constrain the linkage. The table further below gives the same values as numbers and next to them their smallest and largest value over the cycle.

The dimension lines with a number WITHOUT brackets are locked dimensions: the number is the target value, prescribed and not read off. They are drawn in a tone of their own. Whether a dimension is kept is stated in the table further down, not in the drawing.

Computation

Steps per traverse	360
Positions computed	361
Duration of one traverse	0.5 s
Mean speed of the drive	120 1/min
Gravity (positive acting downwards)	9.81 m/s ²
Position shown	90
Superimposed positions in the system sketch	0

Vector arrows

Velocity v_B	340.634 mm/s
Acceleration a_B	2,579.257 mm/s ²
Joint force F_A on koppel	1.079 N

Measured dimensions

Dimension	position shown	smallest value	largest value
Distance M1 [mm]	(107.37)	(60.00)	(120.00)
Angle M2 [°]	(90.0)	(0.0)	(359.0)

The values stand in round brackets because they are READ OFF and not prescribed — auxiliary dimensions in the sense of ISO 129-1:2018, 4.1.4. They constrain nothing and are not toleranced. The second column applies to the position shown above and carries the same number as the dimension in the drawing. The last two columns give the smallest and the largest value across all computed positions, because a dimension hangs on moving anchors and changes over the cycle; they are as fine as the grid of positions and do not come from a closed-form calculation. An angle is measured from the first to the third location counterclockwise, with the second as the vertex, and runs from 0° to 360° — the reverse order gives the opposite angle, and both are correct. A dash instead of a number means the position gives no answer: for an angle two locations then fall onto the vertex, and there is no ray.

ACROSS THE 0° MARK: a measured angle runs from 0° to 360°. If it passes that mark, its smallest and its largest value are the ends of the reading scale and not those of the swing — an angle oscillating between 350° and 10° appears here as roughly 0° and roughly 360°; both are read off, both are correct, and together they say nothing about the motion. In this calculation this applies to: M2.

Locked dimensions

Dimension	Target value	Actual value	Verdict
koppel A–B [mm]	90.00	90.00	kept

A locked dimension is a length between two revolute joints or link points of the same link that is kept while editing with the mouse: a dragged end runs on a circle around the other. The length is measured in the moving frame and therefore holds equally in every position. Kept means that actual and target value differ by at most 0.001 mm. A violated dimension results from a later entry; the calculation uses the length that stands in the linkage, not the target value.

Links

Link	x_o [mm]	y_o [mm]	φ_o [°]	Link line [°]	m [kg]	s_S [mm]	J_S [kg·mm²]
gestell	0	0	0	0	—	at the reference point	—
kurbel	0	0	0	0	0.2	at the reference point	—
koppel	30	0	51.6	—	0.2	at the reference point	—
schwinge	83	73	-74.5	-74.5	0.2	at the reference point	—

Joints

Joint	Type	Links	Attachment 1 [mm]	Attachment 2 [mm]	Extra
fest	Ground constraint	gestell	0 0	—	$\varphi = 0^\circ$
A0	Revolute joint	gestell – kurbel	0 0	0 0	without friction
A	Revolute joint	kurbel – koppel	30 0	0 0	without friction
B	Revolute joint	koppel – schwinge	90 0	0 0	without friction
B0	Revolute joint	gestell – schwinge	100 0	75 0	without friction

Drives

Drive	Link	from φ [°]	to φ [°]	Offset to link line [°]	Segments	Transitions
1	kurbel	0	360	—	linear across the whole range	free of shock and jerk

Marked link points

Point	Link	x [mm]	y [mm]	x on the link [mm]	y on the link [mm]
punkt1	koppel	34.473	53.898	45	30

Structure and degree of freedom

Links n (including the frame)	4
Ground constraints	1
Simple joints g_1 (revolute and prismatic)	4
Higher joints g_2 (cam joints, gear pairs, rack-and-pinion pairs, Geneva drives)	0
Drives	1
Degree of freedom $F = 3 \cdot (n - 1) - 2 \cdot g_1 - g_2$ (Grübler)	1

Verifications

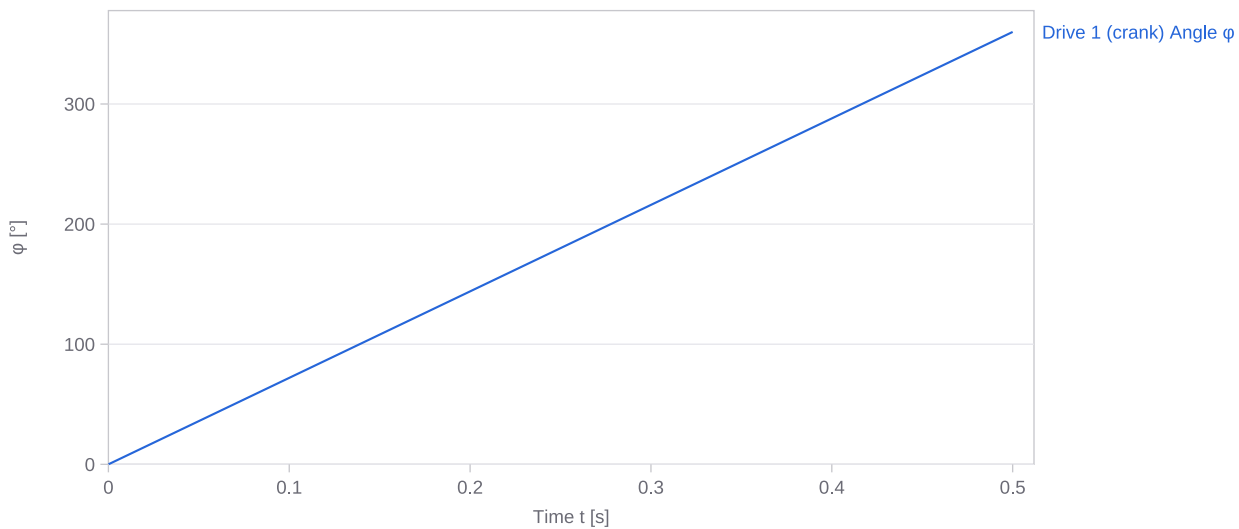
Criterion	Value	Limit	Status
Degree of freedom F, required 1 (number of drives)	1	1	● OK
Drive range complete and without gaps			● OK
Transitions free of shock and jerk			● jerk-free

Characteristic values

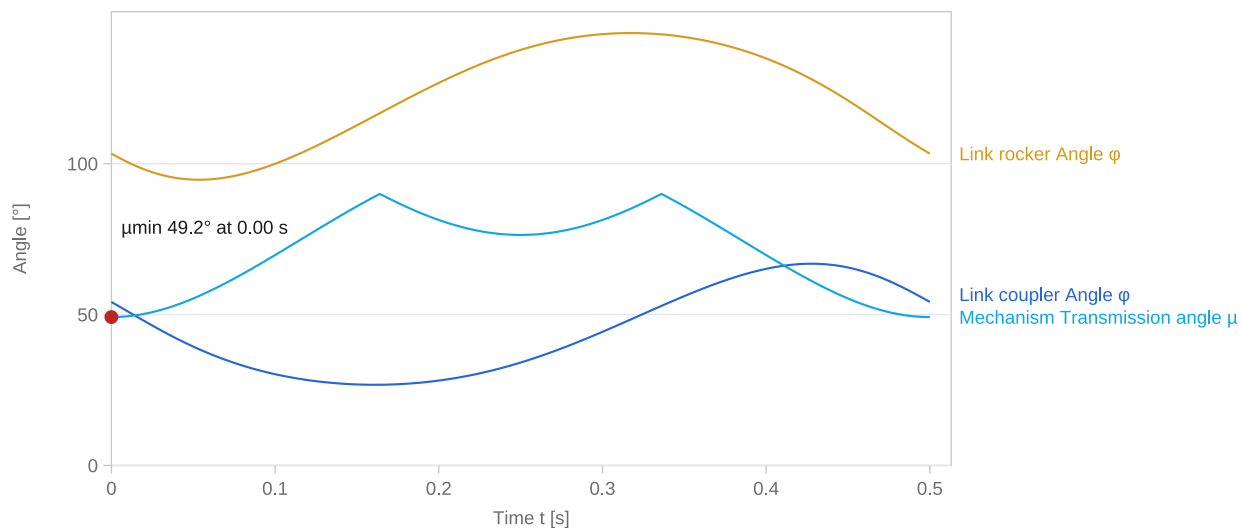
Smallest transmission angle $\mu_{\min}$	49.2°
Largest deviation from the target path	no target path drawn
Largest penetration into a blocked area	no blocked area drawn
Smallest locking factor $r_{\min}$ (self-locking)	no μ_0 entered
Largest drive torque $M_{\max}$	0.1025 N·m
Largest joint force $F_{\max}$	7.316 N
Largest drive power $P_{\max}$	1.288 W
RMS torque M_{rms} at the drive	0.06354 N·m
Largest reduced inertia $J_{\text{red,max}}$ at the drive	470.6 kg·mm²

Smallest reduced inertia $J_{red,min}$ at the drive	180 kg·mm ²
Largest shaking force $F_{R,max}$	2.587 N
Type according to Grashof	crank-rocker
Shortest link	crank
Grashof excess $(s + l) - (p + q)$	-35.0 mm
Position of μ_{min} (drive angle)	0.0°
Reversal positions of the output link	2
Swing angle of the output link ψ_0	48.6°
Time ratio of forward to return stroke	1.115
Smallest quality index	0.672

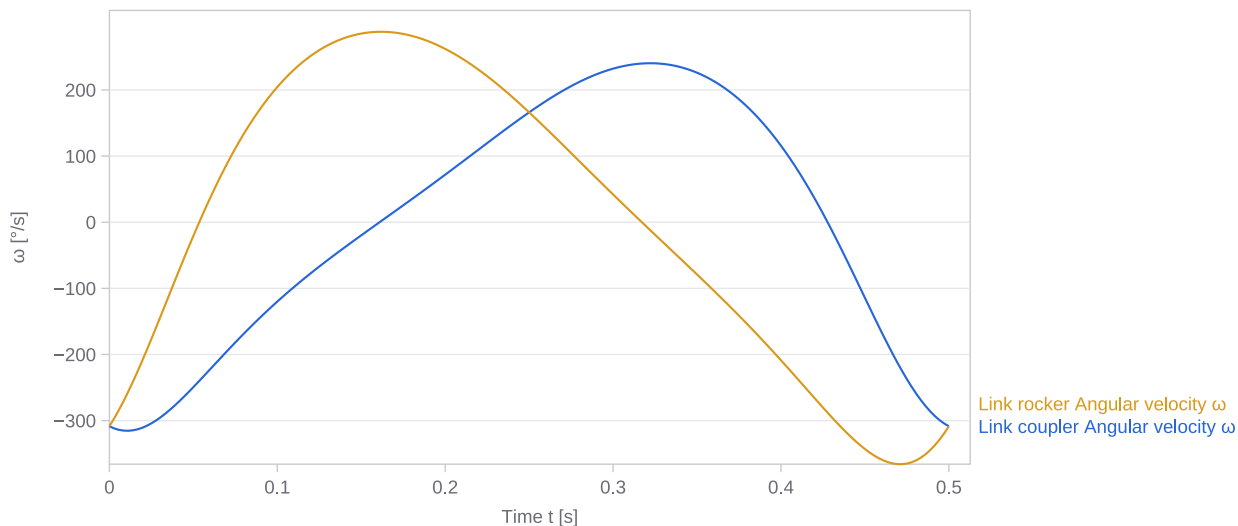
Drive angle over time [°]



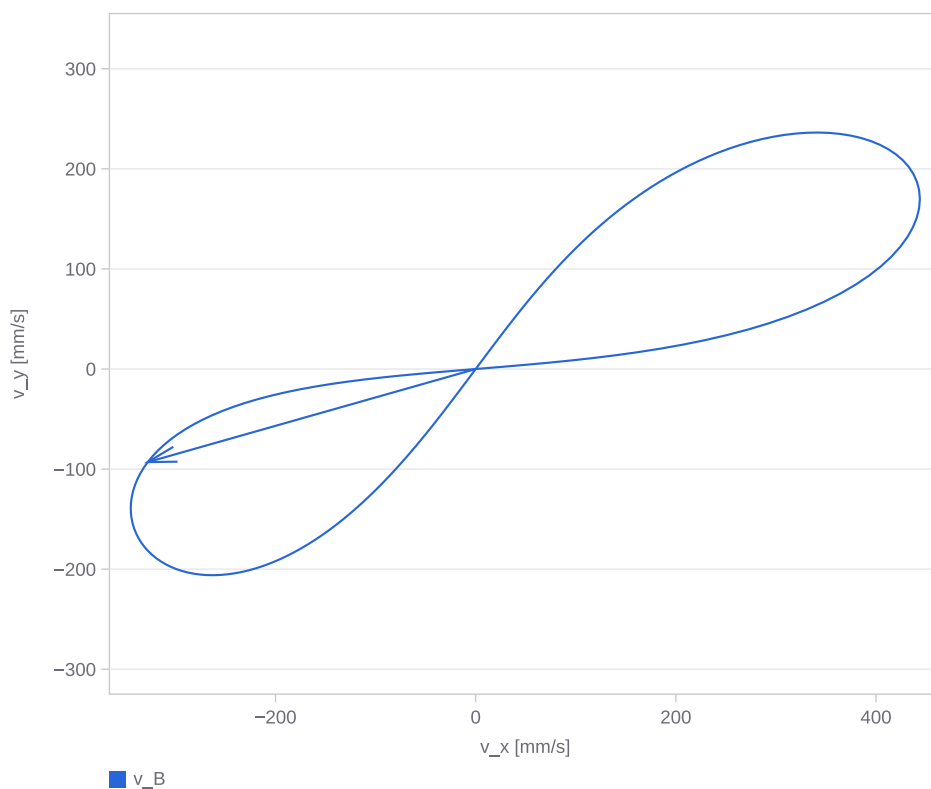
Angle over time [°]



Angular velocity over time [°/s]



Velocity hodograph



The hodograph draws the velocity vectors of the parts with a velocity arrow switched on from one common origin. Each curve is the path of the tip of one vector over the cycle; the arrow is the vector in the position shown and carries the same number as the arrow in the system sketch. Both axes have the same scale; at a gap in the cycle the curve breaks off.

Basis of calculation and model assumptions

The closed constraint equations of the planar linkage are solved: for every progress τ on the common timeline the position of all links is found by Newton's method, after which velocity and acceleration are obtained from the same Jacobian. Drive torque and joint forces follow from d'Alembert's principle (kinetostatics) with the masses and inertias given. The motion laws of the segments are the normalised time laws of VDI 2143.

WHERE THE MASS ACTS: the mass of a link acts at its centre of mass s_S , which the table of links below states for every link. When a mass is entered on screen while the centre-of-mass fields are empty, the tool prefills them visibly — with the midpoint between the two revolute joints of the link, or with the mean of them where there are more than two; a prismatic joint does not

count, because its attachment location along the guide is arbitrary. The suggestion can be overwritten, a centre of mass already set is left alone, and a loaded state is not touched. Where the table reads "at the reference point", none was given, and it coincides with the build location of the link — a joint for everything this tool creates. The entered mass is then not a mass distributed over the link but a point mass in that joint. The consequence has been measured: on the four-bar linkage 10 kg on the crank thus have no effect at all on the drive torque, and on the coupler only through their weight. The moment of inertia J_S refers to the centre of mass; the parallel-axis term $m \cdot s_S^2$ is added by the computation itself.

WHEN MASSES HAVE NO EFFECT AT THE DRIVE: a link running at constant speed about a fixed axis needs no drive torque — no matter where its centre of mass sits or how large its inertia is: its centrifugal force points through the axis and has no lever arm there, and the link is not accelerated. The prefilled centre of mass changes nothing about this, it merely moves where the centrifugal force acts. Mass takes effect through gravity, through a motion law on the drive, or on a link that does not run at constant speed. Where none of this applies, all that is left of drive torque and drive power are the last bits of the computation. Both are therefore compared against the load this model can carry at all and are dropped once they lie nine orders of magnitude below it; the row then states the reason and NO limit — a figure of that magnitude would fall below any limit and thereby pass a check that never took place. The joint force is not affected and is still reported: the centrifugal force of the crank is a real bearing force, it merely lacks a lever arm about the drive axis.

REDUCED INERTIA AND RMS TORQUE, with exactly one rotary drive: the influence coefficients $dq/d\phi$ follow from the same Jacobian as the velocities, with unit rate at the drive. J_{red} is then the sum over the links of $m \cdot |dr_S/d\phi|^2 + J_S \cdot (d\phi_i/d\phi)^2$, even in a dwell in which the mechanism stands still. By the principle of virtual work the drive torque splits into the inertia share M_T , the sum of $m \cdot a_S \cdot dr_S/d\phi + J_S \cdot \alpha_i \cdot d\phi_i/d\phi$, equal to $J_{red} \cdot \alpha + \frac{1}{2} \cdot (dJ_{red}/d\phi) \cdot \omega^2$, and the load share M_L from weight, force elements and loads. The RMS torque $M_{rms} = \sqrt{(1/T) \cdot \int M^2 dt}$ over the motion time T is given only for a traverse without gaps; it is integrated by the trapezoidal rule over the computed positions. If the motor sits on a link other than the driven one, torque and inertia apply at that link: $M_{link} = M/(d\phi_{link}/d\phi)$.

THE SHAKING FORCE is the force the mechanism passes to the frame from its inertia forces, $F_R = -\text{sum of } m \cdot a_S$ over the moving links (VDI 2149 part 1, section 3). Weight and external loads are not part of it: the one is static, the others come from outside.

HOW THE CHARACTERISTIC VALUES ARE OBTAINED: the transmission angle μ is defined for two configurations — for the four-bar chain as the angle between coupler and rocker at joint B, for the slider-crank between coupler and the normal to the guide line (Kerle/Pittschellis/Corves 2007, p. 161, eq. 6.5 and 6.6). The acute value is reported, and as μ_{min} the smallest across all computed positions; the closed form given in the source holds for a full revolution and is therefore not applied but only used as a cross-check. For any other chain the row states that the quantity is not defined there. At a cam joint it appears as the pressure angle $\alpha = 90^\circ - \mu$ in a row of its own. If a cylinder sits on the chain, the chain is taken without it, and a row of its own reports the transmission angle at the cylinder: $\mu = 90^\circ - \alpha$ between the cylinder axis and the motion of its rod-end point relative to the base. As a guide value the same source gives $40^\circ \leq \mu \leq 50^\circ$ for slow-running mechanisms (p. 160, eq. 6.4); that is experience and not a standard — VDI 2130 devotes a section to the transmission angle and names no figure. The row therefore carries the wording of a guide value and not that of a passed verification: at 39° nothing breaks, but bearing forces, friction and sensitivity to backlash grow quickly. The output link is taken to be the non-driven link attached to the frame by a revolute joint; its reversal positions are the zero crossings of its angular velocity, interpolated linearly between two grid points. If it stands still in a dwell and moves back afterwards, the dwell is one reversal; over a closed cycle a dwell across the start of the cycle counts as well. If a reversal lies in a dwell, the time ratio is omitted, because which side the dwell time belongs to would be a convention. If it reverses exactly twice, the swing angle ψ_0 follows as its full excursion and the time ratio as the longer of the two intervals divided by the shorter, hence always ≥ 1 . The time ratio refers to TIME and not to crank angle: with a uniformly running drive the two are the same; if a segment carries a motion law they part company, and time is what counts. It is only stated for a drive that completes at least one full revolution — otherwise there is no return stroke to measure against. If the output link instead slides in a guide on the frame — the piston of the slider-crank, the follower of a cam mechanism —, its velocity along the guide counts, and the stroke $s_0 = s_{max} - s_{min}$ in millimetres takes the place of the swing angle, as fine as the grid. The same holds if the link at the frame rotates through a closed cycle without a reversal and a ram slides behind it, as in the Whitworth quick return. Where no unique output link can be found, the rows are absent: that applies to any mechanism with more than one drive, such as the five-bar — which of its links would be the output is not something the structure states. The swing angle is measured across the computed positions and is therefore as fine as the grid; at 360 steps it sits about 0.002° below the closed-form value. The drive power is, in every position, the sum over the drives of torque times angular velocity, and P_{max} its largest magnitude across the traverse — not M_{max} times ω_{max} , because with a motion law the two peaks do not coincide.

TYPE ACCORDING TO GRASHOF: whether a link of the four-bar chain of revolute joints rotates fully is decided by the four link lengths alone. With s the shortest, l the longest and p, q the remaining two, the condition reads $s + l < p + q$; the Grashof excess

stated is the difference $(s + l) - (p + q)$ and is therefore negative wherever the condition holds. If it holds, the type follows from where the shortest link sits: at the frame a crank-rocker, as the frame itself a double crank, as the coupler a double rocker. For equality the mechanism is a change-point linkage and hence not run-safe — it passes through the aligned position, but which branch it takes afterwards is not determined. If the condition is violated, all four joints merely oscillate (triple rocker). A prismatic joint or a fifth link makes it a different chain, for which there is no Grashof type; the row then says exactly that. The type is a statement about running behaviour and not a grade — it is not assessed.

WHAT THE DRIVE ANGLE REFERS TO: the columns “from φ ” and “to φ ” of the drive table give the absolute angle φ of the driven link against the horizontal, measured about its reference point and anticlockwise. It is the same QUANTITY the link table lists as φ_0 , but not necessarily the same NUMBER: the link table gives the STORED design, that is the position in which the linkage was built, and for the solver that is merely a starting value. At $\tau = 0$ the solver imposes “from φ ” on the driven link and solves the chain from there; where φ_0 and “from φ ” differ, the drawn initial position therefore stands beside the figures of the link table by that difference, and “from φ ” governs everything computed. For a linkage computed from prescribed positions this difference is the rule and not an inaccuracy: the design is stored in the prescribed position at which the drive range begins — as a rule the first one — and the range starts one percent of the position span BEFORE it, but at most one percent of the distance to the limit position beyond which the chain no longer closes. The prescribed position thus lies safely inside the drive range and not on its edge, where rounding alone would decide whether it still belongs to it; the check table gives it as a progress τ just above zero. The drive angle is expressly NOT the direction of the drawn link line between two joints: between the two lies the constant angle that the head point has in the moving frame of the link itself. The column “Offset to link line” gives that angle per link line wherever it is not zero, and a dash stands where there is nothing to give. An offset of 180° , for instance, means that in the drawing the link line points exactly opposite to the drive angle, although both describe the same link.

The quality index states how far the linkage stays clear of a dead-centre position, not how load-bearing it is. It is, across the traverse, the smallest value of the geometric mean of the singular values of the non-dimensionalised Jacobian — known in robotics as Yoshikawa's manipulability. It is 0 in a dead-centre position and approaches 1 the more perpendicular the columns are. Where it approaches zero the linkage passes through a dead centre — joint forces and angular accelerations are unreliable there. Before that, every position is iterated until the chain closes: until the largest remaining gap of the constraint equations falls below 10^{-10} , at most 40 Newton steps. A position that does not get there is not part of this document; it is reported as a gap in the drive range — the row “Drive range complete and without gaps” says so.

Model assumptions: all links are rigid, all joints free of backlash. The computation is without backlash and without elasticity; positions follow first-order theory. Friction is computed only at those joints for which the joint table states a coefficient of friction. Only drawn keep-out areas are checked, and only where some are given; the links are NOT checked against each other. Two links may therefore pass through one another in the calculation without anything being reported here.

The design was built on a background image (grundriss.png, image width 180 mm, top left corner at $-40 \mid 130$ mm). The image is a drafting aid; it enters no calculation and is not part of this verification. Nor is it shown here: its scale was set by hand and its origin is unknown — an unchecked image in a verification would look like evidence and would be none. The image file itself never leaves the user's computer.

The drive torque and the largest joint force stated are INPUT QUANTITIES for a strength verification, not a substitute for one. For a shaft under this torque the verification to DIN 743 applies, for a plain bearing the load rating, for a pin the surface pressure and shear verification.

About this sample

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