

OSMEC. COMPUTER-AIDED MECHANISM DESIGN: BASIC EXAMPLES

1. NOTATION AND UNITS

The units used in this Item are SI. All angles are measured in an anticlockwise sense and the crank is considered to rotate in an anticlockwise direction.

		Units
d_i	diameter of bearing i (Example 2)	m
f_i	magnitude of normal force acting on bearing i (Example 2)	N
f_{ram}	ram force (Example 2)	N
I_{link}	mass moment of inertia of link (Example 1)	kg m ²
I_{louver}	mass moment of inertia of louver (Example 1)	kg m ²
I_3	mass moment of inertia of combined rocker link and louver (Example 1)	kg m ²
i	bearing label (in OSMEC)	
l_E	axial length of bearing i (Example 2)	m
m_{link}	mass of link (Example 1)	kg
m_{louver}	mass of louver (Example 1)	kg
m_3	mass of combined rocker link and louver (Example 1)	kg
p_i	bearing pressure on bearing i (Example 2)	N/m ²
r_i	radius of bearing i (Example 2)	m
r_{link}	distance from mass centre of rocker link to mass centre of combined rocker link/louver (Example 1)	m
r_{louver}	distance from mass centre of louver to mass centre of combined rocker link/louver (Example 1)	m
T_{max}	maximum drive torque (Example 3)	N m
v_{ram}	velocity of ram (Example 2)	m/s
v_i	relative velocity of contacting surfaces in bearing i (Example 2)	m/s

ω_i	magnitude of normal force acting on bearing i (Example 2)	N
x_3, y_3	local coordinates of mass centre of combined rocker link/louver relative to frame bearing of rocker link, in local x - and y -directions, respectively (Example 1)	mm
x_{link}, y_{link}	distances from rocker link frame bearing to mass centre of rocker link, measured in local coordinates in x - and y -directions, respectively (Example 1)	mm
x_{louver}, y_{louver}	distances from frame bearing of rocker link to mass centre of louver measured in local coordinates in x - and y -directions, respectively (Example 1)	mm
ω_{crank}	angular velocity of crank (Example 3)	rad/s
ω_i	relative angular velocity of links connected at bearing i (Example 2)	rad/s

2. INTRODUCTION

The examples in this Item provide insight into the application of the OSMEC software described in Data Item 97026 (Reference 1) for the basic analysis and design of planar linkage mechanisms. Aspects of the design process include determination of the following:-

- (i) position, velocity and acceleration of points in motion on the links and bearings that constitute the mechanism,
 - (ii) angle, angular velocity and angular acceleration of links in motion within the mechanism,
 - (iii) the driving forces/torques necessary to move the mechanism
- and (iv) the bearing forces.

Since it is easier to modify an existing mechanism model file than to create a new one, each example starts with one of the stored mechanism model files that were loaded into the working directory when the program was installed.

Example 1 describes in detail how OSMEC is used to analyse the motion, forces and drive torque in a four-bar linkage used to move the louver of an air-conditioning system through a 90° arc. An existing OSMEC mechanism model file is adapted to start the design process, in which only the coordinates of the motor shaft and the louver pivot bearing are fixed on the mechanism frame. The link lengths and the angular displacement of the motor shaft are varied during the design of the mechanism. Graphs of the drive torque required from the motor and the bearing forces throughout the linkage are plotted. The significance of the magnitude of the transmission angle between the coupler and rocker links is discussed. The procedure for designing the mechanism is described step-by-step by identifying and discussing each software command issued to the OSMEC software.

Example 2 shows how one of three trunnion-mounted rams is selected based on the results of an analysis of a mechanism used to move boxes of breakfast cereal. The motion of the ram moves a slider 200 mm along a horizontal track. The three rams, which have different strokes and load capacities, are incorporated in distinct mechanisms that are able to provide the specified motion. The thrust required from the ram in each mechanism is analysed. The maximum values of bearing pressure and contact surface velocity are analysed for one of the bearings.

Example 3 considers the design of an alternative mechanism to solve the problem described in Example 2 and demonstrates the development of a model of a pivoted-slider mechanism driving a slider entity from an offset point on the sliding link. A method for displaying and printing a graph of the crank torque necessary to drive the mechanism is described.

Example 4 shows how a full analysis of a mechanism for a single position may be carried out using the *Check* command. (See Section D1.1 (d) of Data Item 97026.) A ten-bar linkage used to drive a needle-bar mechanism is analysed for a particular angle, angular velocity and angular acceleration of the crank.

Example 5 shows how a coupler curve can be plotted using the *Loci* command. An example of Stephenson's six-bar linkage, that incorporates an approximate dwell for a segment of the rotation of the driving crank, is modelled. The relationship between the approximately circular locus of the coupler point and the dwell segment is described and the actual movement of the output link plotted. An assessment is made of the sensitivity of the linkage dimensions to small deviations from their nominal dimensions.

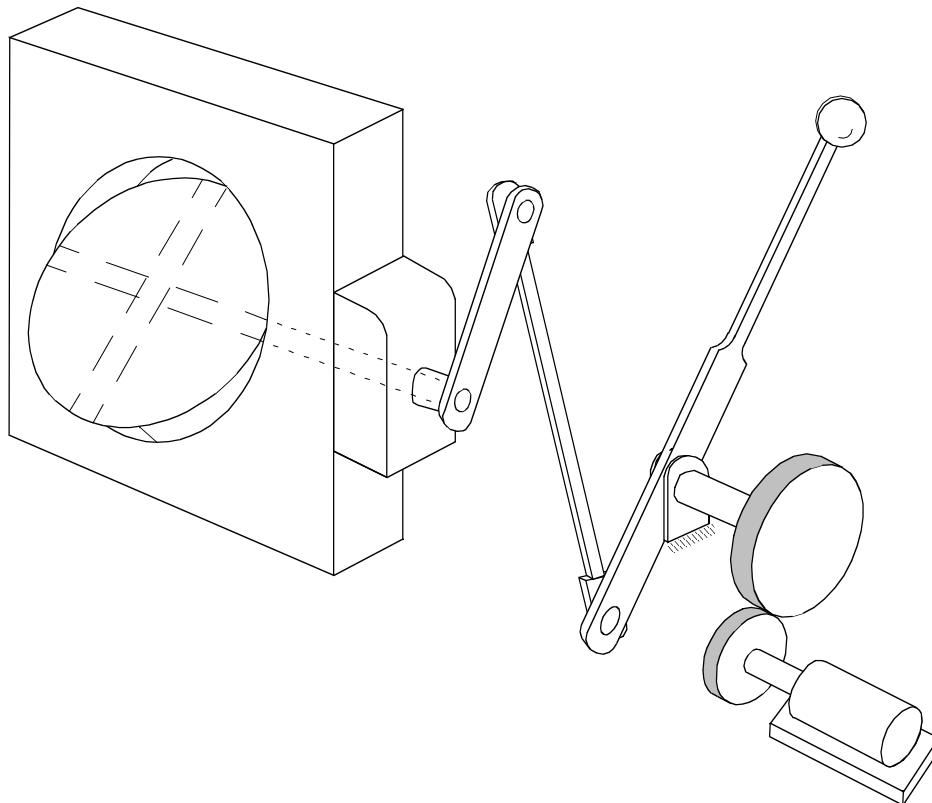
3. EXAMPLE 1. DESIGN OF A FOUR-BAR LINKAGE TO GIVE A SPECIFIED ROCKER MOTION

Although this example describes part of the design process carried out during the development of an actual industrial product, its principal objective is to demonstrate the use of the OSMEC mechanism design software. The commands issued to the software are therefore described step-by-step to provide a guide to show how commonly encountered mechanism design tasks may be accomplished. Program control in OSMEC using the keyboard and mouse is described in Sections 4.3 and 4.4, respectively, of Data Item 97026 (Reference 1).

3.1 Problem Statement

A linkage mechanism, that is driven either by a servo-motor or (in an emergency) a hand-held lever, is required to open and close a louver plate that allows or prevents airflow into ventilation equipment. The arrangement, shown in the half-open position in Sketch 3.1, must traverse an arc of $90 \pm 0.5^\circ$ from the closed to the open position. Since the louver can be attached to the output link (or rocker) of the mechanism at any angle, only the arc traversed is significant and not the absolute values of initial and final angles. The position of the frame bearing about which the louver pivots is fixed as the global coordinate origin for the mechanism. The x - and y -coordinates of the input crank shaft axis of the geared motor that drives the linkage are fixed as 100 mm and 250 mm, respectively. It is assumed that the mechanism travels at its highest speed when the hand-held lever (crank) is operated at a constant speed of 120 rev/min. The motor drives this crank through a gearbox whose ratio is 3:1. Due to the programming requirements of the servo-motor, the initial and final angles of the input motion must be specified to the nearest degree.

A constant torque of 10 N m acts in the opposite direction to the motion of the rocker link. The mass and mass moment of inertia of the louver driven by the mechanism are 2.1 kg and 0.03 kg m^2 , respectively, with the mass centre coincident with the frame bearing of the rocker link.

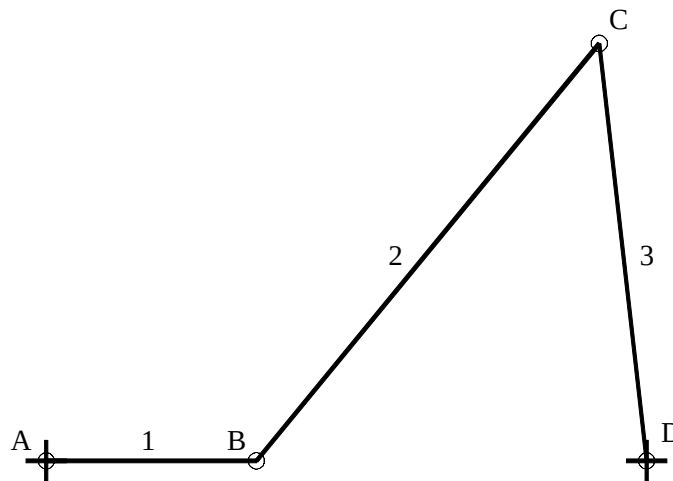


Sketch 3.1 Sketch of louver mechanism

A four-bar linkage is to be designed to rotate the rocker link to which the louver is attached. The coupler and rocker links that form a dyad are assembled in a right-hand configuration, as shown in Sketch 3.1. (The two possible assembly configurations of a dyad are discussed in Section 3.4.1 of Data Item 97026, Reference 1.) Only the lengths of the crank, coupler and rocker links plus the arc travelled by the driving crank are to be varied during the design of the mechanism.

3.2 Running OSMEC and Loading an existing Mechanism Model File

Whenever possible, an existing mechanism model file should be brought into OSMEC and then modified to represent a particular mechanism, rather than creating a new mechanism model file. A list of the available model files provided with OSMEC is given in Appendix B of Data Item 97026. A four-bar linkage assembled with the **left-hand** dyad configuration is provided in the stored mechanism model file M02.OS, shown in Sketch 3.2.



Sketch 3.2 Four-bar linkage mechanism M02.OS assembled with left-hand assembly mode

The first screen to appear when the program is run presents a menu with the choice between loading an existing file, creating a new mechanism, seeking advice on using OSMEC or quitting back to the DOS prompt. To load an existing mechanism model file, select the *File* option on the menu either by using the mouse, by pressing the underlined letter (F) or by moving the cursor over *File* and pressing 'Return'. Mechanism model file M02.OS is selected from the scrolling menu using the vertical arrow keys or the mouse.

The mechanism is displayed on the screen as shown in Sketch 3.2. When viewed on a colour monitor, the pin-jointed bearings appear as small cyan-coloured circles labelled by green letters and the moving links are drawn as cyan-coloured lines labelled by yellow numbers. Where a bearing is attached to the frame, a red cross is drawn through its centre. Points A and D are the crank and rocker frame bearings, respectively.

3.3 Modifying an OSMEC Mechanism Model

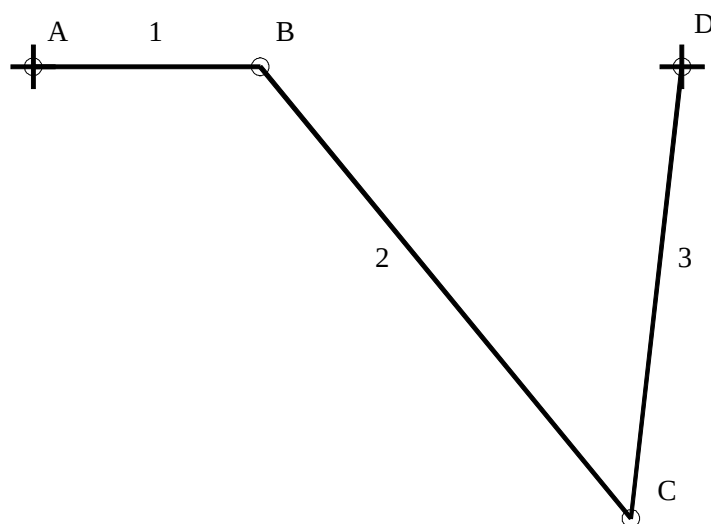
To modify the mechanism data file M02.OS, options on the *Edit* menu are selected. These are described in Section 6.3 of Data Item 97026.

Once M02.OS has been loaded, the *Units* option of the *Edit* menu is selected and it is noted that this

mechanism is defined in 'Default' units, which indicates that the link lengths are therefore measured in millimetres (See Section 2.2.1 of Data Item 97026).

3.3.1 Changing the dyad assembly mode

The first activity in the modelling process is to change the assembly mode of the dyad entity in mechanism model file M02.OS, by selecting the *Assembly* option on the *Dimension* sub-menu of the *Edit* menu. A form appears that lists the identification number, type and current assembly mode of those entities that have an assembly mode. Of the two entities that comprise mechanism model file M02.OS, only the dyad (entity number 2 not link number 2) has an assembly mode. The current entry of **Left** is changed to **Right** using either the horizontal arrow keys or the 'Spacebar'. After pressing 'Return' to confirm the change, the modified mechanism appears as shown in Sketch 3.3.



Sketch 3.3 Mechanism M02.OS after changing the assembly mode from Left to Right

3.3.2 Changing a frame bearing position

The frame bearings are now moved from their original positions (in mechanism model file M02.OS) to the locations specified for this example.

The frame bearing positions are specified in global x- and y-coordinates and the *Co-ordinate* option on the *Dimensions* sub-menu is selected. The coordinates of the two frame bearings, points A and D, in mechanism model file M02.OS are listed as 0, 0 and 200, 0, respectively. Using the 'Tab' key or the mouse to move the cursor across the form, the coordinates of the motor axis (point A) are changed to 100, 250 and the output rocker pivot (point D) to 0, 0. These entries are confirmed by pressing 'Return'.

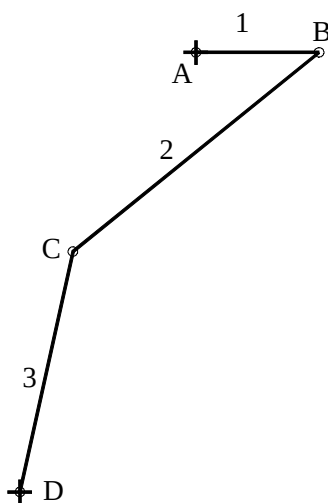
If the revised mechanism is animated using the *Stepped* option on the *Run* menu, the motion of the mechanism can be observed in successive positions by pressing the horizontal left or right arrow keys.

For crank angles between 20 and 116°, OSMEC warns that the dyad cannot be assembled. If a mechanism entity cannot be assembled the links of that entity are not displayed. The screen shows only the crank entity and the rocker link bearing (cross) together with the warning message that the 'Mechanism cannot be fully assembled in this position'.

3.3.3 Changing link lengths

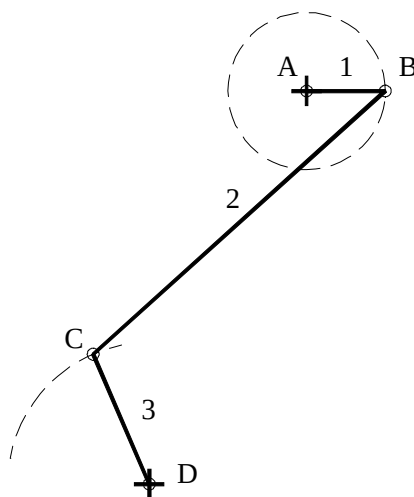
The link lengths must be changed to find a solution to the problem while ensuring that the dyad can be assembled in all positions throughout the specified motion.

It is good practice to try to reduce the crank length to minimise the space occupied by the mechanism. To change the link lengths, the *Length* option on the *Dimensions* sub-menu of the *Edit* menu is selected. The existing 70 mm crank length (link 1) is reduced to 50 mm to produce the modified mechanism shown in Sketch 3.4.



Sketch 3.4 Modified mechanism after changing bearing coordinate and crank length

If this mechanism is animated, the dyad barely assembles when the crank angle is 68° and, following a process of trial and error, to remedy this situation the coupler (link 2) and output rocker (link 3) lengths are changed from 180 and 140 to 250 mm and 90 mm, respectively. To show the arc traversed by the rocker link relative to the motion of the crank, the *Loci* option is selected from the *Run* menu. No timing marks are to be displayed and the paths followed by points B and C are plotted by entering these letters in the 'Draw loci' form presented. Sketch 3.5 shows the modified mechanism including the plotted loci of points B and C.

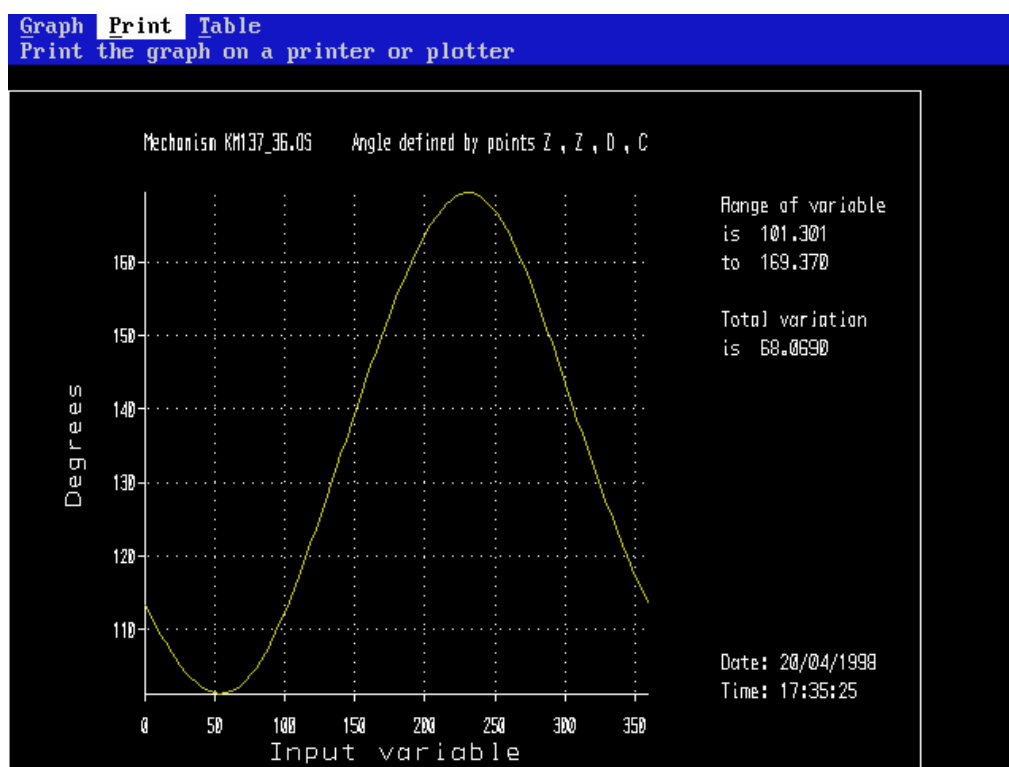


Sketch 3.5 Modified mechanism after changes to coupler and rocker link lengths

3.3.4 Analysing the output rocker link angle

Analysis is carried out using the options on the *Graphs* menu. The *Angle* option is selected, which leads to a further choice between analysing an angle, angular velocity or angular acceleration. Having selected *Angle* (a second time), a form appears in which four points must be entered to identify the two lines between which the angle is to be calculated.

An analysis of the angle of rocker link 3 relative to the frame is required. Section 7.3.1 of Data Item 97026 (Reference 1) notes that the angle of a line is calculated relative to the frame by entering the first two point letters as Z. Link 3 is defined by points C and D - where point D is the frame bearing. The entry on the *Angle* form is therefore Z Z D C. Sketch 3.6 shows the graph produced.



Sketch 3.6 Plot of angle of output rocker relative to frame defined by points Z Z D C

Sketch 3.6 shows that the rocker link angle varies from 101.3 to 169.4° with a 68.1° range which is the locus of point C shown in Sketch 3.5. Animation of the mechanism shows the oscillatory motion of the rocker link as the crank rotates through 360°. As part of the investigation of the behaviour of the mechanism, the effects of reducing the arc travelled by the crank to 105° will be assessed.

3.3.5 Changing input motion and re-analysing the rocker link angle

To modify the input motion of the mechanism, the *Input* option on the *Edit* menu is selected. Since constant speed motion is specified, the *Standard* option is selected from the *Input* sub-menu. A form appears with four values that define the constant speed motion originally specified for mechanism file M02.OS. The crank rotates from an initial crank angle of 0 to a final value of 360° with an increment of 1° at a crank speed of 100 rev/min. As an illustration, the initial and final crank angles are changed to 120 and 225°, respectively.

The crank speed is changed to 120 rev/min which is one third that of the motor to represent the effect of the 3:1 ratio gearbox. Since force analysis is required in this example, a gear train is not included in the OSMEC mechanism model file. (Section 9.7.1 of Data Item 97026 (Reference 1) notes that force analysis is not available for geared mechanisms in OSMEC.)

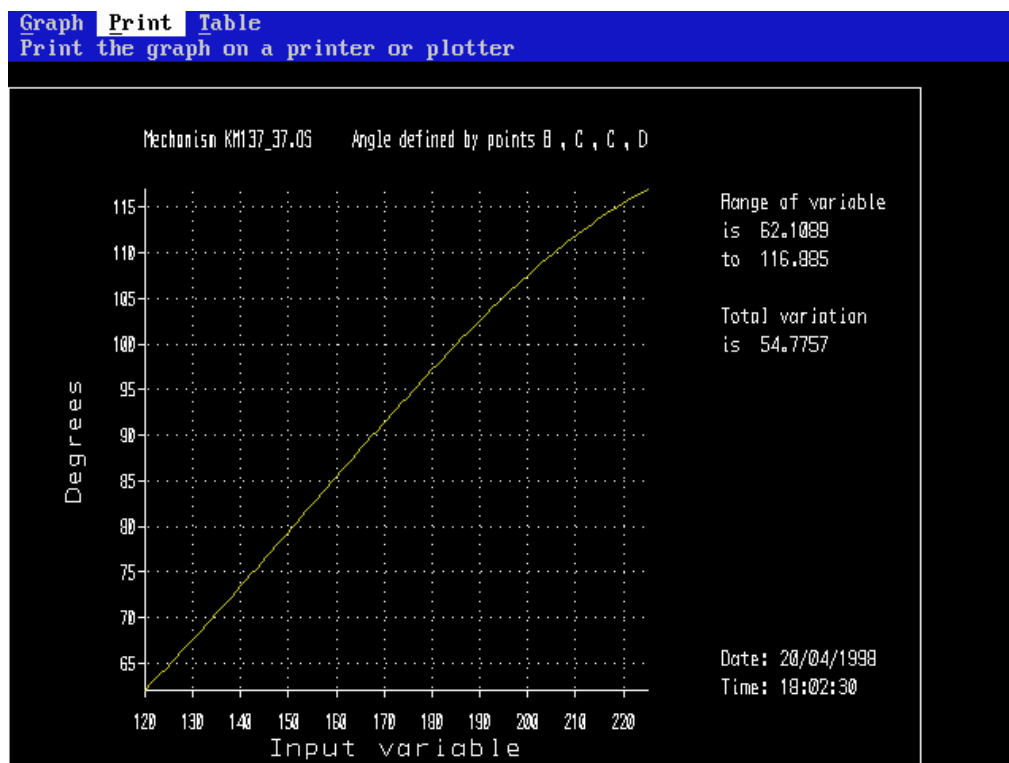
To analyse the arc travelled by link 3 for the revised input motion, it is not necessary to re-enter the *Angle* menus and repeat the procedure described in Section 3.3.4. Instead, select the *Repeat* option on the *Graphs* menu (described in Section 7.3.10 of Data Item 97026 (Reference 1)). For the 105° clockwise movement of link 1 (crank), link 3 moves clockwise from 122.5 to 169.1° through an arc of 46.6°, which is approximately half of the required arc of $90 \pm 0.5^\circ$.

3.4 Developing a Design Solution

Using the methods described in Sections 3.3.2 to 3.3.5, the link lengths and the arc travelled by the crank are changed until the output rocker link 3 moves through the required arc. There are numerous combinations of the parameters that define the mechanism geometry/motion that will provide the motion required in this example. It is important therefore to consider other design characteristics of the mechanism. These include the effect on the forces in the mechanism of the transmission angle of the dyad formed by links 2 and 3.

3.4.1 Transmission angle of a four-bar linkage

To analyse the transmission angle between links 2 and 3, the *Angle* option is selected and points B C C D entered sequentially in the form that appears. (See Section 7.3.1 of Data Item 97026). Sketch 3.7 shows the graph generated of the transmission angle for the mechanism shown in Sketch 3.5.



Sketch 3.7 Graph of the transmission angle between links 2 and 3

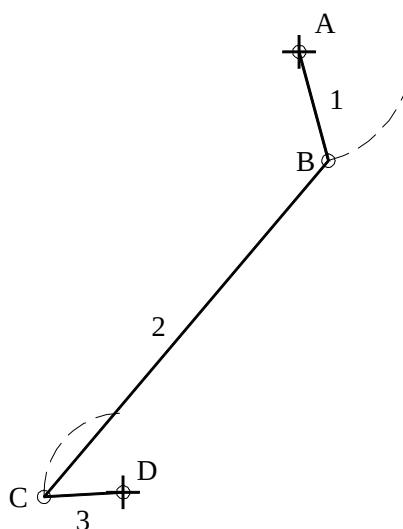
Section 5.2 of Data Item 97026 recommends that this angle should lie between 45° and 135°. In this example the variation in the transmission angle is acceptable as it varies between 62.1 and 116.9°.

3.4.2 Choosing link lengths

No general strategy can be recommended for directing the process of changing the mechanism parameters to produce a specific motion of the output link that will efficiently solve every conceivable problem. (Note, however, that the technique described in Data Item 76005 (Reference 4) can be used to find a solution to this problem). Ideally the designer should modify all variables and progressively develop the 'best' solution. However some designers select the link lengths and adjust the motion of the crank to achieve the desired output motion while others set the motion and then adjust link lengths. Typically a process of trial and error is used, guided by design considerations such as the requirements for the transmission angle. It is also desirable that all links are as short as possible to minimise the space within which the mechanism moves and the manufacturing cost of the mechanism components and to maximise the stability of the link members as struts. However a full design solution of the problem cannot be achieved without consideration of the forces transmitted within the mechanism.

Whatever approach is taken, the designer must ensure that the design geometry chosen is not so sensitive to small deviations from its nominal dimensions that such deviations introduced in manufacture may cause a significant difference between the actual motion of the mechanism and that predicted by the analysis.

The 46.6° arc travelled by link 3 in the mechanism developed in Section 3.3.4 is clearly too small. The link lengths and input motion are therefore modified until a mechanism is found that is acceptable. In the solution found, link 3 moves through an arc of 90.3° with an acceptable transmission angle that changes from 133.6 to 44.1° . The crank moves anti-clockwise from 285 to 345° and the mechanism has link lengths of 64, 250 and 45 mm for the crank, coupler and rocker, respectively. The mechanism, illustrated in Sketch 3.8, is shown in the position taken when the louver in the "open" position.



Sketch 3.8 Design Solution for Louver Mechanism

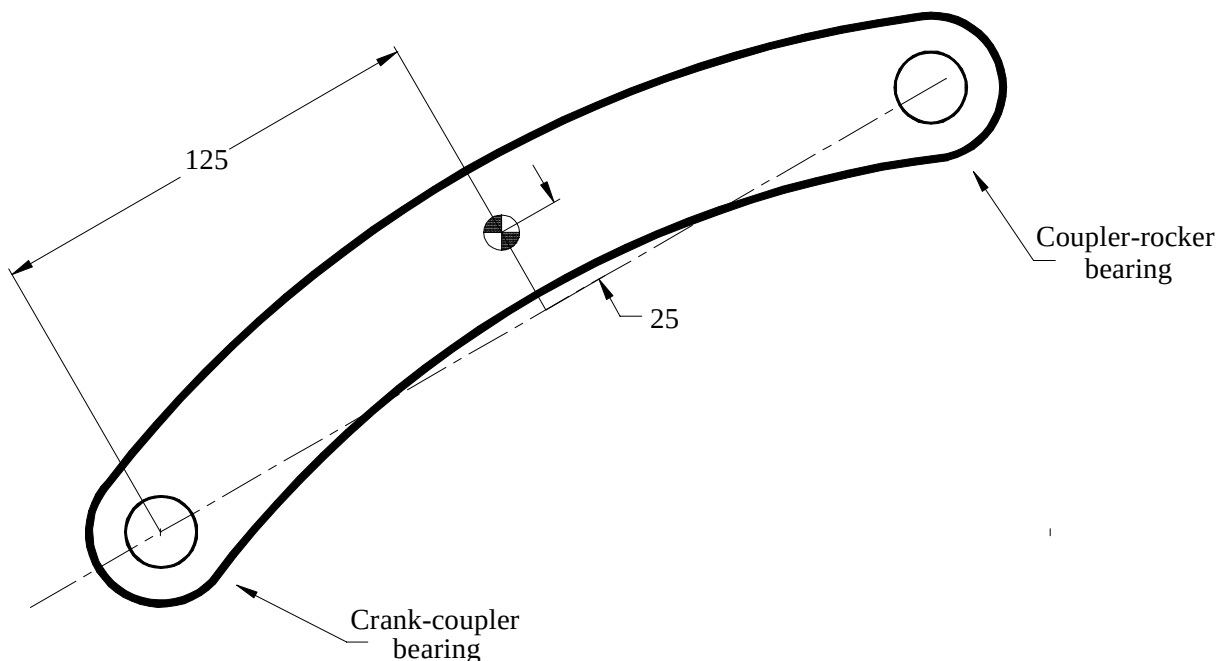
The mechanism model file is saved by selecting the *Save* option on the *File* menu. It is emphasised that the user should not overwrite any of the original OSMEC mechanism model files. When prompted, the file name 980XX_1.OS is entered. Since a copy of this file is supplied in the working directory created when OSMEC is installed, a warning is given that a file with that name exists. A decision must then be made whether or not to overwrite this file.

3.5 Specifying the Loading on a Mechanism

For demonstration purposes only, a force/torque analysis of the linkage saved as mechanism model file 980XX_1.OS in Section 3.4.2 is described. It is assumed that this mechanism is loaded on screen in OSMEC. This mechanism is a four-bar linkage with a right-hand dyad configuration in which the crank moves at an assumed constant speed of 120 rev/min while travelling anti-clockwise from 285 to 345°.

A constant torque of 10 N m acts in the opposite direction to the motion of the rocker link. The mass and mass moment of inertia of the louver driven by the mechanism are 2.1 kg and 0.03 kg m^2 , respectively, with the mass centre coincident with the frame bearing of the rocker link.

The positions of the mass centres of the crank and rocker links are assumed to lie midway between their bearings and directly on the local x-axis (defined along the centrelines of the links). The mass centre of the coupler is also halfway between its two bearings but, to illustrate the use of the sign convention for local coordinates, the link at this stage has been made curved as illustrated in Sketch 3.9. The mass centre is offset 25 mm to the left of the local x-axis when viewed from the crank-coupler bearing. See also Section 3.2.1 in Data Item 97026 (Reference 1).



Sketch 3.9 Position of mass centre of coupler in local coordinates

Due to the severity of the loads that may be expected when the hand-held lever is operated in an emergency, the links are to be manufactured from steel with an appropriately large cross section.

3.5.1 Inertial properties of links

The link lengths for the mechanism may be reviewed using the *Length* option of the *Dimensions* sub-menu of the *Edit* menu. The crank, coupler and rocker link lengths are 64, 250 and 45 mm, respectively. After completing the detail design of the links, their masses and mass moments of inertia were estimated. The values are listed in Table 3.1.

TABLE 3.1 Inertial properties of mechanism components

Link	Link Number	Length	Mass	Mass Moment of Inertia	Position of Mass Centroid (local coordinates)	
					x-coordinate	y-coordinate
Units	-	mm	kg	kg m ²	mm	mm
Crank	1	64	0.934	1.6×10^{-3}	32	0
Coupler	2	250	3.650	2.6×10^{-3}	125	25
Rocker (excluding Louver)	3	45	0.657	0.9×10^{-3}	22.5	0
Louver	–	–	2.1	30×10^{-3}	0	0

Before these values can be entered into the OSMEC mechanism model, the representation of the inertial properties of the rocker must be re-considered. The values listed in Table 3.1 for link 3 refer only to the link and take no account of the specified inertial properties of the louver to which the link is (rigidly) attached.

OSMEC allows only a single entry for the inertial properties of each link. It is therefore necessary to calculate the inertial properties of the combined louver and rocker link and the position of the overall mass centroid relative to the local coordinate origin of the rocker.

3.5.2 Equivalent inertial properties of a link supporting a concentrated mass

OSMEC requires that the mass moment of inertia of a link is specified with respect to the position of its mass centre. In this problem the centroid of the 2.1 kg mass of the louver is located at the rocker frame bearing while the centroid of the (0.657 kg) link is 22.5 mm from this bearing along the local x-axis between the two bearings.

The local x-coordinate of the equivalent mass centroid relative to the rocker frame bearing is given by

$$x_3 = \frac{[m_{louver}x_{louver} + m_{link}x_{link}]}{[m_{louver} + m_{link}]} = 5.36 \text{ mm} \quad (3.1)$$

and the local y-coordinate is

$$y_3 = \frac{[m_{louver}y_{louver} + m_{link}y_{link}]}{[m_{louver} + m_{link}]} = 0.00 \text{ mm} . \quad (3.2)$$

The distance of the link mass centroid from the equivalent mass centroid is

$$r_{link} = \sqrt{[x_3 - x_{link}]^2 + [y_3 - y_{link}]^2} = 17.14 \text{ mm} \quad (3.3)$$

and the distance of the louver mass centroid from the equivalent mass centroid is

$$r_{louver} = \sqrt{[x_3 - x_{louver}]^2 + [y_3 - y_{louver}]^2} = 5.36 \text{ mm} . \quad (3.4)$$

The equivalent mass of the combined link and louver is the sum of the two individual masses, *i.e.*

$$m_3 = m_{louver} + m_{link} = 2.757 \text{ kg} . \quad (3.5)$$

Using the parallel axis theorem (for example, see Reference 2) the equivalent mass moment of inertia of the combined link and louver is given by

$$I_3 = I_{louver} + m_{louver} r_{louver}^2 + I_{link} + m_{link} r_{link}^2 = 31.2 \times 10^{-3} \text{ kg m}^2, \quad (3.6)$$

in which r_{link} and r_{louver} in Equation (3.6) are given in metres. The revised inertial properties for link 3 in OSMEC are summarised in Table 3.2.

TABLE 3.2 Revised inertial properties for the combined rocker and louver - link 3

Link	Mass	Mass Moment of Inertia	x-coordinate	y-coordinate
-	kg	kg m ²	mm	mm
3	2.757	31.2×10^{-3}	5.36	0.00

3.5.3 Specifying external torque

The torque acting on the rocker link always acts in the opposite direction to the (clockwise) motion of the link. During closure of the louver only, it is therefore applied as a positive, *i.e.* anticlockwise, external torque.

To apply an external torque to a mechanism link, select *Torque* from the *Edit* menu. A form appears listing the external torque acting on each of the three links in the mechanism. Using the 'Tab' key to move down the form, enter the value of torque for link 3 as 10.0 N m. Press 'Return' to confirm this entry and return to the *Edit* menu. A red arc with an arrow indicating the anticlockwise direction of application of the torque appears on the display over the geometric centre of link 3.

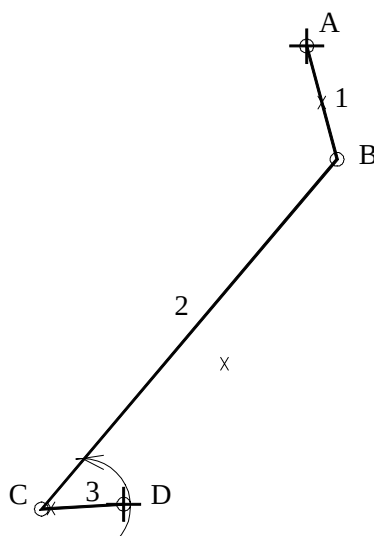
3.5.4 Specifying link inertia

Select the *Dimensions* option from the *Edit* menu. Move the cursor to the right-hand side of this menu and select *Mass*.

On some computer monitors this menu has too many entries to fit on the screen. If so, this is indicated by a row of dots on the right-hand side of the menu. In this case use the horizontal arrow keys to move left or right across the various menu options until *Mass* is highlighted and then press 'Return'. To select off-screen entries such as *Mass* using a Mouse, move the cursor over the line of dots and click the left-hand button. When the previously hidden entries appear, move the mouse to select the desired option in the usual way.

A sub-menu appears offering a choice between *Link* and *Slider*. Select *Link* and a prompt for the link number appears. Enter 1 and a form appears on which the inertial properties (of the crank) are entered. Using the 'Tab' key to move across the form, the mass and mass moment of inertia for link 1, specified in Table 3.1, are entered. Press 'Return' to confirm these entries and exit the form. Repeat this procedure for links 2 and 3, to enter the inertial properties of the coupler and rocker, respectively. In the case of link 3 enter the values specified in Table 3.2.

The modified mechanism appears as shown in Sketch 3.10 where the three (purple-coloured) crosses indicate the positions of the mass centroids of the three links.



Sketch 3.10 OSMEC representation of mechanism showing mass centres and external torque

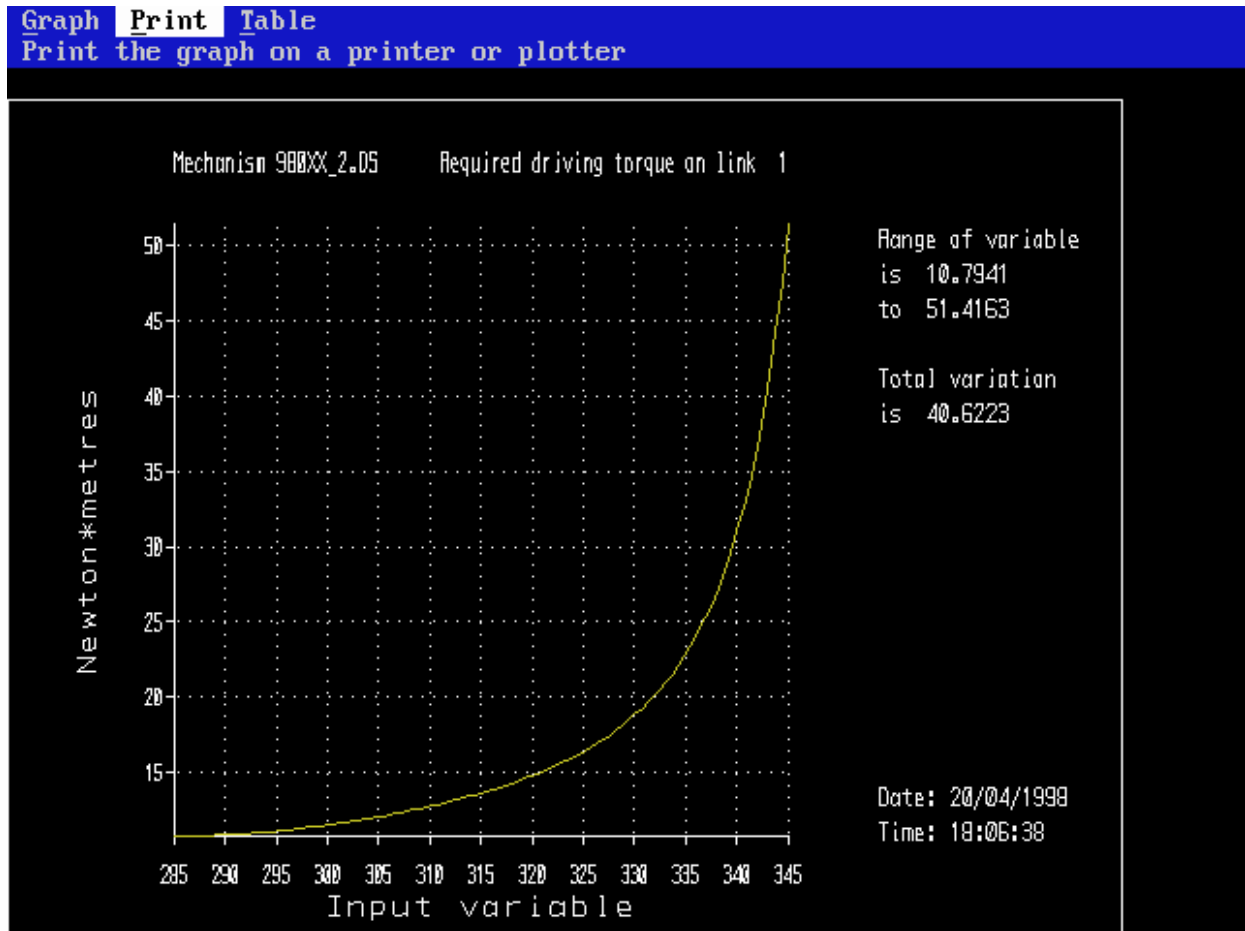
3.5.5 Checking mass centroid positions

In Sketch 3.10, the cross showing the position of the mass centre of the coupler is correctly offset from the line defining link 2 when viewed from bearing B to C but the position of the mass centre for link 3 is clearly in the wrong place, as shown by its proximity to point C rather than point D. This is because the origin of the local coordinates lies at point C and not point D. It is therefore necessary to change the local x-coordinate of the mass centroid for link 3 to 39.64 mm (*i.e.* 45.00 – 5.36 mm).

It is always prudent to check that the mass centres of all links are correctly positioned with respect to their local coordinate origins which are set when the OSMEC mechanism model file is originally created. See Section 3.2.1 in Data Item 97026 (Reference 1).

3.6 Drive Torque Analysis

Select *Torque* from the *Graphs* menu, enter 1 in the dialog box that appears and press 'Return'. A graph of the torque necessary to drive the crank (link 1) is displayed, as shown in Sketch 3.11. (Note that although OSMEC also allows the user to plot the drive torque for links 2 and 3, a graph will be generated showing the torque throughout the motion to be zero, since no torque is applied to those links to drive the mechanism.)



Sketch 3.11 Plot of crank drive torque against crank angle

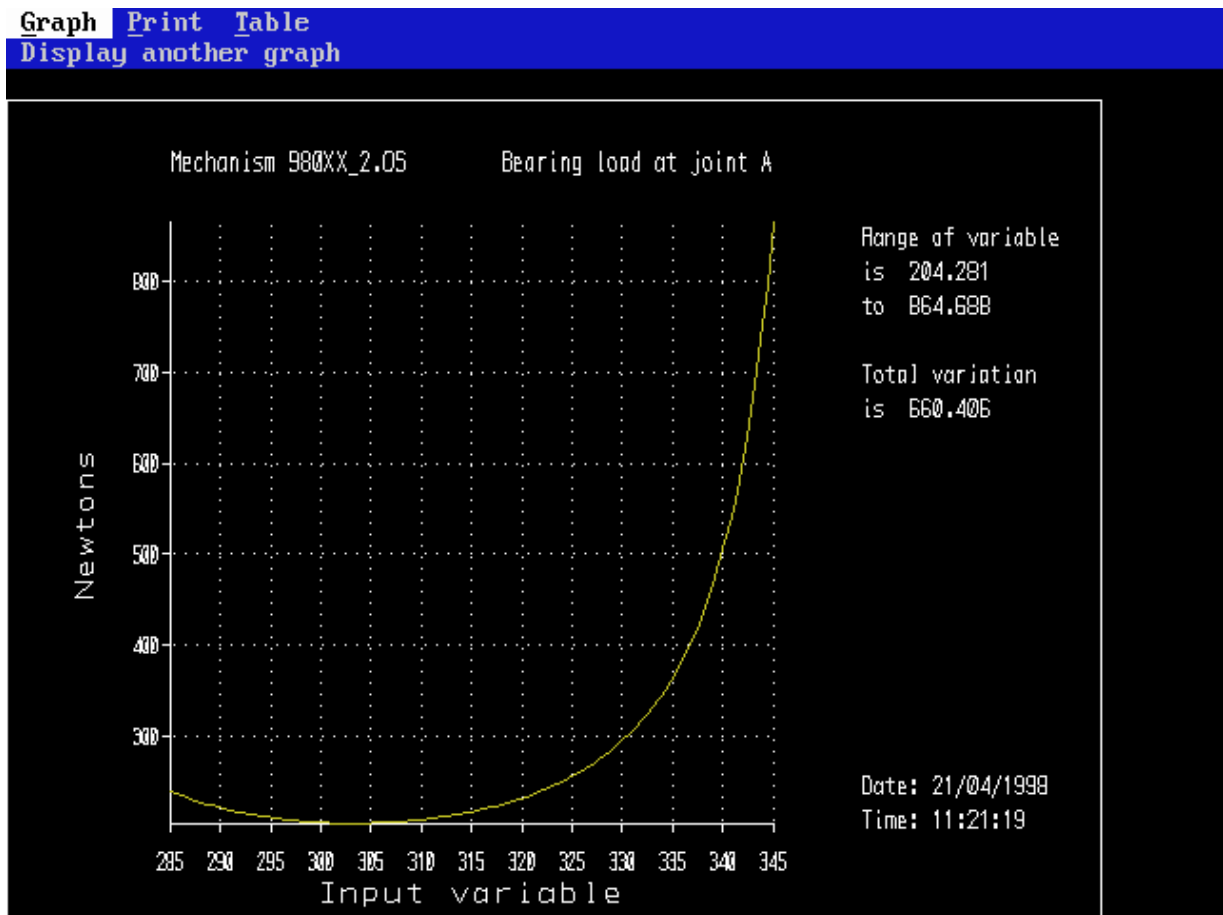
3.7 Bearing Force Analysis

To analyse the bearing forces throughout the mechanism, select the *Force* option from the *Graphs* menu. A sub-menu presents the choice between either a *Magnitude* or *Vector* plot of the forces acting at the point selected. See Section 7.3.6 of Data Item 97026. The point letter is entered and, if *Vector* is requested, the link number for which the vector plot is required.

An analysis of the magnitude of the force is useful when considering the selection of bearings for the mechanism. A vector plot of the *x*- and *y*-components of the bearing forces shows the variation in their direction of action which should be considered when designing both the bearings and their mounting in the machine frame.

3.7.1 Bearing forces - magnitude plot

When *Magnitude* is selected a dialog box appears for which the point letter identifying the bearing is required. To analyse the variation in the magnitude of the forces acting on the crank shaft bearing, enter point A. The resulting graph is shown in Sketch 3.12. Similar graphs may be generated for the crank shaft/coupler, coupler/rocker and rocker/frame bearings by successively specifying points B, C and D, respectively.



Sketch 3.12 Plot of crank shaft bearing force magnitude against crank angle