

GENEVA MECHANISMS. PART 3: EXAMPLES

1. NOTATION AND UNITS

Only those symbols directly used within this Item are given. Data Item 96002 (Reference 2) should be consulted for the full notation and Units for Geneva mechanisms. The units used in this Item are predominantly SI. All angles are measured in an anticlockwise sense and the crank is considered to rotate in an anticlockwise direction.

		<i>Units</i>
I	mass moment of inertia of circular disk (about its longitudinal axis) [†]	kg m ²
m	mass of circular disk	kg
r	radius of circular disk	m
λ	specific film thickness of lubricant	–

[†] See Section 5.5.2 in which the inertial properties of the wheel of an external Geneva are approximated using the theoretical formula for a circular disk.

2. INTRODUCTION

The examples in the Item provide insight into the application of Data Item 96002 (Reference 2) for the design of both external and internal Geneva mechanisms. Aspects of the design process include determination of the following:-

- (i) geometric relationships between the wheel, crank and roller (or pin),
 - (ii) wheel motion,
 - (iii) forces and torques,
 - (iv) contact stress,
 - (v) lubrication film thickness and regime (if applicable)
- and
- (vi) roller performance (if applicable).

Data Item ME3 (Reference 1) presents the underlying theory used to analyse a Geneva mechanism and identifies the interdependent relationships between its design parameters. Analysis of the mechanism is carried out using the ESDUpac A9611 computer software, described in Data Item 96011 (Reference 3).

Example 1 describes in detail how the ESDUpac A9611 software is used to analyse a typical external Geneva mechanism in which the designer has certain timing and spacing constraints that must be satisfied concerning the machine in which it must operate. Although the example includes consideration of a realistic design problem, the primary objective is to illustrate the procedures necessary to use the software effectively. The distance between the crank and wheel shaft, the operating speed of the crank and the load to be driven by the output shaft are all fixed. The two-stage process by which a new design is modelled using the software is described and the performance of the mechanism is assessed from the information generated by the software.

Example 2 describes the analysis of an internal Geneva mechanism capable of fulfilling the same functional requirements of the mechanism as those of Example 1, using the same roller bearing, lubricant and materials. A comparison of the relative merits of the two types of Geneva mechanism is made.

Example 3 demonstrates the most desirable strategy to be used when designing an external Geneva mechanism where only the operating speed of the motor, the driven load and the minimum dwell time required for the operation of the machine are specified. The procedure is described whereby the designer fixes the diameter of the wheel and the dependent distance between input and output shafts together with the crank dimensions is to be found. The example includes an assessment of the interdependent effects on the performance of the mechanism resulting from different combinations of the numbers of slots in the wheel and the bearing size. Replacement of the roller by a pin is considered. A number of acceptable design solutions are considered and the most cost effective design is identified.

3. EXAMPLE 1. ANALYSIS OF A CONSTANT SPEED EXTERNAL GENEVA MECHANISM WITH SPECIFIED CENTRE DISTANCE

This example describes in detail how the ESDUpac A9611 software is used to analyse an external Geneva mechanism. The primary objective of this example is to demonstrate the use of the software and a basic mechanism operating at low speed has been chosen so that inertial effects are not significant.

The Geneva mechanism is analysed in two stages. In the first, which is described step by step, initial estimates are made for the inertial properties of the crank and wheel, in order for the software to be used to calculate the overall dimensions of the mechanism. In the second stage, once these dimensions are known, accurate estimates of the inertial properties may be made and a full analysis carried out. The mechanism performance may be assessed from the program output.

It is assumed in this example that ESDUpac A9611 software is run within the ESDUview interface[†]. If, however, the ESDUpac input data file is created by some other method and run directly within DOS or within some other operating system, the sequence of data specification used in this example should be used, although the order in which these entries appear in the data file is different. Data Item 96011 (Reference 3) describes the data entry order and the procedure for creating the main input file for the software and provides all of the information necessary to use the ESDUpac.

3.1 Problem Statement

A four slot Geneva mechanism that operates at 120 rev/min as part of a one-off custom-built machine is analysed. The centre distance between the two shafts is fixed as 360 mm. An oil-lubricated 16 mm outside diameter crowned track roller bearing is selected from the list presented in Appendix A. The machine specification required 99% reliability for the minimum acceptable life of 10,000 hours. The motion of the wheel was opposed by a constant external torque of magnitude 50 N m.

3.2 Preliminary Design Decisions

Low-carbon steel, for which Young's modulus and Poisson's ratio are 207 GN/m² and 0.3 respectively, was selected for the wheel slot faces. Based on reference data discussed in Section 5.3.4 of Data Item 96002 (Reference 2), this material was to be carburised, case-hardened and ground to raise the allowable contact stress from 350 to 1200 N/mm². Table 4.2 of Reference 2 suggested that the surface roughness (rms) of the slot after grinding would be no greater than 1.5 micron.

A low viscosity index spindle oil that was expected to operate at an average temperature of 80°C was selected. By linear interpolation between the values quoted for this oil in Table 4.7 of Reference 2 for operating temperatures of 60°C and 100°C, the pressure exponent was estimated as $17.8 \times 10^{-9} \text{ m}^2/\text{N}$. From the information on Sketch 4.5 of Reference 2, a dynamic viscosity of 0.057 N s/m² for the (Viscosity Grade 22) oil operating at 80°C was predicted.

3.3 Geometric Analysis to find Crank and Wheel Dimensions

In order that a user may follow the design procedure described in this example, data files for both the VIEWpac and the ESDUpac are available on the appropriate volume disk for the Sub-series. These files have been named using a convention applied consistently throughout this Item. Since this is the first analysis of data (specification 'A') for Example 1 in Data Item 96035, the analysis was named 96035_1A. The file containing the data for the VIEWpac is named 96035_1A.VW2.

[†] Information relating to the ESDUview interface may be found in the Mechanisms Software Volume.

The procedure for sequential data entry into the VIEWpac to create this file is described in Sections 3.3.1 to 3.3.7. If the Main Input file is created by some other method, the decision-making process described in these sections should still be carried out in the same order.

3.3.1 VIEWpac form and run title

A representation of the contents of the main form of the VIEWpac form is shown in Table 3.1. The 'Run title' has three data fields (initially blank) for entering alphanumeric data to describe the analysis. A note was entered that described the details of the analysis uniquely.

TABLE 3.1 Contents of the 'Main form' form of VIEWpac 9611A

3.3.2 Geneva data

The contents of the Geneva data form are represented in Table 3.2. The prompt for the 'Centre distance' appeared only after the design strategy was selected as 'Centre distance specified - (wheel diameter evaluated)'. (If the design strategy had been selected as 'Wheel diameter specified - (centre distance evaluated)' the prompt would have been for the 'Wheel diameter').

TABLE 3.2 Contents of 'Geneva data' form

9611A - Geneva data

Design strategy:
☒ Centre distance specified (wheel diameter evaluated)
☐ Wheel diameter specified (centre distance evaluated)

Centre distance: mm

Geneva type:
☒ External wheel - lubricated
☐ External wheel - unlubricated
☐ Internal wheel - lubricated
☐ Internal wheel - unlubricated

Crank motion:
☒ Constant crank angular velocity
☐ Varying crank angular velocity

Number of slots on wheel:

The problem statement requires a fixed centre distance between the input and output shafts of 360 mm and the number of slots as four. An oil-lubricated external Geneva was specified in the problem statement and the 'Geneva type' was therefore selected as 'External wheel - lubricated'. The operating speed of the crank was constant throughout each rotation and the 'Crank motion' was set accordingly.

3.3.3 Crank data

Table 3.3 shows a representation of the 'Crank data' form. The 'Pin/roller type' was selected as 'Crowned roller' as required by the problem statement. The 'Pin/roller dimensions' were entered after referring to Section 4.5 of Data Item 96002 (Reference 2).

TABLE 3.3 Contents of the 'Crank data' form

9611A - Crank data

Pin/roller type:

- ☐ cylindrical pin
- ☐ cylindrical roller
- ☐ Crowned pin
- ☒ Crowned roller

Pin/roller dimensions...

Mass of crank: 1.5 kg

Mass moment of inertia of crank: 0.001 kg m²

Length defining crank centre of mass: 0 mm

Angle defining crank centre of mass: 0 degree

Angular velocity of crank: 120 rev/min

OK Cancel

At this initial stage of the design process, the inertial properties of the crank could not be specified accurately since the crank length was unknown. In order to run the program, suitable values must be entered for the 'Mass of crank', 'Mass moment of inertia of crank', 'Length defining centre of mass' and 'Angle defining centre of mass'. Since the objective of the analysis at this stage of the design process is to enable the program to run in order to obtain the key dimensions of the crank and wheel, the arbitrary values shown in Table 3.3 were entered. These values were to be revised when more information was available (see Section 3.4). The 'Pin/roller dimensions' form was then activated. The contents of this form are shown in Table 3.4.

TABLE 3.4 Contents of 'Crowned roller dimensions' form

9611A - Crowned roller dimensions

Diameter of roller: 16 mm
 Width of roller: 11 mm
 Crown radius of roller: 500 mm
 Surface roughness (rms): 1 micron

Young's modulus: 205000 N/mm²
 Poisson's ratio: 0.29

Roller ratings... Roller design factors...

OK cancel

The diameter and width of the 16 mm outside diameter bearing were found from the sample catalogue entries listed in Appendix A. A standard 500 mm crown radius was chosen: other values would significantly increase the bearing cost. Appendix A lists the surface roughness of the outer race of the bearing and values for Young's modulus and Poisson's ratio. (The value of 205 GN/m² for Young's modulus must be entered in the program as 205000 N/mm².)

When a roller bearing is specified, the 'Crowned roller dimensions' form has two sub-forms (see Table 3.4), one for the 'Roller ratings' and the other for the 'Roller design factors'. The data entered on these forms were specified based on guidance in Section 4.6 of Reference 2. The two data forms are shown in Tables 3.5 and 3.6, respectively.

TABLE 3.5 Contents of the 'Roller ratings' form

9611A - Roller ratings

Roller manufacturer: Appendix A
 Reference Number: 16 mm

static load rating: 6500 N
 Dynamic load rating: 4850 N
 Maximum allowable load on stud or spindle: 4000 N
 Maximum allowable angular velocity of roller: 11300 rev/min
 Minimum allowable roller life: 10000 hour

OK cancel

The 'Roller manufacturer' and 'Reference number' were entered as 'Appendix A' and '16 mm' to identify uniquely the 16 mm bearing selected from Appendix A.

The values entered for static load rating, dynamic load rating and maximum allowable angular velocity of roller are listed in Appendix A. The higher value of maximum allowable angular velocity of the roller in Appendix A was used since oil rather than grease lubrication was specified.

In the absence of any other information, it is conventional to enter the static load rating of the bearing for the value of the 'Maximum allowable load on stud or spindle'. However a stress analysis of the 5 mm diameter bearing spindle showed that 6500 N was too high and its value was limited to 4000 N. The 'minimum allowable roller life' of 10,000 hours was set by the problem statement. The 'Roller design factors' form, represented in Table 3.6, was accessed from the 'crank data form' shown in Table 3.4.

TABLE 3.6 Contents of 'Roller design factors' form

9611A - Roller design factors	
Material correction factor:	1
Lubrication correction factor:	1
Static safety factor:	1
Service factor:	1
Required reliability:	99 per cent
OK Cancel	

Since standard roller bearings and normal lubrication were specified, both the 'Material correction factor' and the 'Lubrication correction factor' were entered as 1.0. See Section 4.6 of Data Item 96002 (Reference 2).

The machine (and therefore the Geneva mechanism) was expected to operate in a normal environment with average working conditions, which accounts for some variation from the assumed loads without the possibility of severe shock loading. Based on guidance from Tables 4.4 and 4.5 in Data Item 96002 (Reference 2) values of 1.0 were entered for both the static safety factor and the service factor.

The required reliability of 99% specified in the problem statement was entered.

3.3.4 Wheel data

The contents of the 'Wheel Data' form are shown in Table 3.7. Guidance for the data necessary to describe the wheel is given in Section 4.7 of Data Item 96002 (Reference 2). The slot face width is required for comparison with the (calculated) length of the contact area to check that the contact zone does not overlap the width of either the slot or the roller (or pin). If this occurs, stress concentrations due to edge effects could result in damage to either the slot face or the roller/pin. See Section 4.5 in Reference 2. However, to reduce costs and assist the manufacture of the wheel, the slot face should be as small as possible. A slot face width equal to the roller bearing width of 11 mm was chosen. This figure was to be reviewed when the software had calculated the maximum size of the contact zone.

TABLE 3.7 Contents of 'Wheel data' form

9611A - wheel data		
Slot face width:	11	mm
Locking radius:	180	mm
Slot length:	150	mm
Hub diameter of wheel:	60	mm
Surface roughness (rms):	1.5	micron
Mass of wheel:	2	kg
Mass-moment of inertia of wheel:	0.002	kg m ²
Length defining wheel centre of mass:	0	mm
Angle defining wheel centre of mass:	0	degree
Young's modulus:	207000	N/mm ²
Poisson's ratio:	0.3	
Allowable contact stress:	1200	N/mm ²
OK cancel		

Initially there was no information to suggest suitable values for the locking radius and slot length of the wheel. (Such information is usually gained from experience of other Geneva mechanisms with similar wheel and bearing sizes.) Typically, if no other information is available, the initial values chosen for the locking radius and slot length are approximately 50% of the distance between centres. Here, values of 180 and 150 mm were chosen for the locking radius and slot length, respectively. To ensure a smooth, positive meshing of the Geneva wheel at both ends of the dwell period, it is desirable that the locking radius should be as large as possible. Removal of the additional material for a larger locking radius also reduces the mass moment of inertia of the wheel.

An initial value of 60 mm was entered for the 'Hub diameter'. This dimension defines the maximum diameter within which the design features used to connect the wheel to its shaft are contained. At this stage of the design process an accurate figure cannot be given for this dimension since neither the dimensions of the wheel nor the total load transmitted by its shaft are known.

The inertial properties of the wheel were estimated in this initial stage of the design process using a procedure similar to that described in Section 3.3.3. Values of 2 kg, 0.002 kg m², 0 mm and 0° were entered for the 'Mass of wheel', 'Mass moment of inertia of wheel', 'Length defining wheel centre of mass' and

'Angle defining wheel centre of mass', respectively.

All of the values of the inertial properties of the wheel and crank (that had to be entered in order to run the program) were to be reviewed once the geometric analysis had determined the minimum slot length and the tip thickness and generated a DXF drawing output file from which an image of the outline of the wheel could be plotted. The material properties and surface roughness (rms) chosen for the wheel slot faces in Section 3.2 were entered. The specified value of 207 GN/m^2 for Young's modulus must be entered in the program as 207000 N/mm^2 .

3.3.5 Lubricant data

The values for the lubricant properties specified in Section 3.2 were entered on the 'Lubricant data form' depicted in Table 3.8. (The software amends the display of the value of the pressure exponent from $17.8\text{E-}9$ to $1.78\text{e-}08$).

TABLE 3.8 Contents of the 'Lubrication data' form

9611A - Lubricant data

Dynamic viscosity: 0.057 N s/m²

Pressure exponent: 1.78e-08 m²/N

OK cancel

3.3.6 External torque data

'External torque' was selected as 'Constant' as dictated by the problem statement. The form is depicted in Table 3.9.

TABLE 3.9 Contents of 'External torque' form

9611A - External torque

External torque:

- ☒ Constant
- ☐ Trigonometric function
- ☐ Entered via file
- ☐ Linear interpolation
- ☐ None

Torque data...

OK cancel