VIETNAM NATIONAL UNIVERSITY HO CHI MINH CITY
HCM UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING - MECHATRONICS DEPARTMENT

ENGINEERING INTERNSHIP REPORT

Air Compressor Modeling using MATLAB

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HCMC, October 8, 2020

Acknowledgements

Acknowledgements should be expressed as a special thanks to staff members of industrial companies, your supervisors, your collaborator/teammates. This chapter should not be longer than 1 page.

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Abstract

Describe relevancy of the project and its task/ target. A short description of the technical prerequisites for executing the project. The chapter is required by the company. In any case, it should not be longer than 1 page, ideally 1/2 page.

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Contents

List of Figures

List of Tables

Chapter 1

Several Key points

1.1 Morphological Box

Create a morphological box, which is a way of creative thinking in functions and sequence of work steps.

	Sub functions	Solutions of the sub functions				
		1	2	3	4	5
A	Sub function 1	**solution A1 (1) (3)**	solution A2	solution A3		
B	Sub function 2	solution B1 (1) (2) (3)	solution B2 (2)	**solution B3 (2)**	solution B45	
C	Sub function 2		solution C2 (2)	**solution C3 (1)**		solution C5

Table 1.1: A morphological box with 3 concept variants

Legend
(1) = thermal solution
(2) = mechanical solution
(3) = MEM solution

For each bold option, if there are many concept variants, see Table 1.3. In this example, we choose sub function B1 as the optimal solution with 3 variants. If the table does not describe fully or the sub function needs dividing into subgroups, see Table 1.2.

When calling a solution in Table 1.2, we call it position + name of the sub solution (e.g. A2 MEM 1)

	Sub functions	Solutions of the sub functions		
		1	2	3
A	Sub function 1	Thermal treatment	MEM treatment	
			MEM 1	MEM 2
B	...			

Table 1.2: A morphological box with 3 concept variants

	Sub functions	Solutions of the sub functions		
		1	2	3
B	Sub function 2			
Ba	Type	Simple	Complex	Mixed
Bb	Shape	Round	Square	Triangle
Bc	Size (m)	7x2	2x2	3x5

Table 1.3: A morphological box with 3 concept variants

1.2 Evaluation Table

Many evaluation tables are developed in the industry (e.g VDI 2222, VDI 2225). Search for the sheet form on the internet, consult with your supervisor/customer for further information before using it.

General points to remember to make better decisions:

- Use consecutively (following one another).
- Every table should have its own acronym since turning pages is avoided.
- Simple points are related to almost other categories. Examples:
  Parallel point values: load carrying $\uparrow \Rightarrow$ beneficial $\uparrow \Rightarrow$ simple point $\uparrow$
  Opposite point values: self-weight $\uparrow \Rightarrow$ bad $\downarrow \Rightarrow$ simple point $\downarrow$
- Think as a user/customer, not a manufacturer.

1.3 Tabular Re-arrangement

Example:

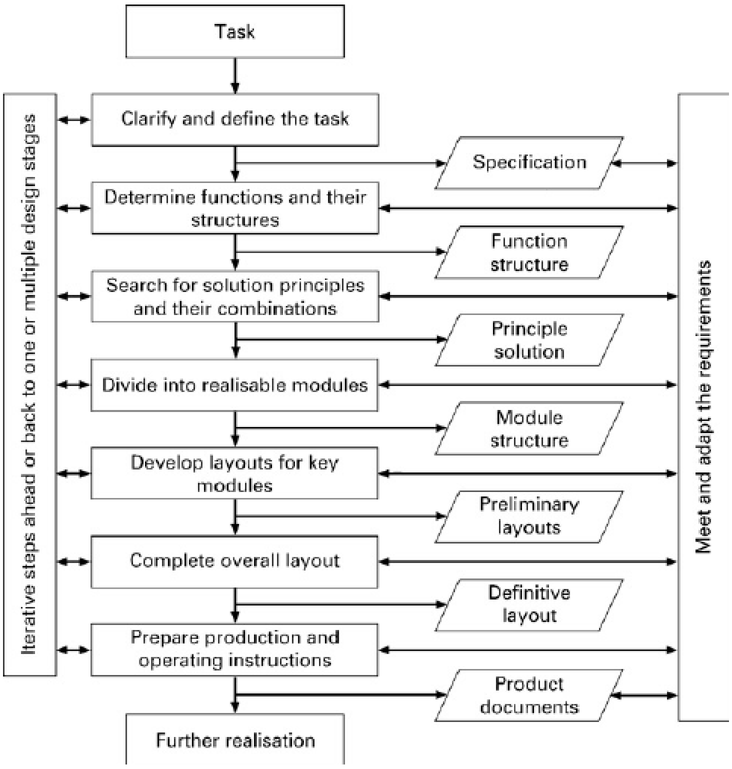


Figure 1.1: A figurative example of VDI 2222

The sterilization temperature for sterilizing the tank should be at least $135°C$ for 30 min. The sterilizing temperature at the condensomat should not fall below $125°C$.

You can "tabularize" the body of paragraph into a table, which is more concise and readable.

Minimum temperatures for sterilizing

location	**temperature**
at the tank	temp. $= 135°C$, 30 min
at the condensomat	temp. $= 125°C$

1.4 Choosing between diagram, table and text descriptions

In general:

- Text description is exact but hard to read.
- Table is exact but still not easy to read.

- Diagram is not exact but easy to visualize and memorable.
- Placing the right thing on a page is essential for a great report.

The next important key point to remember is called text-figure-relationship, which is how and where you place texts and figures in a page:

- Placing figures (diagrams and tables) in an appendix is good for positioning but leads to turning pages multiple times (bad text-figure-relationship).
- Placing figures near/on the same page as the explaining text is a good text-figure-relationship. If the report is double-sided, the figure should be on the same double-page as the text (the diagram and explaining text should either be on odd or even pages).
- Cross referencing to a figure with a statement and add the phrase "Figure xx." at the end after a comma.
- Drawing/scanning the figures as early as possible while writing the explaining text.

Graphics simplify reality (e.g. principle drawing, map), explain abstract ideas by means of spatial arrangement (e.g. bar chart, pie chart, tree chart), create associations (e.g. logo and pictogram).

There are 13 basic rules for information-effective design of figures:

1. Accentuate important items.
2. Delete/leave out unimportant items (use max. 4-7 graphic elements in 1 picture or it is overloaded).
3. Line thickness and font size must be sufficient. Figures should be readable at a distance of 30-40 cm.
4. Relationship of graphic elements should be emphasized (lines, arrows, columns, rows, common color). These should be specified in detail (character of the relationship, meaning behind it) using labels and explanations in the legend.
5. Objects near each other belong together.
6. An element placed above or below other elements is regarded as hierarchically super-ordinate or sub-ordinate.
7. Logical/chronological sequence has its elements placed beside each other.

8. Circular arrangement is thought as a cycle or repeated sequence.
9. An element surrounding another element is understood as the outer includes the inner element.
10. Boxes, bars, lines, columns, etc. must be clearly marked (text labels or graphical explanations).
11. 1 type of element may have only 1 function within one/series of figures (e.g. arrows for vector direction).
12. $x-$axis is horizontal, $y-$axis is vertical
13. Look up for standardized symbols (e.g. DIN 66001 for flow charts, DIN 32520, DIN 66261).

Chapter 2

Internship tasks

2.1 Problem

At the moment, the light duty air compressor market mainly use electricity as the power source, which can be inconvenient at remote locations where power grid is difficult to reach. To solve this problem, we will analyze and model a V-twin air compressor with a compression end and a combustion end. The model is programmed using MATLAB® R2019a.

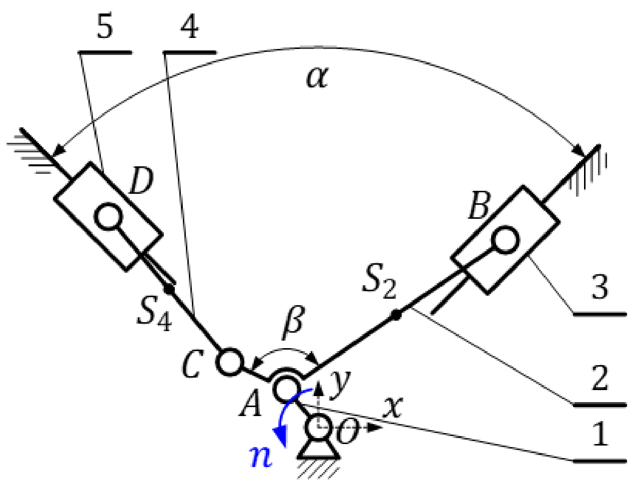


Figure 2.1: Mechanism of the air compressor

2.2 Parameters

Piston lift	$H_C = 39\,\text{mm}$
V-angle	$\alpha = 90°$
Connecting rod dimensions	$\frac{l_{AB}}{l_{OA}} = 5.372, l_{AC} = 25mm, \beta = 120°$
Crankshaft 1 weight	$m_1 = 1.6262\,\text{kg}$
Center of gravity of link 1	$S_1 \equiv O$
Moment of inertia of link 1	$J_{s1} = 0.0045585\,\text{kg}\cdot\text{m}^2$
Connecting rod 2 weight	$m_2 = 0.29597\,\text{kg}$
Center of gravity of link 2	$l_{AS2} = l_{S2B}$
Moment of inertia of link 2	$J_{S2} = 0.004874\,\text{kg}\cdot\text{m}^2$
Connecting rod 4 weight	$m_2 = 0.13865\,\text{kg}$
Center of gravity of link 4	$l_{CS4} = l_{S4D}$
Moment of inertia of link 4	$J_{S4} = 0.00011121\,\text{kg}\cdot\text{m}^2$
Piston weight	$m_3 = m_5 = 0.33513\,\text{kg}$
Center of gravity of link 3 and 5	$S_3 \equiv B, S_5 \equiv D$
Piston crown area	$A = 0.01\,\text{m}^2$
Allowable tolerance factor	$\delta = 1/80$
Average rotational velocity	$n_1 = 500\,\text{rpm}$
Valve lift (trapezoidal acceleration)	$s_0 = 2\,\text{mm}$
Early opening and late closing of combustion end	25°
Early opening of compression end	40°
Pressure angle of cam follower	$\alpha_2 = 6°$
Periodic angles	$\phi_{rise} = \phi_{fall}$, $\phi_{rise,comb} = 5°$, $\phi_{rise,comp} = 20°$

2.3 Displacement analysis

Position of A

$$\vec{r}_A = \begin{bmatrix} x_A \\ y_A \\ 0 \end{bmatrix} = \begin{bmatrix} l_{OA}\cos\phi \\ l_{OA}\sin\phi \\ 0 \end{bmatrix} \tag{2.1}$$

where $\phi = \widehat{xOA}$

Position of B

$$\begin{cases} (x_A - x_B)^2 + (y_A - y_B)^2 & = l_{AB}^2 \\ \dfrac{y_B}{x_B} & = \tan\widehat{xOB} \end{cases} \tag{2.2}$$

Solve equation (2.2) yields 2 positions B_1, B_2. Combining with condition $x_B, y_B > 0$ to find the correct solution.

$$\vec{r}_B = \begin{bmatrix} x_B \\ y_B \\ 0 \end{bmatrix}$$

Position of C

$$\begin{cases} (x_A - x_C)^2 + (y_A - y_C)^2 & = l_{AC}^2 \\ (x_B - x_C)^2 + (y_B - y_C)^2 & = l_{BC}^2 \end{cases} \tag{2.3}$$

Solve equation (2.3) yields 2 sets of positions C_1, C_2, one of which is the correct solution. This can be programmed using MATLAB® to try both sets.

$$\vec{r}_C = \begin{bmatrix} x_C \\ y_C \\ 0 \end{bmatrix}$$

Position of D

$$\begin{cases} (x_C - x_D)^2 + (y_C - y_D)^2 & = l_{CD}^2 \\ \dfrac{y_D}{x_D} & = \tan \widehat{xOD} \end{cases} \tag{2.4}$$

Solve equation (2.4) yields 2 positions D_1, D_2. Combining with condition $x_D < 0, y_D > 0$ to find the correct solution.

$$\vec{r}_D = \begin{bmatrix} x_D \\ y_D \\ 0 \end{bmatrix}$$

Using MATLAB® to plot the positions of the mechanism in figure 2.3

2.4 Velocity and Acceleration analysis

With the analytical solutions of the points A, B, C, D, we can easily find the corresponding velocities and accelerations using derivative with respect to time t. Also, we need to remember that $\phi(t)$ is a time-dependent variable.

2.4.1 Velocity analysis

Velocity of A

$$\vec{v}_A = \dot{\vec{r}}_A = \frac{d\vec{r}_A}{dt} \tag{2.5}$$

where $\phi = \widehat{xOA}$

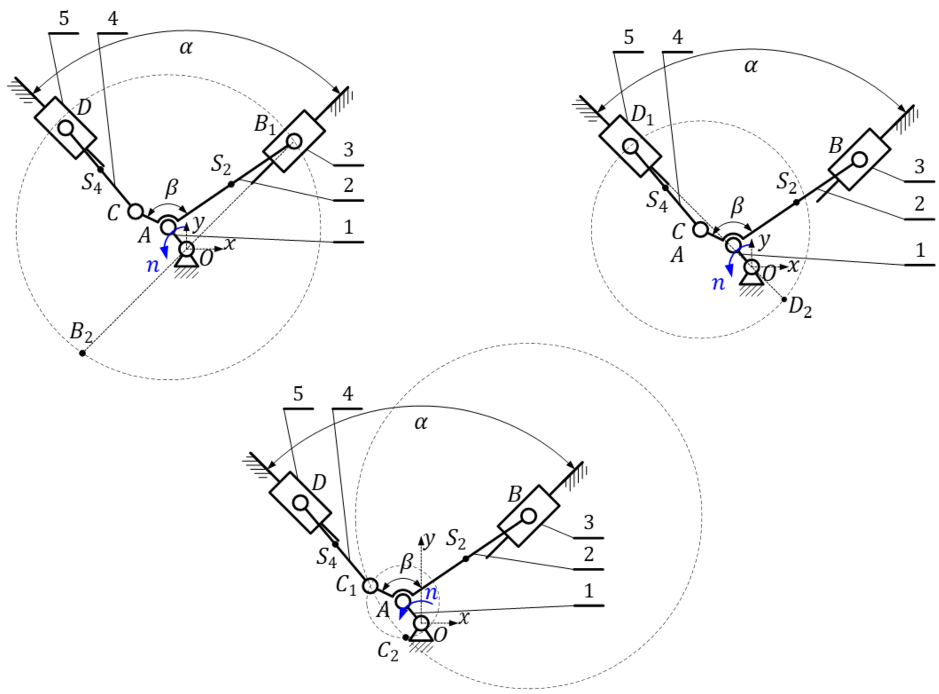


Figure 2.2: Position analysis of B, C and D

Velocity of B

$$\vec{v}_B = \dot{\vec{r}}_B = \frac{d\vec{r}_B}{dt} = \vec{v}_A + \vec{\omega}_2 \times (\vec{r}_B - \vec{r}_A) \tag{2.6}$$

From equation (2.6), we solve analytically for $\vec{\omega}_2$

$$\vec{\omega}_2 = \begin{bmatrix} 0 \\ 0 \\ \omega_2 \end{bmatrix}$$

Velocity of C

$$\vec{v}_C = \dot{\vec{r}}_C = \frac{d\vec{r}_C}{dt} \tag{2.7}$$

Velocity of D

$$\vec{v}_D = \dot{\vec{r}}_D = \frac{d\vec{r}_D}{dt} = \vec{v}_C + \vec{\omega}_4 \times (\vec{r}_D - \vec{r}_C) \tag{2.8}$$

From equation (2.8), we solve analytically for $\vec{\omega}_4$

$$\vec{\omega}_4 = \begin{bmatrix} 0 \\ 0 \\ \omega_4 \end{bmatrix}$$

Using MATLAB® to plot the velocity graph of the mechanism in figure 2.4.

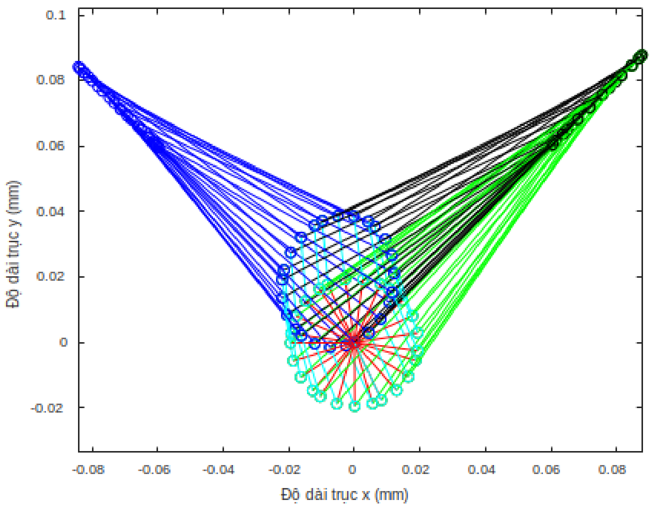


Figure 2.3: Locus of the mechanism using MATLAB®

2.4.2 Acceleration analysis

Acceleration of A

$$\vec{a}_A = \dot{\vec{v}}_A = \frac{d\vec{v}_A}{dt} \tag{2.9}$$

where $\phi = \widehat{xOA}$

Acceleration of B

$$\vec{a}_B = \dot{\vec{v}}_B = \frac{d\vec{v}_B}{dt} \tag{2.10}$$

$$\vec{\alpha}_2 = \frac{d\vec{\omega}_2}{dt}$$

Acceleration of C

$$\vec{a}_C = \dot{\vec{v}}_C = \frac{d\vec{v}_C}{dt} \tag{2.11}$$

Acceleration of D

$$\vec{a}_D = \dot{\vec{v}}_D = \frac{d\vec{v}_D}{dt} \tag{2.12}$$

$$\vec{\alpha}_4 = \frac{d\vec{\omega}_4}{dt}$$

Using MATLAB® to plot the acceleration graph of the mechanism in figures 2.5

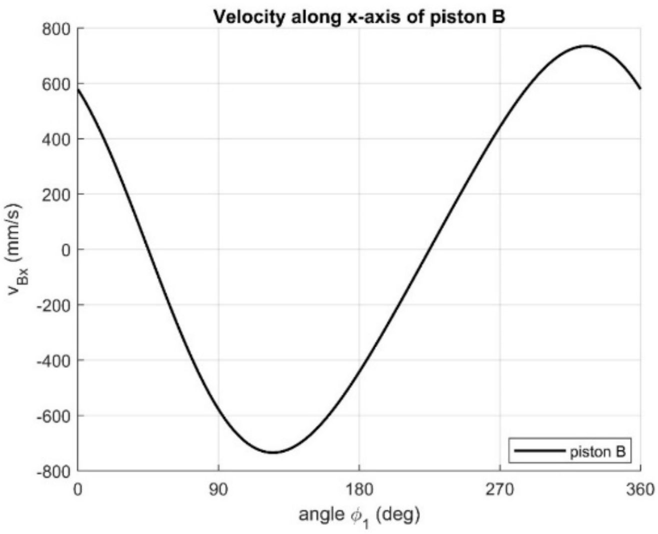


Figure 2.4: Velocity of link 3

2.5 Force analysis

To find the reaction forces, we separate the links and solve the D'Alembert equations analytically.

Position and acceleration equations of the links at their centers of gravity:

$$\vec{r}_{S1} = \vec{0}, \vec{r}_{S2} = \frac{\vec{r}_A + \vec{r}_B}{2}, \vec{r}_{S4} = \frac{\vec{r}_D + \vec{r}_C}{2} \tag{2.13}$$

$$\vec{a}_{S1} = \vec{0}, \vec{a}_{S2} = \frac{\vec{a}_A + \vec{a}_B}{2}, \vec{a}_{S4} = \frac{\vec{a}_D + \vec{a}_C}{2} \tag{2.14}$$

The equations for 5 links are systemized as follows:

Link 5

$$\begin{cases} \vec{Q}_5 + \vec{F}_{45} + \vec{P}_D + \vec{R}_{05} & = m_5\vec{a}_5 \qquad (\vec{a}_5 = \vec{a}_D) \\ \left|\vec{R}_{05x}\right| & = \left|\vec{R}_{05y}\right| \end{cases} \tag{2.15}$$

Link 4

$$\begin{cases} \vec{Q}_4 + \vec{F}_{24} + \vec{F}_{54} & = m_4\vec{a}_{S4} \qquad (\vec{F}_{54} = -\vec{F}_{45}) \\ (\vec{r}_D - \vec{r}_{S4}) \times \vec{F}_{54} + (\vec{r}_C - \vec{r}_{S4}) \times \vec{F}_{24} & = J_{S4}\vec{\alpha}_4 \end{cases} \tag{2.16}$$

Link 3

$$\begin{cases} \vec{Q}_3 + \vec{F}_{23} + \vec{P}_B + \vec{R}_{03} & = m_3\vec{a}_3 \\ \left|\vec{R}_{03x}\right| & = -\left|\vec{R}_{03y}\right| \end{cases} \tag{2.17}$$

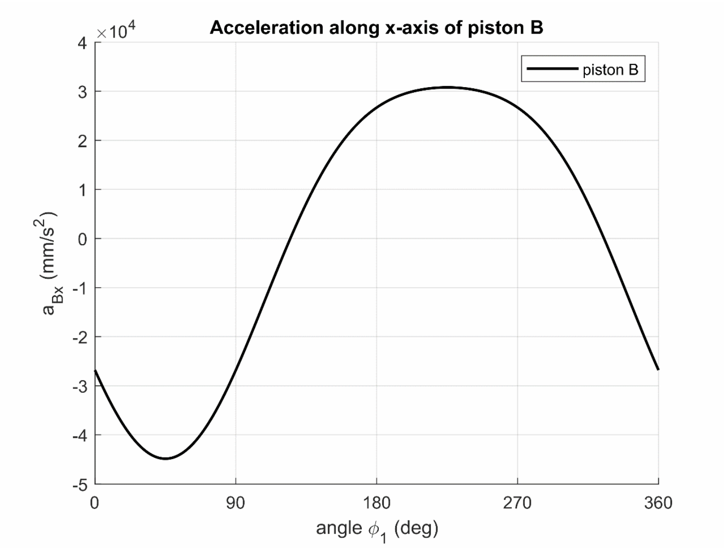


Figure 2.5: Acceleration of link 3

Link 2

$$\begin{cases} \vec{Q}_2 + \vec{F}_{12} + \vec{F}_{42} & = m_2\vec{a}_{S2} \\ (\vec{r}_C - \vec{r}_{S2}) \times \vec{F}_{42} + (\vec{r}_B - \vec{r}_{S2}) \times \vec{F}_{32} + (\vec{r}_A - \vec{r}_{S2}) \times \vec{F}_{12} & = J_{S2}\vec{\alpha}_2 \end{cases} \tag{2.18}$$

where $\vec{F}_{42} = -\vec{F}_{24}, \vec{F}_{32} = -\vec{F}_{23}$

Link 1

$$\begin{cases} \vec{Q}_1 + \vec{F}_{21} + \vec{R}_{01} & = m_1\vec{a}_{S1} \\ \vec{r}_A \times \vec{F}_{21} + \vec{M}_{cb} & = 0 \end{cases} \tag{2.19}$$

Solving for system of equations from (2.13) to (2.19) by rearranging them into matrix form, we obtain $\vec{F}_{45}$, $\vec{R}_{05}$, $\vec{F}_{24}$, $\vec{F}_{23}$, $\vec{F}_{12}$, $\vec{R}_{01}$, $\vec{R}_{03}$, $\vec{M}_{cb}$.

Using MATLAB® to plot the reaction force $\vec{F}_{23}, \vec{R}_{03}$ of the mechanism in figures 2.7 and 2.8

2.6 Energy relation analysis

The energy relation of the machine must satisfy the condition such that the motion of the system is regulated after each cycle. To put it another way, the dynamic work is offset by the resistance work:

$$\begin{aligned} M_c(0) &= M_d(0) \\ M_c(2\pi) &= M_d(2\pi) \end{aligned} \tag{2.20}$$

Let us choose the driving link as the equivalent link of the system: $\omega_{tt} = \omega_1$.

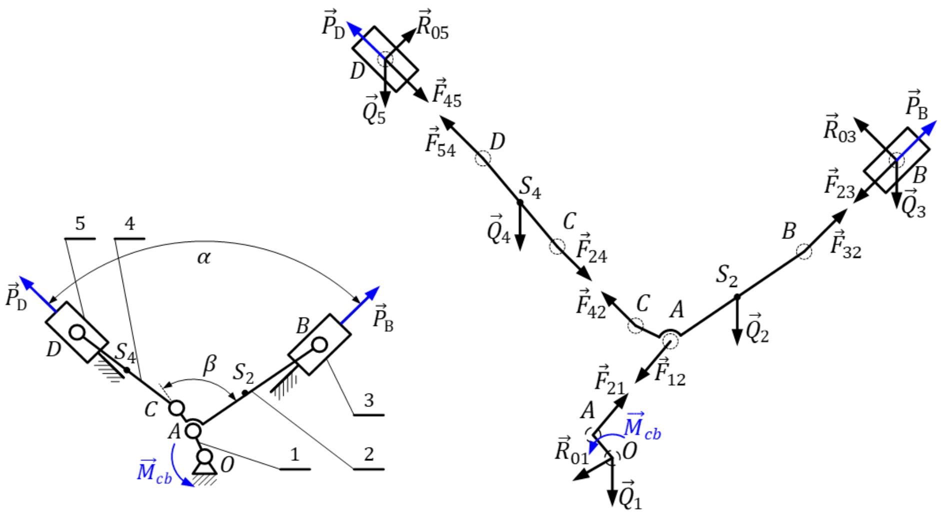


Figure 2.6: Force analysis of the mechanism

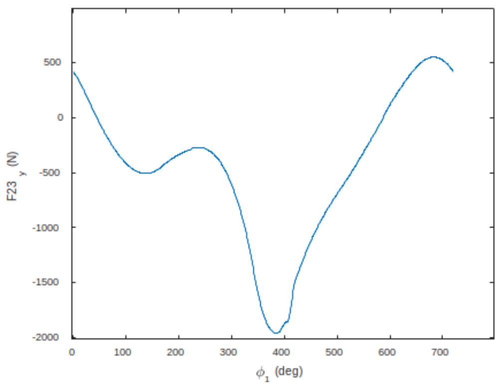


Figure 2.7: Reaction force $\vec{F}_{23}$ along y axis

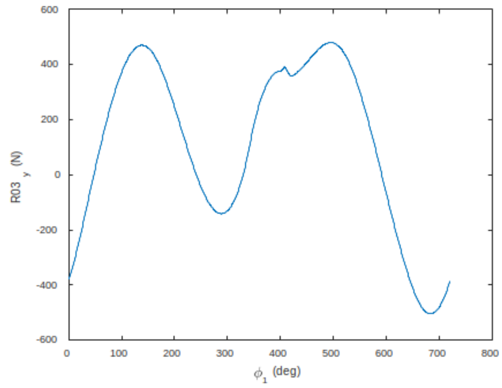


Figure 2.8: Reaction force $\vec{R}_{03}$ along y axis

2.6.1 Find equivalent dynamic moment and dynamic work

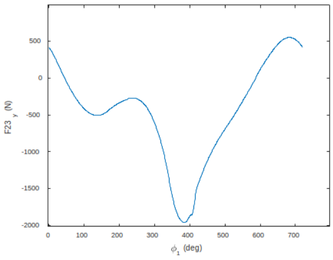
From the displacement - pressure relation graph (figure **??**), we convert it to the external force acting on the system $F_B(\phi) = P_B(\phi)A$ in a cycle (each displacement data corresponds to a specific position and angle $\phi(t)$ of the system).

The equivalent dynamic moment on link 1 is calculated as:

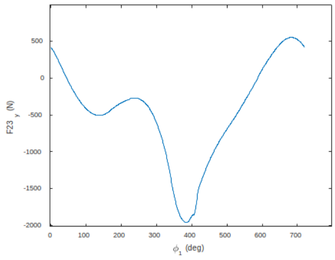
$$M_d(\phi) = \frac{1}{\omega_1}\left(\vec{F}_B \cdot \vec{v}_B + \vec{Q}_2 \cdot \vec{v}_{S2} + \vec{Q}_4 \cdot \vec{v}_{S4} + \vec{Q}_3 \cdot \vec{v}_B + \vec{Q}_5 \cdot \vec{v}_D\right) \tag{2.21}$$

From the moment, we integrate to obtain the dynamic work:

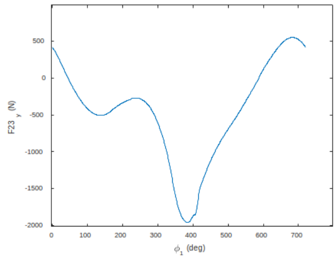
$$A_d(\phi) = \int_{\phi_i}^{\phi_f} M_d d\phi \tag{2.22}$$



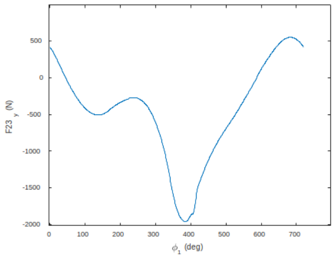
(a) A subfigure



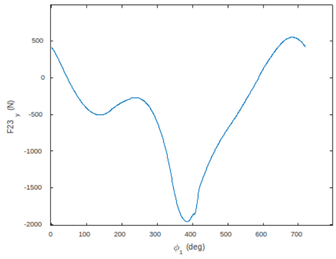
(b) A subfigure



(c) A subfigure



(d) A subfigure



(e) A subfigure

Figure 2.9: A figure with two subfigures

2.6.2 Find equivalent resistant moment and resistant work

From the displacement - pressure relation graph (figure **??**), we convert it to the external force acting on the system $F_D(\phi) = P_D(\phi)A$ in a cycle (each displacement data corresponds to a specific position and angle $\phi(t)$ of the system).

The equivalent resistant moment on link 1 is calculated as:

$$M_c(\phi) = \frac{1}{\omega_1}\vec{F}_D \cdot \vec{v}_D \tag{2.23}$$

From the moment, we integrate to obtain the resistant work:

$$A_c(\phi) = \int_{\phi_i}^{\phi_f} M_c d\phi \tag{2.24}$$

However, the value of M_c in equation 2.23 still does not satisfy condition (2.20). To compensate for this, we multiply the force F_D by a ratio $\dfrac{A_d}{A_c}$ and

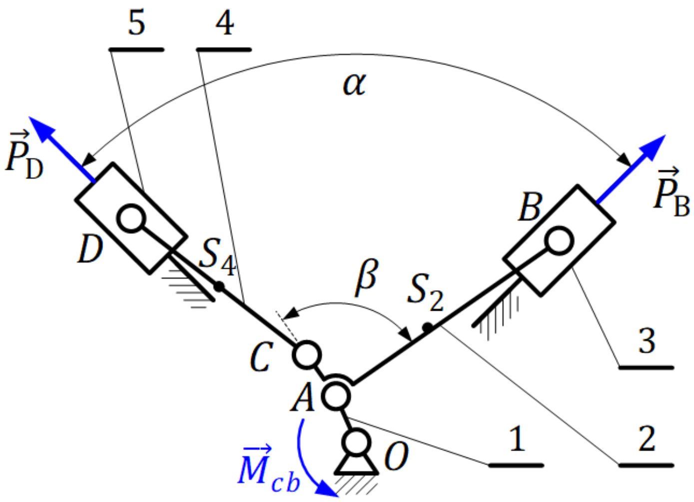


Figure 2.10: Pressure on both ends of the system

recalculate M_c, A_c:

$$\begin{aligned} F_{D,new}(\phi) &= \frac{A_d}{A_c} F_D \\ M_{c,new}(\phi) &= \frac{1}{\omega_1} \vec{F}_{D,new} \cdot \vec{v}_D \\ A_{c,new}(\phi) &= \int_{\phi_i}^{\phi_f} M_{c,new} d\phi \end{aligned} \tag{2.25}$$

We then obtain the figure of equivalent resistant moment and work:

Combining the 2 figures 2.13 and 2.16, we obtain the works applied onto the system in 1 cycle:

2.7 Find the energy equation and calculate the flywheel weight

Since the crankshaft is chosen to be the equivalent link, we obtain the equivalent moment of inertia as follows:

$$J(\phi) = J_1 + J_2 \left(\frac{\omega_2}{\omega_1}\right)^2 + m_2 \left(\frac{v_{S2}}{\omega_1}\right)^2 + m_3 \left(\frac{v_B}{\omega_1}\right)^2 + J_4 \left(\frac{\omega_4}{\omega_1}\right)^2 + m_5 \left(\frac{v_D}{\omega_1}\right)^2 \tag{2.26}$$

where m_k, ω_k, v_k are the weight, rotational speed and instantaneous speed at point k respectively.

Then, we calculate the total energy output of the system:

$$E(\phi) = \Delta E + E_0 = (A_c + A_d) + \frac{1}{2} J_0 \omega_1^2 \tag{2.27}$$

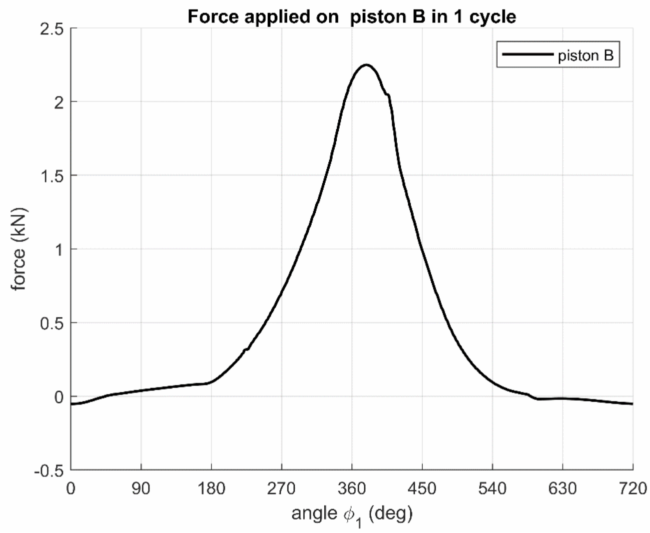


Figure 2.11: Force applied on piston 3 corresponding to angle of crankshaft 1

where ΔE is the total equivalent work and $J_0 = J(0)$

From the equivalent energy equation $E(\phi)$ and moment of inertia $J(\phi)$ we plot the graph of $E(J)$

From figure 2.20 we draw 2 tangent lines at the boundaries. Let the slope of the lower tangent line be ψ_{min} and the upper one be ψ_{max}. The slope of the lines at calculated numerically as follows:

$$\begin{aligned} \psi_{min} &= \frac{\mu_E \omega_1^2}{2\mu_J}\left(1 - \frac{[\delta]}{2}\right)^2 \\ \psi_{max} &= \frac{\mu_E \omega_1^2}{2\mu_J}\left(1 + \frac{[\delta]}{2}\right)^2 \end{aligned} \tag{2.28}$$

where $[\delta] = 1/80$ is given above

$\mu_E = \mu_J = 1$ are the scale of the figure (MATLAB® or similar programs always understands these values as 1)

The lines cross the ordinate $E(J)$ at a, b respectively. We then derive the equations describing these lines and draw them in figure 2.20:

$$\begin{aligned} y_{min} &= \psi_{min} x + a \\ y_{max} &= \psi_{max} x + b \end{aligned} \tag{2.29}$$

Calculating the moment of inertia of the flywheel using:

$$J_d = \frac{\mu_J ab}{\psi_{max} - \psi_{min}} \tag{2.30}$$

Programming with MATLAB®, we estimate $J_d = 1.63\,\mathrm{kg \cdot m^2}$. Assuming the cross section area is $100\,\mathrm{cm}^2$, the weight of the flywheel will be about 16.3 g.

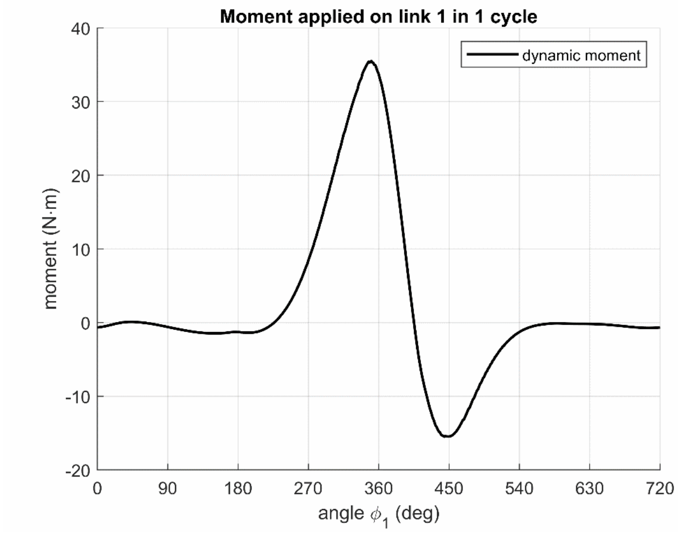


Figure 2.12: Equivalent dynamic moment applied on crankshaft 1

2.8 Combining motion of the system

From the given parameters, we derive the following table:

2.9 Cam mechanism

2.9.1 Tasks

- Modeling 4 cams for 4 valves, 2 of which are intake-outtake of the combustion end, and the remaining are for the compression end.
- The intake cams are identical.
- The outtake cams are identical.

2.9.2 Cam profile determination

For combustion ends, we will find the rise, dwell, fall of the motion:

$$\phi_{rise,comb} + \phi_{dwell,comb} + \phi_{fall,comb} = \frac{230^\circ}{2} = 115^\circ$$

$$\Rightarrow \begin{cases} \phi_{rise,comb} & = 55^\circ \\ \phi_{dwell,comb} & = 5^\circ \\ \phi_{fall,comb} & = 55^\circ \end{cases}$$

Knowing the angles of each interval and the form of acceleration (modified

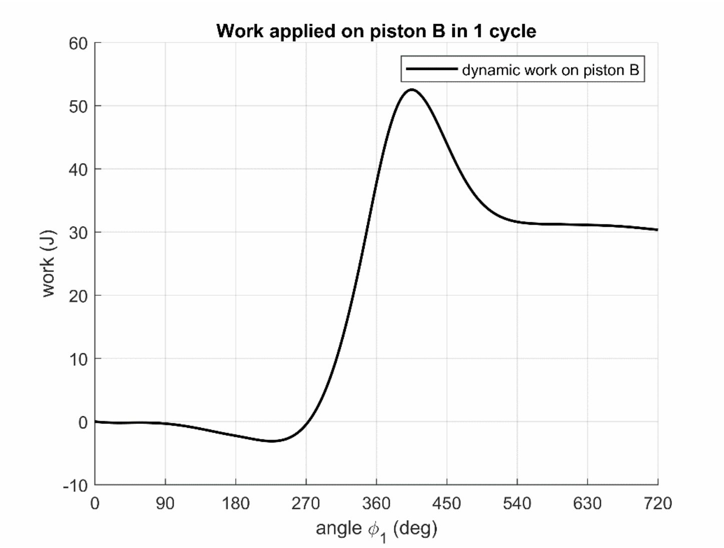


Figure 2.13: Dynamic work of the system in 1 cycle

trapezoidal), we can integrate to find velocity and displacement of the cam follower. For vibration safety, jerk is included using derivative with respect to $\phi(t)$.

For flat faced follower, the pressure angle is constant. This leads to the condition of convex cam profile $R_0 + Y + \frac{dY^2}{d\phi} > 0$ or:

$$R_0 > h_{max} \tag{2.31}$$

where h_{max} is the minimum value of the sum $Y + \frac{dY^2}{d\phi}$.

From the figure, $h_{max} = 9.096$ mm. Then, arbitrarily choose $R_0 = 12$ mm to satisfy the condition (2.31).

From the pressure angle $\alpha_2 = 6°$, we use superposition to create an equivalent cam profile, namely $Y = Y \cos \alpha_2$. Then, apply the following formula to find cam profile:

$$\begin{cases} u &= (R_0 + Y) \sin \phi + Y' \cos \phi \\ v &= (R_0 + Y) \cos \phi - Y' \sin \phi \end{cases} \tag{2.32}$$

where $\phi(t) = \widehat{xOA}$; u, v are the position of cam along x, y-axes respectively; Y, Y' are the displacement and velocity of the cam follower as shown in figure 2.24.

Using MATLAB®, we plot the cam profile numerically. Applying this process to the compression end, we also plot the cam profile in figure 2.27:

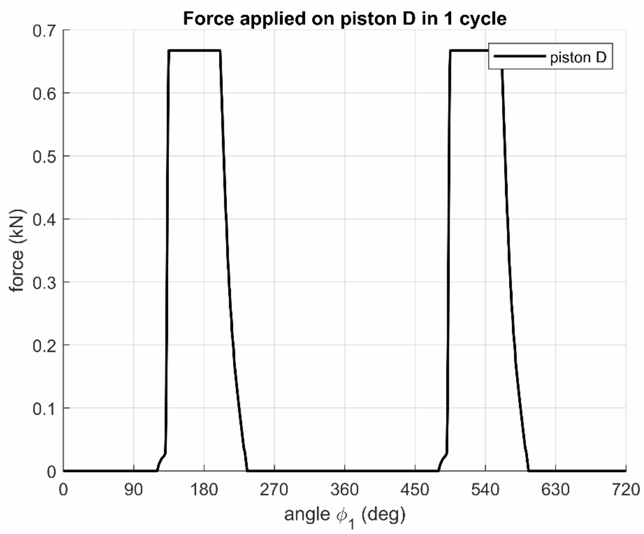


Figure 2.14: Force applied on piston 3 corresponding to angle of crankshaft 1

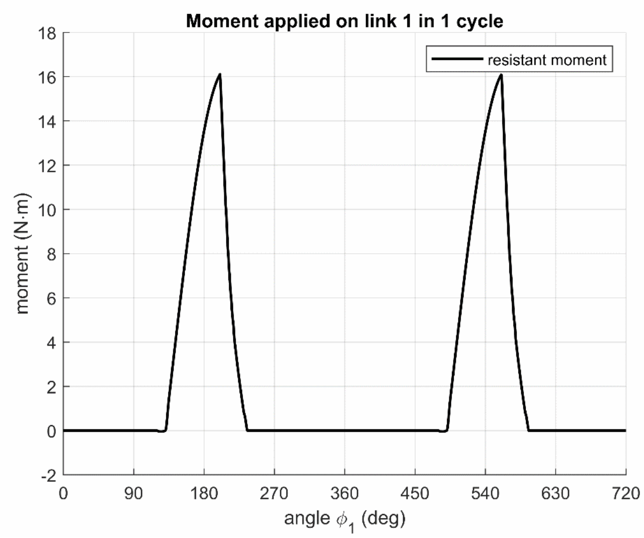


Figure 2.15: Equivalent resistant moment applied on crankshaft 1

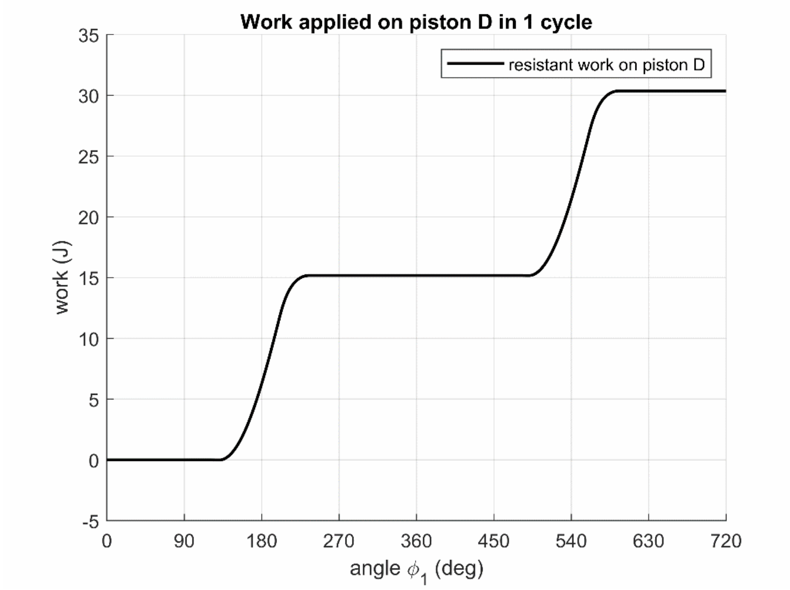


Figure 2.16: Resistant work of the system in 1 cycle

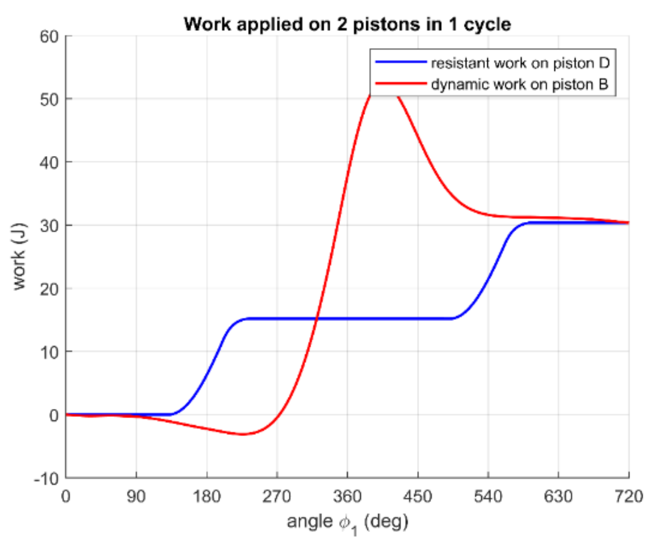


Figure 2.17: Resistant and dynamic moment of the system in 1 cycle

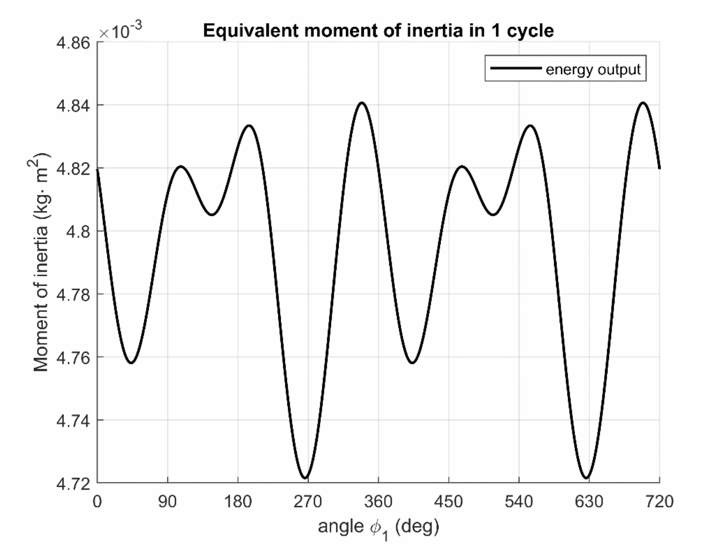


Figure 2.18: Equivalent moment of inertia of the system

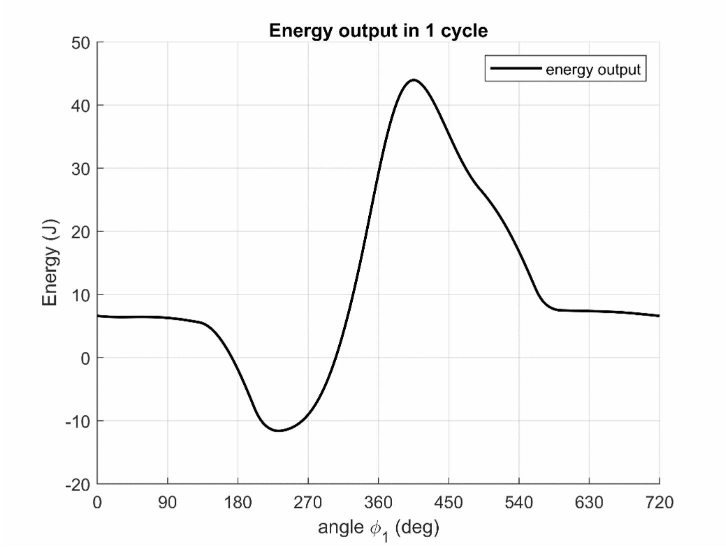


Figure 2.19: Energy output of the system in 1 cycle

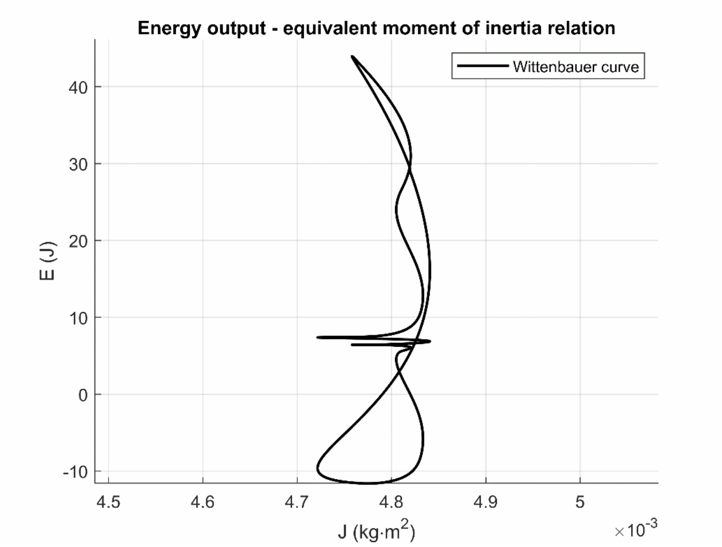


Figure 2.20: Equivalent moment of inertia - energy output relations

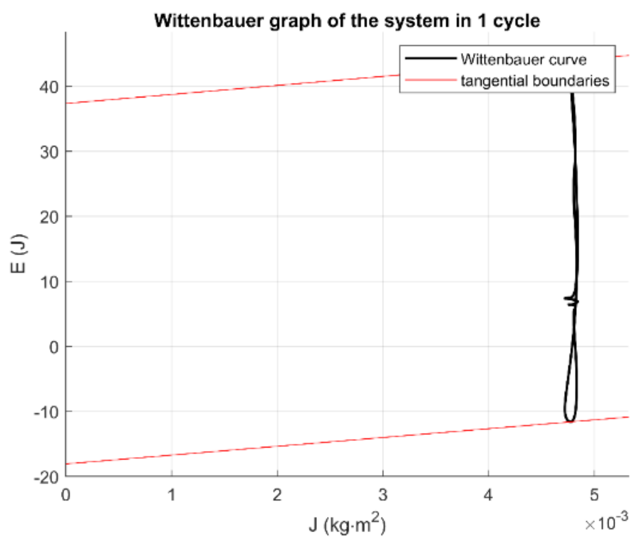


Figure 2.21: Wittenbauer curve with tangent boundaries

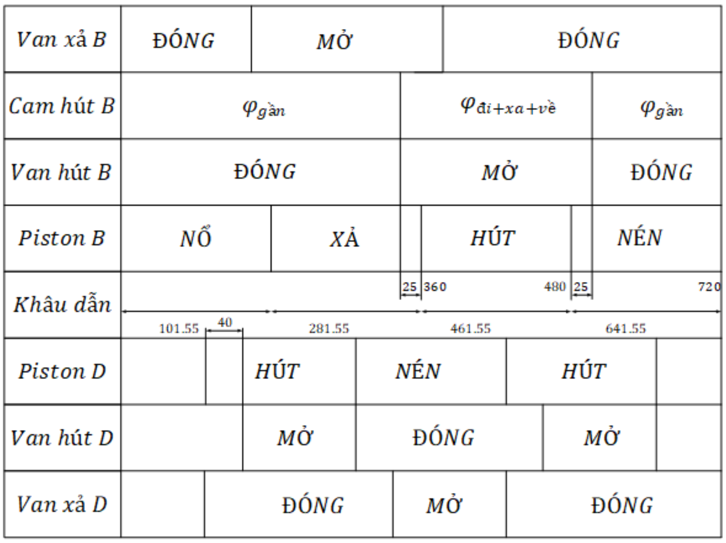


Figure 2.22: Timing chart of the system

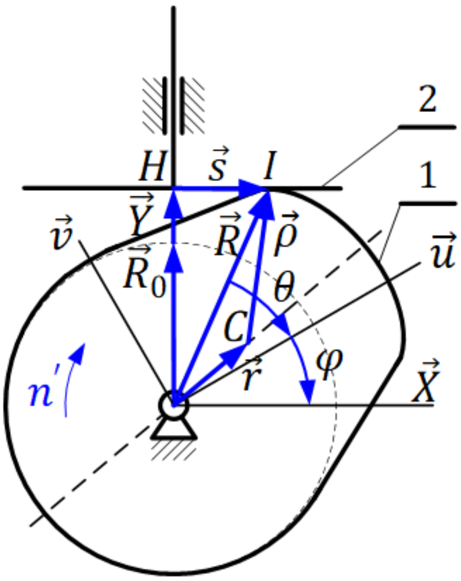


Figure 2.23: Position vectors of the cam

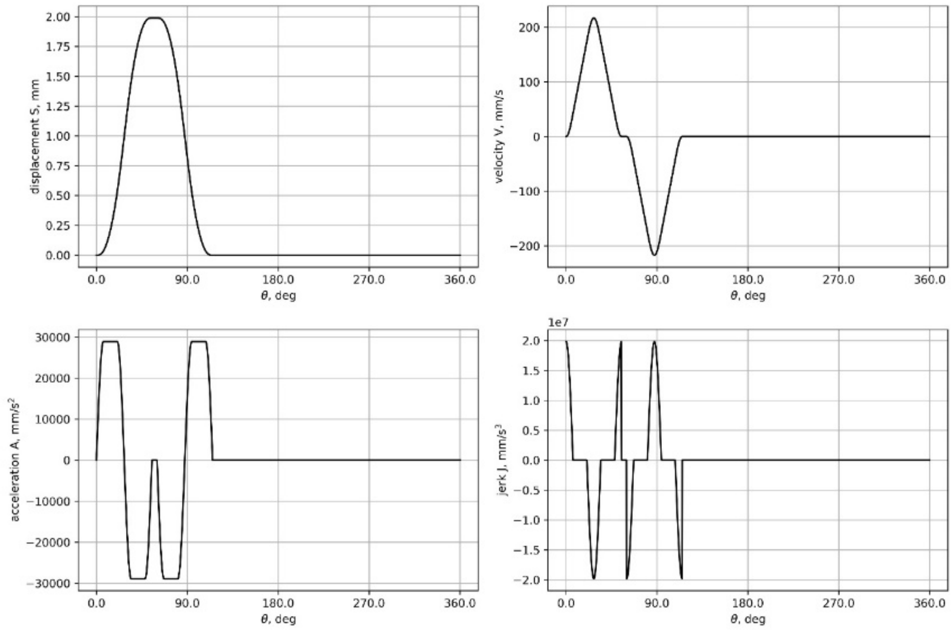


Figure 2.24: Displacement, velocity, acceleration and jerk of the cam follower

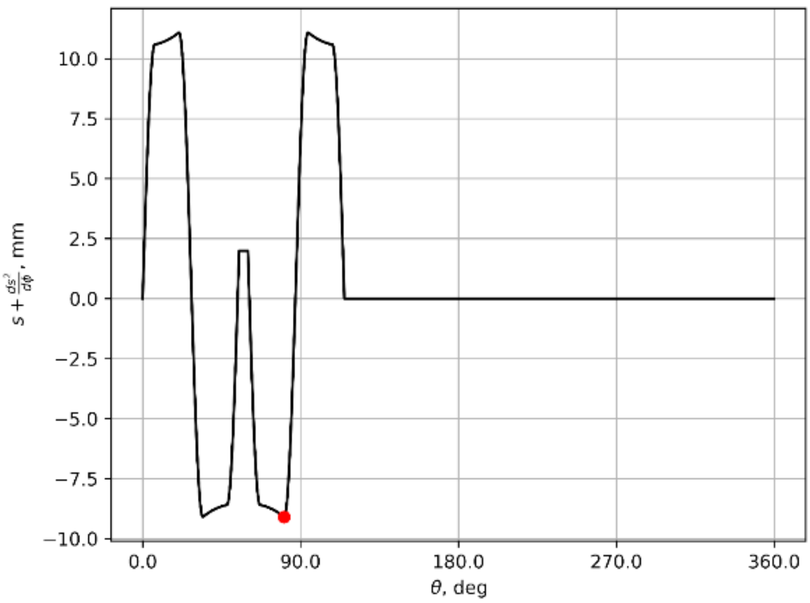


Figure 2.25: Displacement - acceleration diagram of the cam

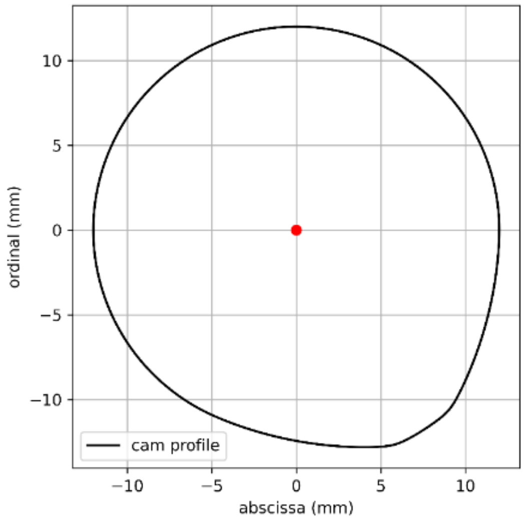


Figure 2.26: Cam profile of the combustion end

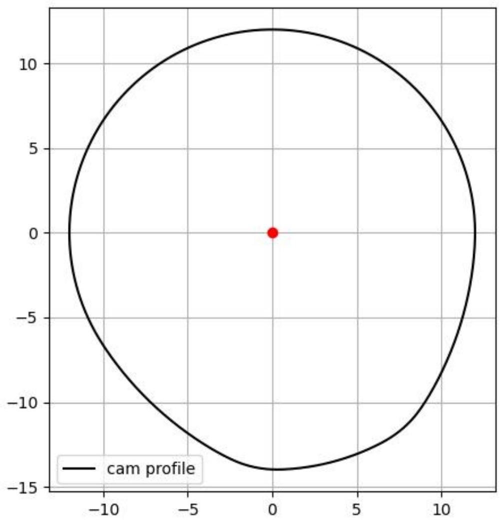


Figure 2.27: Cam profile of the compression end

Chapter 3

Summary and Conclusions

Last chapter. Provide discussions: what should be done/ has been reached; difficulties in the making of this project. Describe logical relation of the previous chapters. (optional) give advice for a reasonable continuation of the project.

During the internship, I had a chance to get acquainted with a new working environment. I have accumulated experience in industry knowledge as well as experience skills above Marghitu, 2009.

I was trained in problem solving skills in many stages, trying to complete the job in the shortest time, boldly exchanging and sharing knowledge. At the same time, it also fosters a lot of knowledge about graphic software as well as programming skills to solve the problems learned in school but professionally and saves more time Khac Liem, 1984.

Shortcomings: the skill is not mature which still takes a long time to execute; the ability to think and propose design plans is limited due to the lack of practical experience and in-depth knowledge Khac Liem, 1984.

Solution: practice more software skills, add additional specialized knowledge that is lacking.

latex

mathematics

Chezy equation

Glossary name Complicated name (thuật ngữ tiếng Việt)

Appendix A

Appendix

A.1 List of Abbreviations

A.2 List of Tables

Should be limited unless the table is out of context at that part of writing How to reference table:

- abc xyz, Table A.1.
- abc xyz, see Table A.1.
- abc xyz shows the following table. (direct referencing)
- abc xyz shows Table A.1

Pr	Parameters				Pr	Parameters				Pr	Parameters			
	P_3	u_1	u_2	u_3		P_3	u_1	u_2	u_3		P_3	u_1	u_2	u_3
1	2.5	2	2	3	31	6.5	4	2	3	61	12	3	2	4
2	2.5	2	2.24	4	32	7	3	2.24	3	62	12	4	2.24	2
3	2.5	4	2.5	4	33	7	4	2.5	4	63	12.5	3	2.5	3
4	3	2	3.15	3	34	7	3	3.15	4	64	12.5	3	3.15	4
5	3	2	3.55	3	35	7	2	3.55	3	65	12.5	4	3.55	2
6	3	4	4	2	36	7	3	4	4	66	12.5	3	4	4
7	3	2	2	3	37	7.5	4	2	2	67	12.5	4	2	3
8	3	4	2.24	3	38	7.5	4	2.24	3	68	12.5	4	2.24	2
9	3.5	3	2.5	2	39	7.5	4	2.5	3	69	13	4	2.5	4
10	3.5	4	3.15	2	40	8	4	3.15	3	70	13	3	3.15	4
11	3.5	3	3.55	2	41	8	4	3.55	2	71	13	2	3.55	2

	P_3	u_1	u_2	u_3		P_3	u_1	u_2	u_3		P_3	u_1	u_2	u_3
12	3.5	3	4	4	42	8	4	4	3	72	13	3	4	2
13	4	4	2	3	43	8	2	2	3	73	13	4	2	3
14	4	3	2.24	3	44	8.5	2	2.24	2	74	13	3	2.24	3
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21	4.5	3	2.5	2	51	10	4	2.5	4	81	14	3	2.5	4
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25	6	3	2	4	55	10.5	2	2	4	85	15	2	2	3
26	6	2	2.24	4	56	10.5	2	2.24	2	86	15	4	2.24	3
27	6	4	2.5	4	57	10.5	2	2.5	2	87	15.5	3	2.5	3
28	6	4	3.15	3	58	11	4	3.15	3	88	15.5	3	3.15	4
29	6	4	3.55	3	59	11	3	3.55	3	89	16	4	3.55	2
30	6.5	2	4	3	60	11.5	2	4	4	90	16	4	4	3

Table A.1: A long table

A.3 List of Figures

Should be limited unless the figure is out of context at that part of writing

A.4 Important Standards

A.5 Bill of Materials

A.6 Drawings (in drawing roll)

Could be included in this appendix section as figures

A.7 Manufacturer Catalogues (in separate folder)

Appendix B

Drawings (if you don’t have drawing rolls)

B.1 Bill of Materials

B.2 Assembly drawing

B.3 Component drawings: 1

B.4 Component drawings: 2

B.5 Component drawings: 3

Glossary

Chezy equation Chezy equation,

$$a = b + c$$

which is commonly used. 33

complicated name (thuật ngữ tiếng Việt) glossary description. 33

glossary name glossary description. 33

latex Is a mark up language specially suited for scientific documents. 33

mathematics Mathematics is what mathematicians do. 33

References

Khac Liem, L. (1984). *Huong dan Thiet ke Mon hoc Nguyen Ly May*. Service Education School HCMC.

Marghitu, D. B. (2009). *Mechanisms and Robots Analysis with MATLAB*. Dordrecht Springer.

Index