



Thermodynamics 7th Report

Ideal Gas Process Investigation

Mariam Mohamed Farag – 221007535 -

Mechanical Engineering Department

College of Engineering and Technology

Arab Academy for Science, Technology, and Maritime Transport

Smart Village Campus

November 19, 2023

Thermodynamics I (ME232)

Dr. Micheal A. William

Eng. Ziad Aboulseoud

Abstract

Internal combustion engines are used to produce mechanical work. This happens during a cycle based on the principle of the Otto, which consists of four strokes. This research sheds light on one single stroke out of the 4-strokes; the power stroke, where the mechanical work is produced as this report focuses more on the maximum power that can be obtained from the engine. This was done by questioning two Thoughts. One, [how various thermodynamics processes can affect the work output?](#) Two, [what can be the effect of the polytropic index value, \$n\$, on the work output using the parametric analysis technique?](#) The conclusions drawn are based on excel calculations and graph demonstrations of those result. Another thing that this report discusses are the limitations from using the isobaric or isothermal process on a real engine and the recommendations on which process and value of polytropic index we could use to deliver the max power instead.

Table of Contents

Abstract.....	2
Table of Contents.....	3
List of Figures	4
List of Tables	5
1 Introduction	6
2 Methodology.....	7
3 Results and discussion	7
4 Conclusions and recommendations.....	10
5 Acknowledgements.....	11
6 References	11

List of Figures

Figure 1	6
Figure 2	8
Figure 3	8
Figure 4	10

List of Tables

Table 1..... 7

Table 2..... 7

Table 3..... 9

1 Introduction

Internal Combustion Engines (ICE) are engines used to turn chemical energy in a fuel to useful mechanical work, by deliberately managing small explosions. This is done in a 4 stroke cycle , which is based on the principle of the Otto cycle. Those 4 strokes are **Intake**, **Compression**, **Power** and **Exhaust stroke**.

The **Intake stroke** or the suction stroke happens when the piston is moved downward by rotation the crankshaft, thus creating space for the fuel and some air to enter the cylinder through the inlet valve.

In **Compression stroke**, the crankshaft is moved upwards while the valves are ensured to be closed in order to compress the fuel- air mixture.

Then in the **Power / Combustion stroke** a spark is used to ignite the mixtures that causes an explosion pushing the crankshaft down again and generating work. This is where we focus our research on.

Finally comes the **Exhaust stroke** where the combustion is complete and the exhausts from the explosion are expelled by moving the crankshaft up again, forcing the gases outwards through an open outlet valve.

In that way One operation cycle has been completed. The whole process is then repeated again and again so long as the engine is running.

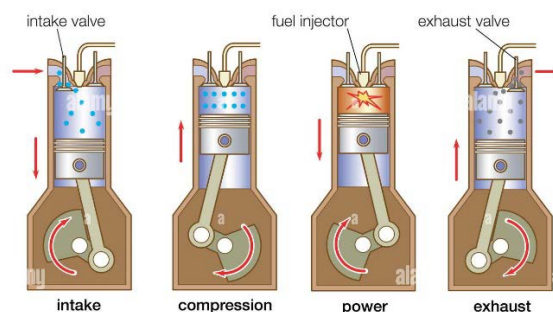


Figure 1

2 Methodology

Methods used in calculations are dependent on the thermodynamics process being researched in the following way:

Table 1

process	Pressure in state 2	Temperature in state 2	Work Done
Isochoric	-	$\frac{P_2}{P_1} = \frac{T_2}{T_1}$	$W=0$ due to lack of change in V
Isobaric	-	$\frac{V_2}{V_1} = \frac{T_2}{T_1}$	$W=P\Delta V$ $W = P(V_2 - V_1)$
Isothermal	$\frac{V_2}{V_1} = \frac{P_1}{P_2}$	-	$W = P_1 V_1 \ln \frac{V_2}{V_1}$
Polytropic	$P_2 = P_1 \frac{V_1^\gamma}{V_2}$	$T_2 = T_1 \frac{V_1^{\gamma-1}}{V_2}$	$W = \frac{P_2 V_2 - P_1 V_1}{\gamma - 1}$
Adiabatic	$P_2 = P_1 \frac{V_1^n}{V_2}$	$T_2 = T_1 \frac{V_1^{n-1}}{V_2}$	$W = \frac{P_2 V_2 - P_1 V_1}{n - 1}$

3 Results and discussion

Task 1; how various thermodynamics processes can affect the work output.

Table 2

process	pv ^x	state#1			state#2			Work Done KJ
		P1	T1	V1	P2	T2	V2	
		Kpa	K	m ³	Kpa	K	m ³	
isochoric	∞	75000	1800	0.000058	400.00	9.60	0.000058	0.00
isobaric	0	75000	1800	0.000058	75000.00	15206.90	0.00049	32.40
isothermal	1	75000	1800	0.000058	8877.55	1800.00	0.00049	9.28
adiabatic	1.4	75000	1800	0.000058	3780.82	766.59	0.00049	6.24
polytropic	1.25	75000	1800	0.000058	5207.16	1055.80	0.00049	7.19

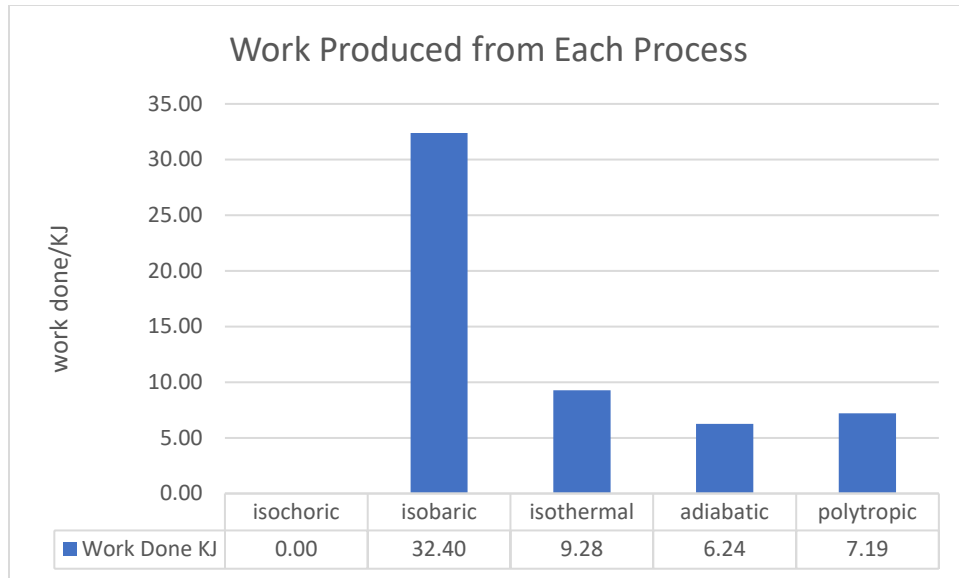


Figure 2

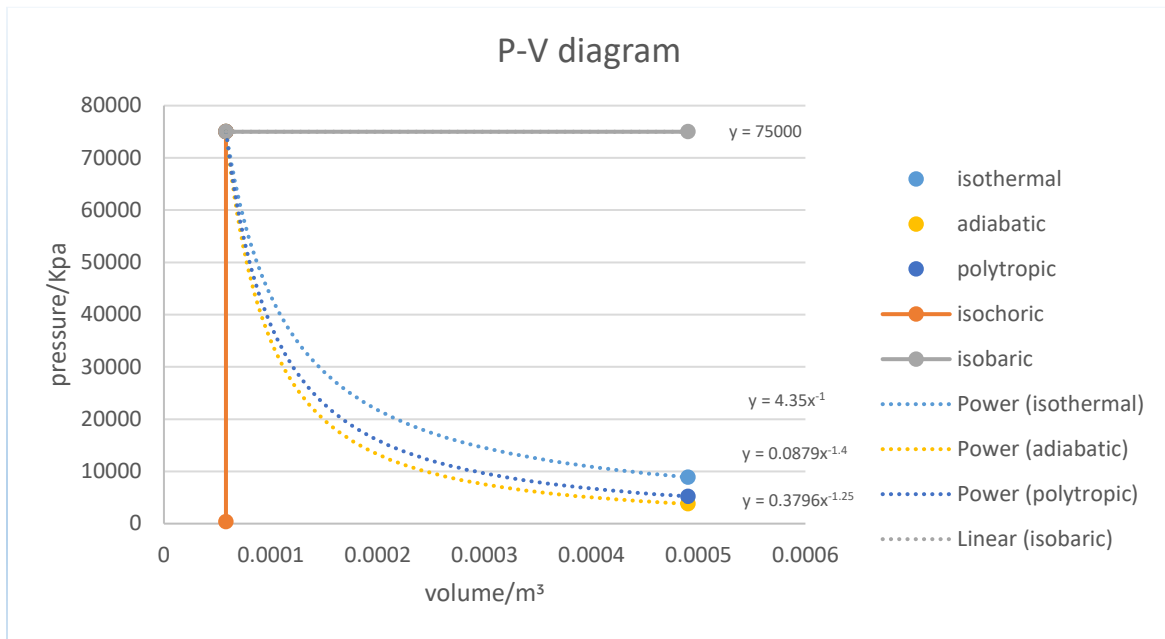


Figure 3

We can conclude from task 1 by looking at figure 2 that the **isobaric** process produces the most work of **32.40 KJ** and that can be understood clearly if we look at figure 3 as the area under the PV

diagram represent the work obtained. The process that produces the second most amount of work is **isothermal**; 9.28KJ , followed by the **polytropic process**; 7.19KJ , followed by **adiabatic**; 6.24. In the last place is the **isochoric** process, which produces no work ($W=0$) due to the lack of any change in V, thus creating no area under the PV diagram.

Task 2; what can be the effect of the polytropic index value, n, on the work output.

Table 3

process	PV^x	state#1			state#2		Work Done KJ
	polytropic Index	P1	T1	V1	P2	V2	
	x=	Kpa	K	m ³	Kpa	m ³	
isothermal	1	75000	1800	0.000058	8877.55	0.00049	9.28
polytropic	1.025	75000	1800	0.000058	8416.35	0.00049	9.04
	1.05	75000	1800	0.000058	7979.12	0.00049	8.80
	1.075	75000	1800	0.000058	7564.59	0.00049	8.58
	1.1	75000	1800	0.000058	7171.61	0.00049	8.36
	1.125	75000	1800	0.000058	6799.03	0.00049	8.15
	1.15	75000	1800	0.000058	6445.82	0.00049	7.94
	1.175	75000	1800	0.000058	6110.95	0.00049	7.75
	1.2	75000	1800	0.000058	5793.48	0.00049	7.56
	1.225	75000	1800	0.000058	5492.50	0.00049	7.37
	1.25	75000	1800	0.000058	5207.16	0.00049	7.19
	1.275	75000	1800	0.000058	4936.65	0.00049	7.02
	1.3	75000	1800	0.000058	4680.18	0.00049	6.86
	1.325	75000	1800	0.000058	4437.04	0.00049	6.69
	1.35	75000	1800	0.000058	4206.53	0.00049	6.54
	1.375	75000	1800	0.000058	3988.00	0.00049	6.39
adiabatic	1.4	75000	1800	0.000058	3780.82	0.00049	6.24

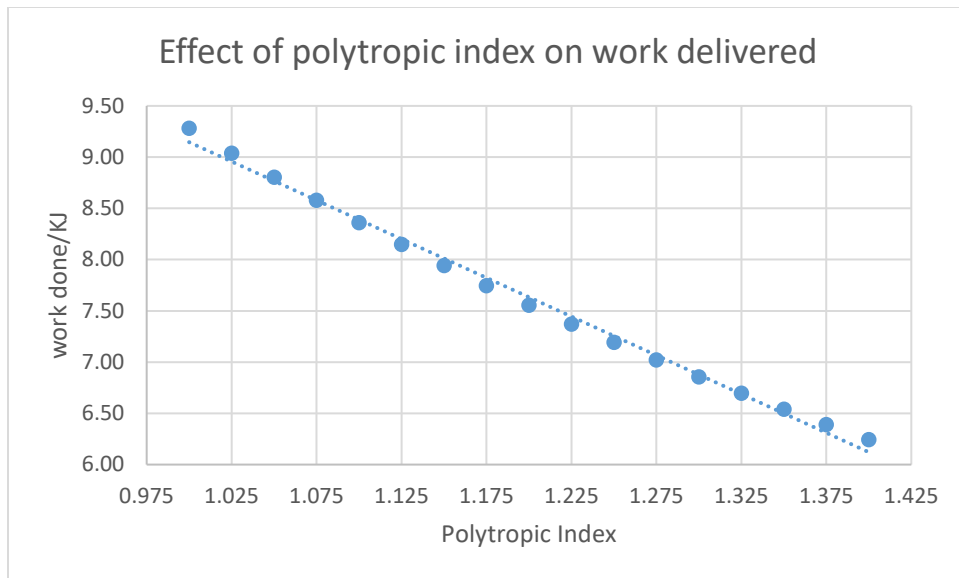


Figure 4

In the second task we can observe from table 3 that as the [polytropic index increases the work produced decreases](#) (Inverse relation) with the highest work of 9.04KJ at polytropic index 1.025 and the lowest work of 6.39KJ at polytropic index 1.375. Furthermore, figure 4 shows that it happens almost in a linear form.

4 Conclusions and recommendations

From such observations we can also come to terms that theoretically the Isobaric followed by the Isothermal process would be the best cycles for use ; however, that is not the case in real life as those two processes have limitations in real life applications.

For the [Isobaric](#), Limitations could be things like the require of a moving boundary to keep that pressure constant else the pressure will change. Another problem would be that its efficiency is dependent on the change if volume, which could be negative or of an insignificant change. Lastly, it could cause metabolic damage to tissues due to not bringing metabolism to a complete halt, if biological tissues were to be stored under constant pressure.

On the other side of the harbor, the idea of an **isothermal** process is impractical in real life for several reasons, one of them being that the process of maintaining a constant temperature is both extremely slow and challenging. Not to mention that a reservoir is needed so heat can be added or removed in order to keep that temperature the same during the exchange.

Thus the actual solution that should be used in real life applications, is to ensure that the work output is at its optimum by using a **polytropic process** where the polytropic index is as close as it can be to the isothermal index value ($\gamma=1$).

5 Acknowledgements

This work was fully conducted by the author with no external aid, yet a special thanks to Dr. Micheal A. William and Eng. Ziad Abouleoud for their insight and fruitful material that gave me a helping hand to complete this report.

6 References

- [1] Bowie, D. (2023, July 18). *What is an internal combustion engine?* HowStuffWorks. <https://science.howstuffworks.com/innovation/inventions/internal-combustion-engine.htm#pt1>
- [2] Admin. (2022, December 9). *Four Stroke Engine – Parts, Operation & Comparison*. BYJUS. <https://byjus.com/physics/four-stroke-engine/>
- [3] Nida, S., Moses, J., & Anandharamakrishnan, C. (2021). Isochoric freezing and its emerging applications in food preservation. *Food Engineering Reviews*, 13(4), 812–821. <https://doi.org/10.1007/s12393-021-09284-x>
- [4] Testbook. (2023, June 29). *Isothermal Process: Definition, Work done, Condition, Application*. Testbook. <https://testbook.com/physics/isothermal-process>
- [5] *Maximum work done in isothermal or isobaric process?* (n.d.). Physics Stack Exchange. <https://physics.stackexchange.com/questions/478362/maximum-work-done-in-isothermal-or-isobaric-process>