

Analysis of YM-0185P Compressor with 1 HP Motor on Basic Phenomenon Engine Laboratory

Agung Sudrajad, Ipick Setiawan

Abstract - The basic principle of the compressor is basically a tool or machine that is used to compress an air and increase the pressure. The previous compressor is still works, but there is some defect in the compressor. Because the compressor is no longer representative, it is necessary to repair and upgrade the installation of the reciprocating compressor. The modification of reciprocating compressor is designed to have movable frame with 1 HP motor and 2-cylinder compressor. This tool was tested with several parameters such as pressure, velocity, temperature and turbulence analysis with Fluent. From the compressor performance analysis, the maximum air delivery with 50 Hz frequency is 151.99 Liter/min, maximum pressure 8 kg/cm², maximum temperature 42°C.

Keywords – reciprocating, compressor, fluent, performance, pressure, velocity, power

1 INTRODUCTION

This research is aim to build and analysis of performance compressor equipment in student's engine laboratory. The main idea to build this compressor is to make a practical device with easier operational procedure and higher data accuracy to find out the problem might have occurred on the process of making the compressor, we also do some fluid simulation to help students conceive the fluid characters.

2 COMPRESSOR

Compressor is a machine that compressing air from low pressure to higher pressure using piston or rotor. Figure 1 showing the fluid placed on a cylinder with "A" the areal of piston (m²) and "L" the length of the stroke (m) being compressed by "F" force (Newton) and we can calculate the requirement force to compress the fluids with equation:

$$P = \frac{F}{A} \quad (1)$$

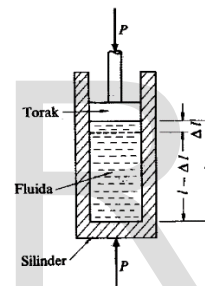


Figure 1. Compressed Fluid

A compressor basically designed to compress air using a motor, either with rotating or reciprocating motion. On reciprocating compressor the cycle divided by 2 step:

A. Suction

The air entering the cylinder while the piston moving from the top to the bottom dead end and the suction valve automatically open because the pressure inside the cylinder is lower than ambient pressure.

B. Discharge

The air being compressed by the piston while it's moving from the bottom to the top dead end of the cylinder. The discharge valve automatically open when the pressure inside the cylinder is higher than the storage tank.

3 BOYLE'S LAW

In the case of a gas or air temperature keep being steady, the volume shrinkage will increase the pressure. If the volume become 0.5 times before the shrinkage, the pressure will increase 2 times, and if the volume 0.25 times before the shrinkage the pressure will increase 4 times. So if the gas is compressed or expanded on a steady temperature the pressure will be increased or decreased depend on the volume changes.

$$P_1V_1 = P_2V_2 = \text{Constant} \quad (2)$$

$$P.V = m \cdot R_{\text{Specific}} \cdot T \quad (3)$$

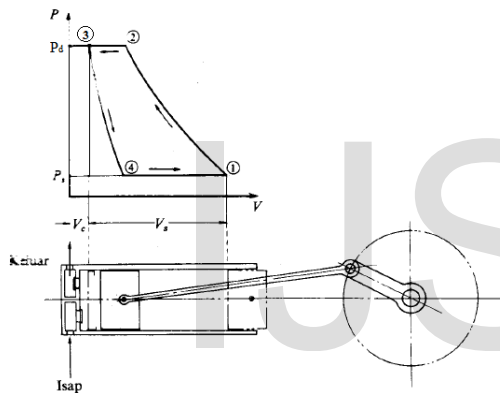


Figure 2. P-V Diagram on a Compressor

The figure 2 show the compression process of start with point 1. The piston move to the left and the air is being compressed to point 2 on P-V diagram, in this point the pressure inside the cylinder reach "Pd" which is a compressed air that have bigger pressure than the transfer tube and then the discharge valve will automatically open and if the piston keep moving to the top dead end on point 3, the air will be pushed to the transfer tube before going to the storage tank. But, there is a gap between a piston and the cylinder head so not all of the compressed air can be moved, this gap called "Vc" volume clearance. This gap is used to avoid the piston knock the cylinder head, after the piston reach top dead end the

crank will pull the piston back to the bottom and start the suction process, but the suction valve won't be opened before the compressed air "Pd" being expanded to "Ps" which is equal with ambient pressure and the piston keep moving to the bottom dead end and the pressure inside the cylinder is lower than ambient pressure. The valve usually used in reciprocating compressor is a reed valve because it can operate automatically just based by temperature difference. We have to know that the expansion process on point 3-4 is not a suction process because it is just expanding the "Vc" from "Pd" to "Ps". The length ratio between point 4-1 and point 3-1 is called volumetric efficiency [Sularso and Haruo Tahara. 2000].

4 COMPRESSION PROCESS

1. Isothermal Compression

If a gas being compressed, there is a mechanical energy given to the gas. This energy produce heat which affecting the temperature of the gas, the higher the pressure the hotter the temperature. But if the compressor have cooling system to release the heat, the temperature might be steady. This process called isothermal compression (steady temperature) the correlation between "P" pressure and "V" volume are constant.

$$P_1V_1 = P_2V_2 \quad (4)$$

2. Adiabatic Compression

Adiabatic is a compression process without heat transfer from the gas. This process actually can not be done perfectly because the isolation inside the cylinder was never be perfect, the constanta for adiabatic process is "k" with the value for air is 1.4.

$$P.V_k = \text{constant} \quad (5)$$

3. Polytropic Compression

The real compression process on a compressor is not an isothermal and also not an adiabatic process, the real compression process have a condition between isothermal and adiabatic, this process is called

polytropic. The correlation between "P" and "v" can be calculated by this equation.

$$P.V^n = \text{constant} \quad (6)$$

With "n" polytropic index between 1 (isothermal process) and "k" (adiabatic process). So polytropic index is $1 < n < k$. The polytropic index for a compressor usually between 1.25 ~ 1.4.

5 DESIGN METHODOLOGY

A. Table

The table was designed to be tough to reduce compressor vibration and also have high mobility to accommodate laboratory needs, this table also built with display board. The most important factor to build this table is the material selection, because the right material can build this table with more efficient and also have proper ability (strong, cheap and low maintenance) we need about 25 meters of L beam steel and 2 sheets of steel plate with 1200 mm length and 710 mm width to make this table, the material we've been used is ASTM A-36 steel. The specification of table is:

Length : 1200mm
Width : 710mm
Height : 1700mm

B. Motor

The motor that we used for this test must be strong enough to accommodate compressor requirement's power and torque to maintain the rotation keep running smoothly. So we decide to use Hitachi Motor because this motor have a good quality with affordable price. Motor specification:

Model / Type	: TFO
Phase	: 3
Voltage	: 220 V - 380 V
Current	: 3.3 A - 1.9 A
Speed	: 1420 rpm / min
Output/Pole	: 1 HP / 4 Pole

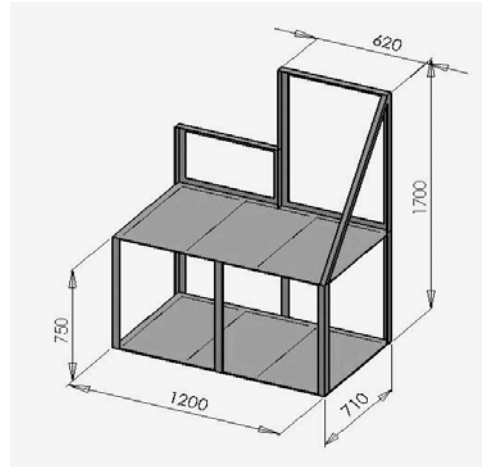


Figure 3. Table Design

C. Compressor

The previous model of the compressor is single cylinder compressor with 0.5 HP motor with low air delivery. So we are upgraded the compressor with dual cylinder and 1 HP motor that can delivering air up to 172 Liters per minute.

Model / Type	: YM - 0185P
No. of cylinder	: 2 cylinder
Piston Diameter	: 65 mm
Stroke	: 51 mm
Air Delivery	: 172 L / min
Pressure	: 8 kg / cm ²
Power	: 1 HP / 0.73 kW
Weight	: 58 Kgs

D. Variable Frequency Drive (VFD)

Variable frequency drive is an electrical tool to control the electricity frequency, this tool can manipulate input frequency to the motor to reduce the speed, this vfd works effective on 3 phase motor, the inverter capacity should be bigger than motor requirements because the motor will consume bigger energy while working on high pressure. The inverter that we used is Shihlin SS2-021-1.5K with specification:

Voltage	: 200 ~ 240 V
Input	: 15.7A 1 Ph/AC 200~240v 50/60 Hz
Output	: 8 A MAX 3 Phase AC 200 - 240v
Power Output	: 1.5 kW
Freq. Range	: 0.1 ~ 50 Hz

6 TEST AND ANALYSIS RESULTS

After the rig has completely built, we do some test to analyze the performance of our compressor we also do computerized fluid dynamic to visualized the fluid characters. We tested the compressor with 3 different frequencies first at full speed at 50 Hz, 40 Hz and 30 Hz. We took several parameters like power consumption (Watt), rotation per Minute of motor and compressor (rpm) and time to increase the pressure every 0.5 kg/cm² (secs). On simulation process we have to make 2D compressor modeling on Gambit 2.2.30 before continue with fluent. Here is the data:

Presure (kg/cm ²)	Watt	RPM		ΔT (seconds)
		Motor	Comp	
0.5	352	1160	458	9.11
1	418	1154	454	17.36
1.5	484	1140	449	26.25
2	550	1128	444	34.45
2.5	616	1117	441	42.76
3	682	1108	436	51.18
3.5	726	1099	432	59.47
4	792	1088	423	69.03
4.5	836	1070	420	77.59
5	880	1062	417	86.25
5.5	946	1033	406	95.99
6	990	1028	405	107.43
6.5	1034	1019	399	119.46
7	1056	1004	392	129.99
7.5	1144	998	385	143.71
8	1188	971	376	158.64

Table 1. Frequency of 50 Hz

Pressure (kg/cm ²)	Watt	RPM		ΔT (seconds)
		Motor	Comp	
0.5	264	1467	579	7.21
1	396	1440	576	13.87
1.5	462	1437	572	20.45
2	506	1425	567	27.19
2.5	572	1411	564	34.04
3	616	1411	560	40.74
3.5	616	1397	558	47.28
4	660	1380	552	54.16
4.5	726	1377	550	61.27
5	748	1372	547	68.51
5.5	770	1362	544	76.14
6	814	1350	540	83.64
6.5	858	1345	537	91.52
7	880	1340	532	99.76
7.5	946	1330	530	108.11
8	990	1332	525	116.57

Table 3. Frequency of 30 Hz

Presure (kg/cm ²)	Watt	RPM		ΔT (seconds)
		Motor	Comp	
0.5	352	980	380	10.3
1	418	859	339	21.59
1.5	462	866	336	32.82
2	550	831	328	44.36
2.5	616	824	323	55.81
3	704	809	317	67.53
3.5	770	784	312	80.68
4	880	756	301	94.43
4.5	990	741	288	110.98
5	1078	789	294	125.87
5.5	1320	694	264	144.07
6	1540	594	222	166.14
6.5	1980	403	148	200.82
7	NA	NA	NA	NA
7.5	NA	NA	NA	NA
8	NA	NA	NA	NA

Table 2. Frequency of 40 Hz

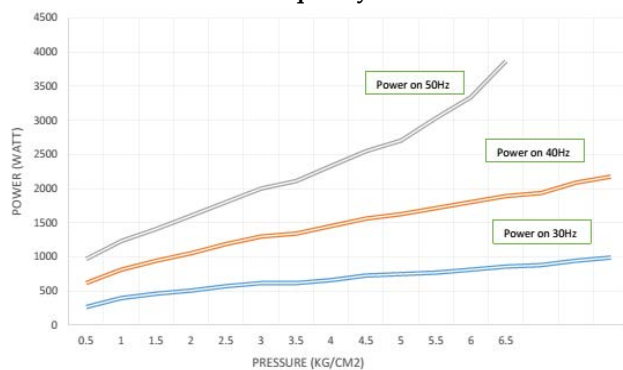


Figure 4. Graphic of Power Consumption

From Fig.4 we can see the power consumption is getting higher on higher pressure, the grey line is

for 30 Hz frequency the maximum pressure is 6.5 kg/cm² before the motor trips. Orange line for 40 Hz and blue line for 50 Hz the maximum pressure is 8 kg/cm².

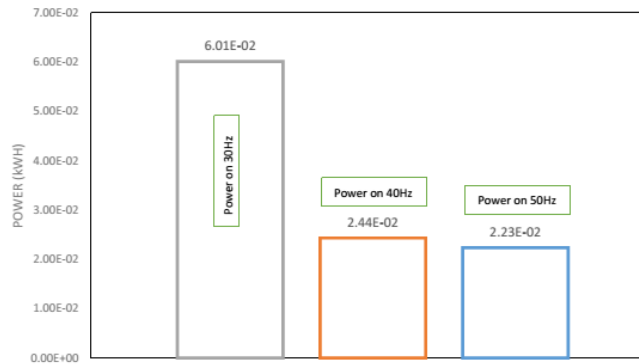


Figure 5. Graphic of Total Power Consumption

Total power consumption on 30 Hz is 6.01×10^{-2} kWh, 40 Hz 2.44×10^{-2} kWh and 50 Hz 2.23×10^{-2} kWh, Fig. 5 shows lower frequency consumes more power.

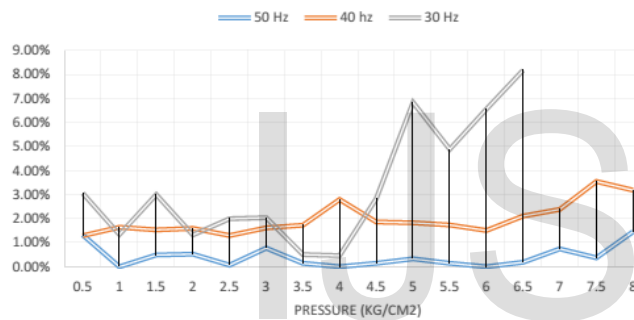


Figure 6. Graphic of Belt Slip

Belt slip on compressor's pulley on 30 Hz is bigger than belt slip on 40 Hz and 50 Hz, this is caused by the tension of the belt, vibration of compressor and impact force from low speed compression process. Maximum slip of the belt occurs on 30 Hz with 8% belt slip.

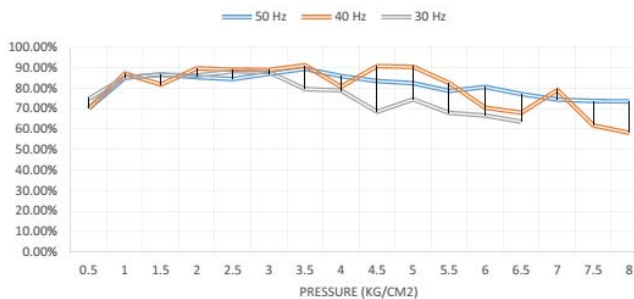


Figure 7. Graphic of Volumetric Efficiency

Fig. 7 Shows the average volumetric efficiency of this compressor is about 85 – 87%.

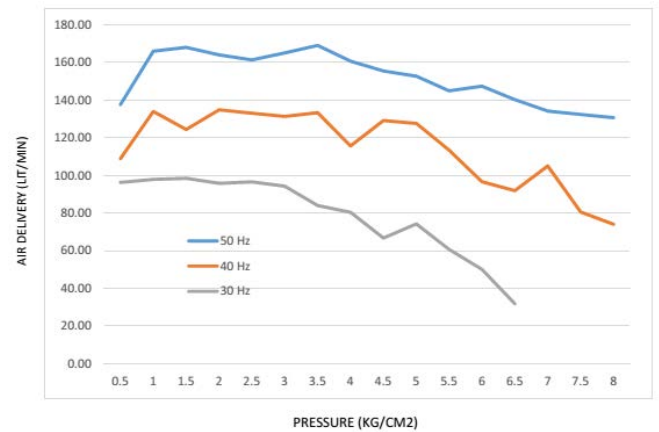


Figure 8. Graphic of Air Delivery

Air delivery of the compressor is decreasing on higher pressure, air delivery of the compressor is affected by the speed of the motor and volumetric efficiency of compressor.

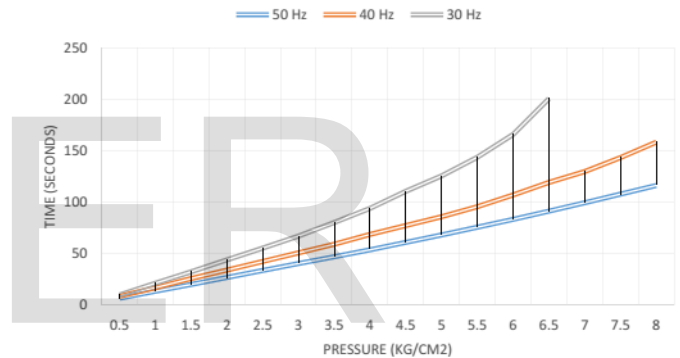


Figure 9. Graphic of Time

The Fig. 9. shows the compressor need longer time to fill the tank if the frequency is reduced.

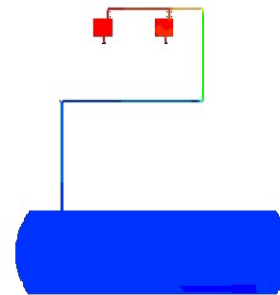


Figure 10. Graphic of Pressure Simulation on Fluent

Fig. 10 shows the pressure of compressed air on the cylinder, the red spot indicates maximum pressure, and blue is the lowest. The red spot will spread into tubing and tank during filling process.

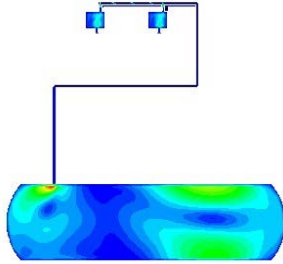


Figure 11. Graphic of Velocity Simulation

The Fig.11 shows velocity inside the compressor, maximum velocity of the compressor occurs on tank's inlet, this phenomenon caused by the differences of pressure.

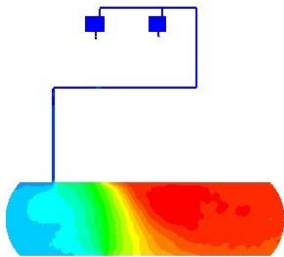


Figure 12. Graphic Temperature Simulation

Actually the temperature of the cylinder is much hotter than the tank, because there is compression process and friction inside the cylinder.

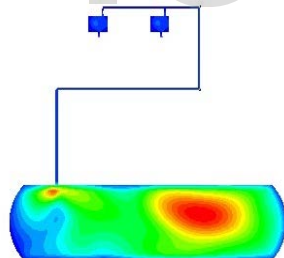


Figure 13. Graphic of Turbulence Simulation

The maximum turbulence occurs in the end corner of the tank; this is caused by the back pressure of flowing air.

7 CONCLUSION

The build and performance experimental of a new student's compressor laboratory was done. The compressor has some improvement such as using variable frequency drive and 3 phase induction motor which make it easier to operate, this compressor also built with digital instrumentation with higher data accuracy. One of the most

influential factor that affect compressor performance is reed valve, voltage input, motor performance and also built quality. On 30 Hz freq. we've got 6.5 kg/cm² Maximum pressure, consumes 6.01 x 10⁻² kWh with air delivery 85.05 Lit/min, 83.31% volumetric efficiency and took about 200.82 secs to fill the tank. On 40 Hz freq. we've got 8 kg/cm² Maximum pressure, consumes 2.44 x 10⁻² kWh with air delivery 122.24 Lit/min, 85.7% volumetric efficiency and took about 158.64 secs to fill the tank. The 50 Hz freq. we've got 8 kg/cm² Maximum pressure, consumes 2.23 x 10⁻² kWh with air delivery 85.05 Lit/min, 86.93% volumetric efficiency and took about 116.57 secs to fill the tank.

Contact

Dr.Eng. Agung Sudrajad
Department of Mechanical Engineering, Faculty of Engineering, University of Sultan Ageng Tirtayasa
Jl. Jendral Sudirman KM. 3 Cilegon Banten 42435
Email: agung@untirta.ac.id

REFERENCES

- [1] Arifin, Masykun., 2010, "Pembuatan Alat Praktikum Perawatan Kompresor Torak Ganda", Surakarta: Fakultas Teknik Universitas Sebelas Maret.
- [2] Keputusan Menteri Tenaga Kerja. 1999. Tenaga Kerja, Nomor : KEP-51/MEN/1999
- [3] Kurowski, P.M., 2012, "Engineering Analysis with SolidWorks Simulation 2012", Dassault Systemes SolidWorks Corp : Schroff Development Corporation.
- [4] Mulyadi, Yadi., 2000, "Analisa Unjuk Kerja Pada Perangkat Praktikum Kompresor Torak Kerja Tunggal", Cilegon : Fakultas Teknik Universitas Sultan Ageng Tirtayasa.
- [5] Nurdiansyah, Andri., 2014, "Analisa Komparasi Kebisingan Mesin Berbahan Bakar Gas Dengan Bahan Bakar Minyak", Cilegon: Fakultas Teknik Universitas Sultan Ageng Tirtayasa.
- [6] Popov, E.P., 1978, "Mechanics of Material". New Jersey : Prentice Hall.
- [7] Saputra, A.J., 2007, "Analisis Kebisingan Peralatan Pabrik Dalam Upaya Peningkatan Penataan Peraturan Keselamatan dan Kesehatan Kerja PT.Pupuk Kaltim", Semarang : Fakultas Ilmu Lingkungan Universitas Diponegoro.
- [8] Sularso, Haruo Tahara., 2000, "Pompa dan Kompresor : Pemilihan, Pemakaian dan Pemeliharaan", Jakarta : PT. Pradnya Paramitha.
- [9] World Health Organization. 1999. Guideliness for Community Noise.
- [10] Zainuri, Muhib., 2008, "Kekuatan Bahan", Yogyakarta : CV Andi Offset