**Pressure Distribution And Flow Past A Cylinder**

**DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING**

by

**NATHAN ROBINSON**

**TEAM B**

**Akshay Patel**

**Josh Gurtatowski**

**Brandon Negri**

**Nathan Robinson**

**Instructor : Samardzic Veljko**

**Teaching Assistants : Rajasekhar Tripuraneni**

**Subhajit Rakshit**

**ME405, MECHANICAL LAB-II**

**Summer 2016**



***written with passion***



**Table of Contents**

Abstract 4

Introduction 5

Theoretical principals 6

Experimental methodology 7

Analysis 10-12

Results 13-17

Conclusion 18

Nomenclature 19

References 20

**Table of Figures, Tables and Charts**

Photos taken by Josh Gurtatowski.

Fig 1; Pump over Oil Tank 7

Fig 2; Suction Gauge 7

Fig 3; Electric Motor Dial 8

Fig 4; Discharge Gauge 8

Fig 5; Thermometer 9

Fig 6; Gallon Counter 9

Table 1; Data and Conversions 1250 RPM 10

Table 2; Data and Conversions 1550 RPM 11

Table 3; Data and Conversions 1550 RPM 11

Table 4; Data and Conversions 1250 RPM 11

Table 5; Data and Conversions 1550 RPM 12

Table 6; Data and Conversions 1850 RPM 12

Chart 1; 1250 RPM Flow Rate vs Pump Head 13

Chart 2; 1550 RPM Flow Rate vs Pump Head 13

Chart 3; 1850 RPM Flow Rate vs Pump Head 14

Chart 4; 1250 RPM (Eb, Ef, Eh) vs Pump Head 14

Chart 5; 1550 RPM (Eb, Ef, Eh) vs Pump Head 15

Chart 6; 1850 RPM (Eb, Ef, Eh) vs Pump Head 15

Chart 7; Power Efficiency vs Pump Head for all speeds 16

Chart 8; Volumetric Efficiency vs Pump Head for all speeds 16

Chart 9; Flow Rate vs NPSH for all speeds 17

**Abstract**

For this experiment the objective was to investigate the pressure distribution, drag and separation point for the flow past a cylinder, that was set up with gauges and was used to measure the impact force of the air flowing through the wind tunnel, the gauges were visible throughout the transparent cylinder and were placed in a circulating manner across 90 degree a section of the cylinder in intervals of 5 degrees in between each gauge giving a total of 19 different readings and on top of that the cylinder could also be rotated to any other 360 degree position in order to obtain the pressure readings from all angles although in this experiment only pressure for the first 180 degrees were recorded.

The stagnation and static pressure were also recorded and all the recordings were repeated with 3 different speeds that were 40, 65 and 80mph. The first 0 to 90 degrees were recorded then the cylinder was rotated 90 degrees in order to record the other 90 to 180 degrees.

**Introduction**

As previously mentioned the objective to this experiment is basically to observe the pressure distribution exerted by the air impacting the cylinder at various speeds, speeds which were in this case 40, 65 and 80 mph.

This kind of air flow pressure study can be widely useful in the aeronautical industry were the airplane manufacturing relies heavily on controlling the air that impacts the wings in order to lift and orientate the aircraft. Race car manufacturing is another industry that could find this study useful in terms of creating an aerodynamic chassis in order to reduce the drag and skin force affecting the speed of the car. Parachute manufacturing is also another area that depends on the understanding of air flow pressure distribution.

**Theoretical Principals**

**Hydrodynamic Drag Force**

The total drag force being applied to the cylinder by the flowing air is consists of the force applied by the air impacting the cylinder and the friction of the air on the cylinder wall, the total drag force can be determined with the following formula:

**Analysis**

Calculation for N = 1553

Ps = -14.5 in Hg 🡪 Ps = -49.103 KPa

Pd = 45 psi 🡪 Pd = 310.264 KPa

Q = 1.8 GPM 🡪 Q = 0.000113562 m3

BHP = 342 Watts 🡪 BHP = 0.4586 Hp

Cross-sectional Internal Area of Pipe= 0.000194 m2

Temp = 21 oC

Ɣ = 8632.8 N/m3

Hp = (Pd-Ps)/ Ɣ = (314.264 + 49.103)/8632.8 🡪 Hp = 42.09 m

En = Q ƔHp = (0.000113562)(8632.8)(42.09) 🡪 En = 41.2633 W

HHP = (1.341)(Q)(Pd-Ps)/1000 🡪 HHP = 0.055336 Hp

FHP = BHP – HHP 🡪 FHP = 0.40326 Hp

Ŋ = HHP/BHP X 100 🡪 Ŋ = 12.0663 %

Vs = Q/A 🡪 Vs = 0.5854 m/s

Pv = 1 mmHg 🡪 Pv = 13.33 Pa

NPSH = Ps/Ɣ + Pa/ Ɣ + Pv/ Ɣ + (Vs^2)/2g 🡪 NPSH = 6.0642 m

**Table 1; Data and Conversions 1250 RPM**



**Table 2; Data and Conversions 1550 RPM**



**Table 3; Data and Conversions 1550 RPM**



**Table 4; Data and Conversions 1250 RPM**



**Table 5; Data and Conversions 1550 RPM**



**Table 6; Data and Conversions 1850 RPM**



**Results**

As shown in the charts below, it is seen that the flow rate in the gear pump decreases as the pump head (Hp) increases, ideally the flow rate should stay constant but due to the clearance in the gear pump, some of the oil is returned to the tank, the flow rate of this oil is called slip.

**Chart 1; 1250 RPM Flow Rate vs Pump Head**

**Chart 2; 1550 RPM Flow Rate vs Pump Head**

**Chart 3; 1850 RPM Flow Rate vs Pump Head**

So it is clearly observed a higher Hp value increases the slip and this causes the actual flow rate to decrease somewhat linearly.

**Chart 4; 1250 RPM (Eb, Ef, Eh) vs Pump Head**

**Chart 5; 1550 RPM (Eb, Ef, Eh) vs Pump Head**

**Chart 6; 1850 RPM (Eb, Ef, Eh) vs Pump Head**

Ideally the friction force power would remain constant throughout the pressure variation; the data seems to withhold this statement as in some cases the readings tend randomly upward and downward most likely due to reading error variations.

The hydraulic force, being the difference of Brake force and friction force can be observed to increase along with the higher pump head value this also gives result to the efficiency behavior to increase as well observed in the chart below.

**Chart 7; Power Efficiency vs Pump Head for all speeds**

Besides observing a higher efficiency with higher pump head, it can also be observed that with higher speed comes higher power efficiency as well.

Contrary to the power efficiency, the volumetric efficiency decreases with the increase in Hp and this is shown in the chart below.

**Chart 8; Volumetric Efficiency vs Pump Head for all speeds**

The volumetric efficiency does prove to be higher at the highest speed 1850 RPM although the data shows the intermediate speed 1550 RPM to have the lowest volumetric efficiency this may be due to measurement error.

**Chart 9; Flow Rate vs NPSH for all speeds**

Although somewhat unclear due to the data range it can be observed in this chart clearly that the flow rate decrease as the net positive suction head increases and would eventually come to a critical point where the flowrate would theoretically have a negative value and this is problematic cavitation would occur and this is highly undesirable because it can damage or even destroy the pump itself.

**Conclusions**

The gear pump has shown in this experiment to have viable efficiency at high speeds, more so then low speeds, as well as being able to pump highly viscous fluids such as the oil used in this experiment due to the mechanics of how it pumps the fluid through the meshed gears. And due to the gear pump having increased efficiency at higher speeds, says that this kind of pump could very well be a viable choice in processes where the pump will be left turned on for long periods of time and maintained at a high speed thus not having to cross through the low speeds when restarting the pump and just as in automobile the oil must an elevated temperature in order to avoid damaging the gears when not fully optimized in regards to being completely lubricated which increases the friction force power thus lowering the efficiency as well.

The volumetric efficiency just as the flow rate is shown to decrease as the pump head value increases, this gives way to understand that the more fluid that is being pumped through the gears is going to create a larger clearance between the pump casing and the gears themselves thus giving the effect of some fluid being pumped back into the inlet valve as slip and the more slip there is results in less net flow rate and this results in less hydraulic force power thus giving the pump again an overall lower power efficiency than would ideally had been acquired by having no slip effect.

And as explained in the discussion segment regarding the Net Positive Suction Pressure the gear pump does have a critical limit on how flow rate it can potentially handle at a set suction pressure in order to operate without any failure due to cavitation inside the pump casing.

**Nomenclature**

Q – Flow Rate

RPM – Revolutions Per Second

Vs – Suction Velocity

Ps – Suction Pressure

Pd – Discharge Pressure

⧍P – Pressure Difference

Hp – Pump Head

Eh – Hydraulic Power

Eb – Brake Power

Ef – Friction Force Power

Ŋ – Efficiency

HHP – Hydraulic Horse Power

BHP- Brake Horse Power

NPSH – Net Positive Suction Head

Vol.ƞ - Volumetric Efficiency

**References**

ME 405 Laboratory Manual Harnoy. New Jersey Institute of Technology