[FLUID REPORT]

SpongeBob SquarePants

Team members

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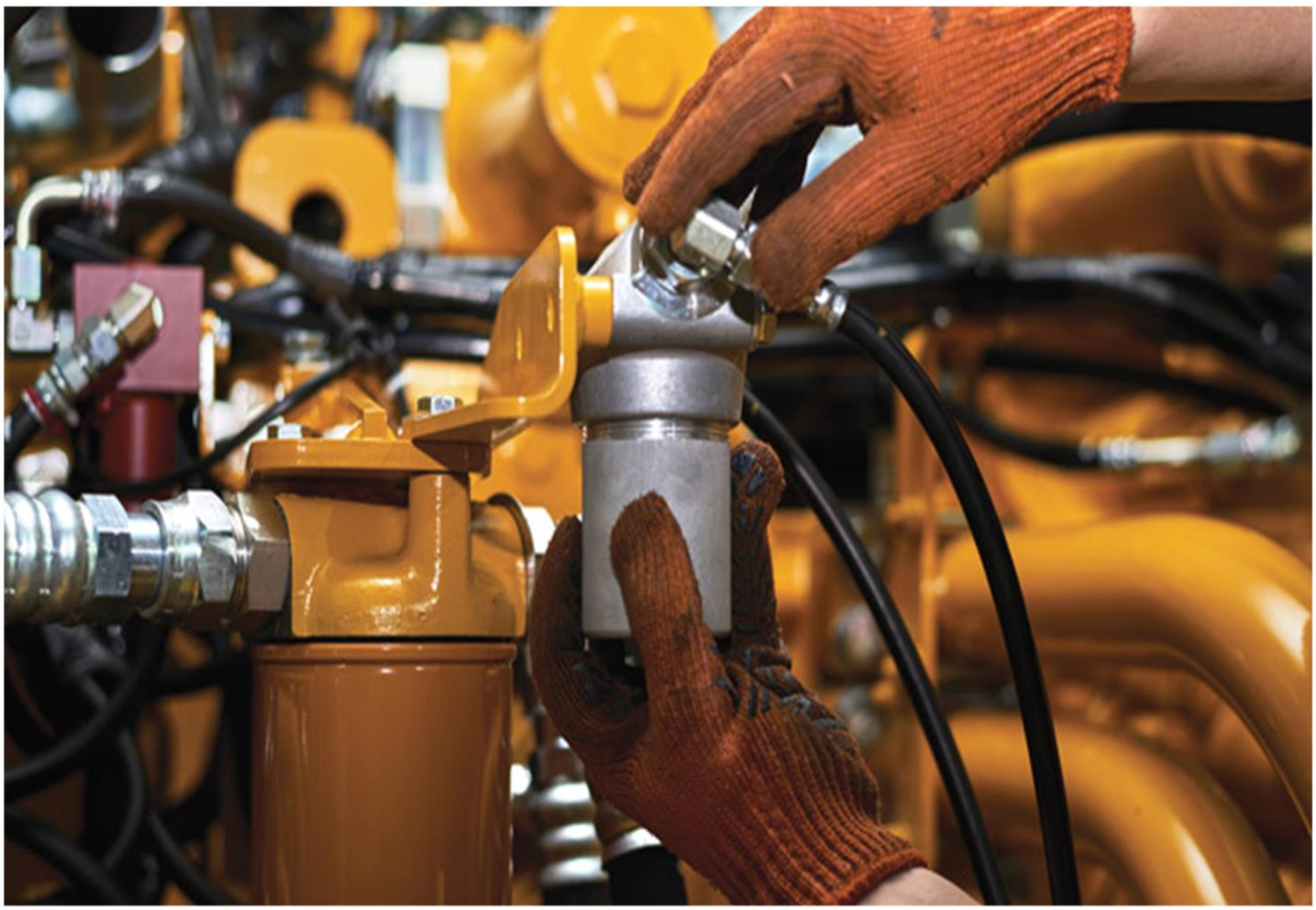
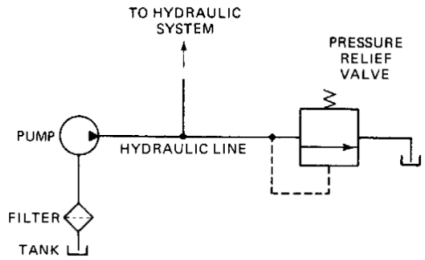


a) Performance of a Pressure Relief Valve

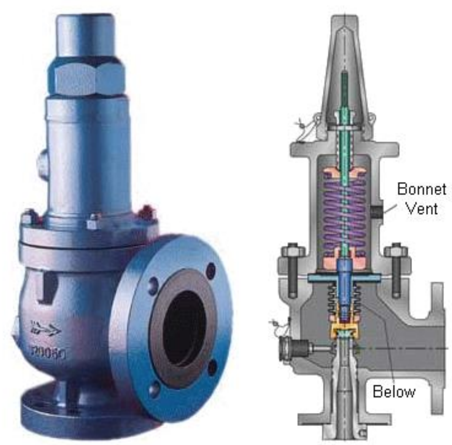
Pressure Relief Valve

It is used as a safety device to prevent over pressurizing the system. Pressure Relief Valve are designed to release excessive pressure that builds up in equipment and piping systems. To prevent major damage to equipment, and more importantly, injury to workers, relief valves can release elevated pressures before they become extreme.



PRV Operation

It is normally a closed valve whose function is to limit the pressure to a specified maximum value by diverting pump flow back to the tank. A poppet is held seated inside the valve by the force of a stiff compression spring: When the system pressure reaches a high enough value, the resulting hydraulic force (acting on the piston-shaped poppet) exceeds the spring force, and the poppet is forced off its seal. This permits flow through the outlet to the tank as long as this high-pressure level is maintained. Note the external adjusting screw, which varies the spring force and, thus, the pressure at which the valve begins to open (cracking pressure).



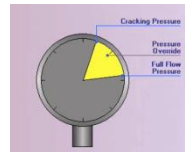
It should be noted that the poppet must open sufficiently to allow full pump flow. The pressure that exists at full pump flow can be substantially greater than the cracking pressure.

Cracking Pressure

Cracking pressure refers to the inlet pressure level at which the first sign of flow is present. It can also be described as a measure of the pressure differential between the inlet and outlet ports of the valve when flow is initially detected. Specifically, cracking pressure is the least differential pressure that the valve experiences during flow.

Cracking pressure can have a significant effect on the compatibility of valve with its intended application. Certain issues can occur if the cracking pressure is too high or too low.

- **Too high.** High cracking pressure causes a higher pressure to drop across valve. If the cracking pressure is too high, the valve may not open fully or at all. When valve isn't fully open throughout normal flow, it may pop or chatter, which can lead to premature wear.
- **Too low.** Low cracking pressure can reduce the valve's closing speed. If the cracking pressure is too low, the valve may also be unable to close entirely in the vertical flow down position because of the stem and disc weight overcoming the opposing force of the spring



Lab Experiment

Components

Pump	
Throttle valve	
Manometer	
Motor	
Pressure relief valve.	
Pressure gauge	

Performance of a Pressure Relief

Valve Objectives It is required to study the performance of a direct-acting pressure relief valve

. **Experimental Procedure**

1) Close the throttle valve completely then, unload the pressure relief valve.

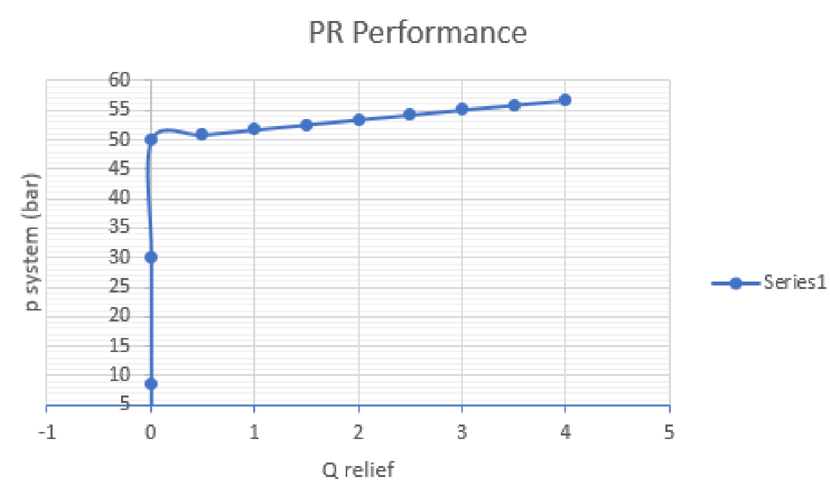
2) Set the pressure relief valve approximately to 50 bar then, open the throttle valve completely.

3) Close the throttle valve in several steps, measure and note down the system pressure and the flow rate through the pressure relief valve.

Lab results

As we decrease the area of throttle valve, we will get high pressure in the system and flow will be through in two ways through pressure relief valve and throttle valve. While closing throttle we will show that pressure relief valve will open at cracking pressure and the flow will be decrease though throttle valve.

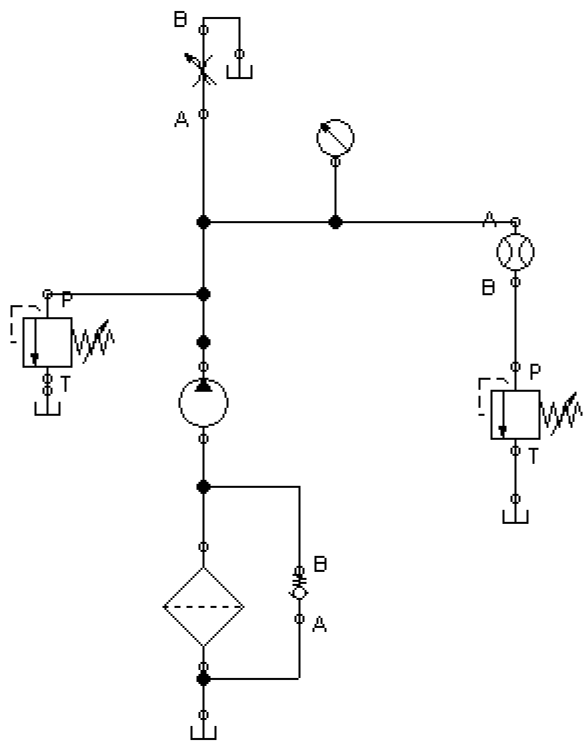
Th Op%	PR(bar)	Q(l/min)
100	0	0
100	8.69	0
100	30	0
36.6	50.89	0.5
31.71	51.75	1
26.8	52.61	1.5
22	53.46	2
17.3	54.29	2.5
12.6	55.12	3
8	55.93	3.5
3.5	56.73	4

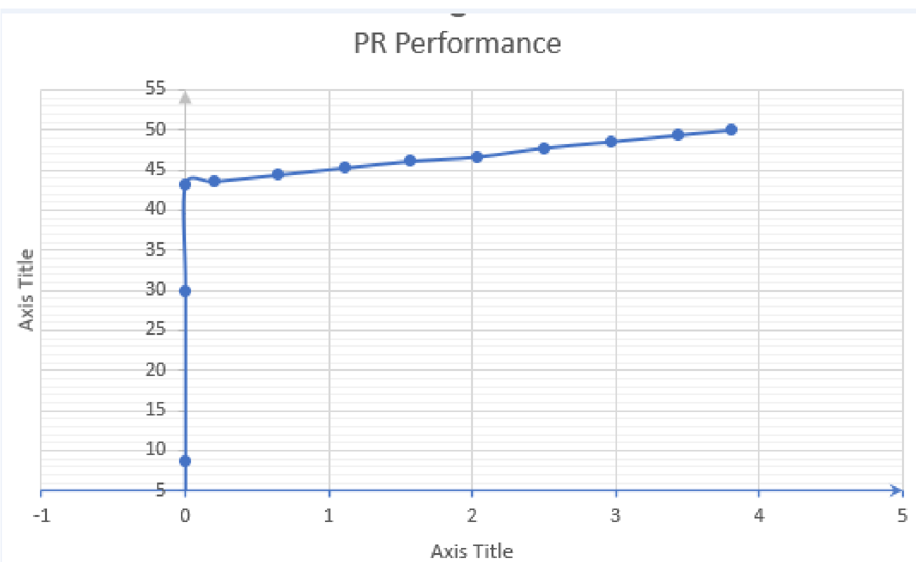


Cracking=50bar

FESTO Results

Th Op%	PR(bar)	Q(l/min)
100	8.6	0
100	30	0
36.6	43.58	0.2
31.71	44.43	0.65
26.8	45.29	1.11
22	46.13	1.57
17.3	46.65	2.03
12.6	47.78	2.5
8	48.56	2.97
3.5	49.38	3.43
0	50	3.8

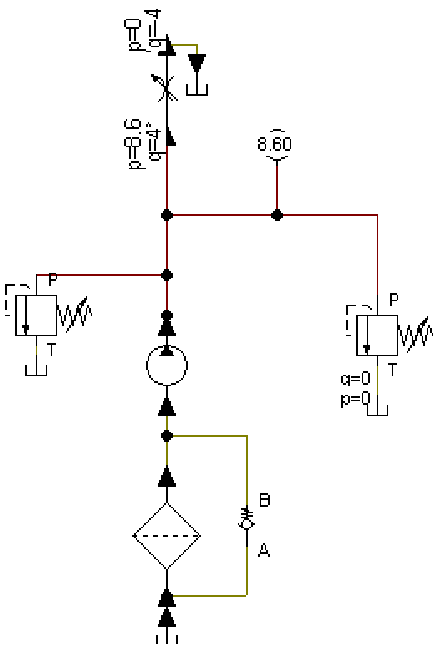


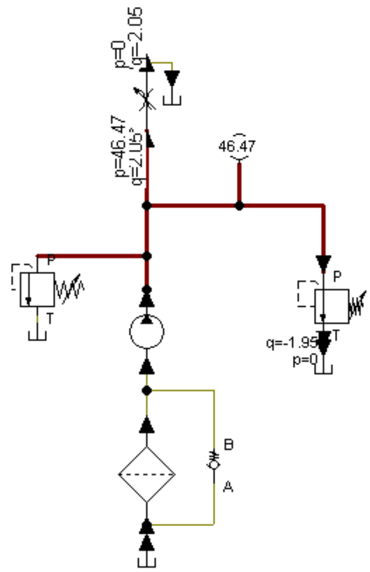


Craking=43.2567bar

Cracking pressure not the same ..resistance in throttle valve in festo different from lab.

There are an internal resistance in lab pressure relief valve.





b) Regenerative Circuit Characteristics

Required: study the change of the circuit behavior when it turns to regenerative circuit.

Steps:

- Use $\frac{4}{3}$ DCV and notice the $V_{ext.}$, $V_{ret.}$, upstream pressure and downstream pressure.
- We plug one port of $\frac{4}{3}$ DCV to use as $\frac{3}{3}$ DCV to create a regenerative circuit and notice the same parameters.

	downstream pres.	upstream pres.	Time(sec.)	Load(N)
Regenerative	59 bar	58bar	Ext. 1.6 Ret. 1.6	2121.19 2084.6
Normal	58 bar	0	Ext. 3.51 Ret. 1.7	4170.46 2084.6

The component of the circuit:

- Pump unit with pressure 60 bar.
- Filter and check valve.
- Direction control valve.
- Double acting cylinder.
- Pipelines from pump to cylinder to tank.

Note:

- ➢ $V_{ext.}$ is higher in the regenerative cycle.
- ➢ The load in regenerative circuit is lower than that in normal circuit.
- ➢ $V_{ret.}$ Doesn`t change in regenerative circuit.

Equations:

$A_{piston}=\frac{\pi}{4}D^2 = \frac{\pi}{4}0.03^2 = 7.068*10^{-4}$ m=0.7068mm

$A_{piston}=\frac{\pi}{4}D^2 = \frac{\pi}{4}0.02121^2 = 3.533*10^{-4}$ m=0.3533mm

Load(N) extention $=P_1*A_{piston} – P_{2*}A_{rod}$

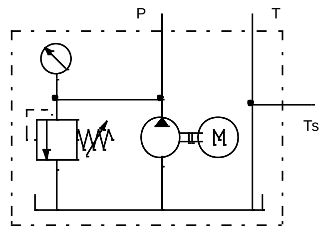
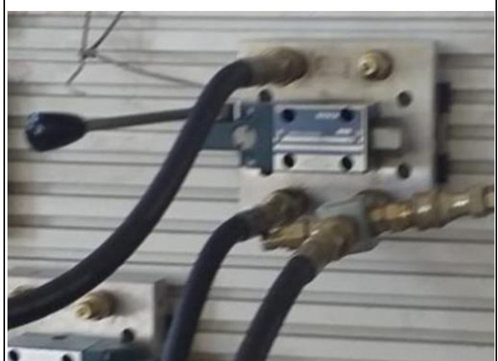
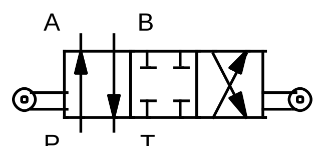
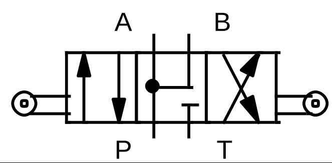
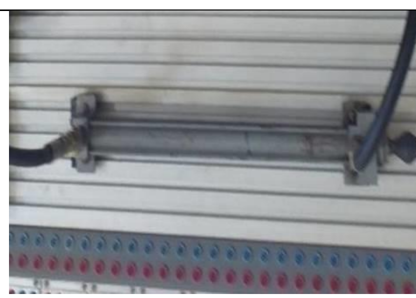
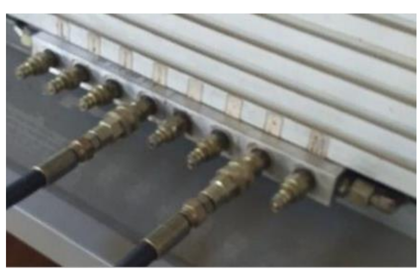
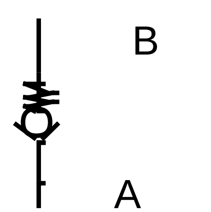
Load(N) retraction $=P_1*A_{rod} – P_{2*}A_{piston}$

- Load in natural extension circuit =
  $(58 * 10^5 *0.7068 *10^{-3}– 0)$ $\boxed{4170.46}$

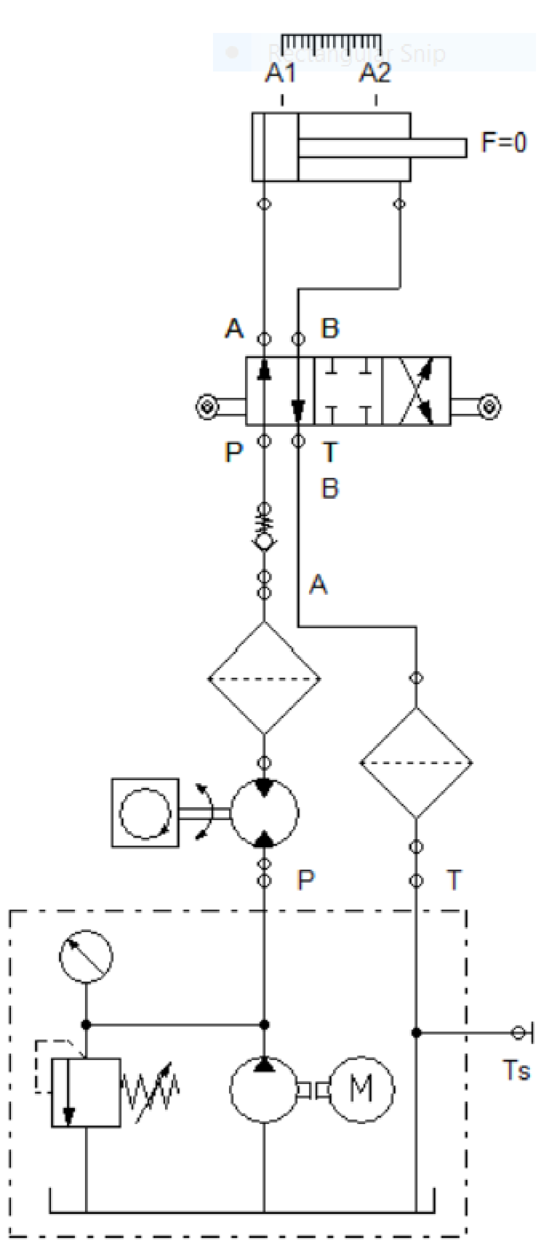
- Load in natural retraction circuit =
  $(58 * 10^5 *0.3533 *10^{-3})$ = $\boxed{2084 \text{ N}}$

- Load in regenerative extension circuit =
  $(59 * 10^5 *0.7068 – 58*10^5*0.3533)*10^{-3}$ $\boxed{2121.19}$

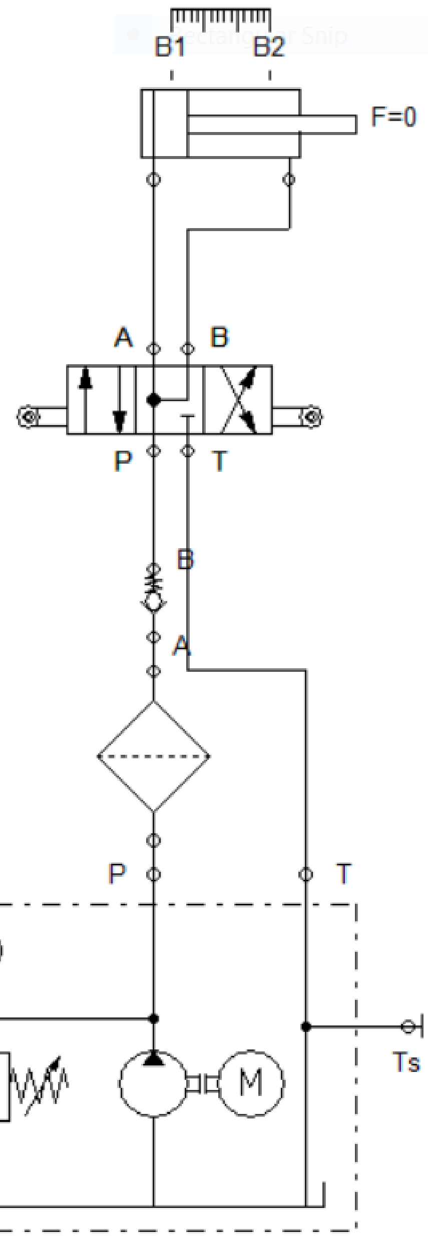
- Load in regenerative retraction circuit =
  $(58 * 10^5 *0.3533 *10^{-3})$ $\boxed{2084 \text{ N}}$

component	In lab.	In FESTO
PUMP The first component in the circuit which pumps flow to the cylinder.		
4/3DCV (NORMAL CIRCUIT) **4/3DCV** (REGENERATIVE CIRCUIT)		 
CYLINDER Double acting cylinder.		 Double acting cylinder
PIPELINES		

Circuits on FESTO:



NORMAL HYDRAULIC CIRCUIT



REGENERATIVE CIRCUIT

c) Pressure Intensification

If we have a large load and needs high pressure to raise it, the best solution is using hydraulic pressure intensifiers.

These pressure intensifiers are based on a piston principle, where a larger diameter piston pushes a smaller diameter piston, thus increasing the pressure to a factor equal to the ratio larger diameter area divided by smaller diameter area.

Pressure intensifier is usually located in between the pump and machine that needs high pressure.

Results of festo measuring

$P_{upstream}$ (bar)	20	30	40
$P_{downstream}$ (bar)	41.53	56.69	72.25
Pressure ratio=$P_{upstream}/P_{downstream}$	0.4816	0.5292	0.5536

Results of calculating measuring

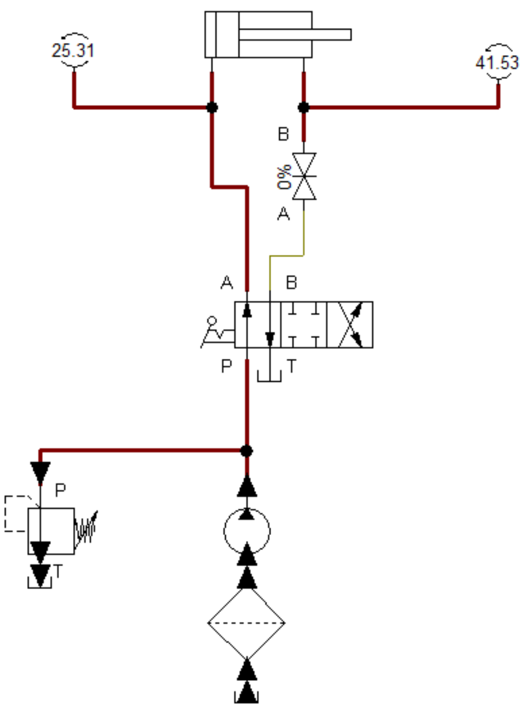
$P_{upstream}$ (bar)	20	30	40
$P_{downstream}$ (bar)	41.528	62.29	83.056
Pressure ratio=$P_{upstream}/P_{downstream}$	0.4816	0.4816	0.4816

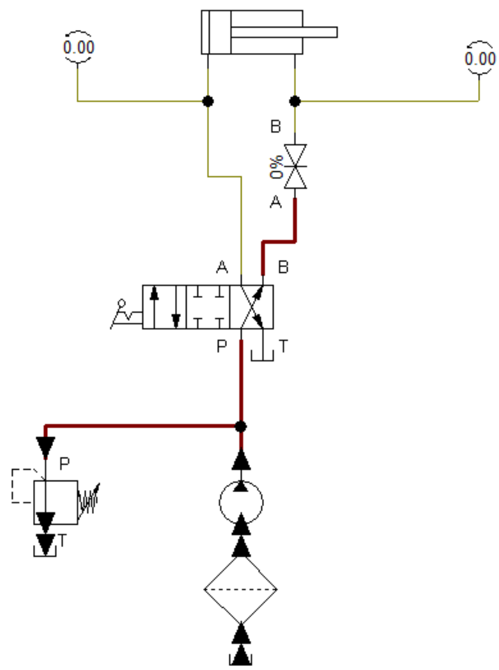
Comment

we noticed that the pressure of downstream at festo results is smaller than calculating results, this happened due to internal leakage in pump.

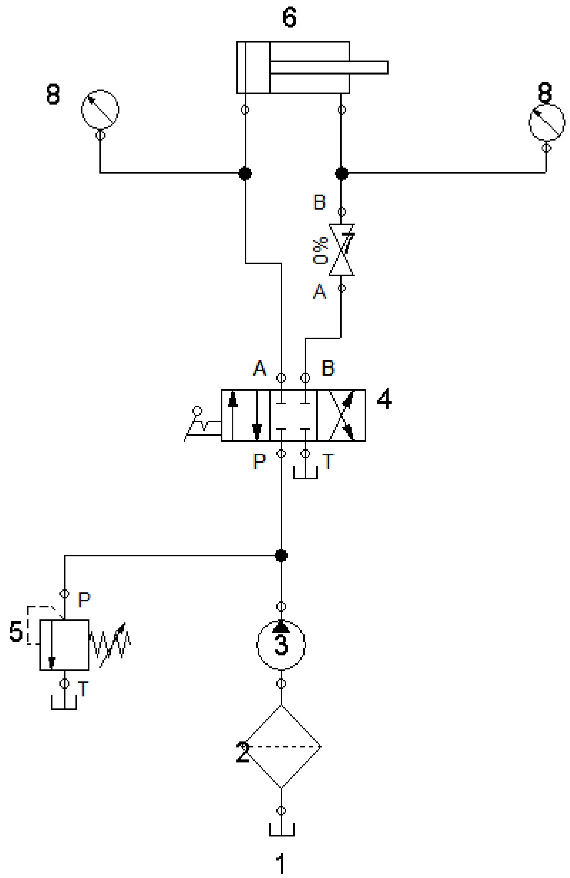
Hydraulic circuit on festo

At extension stroke **At retraction stroke**





List of components



Designation	Description
1	Tank
2	Filter
3	Fixed displacement pump
4	4/3-way hand-lever valve with shutoff position
5	Pressure relief valve
6	Double acting cylinder
7	Shutoff valve
	Tank
	Tank
8	Manometer
8	Manometer

d) Check Valve, hydraulically pilot operated

Description of the circuit

- In this circuit we used pilot operated check valve to prevent the over running of the load.
- We connect 4/2 DCV with the signal line of the pilot check valve to control the signal.
- We connect 4/3 DCV with tandem position to release the pressure throttled in the signal line to the tank in closed position with the signal line of the pilot check valve to control the signal.
- The fluid flows from the pump to the 4/3 DCV in the tandem position which makes it go to the tank without drop in pressure.
- When the 4/3 DCV becomes in the parallel position with the 4/2 DCV closed the cylinder moves very small stroke until the line attached to the check valve fills with fluid.
- When we make the 4/2 DCV in the open position, the cylinder will move in the extension stroke until it reaches the end of the stroke.
  - ✓ If the force is small, less than 900N, there will be a jerky motion.
  - ✓ We increase the force greater than 900N to increase the pressure drop then get rid of the jerky motion.
  - ✓ There is another solution to the jerky motion is to add the counterbalance valve.
  - ✓ The last solution is to increase the area of the piston to increase the pressure drop.
- In the retraction stroke the flow will be from the pump to the check valve then to the cylinder which will move smoothly without any problem.

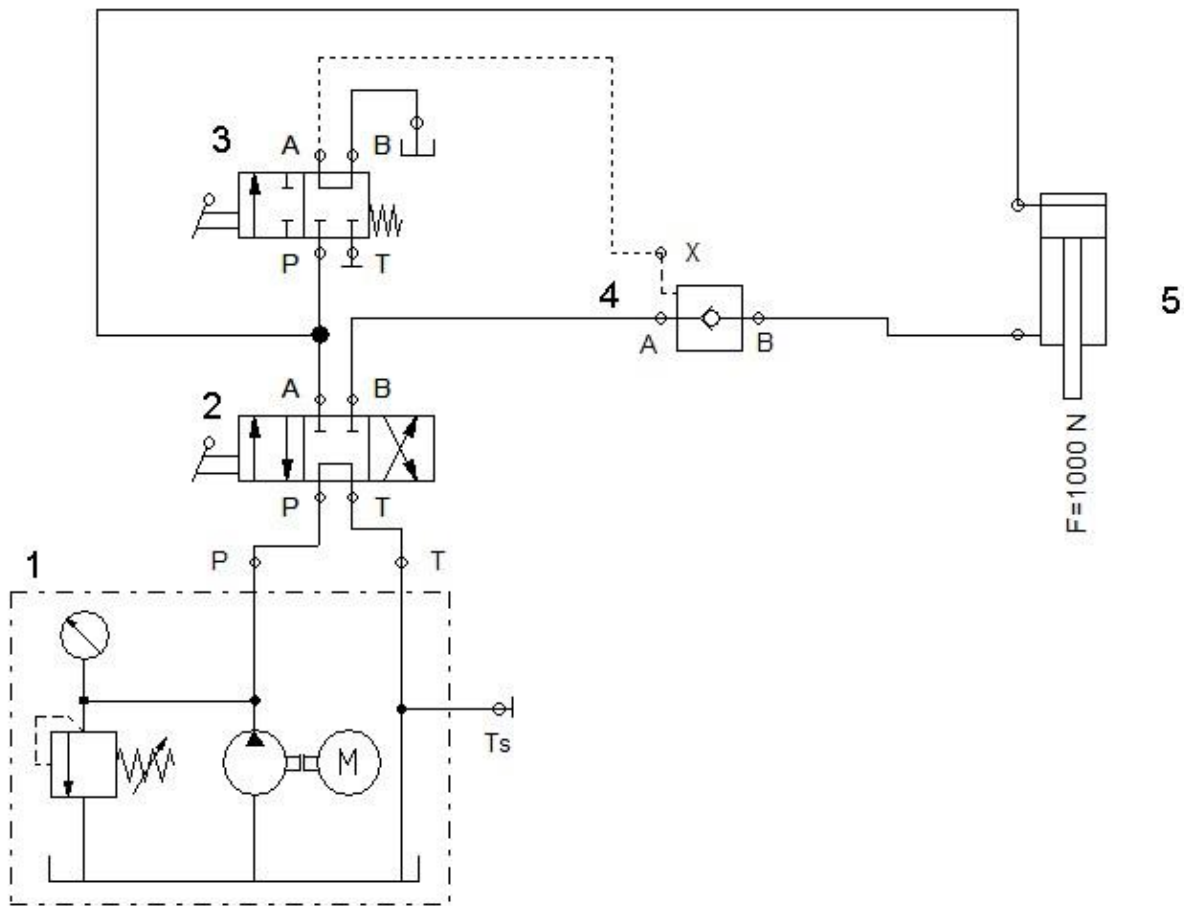
Comparison

Extension stroke	V(m/s)	Time (sec)	$P_{up\ stream}$ (bar)	P_{down} (bar)	Fr(N)
Normal circuit	0.06	1.445	56	59	1000
Regenerative circuit	0.22	2.315	58	0	4099.78
Pilot check valve circuit	0.06	1.445	56	0	1000

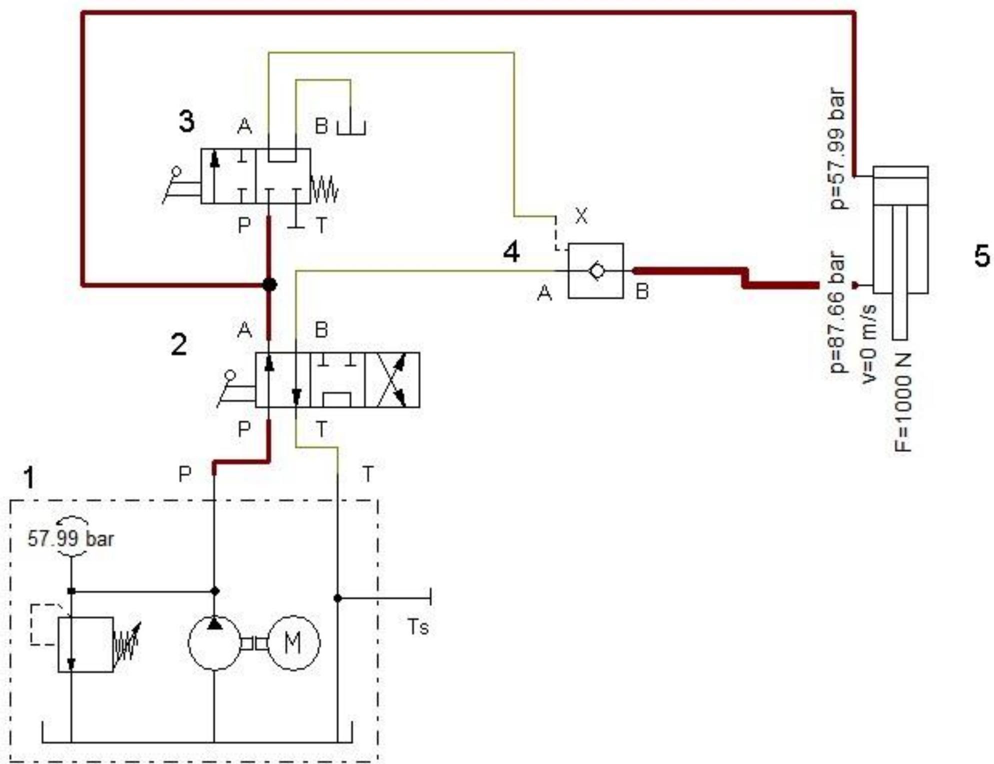
Notes

- In the above comparison the velocity of the regenerative circuit is greater than the other.
- The velocity of the normal circuit and the pilot check valve is equal because that the pilot check valve doesn't change in the flow in the circuit, it just increases the safety of the circuit that it prevents the over running load.

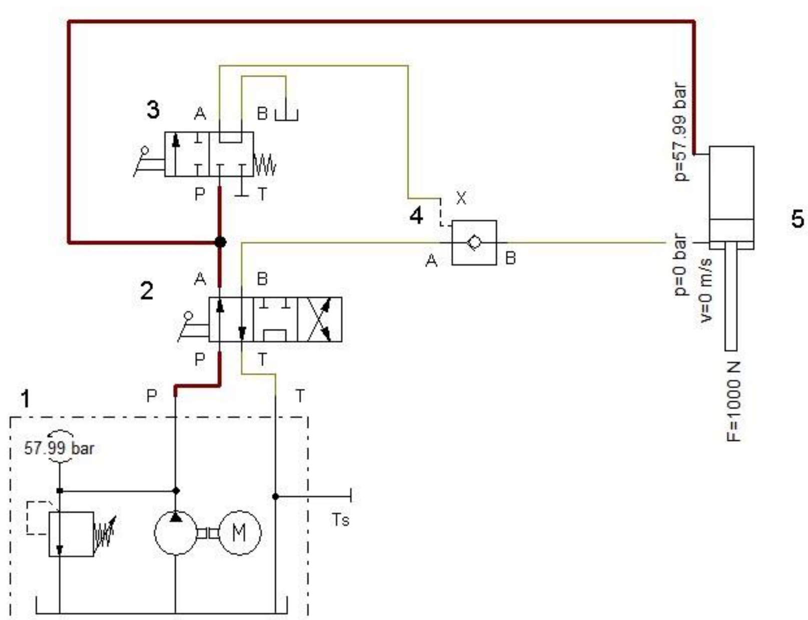
Main circuit



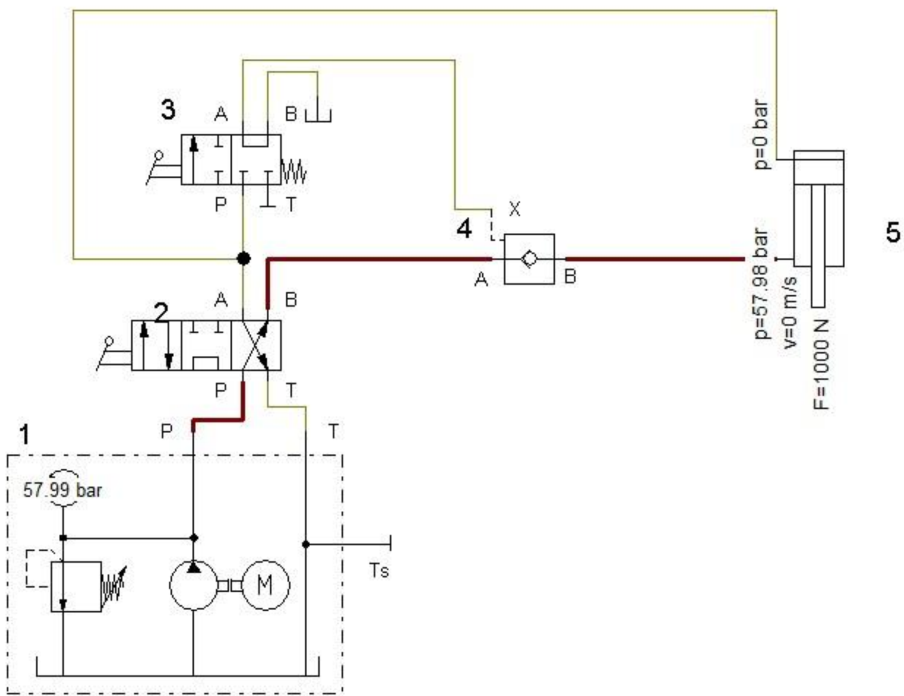
Extension stroke with 4/2 DCV closed

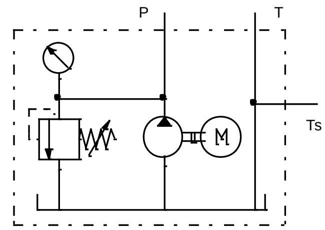
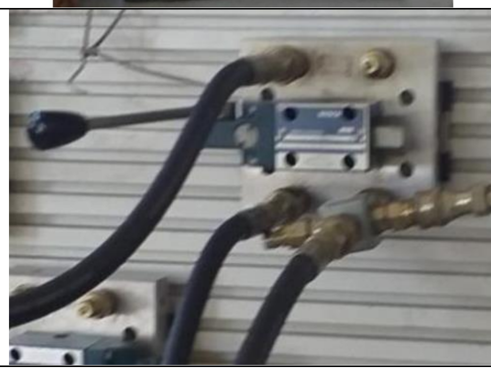
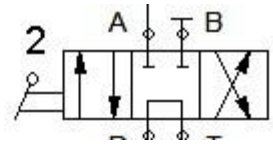
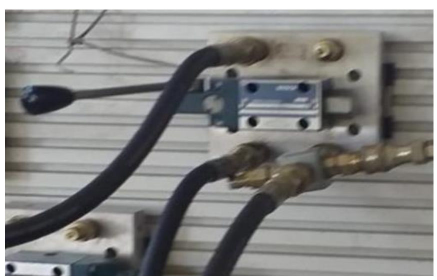
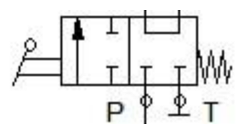
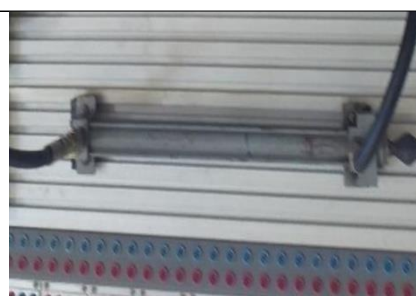
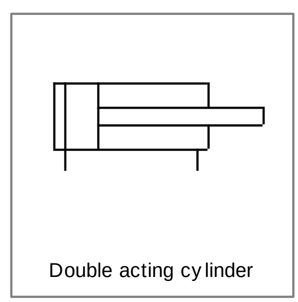


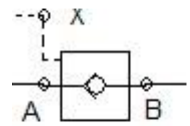
Extension stroke with 4/2 DCV open



Retraction stroke



Component	In lab	In festo
PUMP The first component in the circuit which pumps flow to the cylinder		
4/3 DCV		
4/2 DCV		
CYLINDER Double acting cylinder.		

PIPELINES		
Pilot operated check valve		

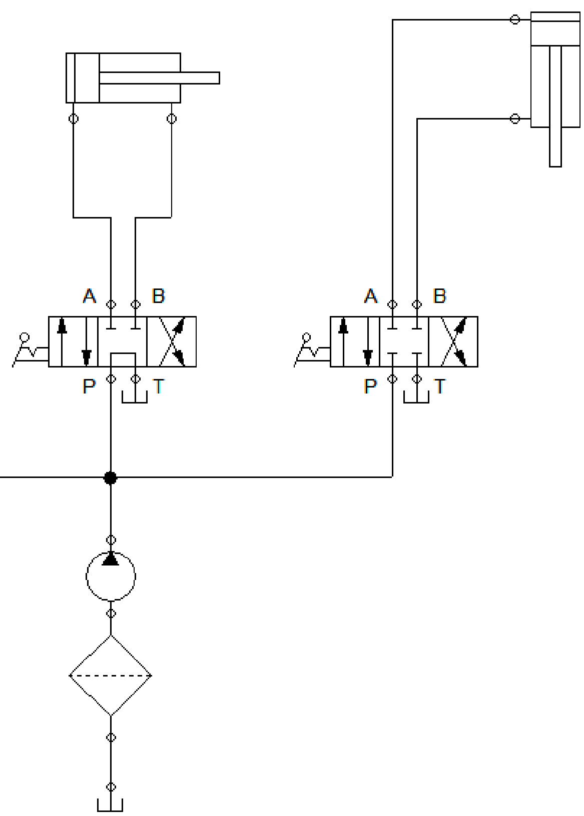
e) Parallel and Series Cylinders' Connections

Parallel connection

In a parallel circuit, we usually have more than one possible flow path.

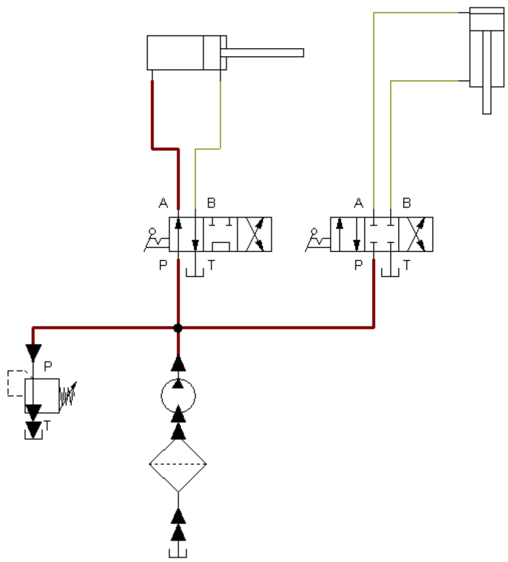
The flow paths are said to be in parallel with each other.

Circuit diagram on fluidsim:

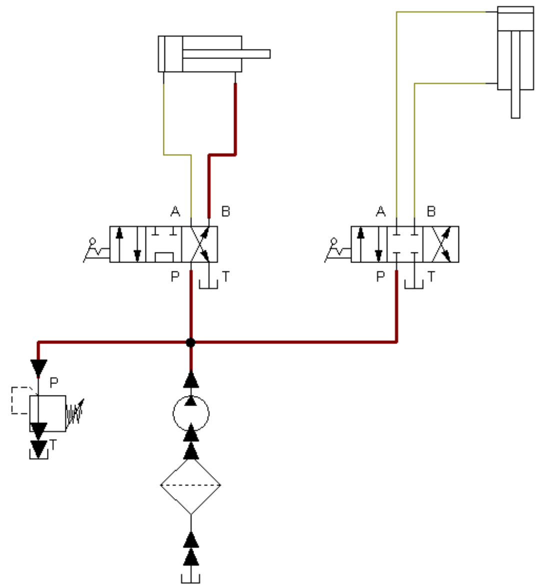


When this circuit work, the cylinder is connected to tandem center will work at extension & retraction; but the other cylinder will work only in extension stroke (under its weight) as the fluid flows through the path of least resistance.

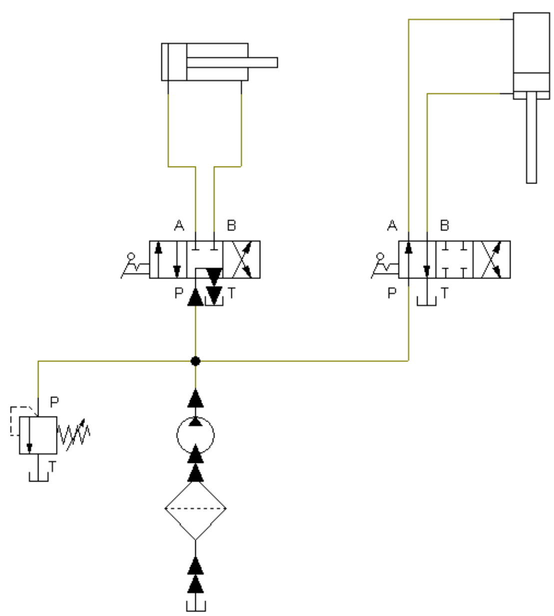
At extension stroke of 1



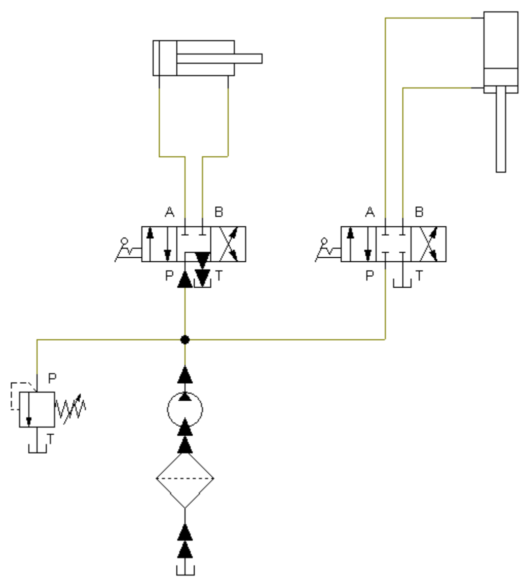
At retraction stroke of 1



At extension stroke of 2



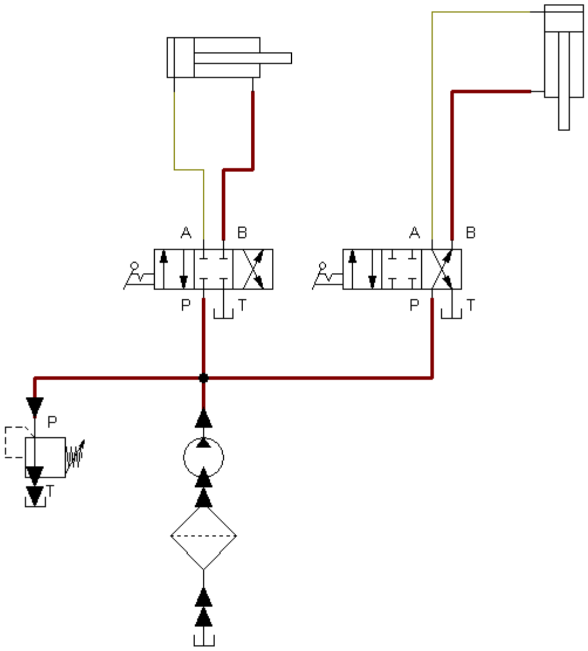
At retraction stroke of 2



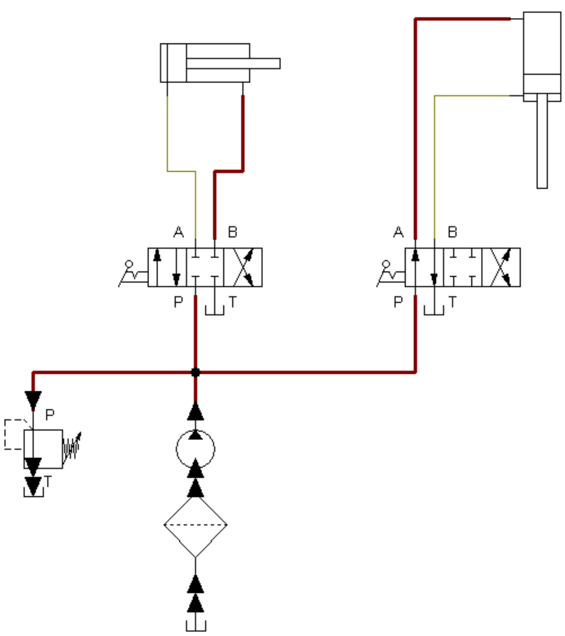
To solve this problem, we have two solutions:

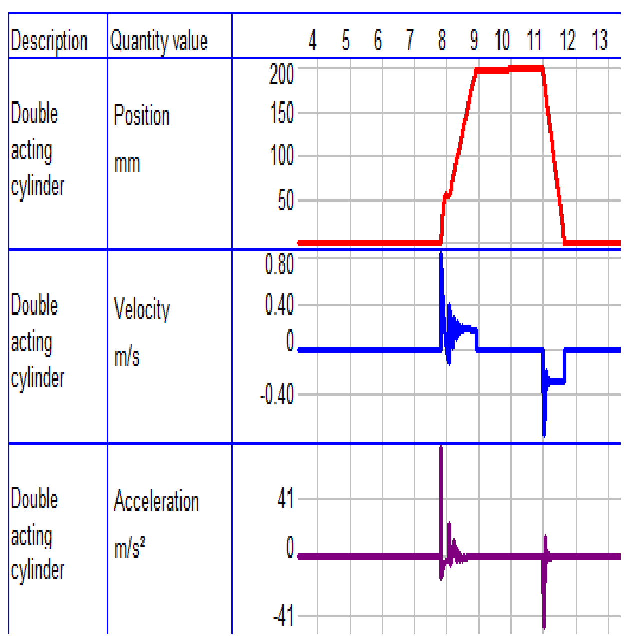
- The first solution, we should use 2 DCV closed center.
- Second solution, we can use throttle valve to compensate the pressure difference.

At retraction stroke of 2



At extension stroke of 2





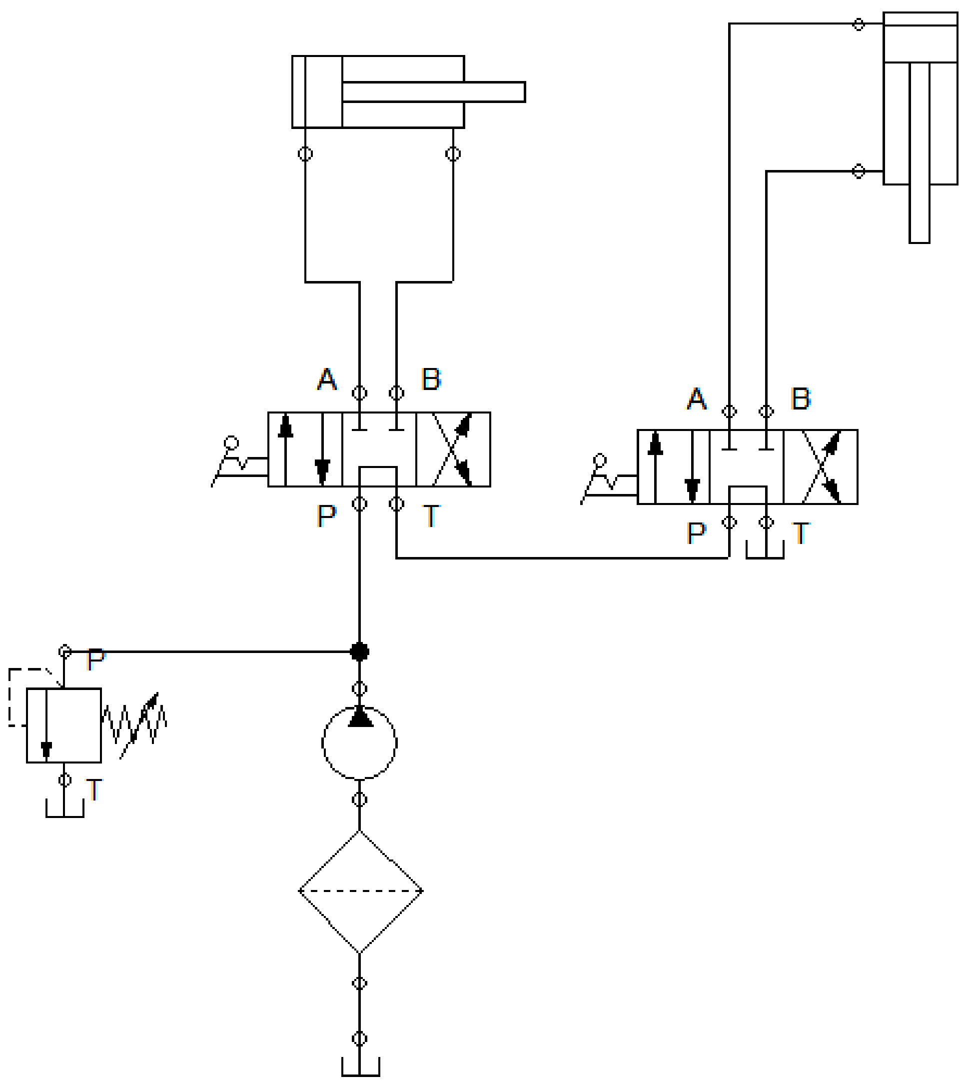
Series connection

A circuit is said to be connected in series when the same flow path through all cylinders.

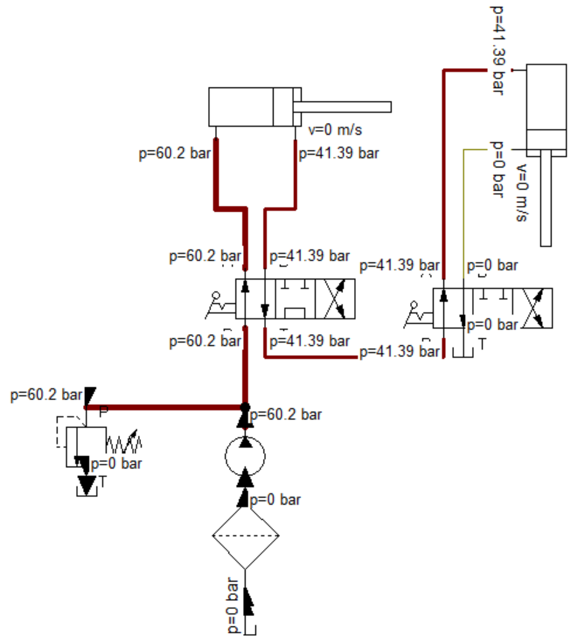
The cylinders hooked in series will operate in synchronization, the speed of each cylinder depends on its piston and rod areas.

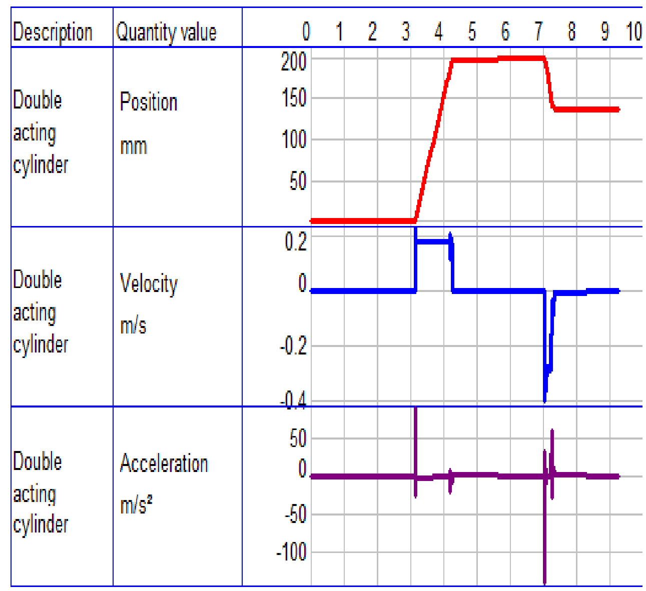
In series connection, DCV should be tandem center.

Circuit diagram on fluidsim:

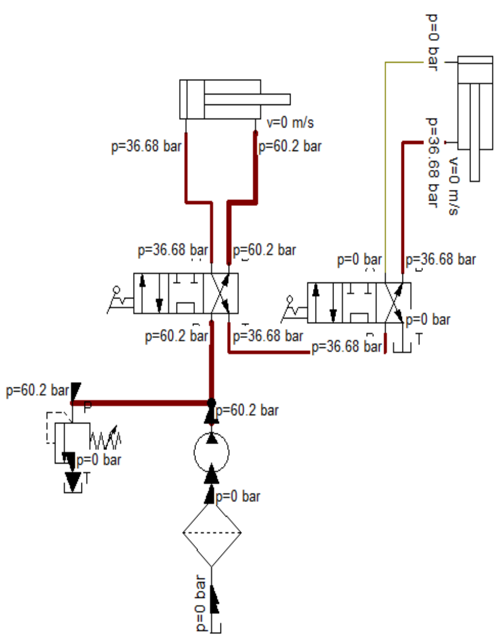


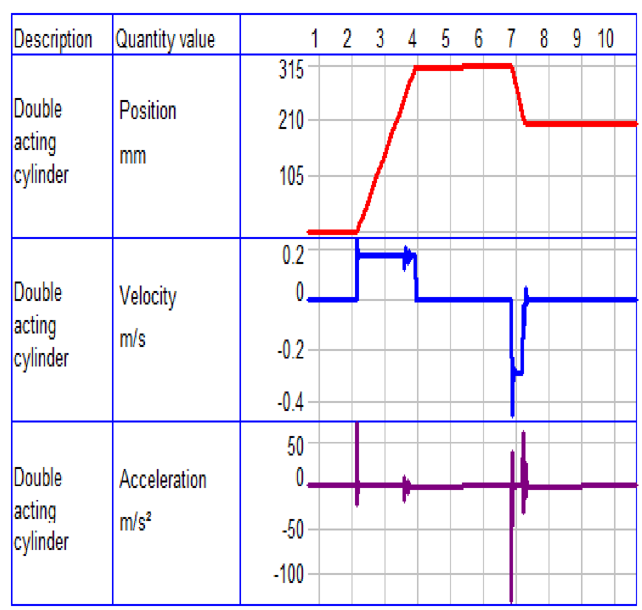
At extension stroke





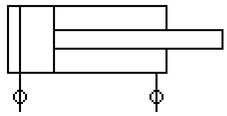
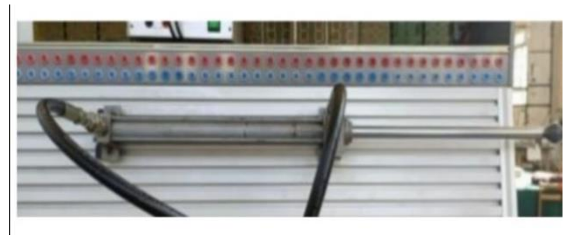
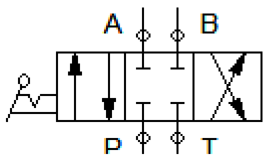
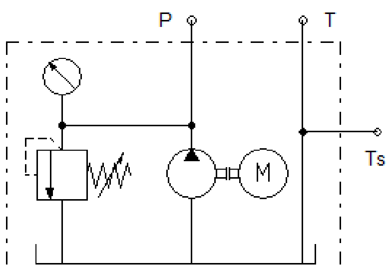
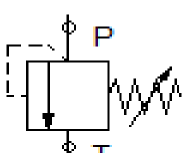
At retraction stroke





In series connection, two cylinders move at different speeds.

List of components

Double acting single rod cylinder		
4/3 closed center manual actuated DCV		
Pump unit		
Pressure relief valve		

Forklift

Forklifts use a combination of hydraulics, a pulley system, and other things to lift heavy materials across different distances.

They are commonly used in warehouses, construction sites and other places that need to transport lots of heavy materials,

Uses

Construction sites: Carry building material across long distances and rough terrain.

Warehouses: Unload and load trucks to store goods in a warehouse.

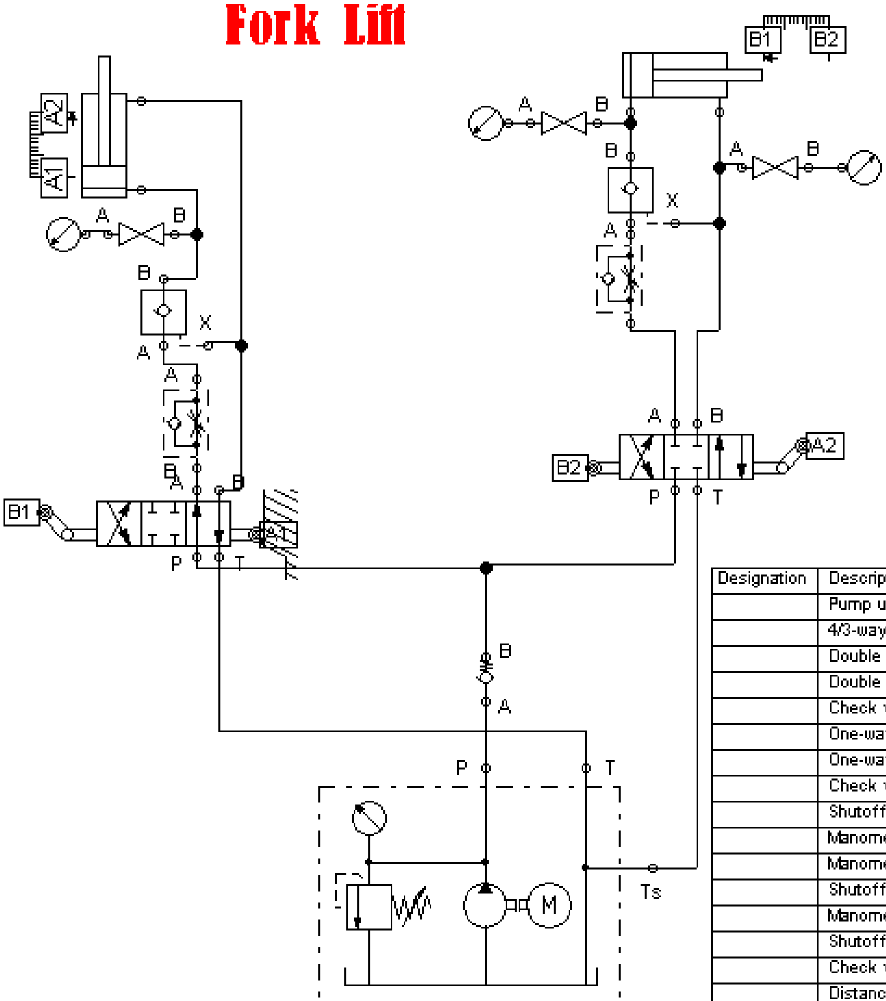
Recycling operations: Unload recycling materials and transport to their respective sorting areas.

Dockyards: Load girth materials on and off ships and barges, especially when swift loading is needed.

WE SUPPLY METER OUT TO PREVENT THE FLOW UNDER ITS WEIGHT AND DECREASE THE VELOCITY.

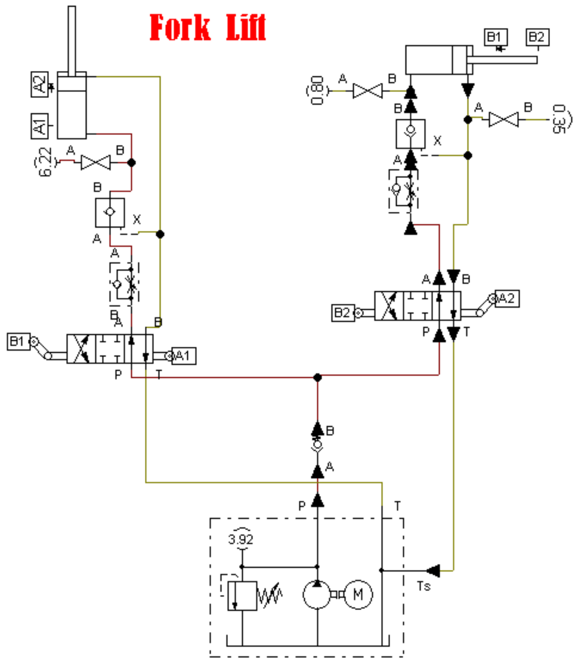
FESTO Results

Fork Lift

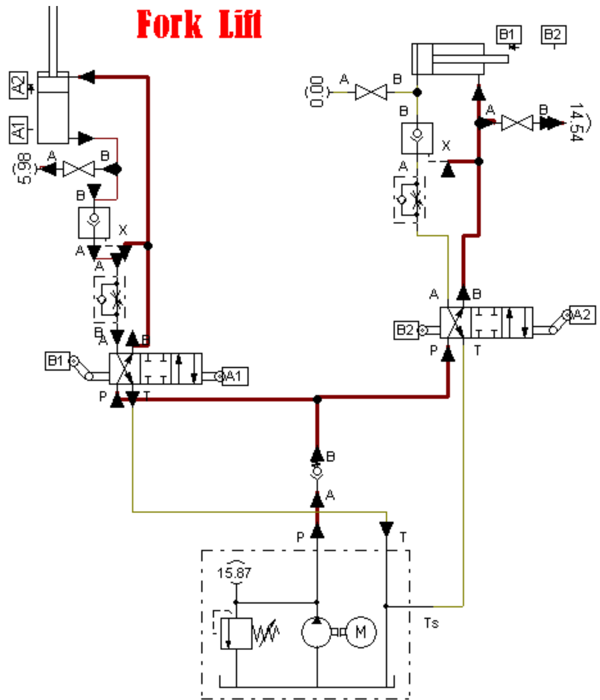


Designation	Description
	Pump unit
	4/3-way hand-lever valve with shutoff position
	Double acting cylinder
	Double acting cylinder
	Check valve
	One-way flow control valve
	One-way flow control valve
	Check valve with pilot control
	Shutoff valve
	Manometer
	Manometer
	Shutoff valve
	Manometer
	Shutoff valve
	Check valve with pilot control
	Distance rule
	Distance rule
	4/3-way hand-lever valve with shutoff position

EXTENSION

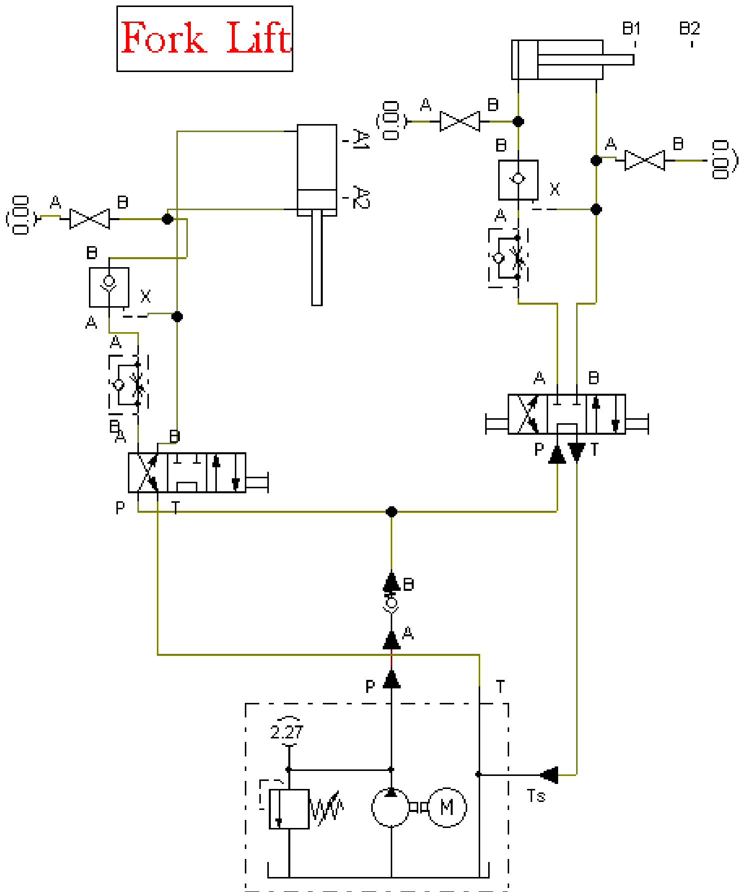


RETRACTION

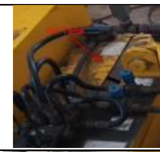
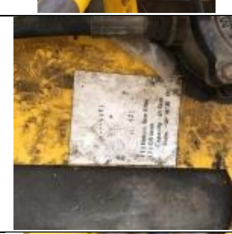


Fork Lift
A2
A1
5.98
A
B
B
X
A
A
B
A
B
B1
A1
P
T
B1
B2
0.00
A
B
B
X
A
A
14.54
A
B
B2
A2
P
T
B
A
P
T
15.87
M
Ts

You can Operate the circuit in series, but you can Operate one cylinder only.

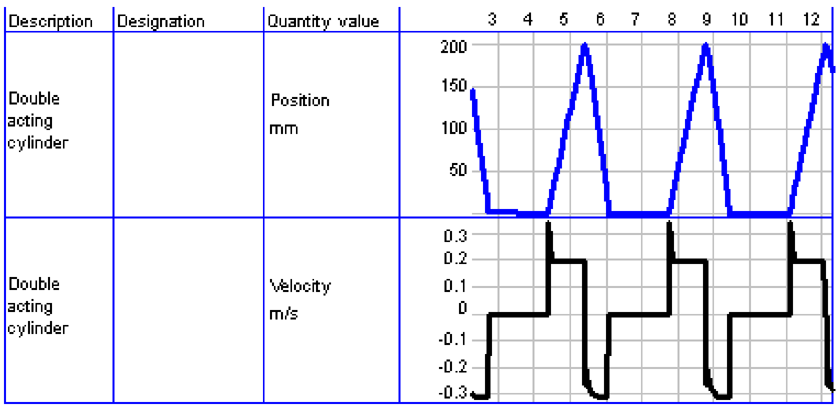


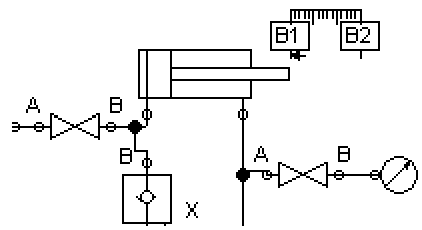
Components

Tank	
Pump,motor,coupling	
Pipes & fittings	
Cylinder(titling)	
Cylinder(lifting)	
FILLTER	
Control Valves	

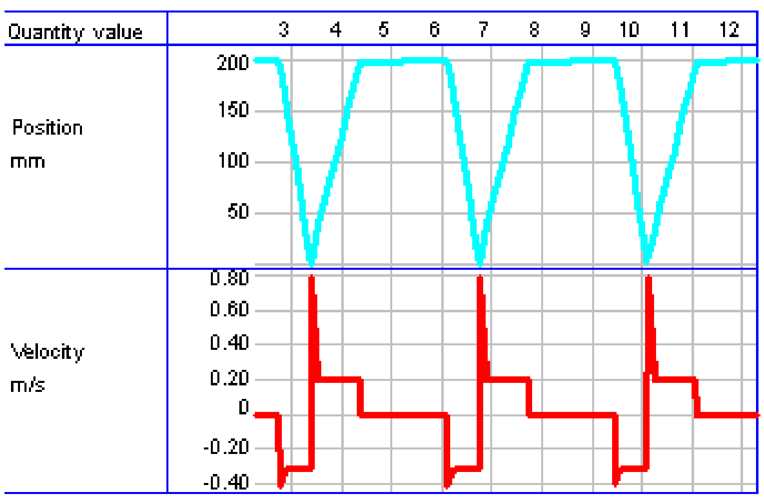
SIMULATION

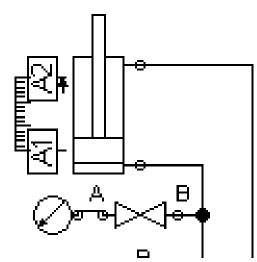
Cylinder(titling)





Cylinder(lifting)





We can notice that the cylinder descends under the influence of its weight so we will supply pilot operated check valve which cause jerky motion so we need to supply meter out to reduce descending velocity.

Loader

Definition

A loader is a heavy equipment machine used in construction to move aside or load materials onto another type of machinery.

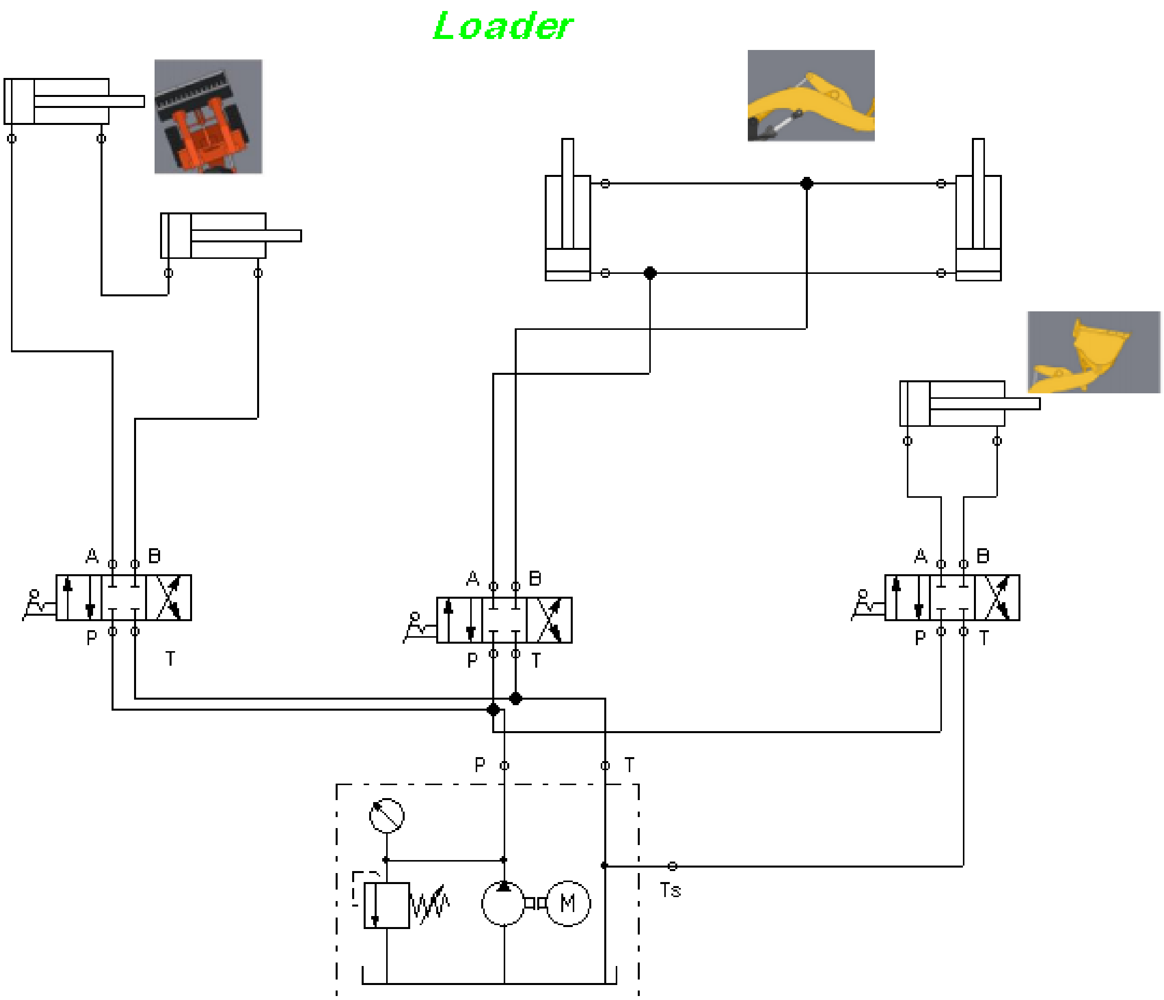
There are many types of loader, which, depending on design and application, are variously called a bucket loader, front loader, front-end loader, payloader, high lift, scoop, shovel, skip loader, wheel loader Beside that, the component of the loader hydraulic system:

- The engine (diesel in almost all cases)
- The hydraulic components (such as pumps, motors and valves)
- The transmission components (gearbox, axles, wheels/tracks, pumps, motors).

The engine runs both the hydraulics and the transmission, and these in turn move the front attachment (a bucket, forks, sweeper, etc.) to manipulate the material being handled, and the wheels or tracks to move the machine around the jobsite The transmission system consists of torque converter, gearbox, transmission shaft, front and rear drive axle, and wheels.

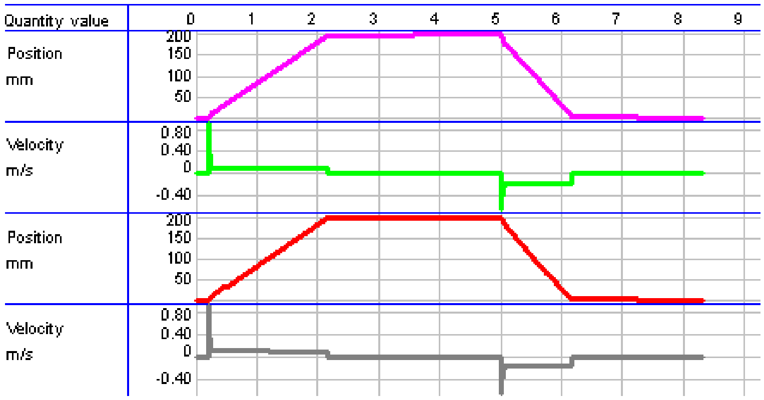
By the output torque and speed of automatic adjustment of the transmission system, the wheel loader can automatically change the speed and force according to the road condition and resistance, so as to adapt to the changing conditions. After putting the wheel loader in gear, from the start to the maximum speed of the gear, it can be continuously variable transmission automatically. Besides. It can have a smooth start and good acceleration performance. If there is a slope or sudden road obstacle, it can automatically decelerate without changing gear, increase traction force, drive at any speed, and cross obstacles. When the external resistance is reduced, it can quickly increase speed automatically to improve the operation rate. When shoveling material, it can cut into the material pile at a larger speed and automatically decelerate and improve traction force of wheels to ensure the cut with the increase of resistance.

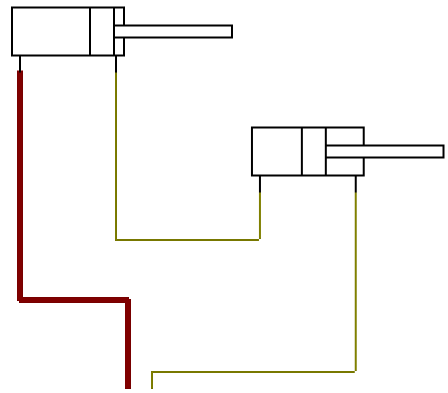
FESTO Results



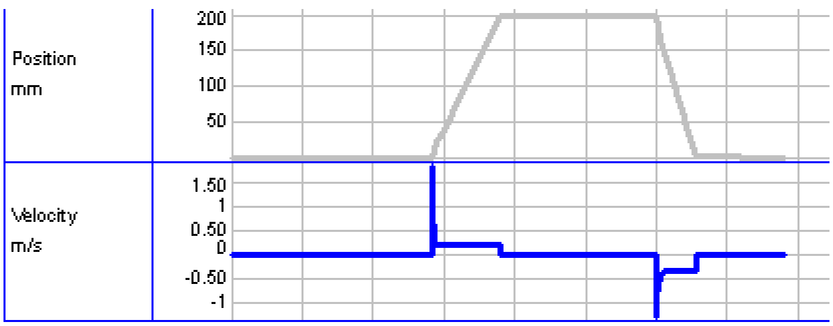
SIMULATION

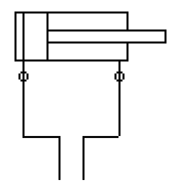
Boom cylinders



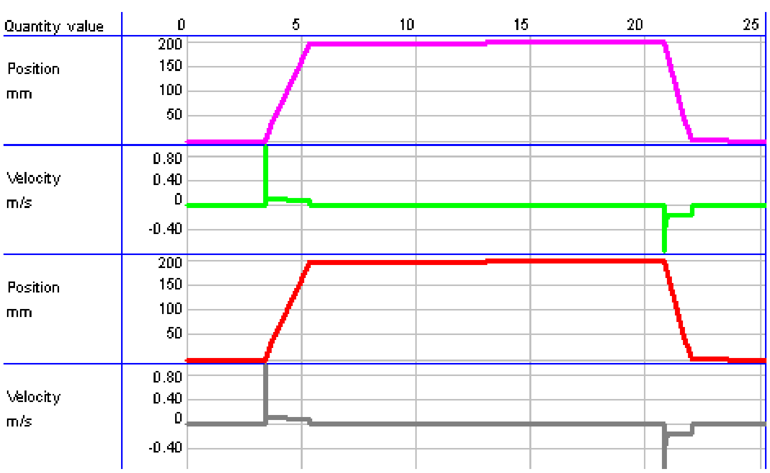


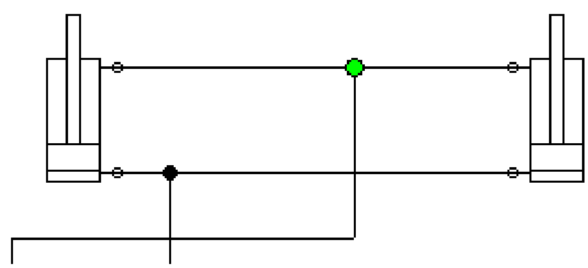
Tilting cylinder



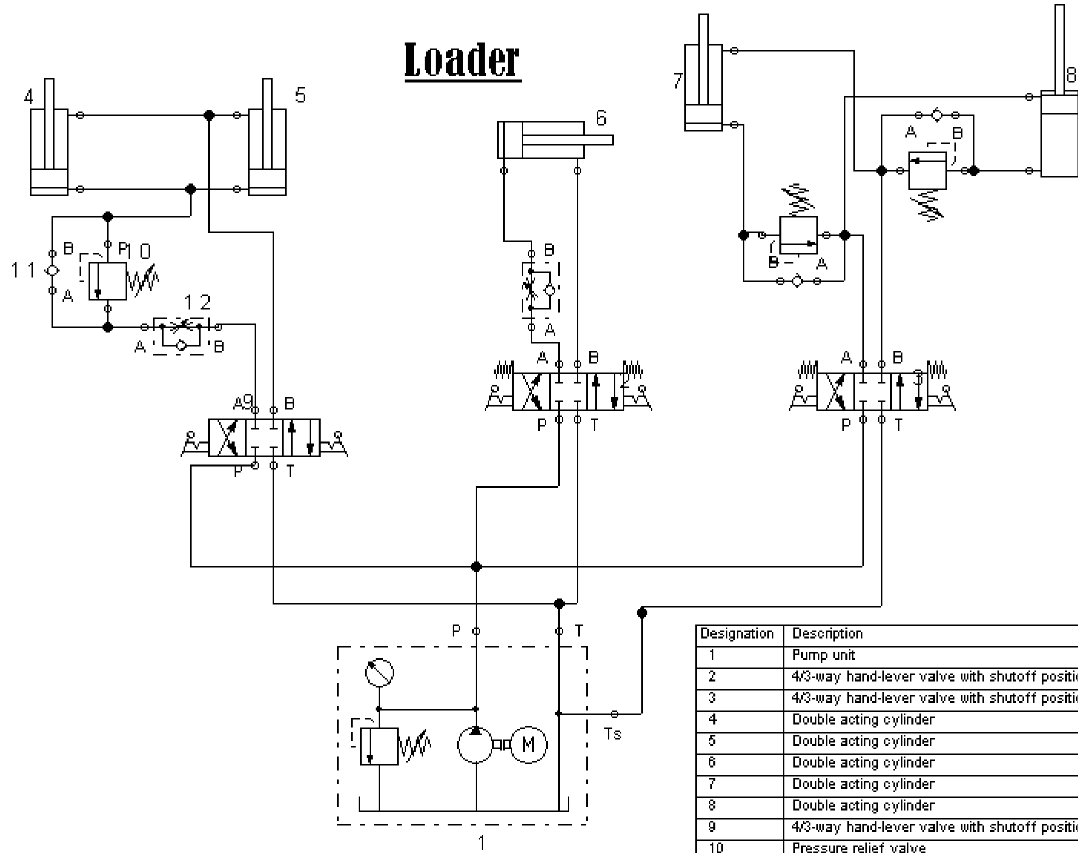


Steering cylinders



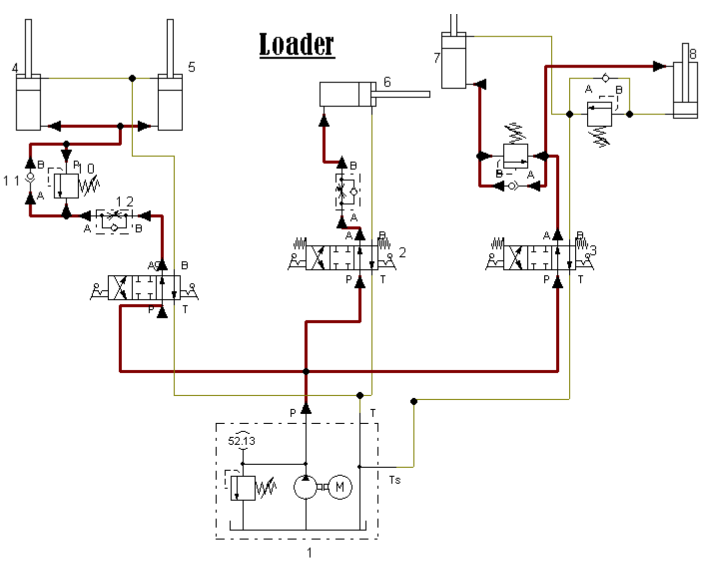


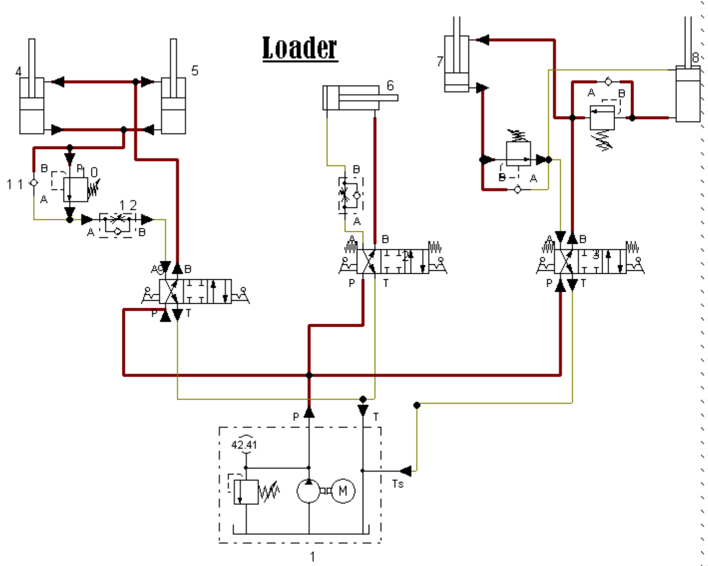
Some Modification



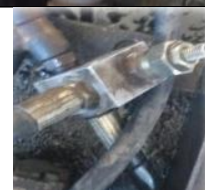
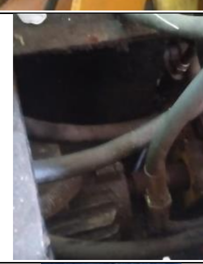
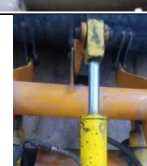
Designation	Description
1	Pump unit
2	4/3-way hand-lever valve with shutoff position
3	4/3-way hand-lever valve with shutoff position
4	Double acting cylinder
5	Double acting cylinder
6	Double acting cylinder
7	Double acting cylinder
8	Double acting cylinder
9	4/3-way hand-lever valve with shutoff position
10	Pressure relief valve
11	Check valve
12	One-way flow control valve

OPERATION





Components

Positive displacement Pump	
Pressure relief valve	
Three 4/3 manually actuated direction control valves	
Boom cylinders	
Motor	
Tilting cylinder	
Steering cylinders	

- **DCV:** Starts and stops the direction of fluid and controls where the fluid moves using spools.
- **Throttle valve:** control the flow and velocity
- **Filter:** continuously remove contaminants in the hydraulic oil.
- **Two cylinders** connecting in parallel to lift the load.
- **One cylinder** used for tilting.
- **Two cylinders** in between cross connection to leading the loader.
- **Pump:** Produces a constant flow of hydraulic fluid to supply the control valve
- **Relief Valve**: Protects the hydraulic system from too much pressure. This part is considered a critical safety component of hydraulic forklift hydraulic pressure.

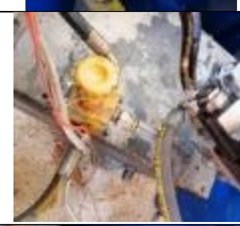
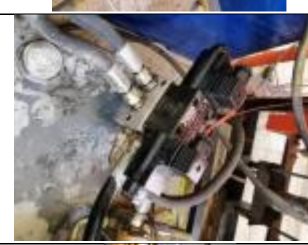
Hydraulic Lift

lifts have been the most common type of lifting mechanism used in buildings throughout the second half of the 20th century. They work on the principle of an electrically powered pump that pushes pressurized hydraulic fluid to a jack lifting system. A piston within a cylinder at the base of the elevator pushes up and down.

Hydraulic elevators have a low initial cost and their ongoing maintenance costs are lower compared to the other elevator types. Hydraulic elevators use more energy than other types of elevators because the electric motor works against gravity as it forces hydraulic fluid into the piston. A major drawback of hydraulic elevators is that the hydraulic fluid can sometimes leak, which can cause a serious environmental hazard.

Applications ideal for low traffic low rise buildings and establishment These push the elevator Cars descends under the pull of gravity ideal for low. traffic low rise buildings and establishments These push the elevator Cars descends under the pull of gravity

COMPONENTS

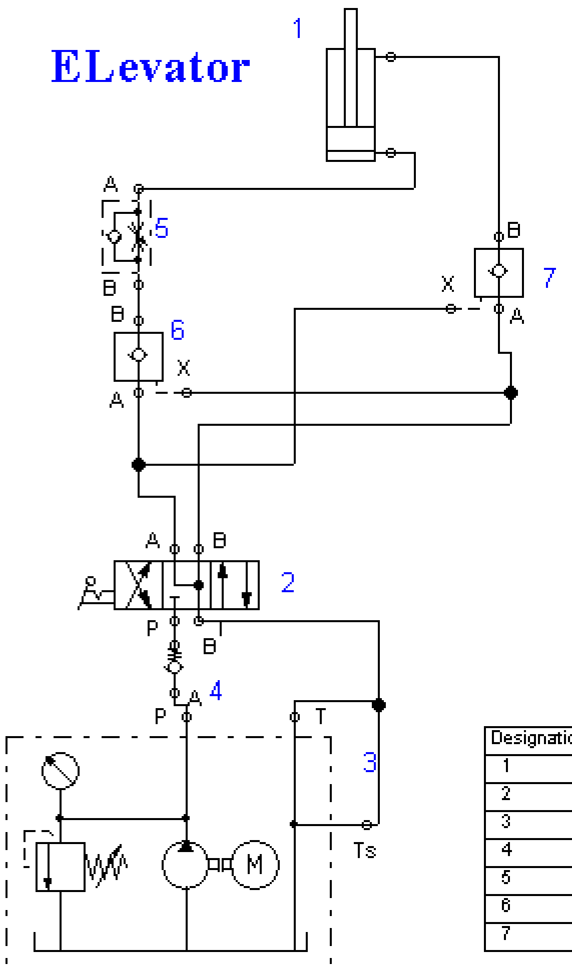
PUMP	
Two POCV	
FCV	
PRV	
Three 4/3 DCV solenoid actuated s	
Double acting cylinder	
Control panel	

In lab experiment we connect the meter out on the rod side, but in this case, we cannot control the retraction speed. To control it we have to reverse the direction of nonreturn valve then the flow will be controlled by meter in, and vapor pressure will be formed.

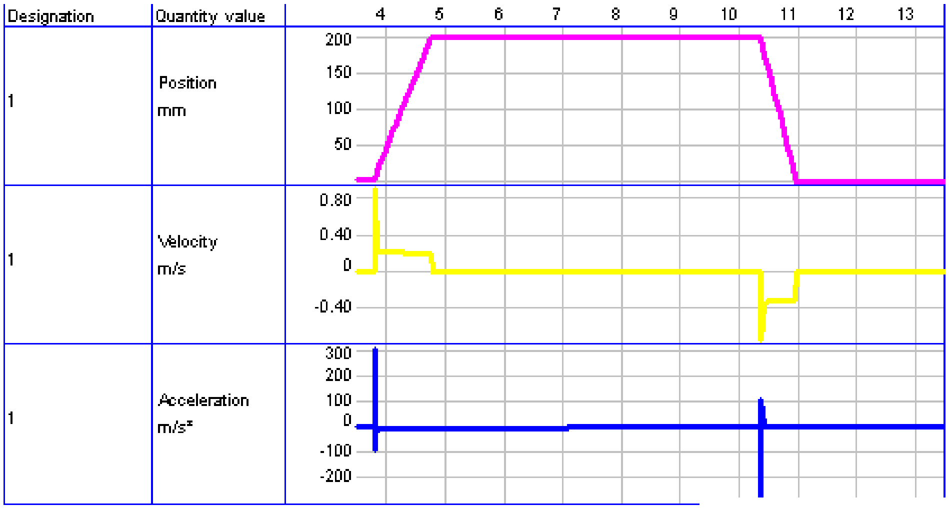
We can notice that the cylinder descends under the influence of its weight so we will supply pilot operated check valve which cause jerky motion so we need to supply meter out to reduce descending velocity.

- **Two pilot operated check valves** in the same package to save the load from falling under its load (over running).
- **Flow control valve with check valve** connected in parallel to control the speed of the cylinder.
- **Pump**: Produces a constant flow of hydraulic fluid to supply the control valve.
- **Relief Valve**: Protects the hydraulic system from too much pressure. This part is considered a critical safety component of hydraulic forklift hydraulic pressure
- **DCV**: Starts and stops the direction of fluid and controls where the fluid moves using spools. Without a control valve, forklift hydraulic pressure would be useless. 6- Filter: continuously remove contaminants in the hydraulic oil.
- **Float center spool** is used in circuits where both work ports are required to be open to tank while in the neutral position. It is used in conjunction with load holding or motion control valves, which themselves necessitate draining of their spring chambers, a function that wouldn't occur with a closed center. These spools are also called motor spool because they allow fluid to pass through the center of the valve from one port of the motor to the other. This operation allows a motor to spin down naturally under its own energy, rather than an abrupt stopas would occur with a closed center p-port blocked, so pressure needed.

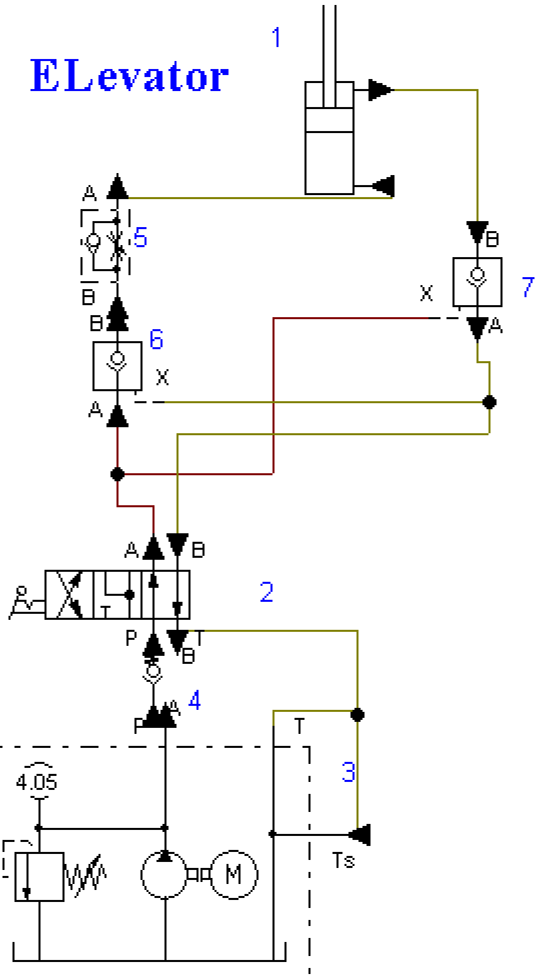
FESTO RESULTS

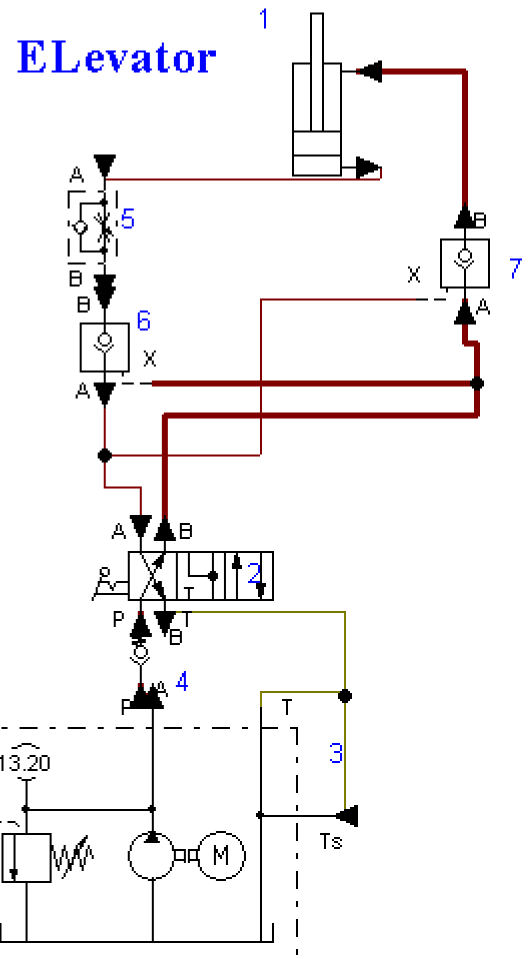


Designation	Description
1	Double acting cylinder
2	4/3-way hand-lever valve with floating position
3	Pump unit
4	Check valve
5	One-way flow control valve
6	Check valve with pilot control
7	Check valve with pilot control



EXTENSION
RETRACTION





Chapter 2: Drag and Lift forces

Wind Tunnel

Wind tunnel used to test new ideas of crafts which look perfect on computer systems and simulations.

Idea of work: passing air with different velocities over the fixed model whatever it is to create relative velocity to know how much the model`s efficiency to create the actual design or to create another idea of the design.

Types: there are many types of wind tunnel, some of them**:**

- **Airspace wind tunnel:**
- **Motor space wind tunnel:**

Why we use wind tunnel?

To know the magnitude of forces acting on the body (Lift and Drag forces).

Lift force is the force acting perpendicular on the flow.

Lift force (F_L) = C_L * 0.5*A*V*ρ

So $C_L = \frac{Fl}{0.5\ \rho * A * V}$

C_L: Lift coefficient

P: density of flow

A: area projected

V: velocity of flow over the body.

Drag force is the force acting in the direction of the flow.

Drag force (F_D) = C_D * 0.5*A*V*ρ

So $C_D = \frac{Fd}{0.5\ \rho * A * V}$

C_D: Drag coefficient

P: density of flow

A: area projected

V: velocity of flow over the body.

Hint: **according to R_e, shape of the body and the velocity of the flow above it, both of C_D and C_L change.**

$R_e = \frac{\rho * V * L}{\mu}$

L_c: characteristic length

Laboratory results of drag coefficient (C_D) on different shapes:

Using the wind tunnel shown in the *[figure 1-2].*

The shapes here are:

1. **Sphere.**
2. **Disk.**
3. **Hemisphere.**

$C_D = \frac{Fd}{0.5\ \rho * A * V}$

ρ_{air} = 1.187 Kg/m^3

μ_{air} = 1.849* 10^{-5} Pa.s

hint: **this properties at atmospheric pressure and temperature 25° c.**

Figure 1-2. wind tunnel used to calculate (C_D).

Sphere shape

Velocity (m/sec.)	Force(N)
16	0.2
21	0.4

Area(m)=$\frac{\Pi}{4}$*D^2

@ velocity =16 m//sec.:

C_D= $\frac{Fd}{0.5\ \rho*A*V^\wedge2}$ = $\frac{0.2}{0.5\ \rho*A*16^\wedge2}$ = 0.4

R_e = $\frac{\rho*V*D}{\mu}$ = R_e = $\frac{1.187*16*0.064}{1.849*\ 10-5}$ = 65571.444

@ velocity =21 m//sec.:

C_D= $\frac{Fd}{0.5\ \rho*A*V^\wedge2}$ = $\frac{0.4}{0.5\ \rho*A*21^\wedge2}$ = 0.476

R_e = $\frac{\rho*V*D}{\mu}$ = R_e = $\frac{1.187*16*0.064}{1.849*\ 10-5}$ = 86062.52

Note**: increasing velocity causes increasing in C_D and R_e.**

Disk

Velocity (m/sec.)	Force(N)
17	0.75
22.5	1.33

Area (m) =$\frac{\Pi}{4}$*D^2

@velocity =17 m//sec.:

$C_D = \frac{Fd}{0.5\ \rho * A * V\^2} = \frac{0.75}{0.5\ \rho * A * 17\^2} = 1.363$

$R_e = \frac{\rho * V * D}{\mu} = R_e = \frac{1.187 * 17 * 0.064}{1.849 * 10-5} = 69669.66$

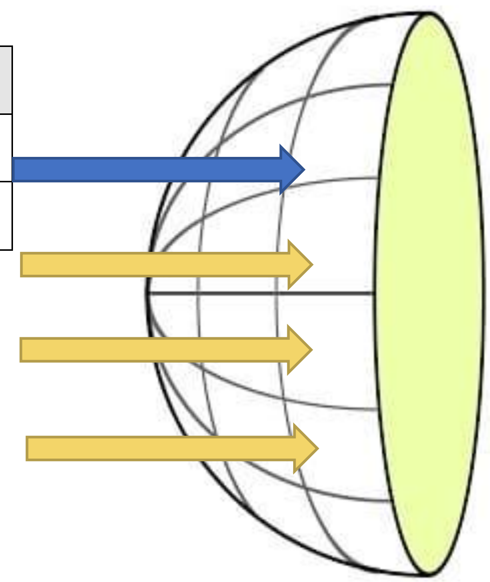
@velocity =22.5 m//sec.:

$C_D = \frac{Fd}{0.5\ \rho * A * V\^2} = \frac{1.33}{0.5\ \rho * A * 22.5\^2} = 1.379$

$R_e = \frac{\rho * V * D}{\mu} = R_e = \frac{1.187 * 22.5 * 0.064}{1.849 * 10-5} = 92209.84$

Note**: increasing velocity causes increasing in C_D and R_e.**

Hemisphere



Velocity (m/sec.)	Force(N)
17-10	0.26-0.18
23-13	0.511-0.44

Area (m) $= \frac{\Pi}{4} * D^2$

@velocity =17 m//sec.:

$C_D = \frac{Fd}{0.5\ \rho * A * V\^2} = \frac{0.26}{0.5\ \rho * A * 17\^2} = 0.472$

$R_e = \frac{\rho * V * D}{\mu} = R_e = \frac{1.187 * 17 * 0.064}{1.849 * 10-5} = 69669.66$

@velocity =23 m//sec.:

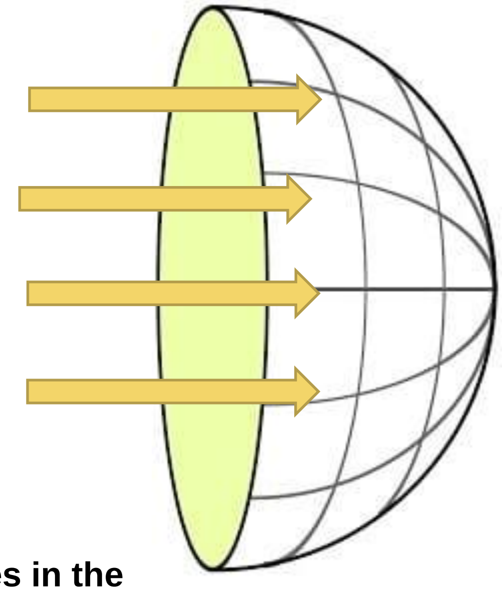
$C_D = \frac{Fd}{0.5\ \rho * A * V\^2} = \frac{0.511}{0.5\ \rho * A * 23\^2} = 0.5$

$R_e = \frac{\rho * V * D}{\mu} = R_e = \frac{1.187 * 23 * 0.064}{1.849 * 10-5} = 94258.95$

@velocity =10 m//sec.:

$$C_D = \frac{Fd}{0.5\ \rho * A * V^{\wedge}2} = \frac{0.18}{0.5\ \rho * A * 10^{\wedge}2} = 0.945$$

$$R_e = \frac{\rho * V * D}{\mu} = R_e = \frac{1.187 * 10 * 0.064}{1.849 * 10 - 5} = 41085.99$$



@velocity =13 m//sec.:

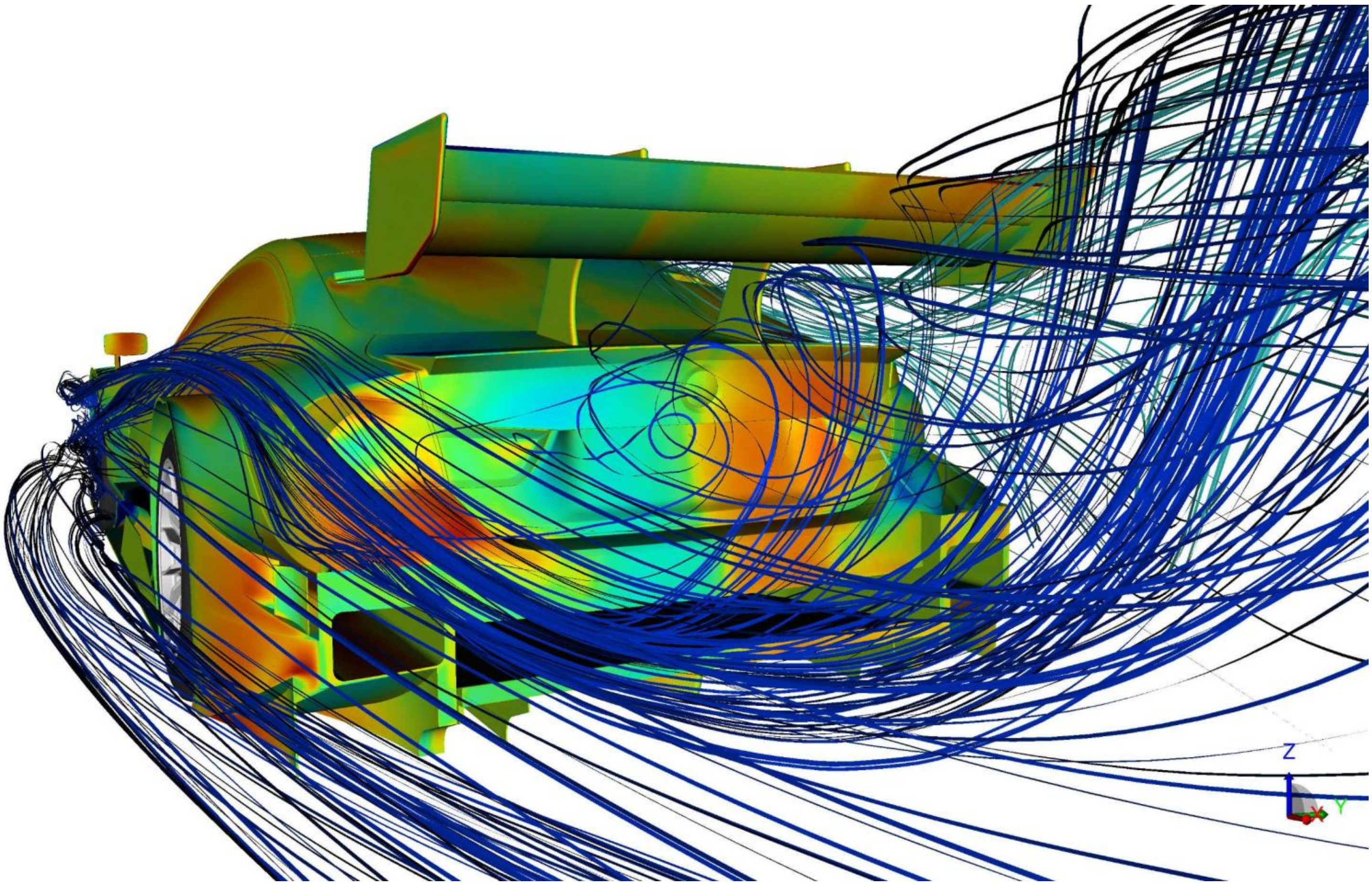
$$C_D = \frac{Fd}{0.5\ \rho * A * V^{\wedge}2} = \frac{0.44}{0.5\ \rho * A * 13^{\wedge}2} = 1.367$$

$$R_e = \frac{\rho * V * D}{\mu} = R_e = \frac{1.187 * 13 * 0.064}{1.849 * 10 - 5} = 53411.79$$

Hint: **all values of C_D are around the values in the reference because of R_e in a range which must be $>10^4$**

Note**: increasing velocity causes increasing in C_D and R_e.**

Chapter 3: Drag and Lift application



Dragonfly wings and their role in MAVS

Introduction

Dragonfly wings possess great stability and high load-bearing capacity during flapping fight, glide, and hover. Scientists have been intrigued by them and have carried out research for biomimetic applications. Relative to the large number of works on its flight aerodynamics, few researchers have focused on the insect wing structure and its mechanical properties. The wings of dragonflies are mainly composed of veins and membranes, a typical nanocomposite material. The veins and membranes have a complex design within the wing that give rise to whole-wing characteristics which result in dragonflies being supremely versatile, maneuverable fliers. The wing structure, especially corrugation, on dragonflies is believed to enhance aerodynamic performance. The mechanical properties of dragonfly wings need to be understood in order to perform simulated models. This paper focuses on the effects of structure, mechanical properties, and morphology of dragonfly wings on their flyability, followed by the implications in fabrication and modeling.

Its application in industry (MAVS):

There is an interest in the development of Micro Air Vehicles (MAVs) which have the potential to revolutionize information gathering in environmental monitoring, homeland security, and other time-sensitive areas.

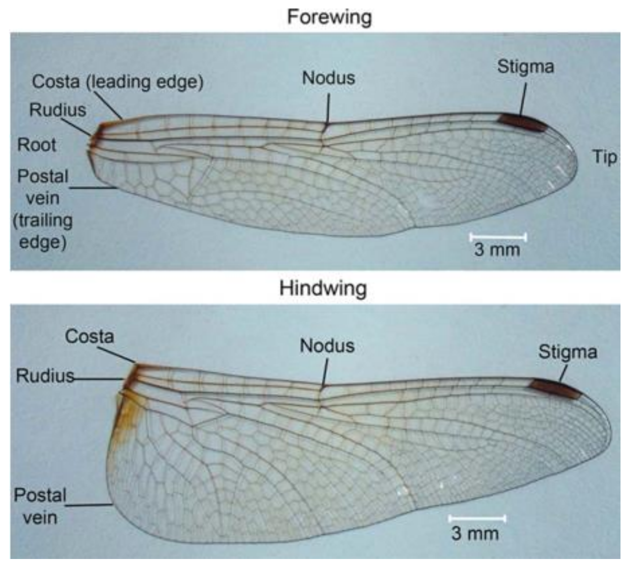
Because of their excellent flying characteristics, flying insects give researchers inspiration for biomimetic designs of MAVs. The understanding of the functions provided by objects and processes found in nature can guide researchers to imitate and produce nanomaterials, nanodevices, and processes.

The insect wing is a complex mechanical structure. Some researchers have modeled it using the finite element method (FEM)

In this report we are going to talk about the structure of the dragonfly and how its structure makes it easy for it to fly in a high speed and how we use it in industry.

Structure

There are a number of key structures in the wing (in this figure) which contribute to the manner in which it bends in flight and therefore help to facilitate the wing's aerodynamic properties.



The main structures

a. Veins

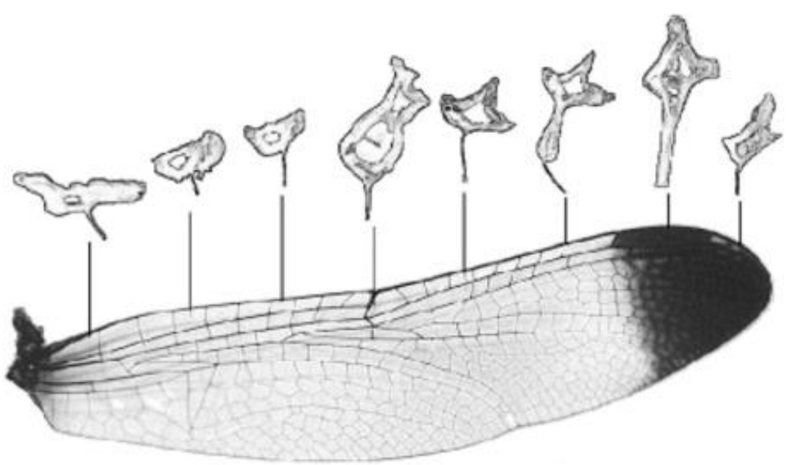
Veins shape deform from one point to another according to the force that acts on the wing.

It has different shapes:

- Rectangular frames at leading edge.
- Hexagons and other polygons with more than 4 sides at trailing surface.

Veins and membranes thickness increases from tip to root but nodus and stigma have almost the same thickness across the wing.

This difference in thickness allows the wing to effectively bear both inertial and aerodynamics loads.



b. Membranes

The microstructure of the membrane surface has excellent super hydrophobicity with a water angle of about 174°.

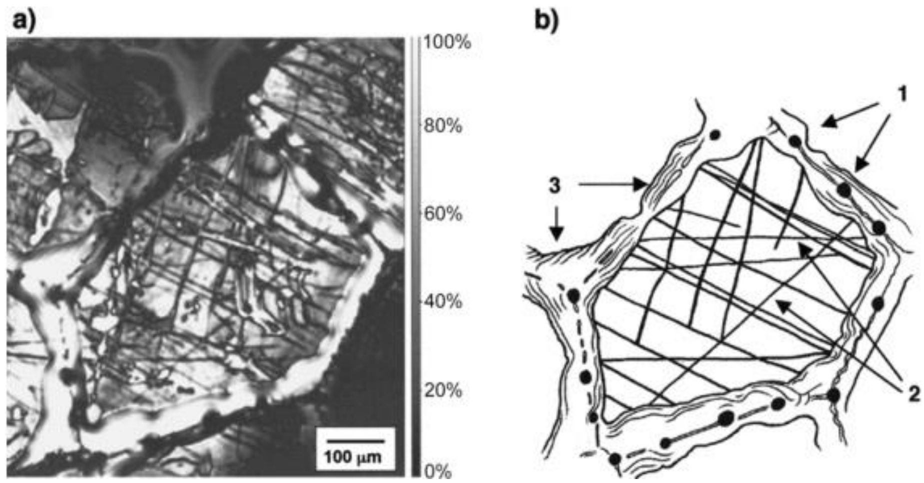


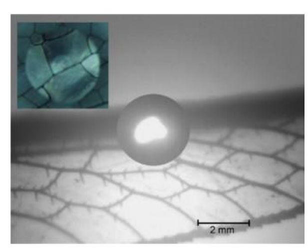
Fig. 7. The superficial wax layer in dragonfly wing membrane. (a) SAM micrograph of the wing cuticle of the posterior part of a natural dragonfly forewing. The wing membrane shows distinctly arranged contrast lines. (b) Schematic of the SAM image, 1) spine on the membrane framing veins, 2) interference lines along the vein, 3) contrast lines within the membrane.

c. Stigma

The stigma (also called pterostigma) is developed upon the costa of the wing at the point of greatest impact against the air. It would seem to serve the double purpose of firmly uniting the veins of the front margin and of increasing the efficiency of the wing stroke by adding weight at this striking point, shifting the center of mass towards the axis and regulating the pitching of the wing.

d. Nodus

The role of the nodus is to both provide reinforcement and shock absorber capability, coping with combined torsion and bending stress concentrations at the junction of the rigid concave ante nodal and the torsional compliant post nodal spars.



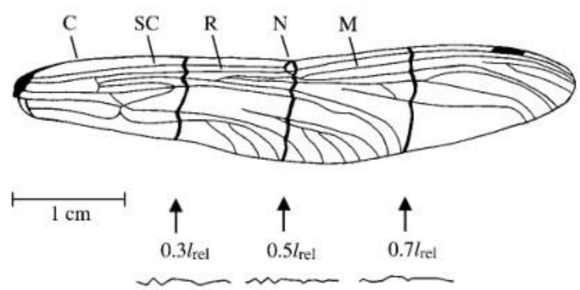
e. Corrugation

This is the most important part in this topic, dragonfly wings are highly corrugated, which increases the stiffness and strength of the wing significantly and results in a lightweight structure with good aerodynamic performance.

The configuration varies along the spanwise and chordwise directions and enhances the flight performance in several ways, such as absorbing stress against spanwise bending, allowing torsion to occur, and the development of the camber.

Aerodynamics

The aerodynamic characteristics of an airfoil can be determined using simple steady-state analyses by disregarding unsteady effects. The air surrounding a wing is accelerated to generate the aerodynamic forces lift L and drag D, and the resultant force thrust T, that enables the insect to fly. The aerodynamic performance of the wing can be quantified by the relationship between lift and drag.



Dragonfly wings are not smooth but have a well-defined corrugated configuration.

However, from aerodynamic point of view, this cross-section area doesn't appear to be very suitable. The pronounced bends and edges should lead to high drag values, but in visualizing experiments using profile models have shown that this geometry induces positive flow conditions.

This profile makes the vortices fill the valleys forms by the bends.

Corrugation and orientation

- Corrugation decreases gradually towards the wing tip, where the wing moves or less flatness out.
- Orientation of the leading-edge changes at the nodus, however this change there is no change in the aerodynamic characteristics along the wing axis.

The present study aims to clarify the aerodynamics influence of the "dynamic smoothing" of the profile by the vortices generated in the valleys of the bends.

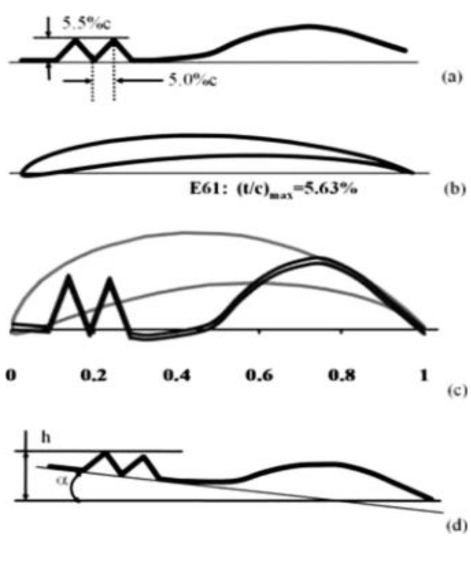
Corrugated airfoils provide superior aerodynamic efficiency compared to "classical" smooth airfoils at the current range of Reynolds numbers. However, the more detailed studies known to the authors at Reynolds numbers lower than 20 000 were essentially experimental and performed on finite wings. These measurements are affected by 3D effects, such as wing-tip vortices. Therefore, 2D airfoil properties cannot be isolated. Furthermore, only the integral forces were measured, and no detailed flow features were presented. This is apparently due to the difficulty in measuring properties such as pressures and velocities over these very thin airfoils at very low speeds. The purpose of the current study is to analyze the 2D flow around a simplified corrugated dragonfly airfoil.

First, the 2D flow around the corrugated airfoil and a known low Reynolds number, airfoil Eppler-E61- are numerically analyzed. Their performances, such as lift, drag coefficients Cl and Cd, and lift-to-drag ratio are compared.

A COMPARISON OF CORRUGATED AND TRADITIONAL AIRFOILS

The corrugated airfoil geometry analyzed in this work is based on simplified dragonfly airfoil. The airfoil thickness is 0.05 mm, one of the significant parameters of low Reynolds number aerodynamics is the airfoil thickness, a "classical" airfoil with a thickness-to-chord ratio close to that of the corrugated airfoil thickness ratio 5.5% based on the corrugation's height.

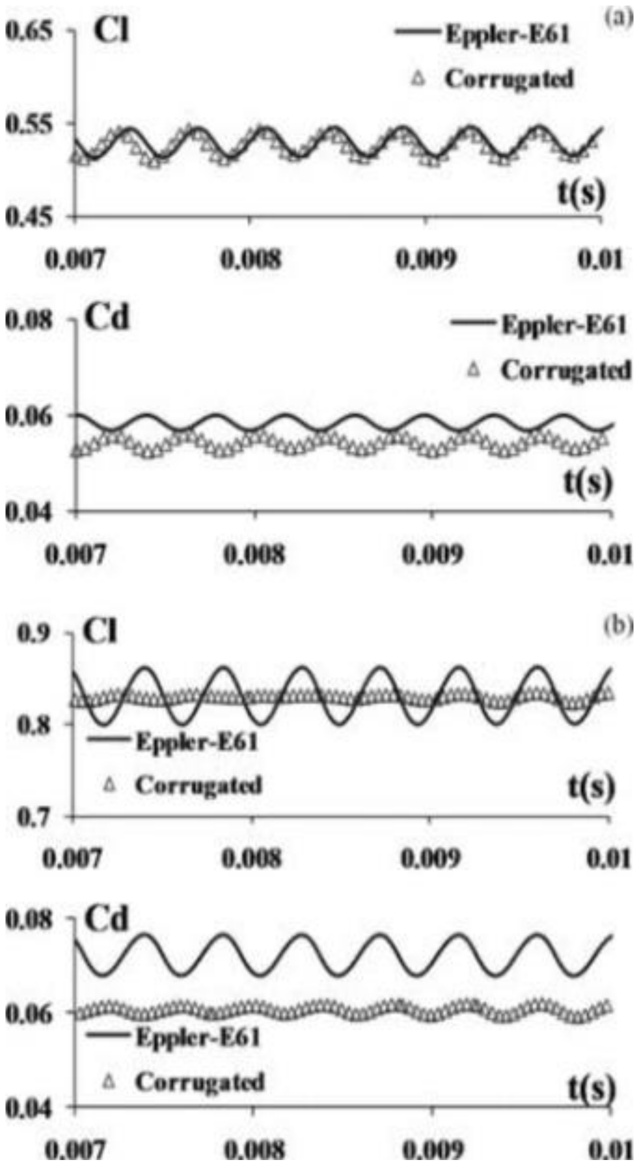
The Navier–Stokes equations around these airfoils were numerically solved using the commercial code FLUENT. The grid which contains 64 000 points is structured in the region close to the airfoil for convenience-while it is unstructured in the far field. The origin of the grid is situated on the lower leading-edge point of the airfoil geometry.



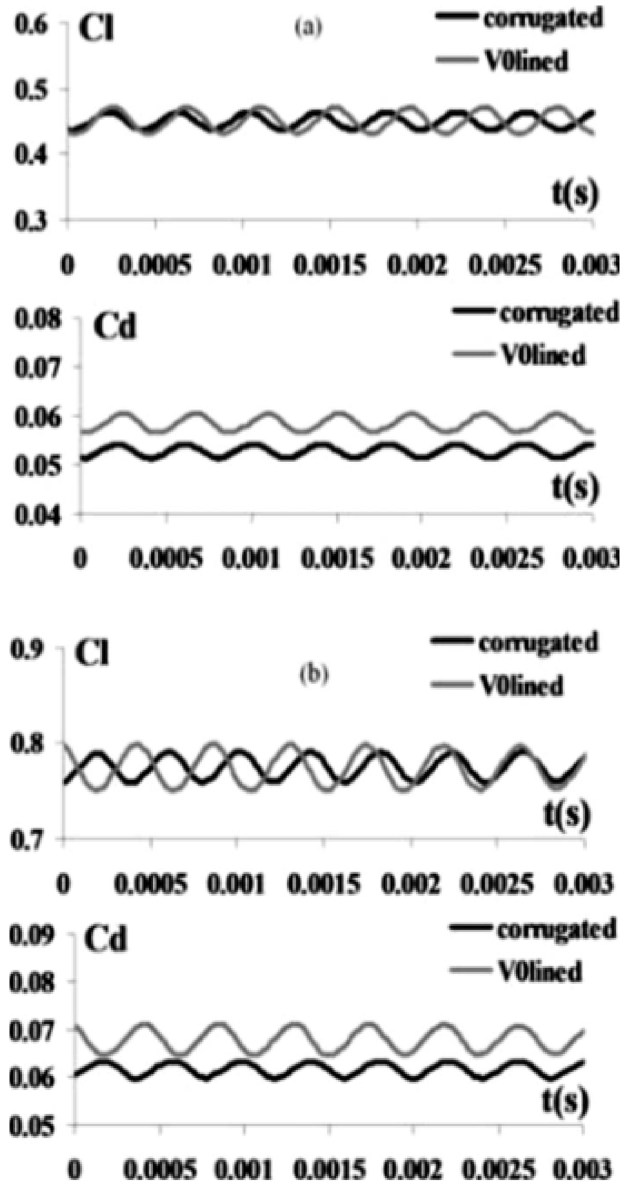
Simplified corrugated airfoil geometry, (b) Eppler-E61 airfoil

geometry. The airfoils are plotted at α=0°, (c) comparison of the two airfoils shapes (stretched four times in the vertical direction), and (d) schematic

definition of the projected height (h) on the Y axis.



Comparison of calculated lift and drag coefficients vs time at Re =6000, (a) Clmean=0.53 (α =3.7° for the corrugated airfoil and α =1° for the Eppler E-61); (b) Clmean=0.82 (α =7° for the corrugated airfoil and α =4°for the Eppler E-61).



Comparison of calculated lift and drag coefficients’ oscillations as a function of time at Re=6000, (a) Clmean=0.45, and (b)Clmean=0.77.

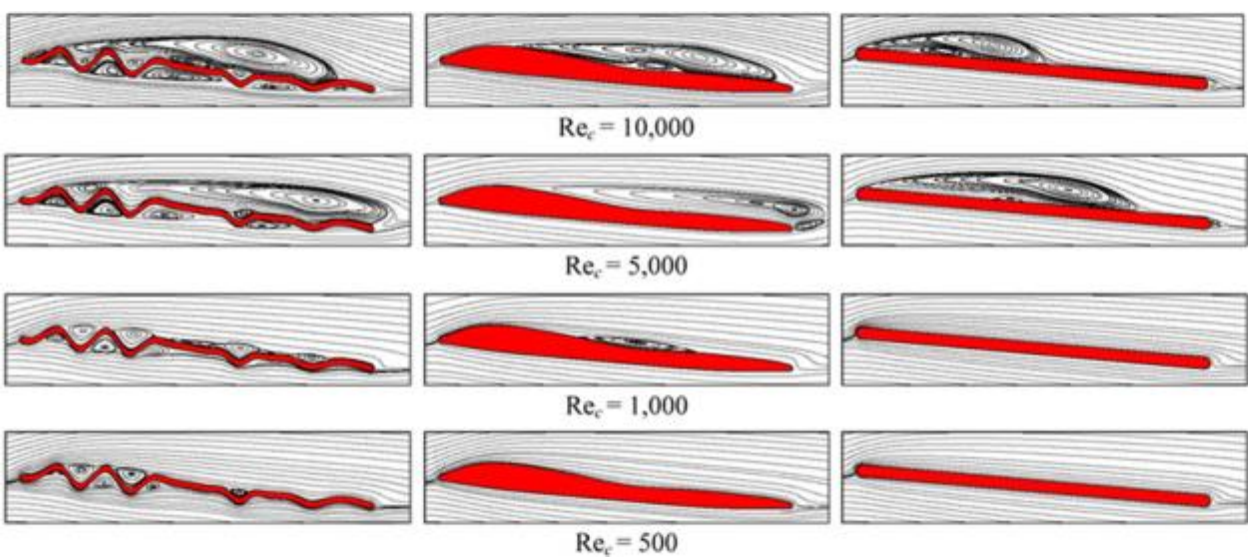
A numerical and experimental study of corrugated airfoil aerodynamics, based on a simplified dragonfly wing cross section, was performed at Reynolds numbers between 2000 and 8000. The results of the corrugated airfoil analysis were compared to the performance of a “traditional” low Reynolds number airfoil, the Eppler-E61, and also to a family of smooth airfoils designed on the basis of the flow field around the corrugated airfoil.

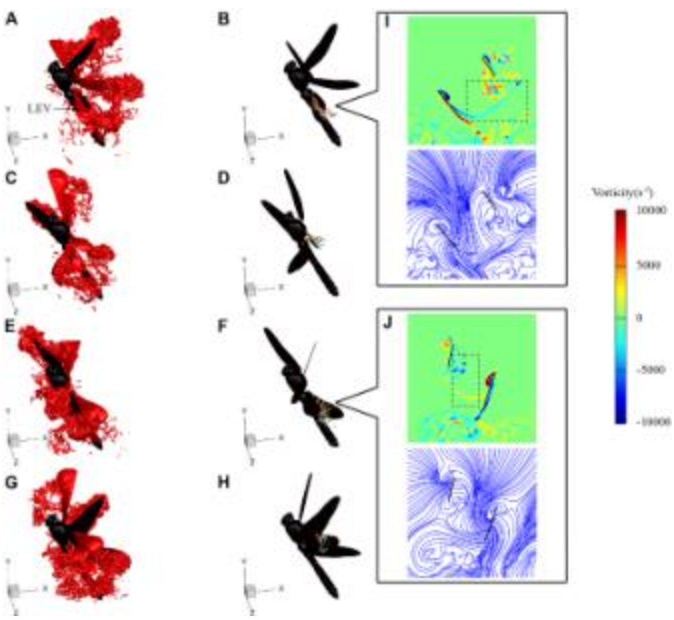
Here the aerodynamic of dragonfly in details

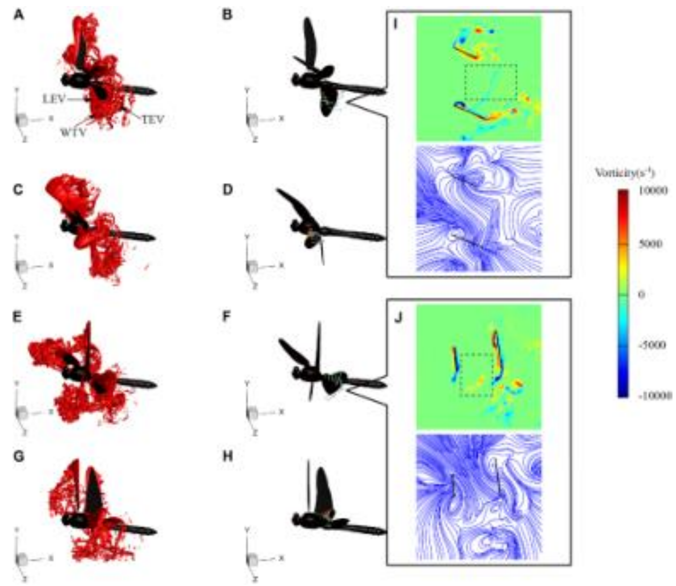
The vortices formed on the corrugated airfoil and shed into its wake produce lower integral force fluctuations due to their upstream pinch-off location and shorter wavelength, leading to lower mean drag and lower integral forces fluctuations, as compared to smooth airfoils.

It was also found that the vortices’ magnitude in the wake of the corrugated airfoil is lower, leading to weaker induced velocities on the airfoil and therefore lower fluctuating lift.

the calculated maximum range coefficient (L/D) max and the maximum endurance coefficient (L1.5/D) max of specific flying configuration with corrugated airfoil should be superior to a similar configuration with the smooth airfoils examined. In parallel, the ability of the corrugated airfoil to reduce drag allows reaching greater velocities.







Dragonfly-inspired M.A.V

Micro air vehicles (MAV) are small kind of unmanned air vehicles (UAV) which are used for surveillance, armed attacking, search and rescue operations, scientific research and transportation.

MAVS have relatively small sizes and weights than UAVS, therefore they are very suitable for surveillance applications and image recording. They have also low noise and low production cost. Due to their small size the, the probability of being intercepted by radar is low.

Dragonfly as (MAV)

Finally, we introduce several dragonfly robots we have developed in our lab. Shows the latest designs. This model has two pairs of wings driven by a double crank rocker mechanism. The current prototype weighs 4g including battery and electronics.

The following table shows some specifications.

Motor	Battery & Control	Gear
Torque: 44mNm	4V	Maximize Torque
Power: 176mW	0.4A	Ratio: 1:7
16k rpm	Infrared Chip	Precision Molded
Weight: 1.4g	Weight:1.1+1.3g	Weight:0.23g

This prototype was able to generate 28 Hz flapping frequency with four carbon fiber leading edges only and 9 Hz after adding (gluing) the polymer wing onto two leading edges. With all four wings the frequency reduced to 7 Hz. The total weight is 7 grams, and the total length is 2 inches.

In order to test different wing performance and property, they have developed a mechanical wing tester. It can be used to study the fatigue cycles of each wing developed and can also be used to visualize the wing kinematics by a high-speed camera. Fig.12 shows the wing tester and a sample dragonfly wing made of carbon fiber and polymers. Fig.13 shows the camera images of test wings and shows the frequency plot of different robotic wings under investigation.

Development of a Wing Root Rotation Mechanism

In the flight of insects, wing rotation is an essential factor for a positive angle of attack at flapping. To generate the wing rotation passively, this study used a wing rotation mechanism using a loose wing membrane, The proposed wing rotation mechanism was fabricated with a wing membrane larger than the designed wing membrane to generate wing rotation, and this changes the angle of attack by rotating the wing root. This wing rotation made by the loose wing membrane not only generates more lift force by the camber wing structure in flight but also increases efficiency while gliding.

The frame of the wing is made of carbon rods to reduce weight, and the wing membrane is made of 25 μm thick polypropylene film. For the passive rotation of the wing, a polyolefin tube attached at the leading edge and root of the wings reduces the friction at wing rotation. In addition, two 0.6 mm carbon rods attached to the wing membrane maintain the rigidity of the wing after rotation.

(a) (b)

In the above experiments, they have finished different designs of the MAVS and calculated the drag and lift forces, and they found the low value of it according to following the structure of the dragonfly.

Overall, wing-wing interaction is detrimental to total lift force generation. Hindwing lift was significantly reduced in forward flight due to the downwash from forewing. In-phase flight generates higher lift than other phase differences, while 270° phase difference generates the lowest lift. In hovering, dragonflies use anti-phase flight which generates a regular lift force for stability and vibration reduction purposes. A prototype for dragonfly-inspired M.A.V has been shown. Many jobs need to be done in the future aiming to build up a sophisticated M.A.V. The mechanical design should be further improved to achieve a higher flapping frequency and better efficiency, in order to minimize the weight and maximize the lift force. How to make phase difference controllable on a four-wing M.A.V is also challenging the engineers.

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