WIEFP 2022

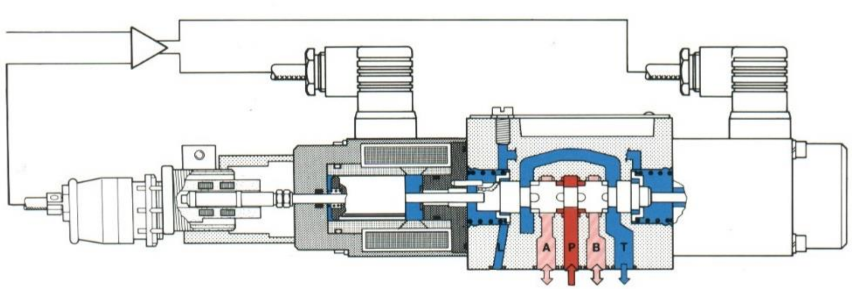
NOVEMBER 22-23 ▪ SÃO PAULO ▪ BRAZIL

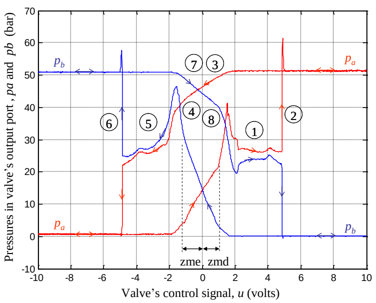
PRACTICAL METHOD FOR IDENTIFICATION AND COMPENSATION OF DEAD ZONE IN DIRECTIONAL SPOOL VALVES

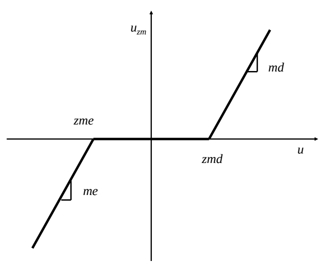
Prof. Antonio Carlos Valdiero, Department of Mechanical Engineering (EMC), UFSC

Purposes of this short-course/ *Objetivos*

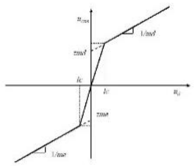
- This short-course presents a new methodology for identification of the dead zone nonlinearity in proportional directional hydraulic or pneumatic valves, it is based on observing the dynamic behavior of the pressure in the valve gaps/ *Apresentar uma nova metodologia para identificação da não linearidade da zona morta em válvulas direcionais proporcionais hidráulicas ou pneumáticas, baseada na observação do comportamento dinâmico da pressão nos orifícios das válvulas.*







- It is presented a control scheme with fixed and smoothed inverse compensation linearly close to the origin/ *Apresentar um esquema de controle com a compensação baseada na inversa fixa e suavizada linear próxima da origem.*



Covered Topics/ *Tópicos abordados*

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- Context and justifications/ *Contexto e justificativas.*
- Dead Zone Concept/ *Conceito de zona morta.*
- Dead zone in hydraulic or pneumatic proportional directional valves/ *Zona morta em válvulas direcionais proporcionais hidráulicas ou pneumáticas*
- Dead Zone mathematical model/ *Modelo matemático de zona morta*
- Identification of the dead zone nonlinearity in valves/ *Identificação da não linearidade da zona morta em válvulas*
- Proposed methodology/ *Metodologia proposta*
- Application in a hydraulic positioning system/ *Aplicação em um sistema de posicionamento hidráulico*
- Application on a pneumatic servo positioner/ *Aplicação em um servoposicionador pneumático*
- Advantages of the proposed method/ *Vantagens do método proposto*

Context and justifications/ *Contexto e justificativas*

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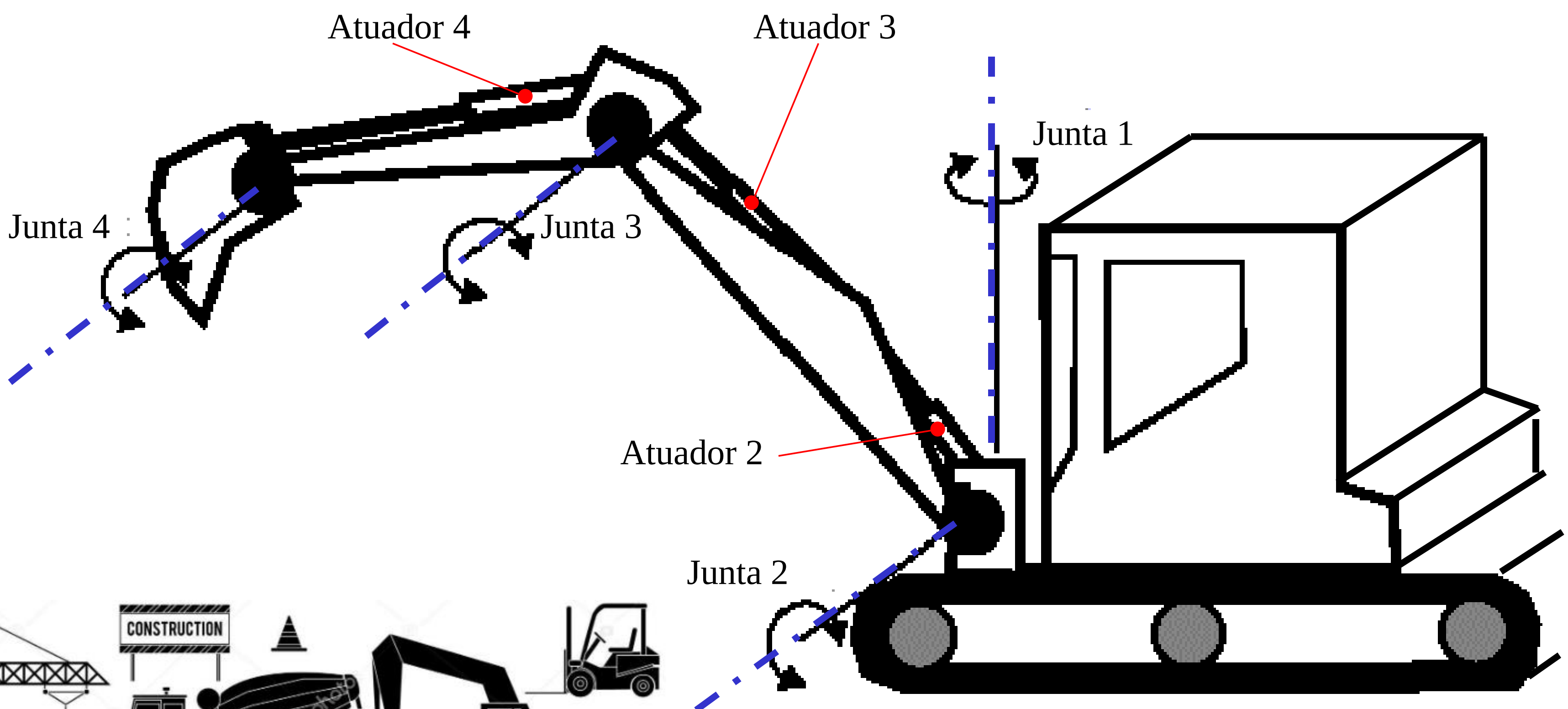
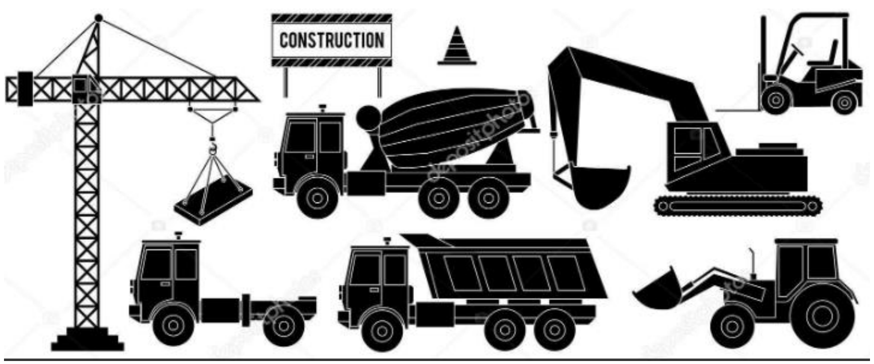
- The dead zone nonlinearity is among the key factors limiting both static and dynamic performance of feedback control hydraulic systems/ *A não-linearidade da zona morta está entre os principais fatores que limitam o desempenho estático e dinâmico dos sistemas hidráulicos de controle de feedback.*
- Fluid Power systems have a great potential of application in the construction industry, agricultural equipments, transport and material handling equipments, mining equipments, manufacture, siderurgy, metallurgy, aviation, navy and others industry fields, it due to advantages of the high relationship torque/dimension and the flexibility of installation their actuators/ *Os sistemas hidráulicos e pneumáticos têm um grande potencial de aplicação na indústria da construção, equipamentos agrícolas, equipamentos de transporte e manuseio de materiais, equipamentos de mineração, fabricação, siderurgia, metalurgia, aviação, marinha e outros campos da indústria, devido às vantagens da alta relação torque/dimensão e à flexibilidade de instalação de seus atuadores*

Context and justifications/ *Contexto e justificativas*

construction industry





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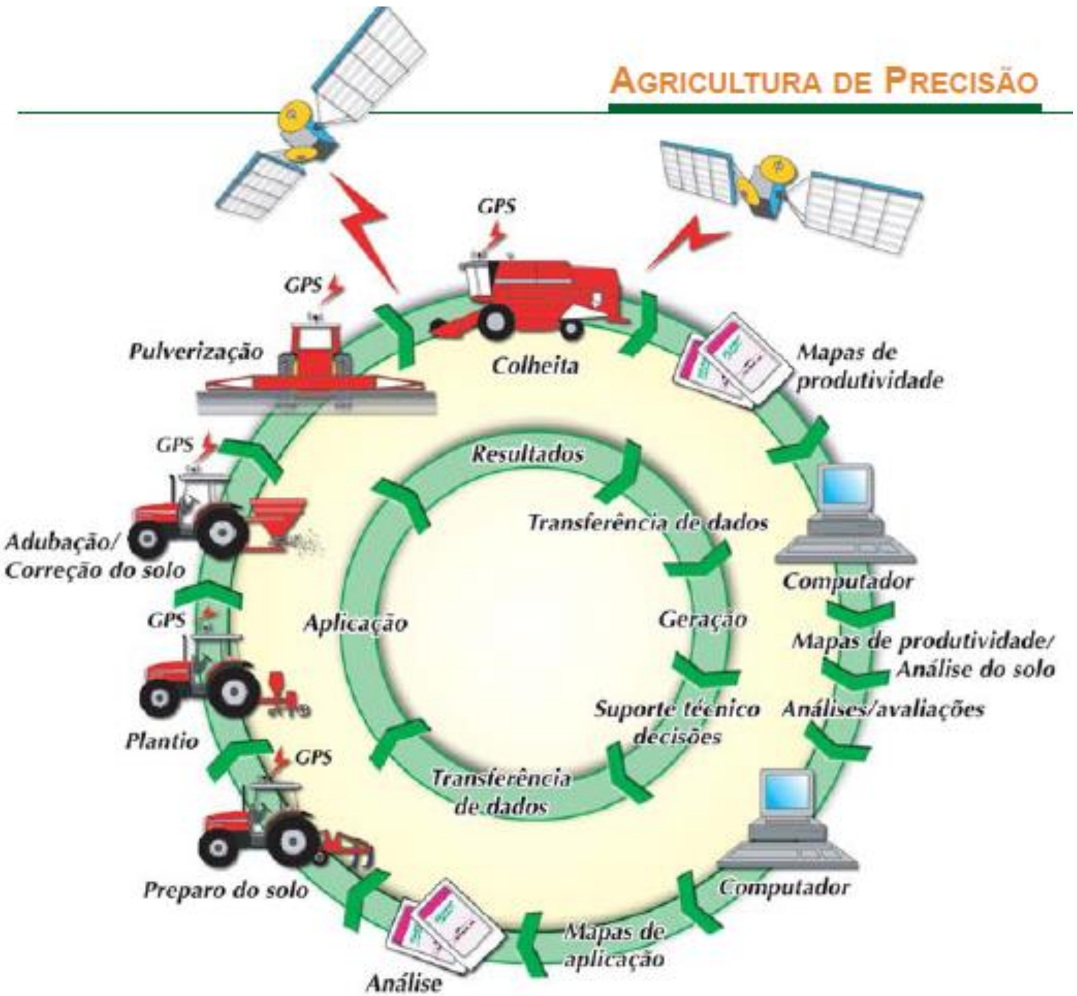
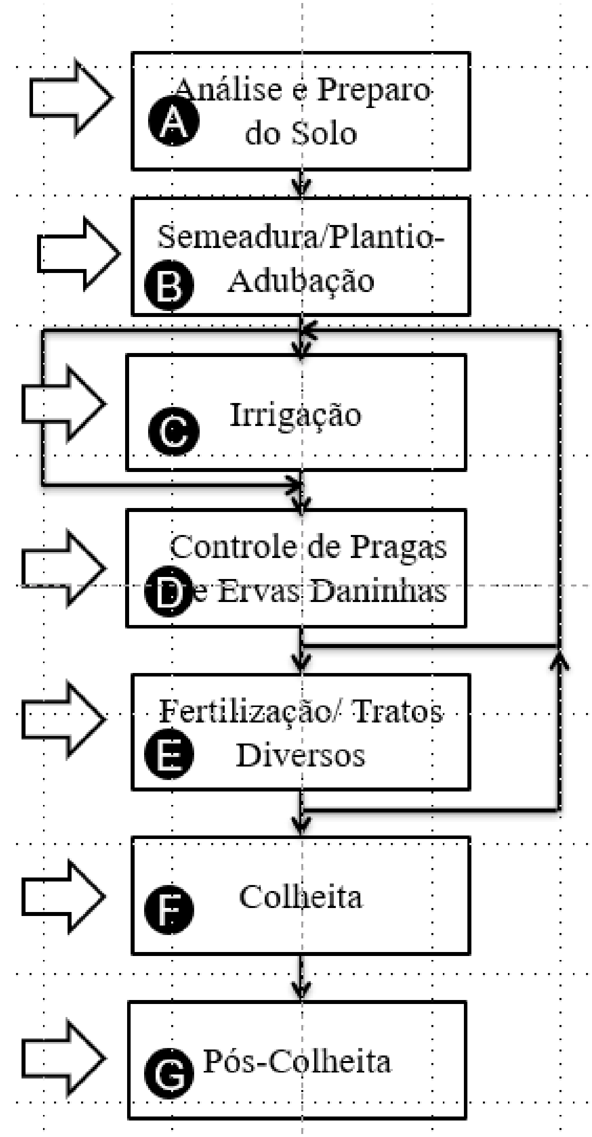
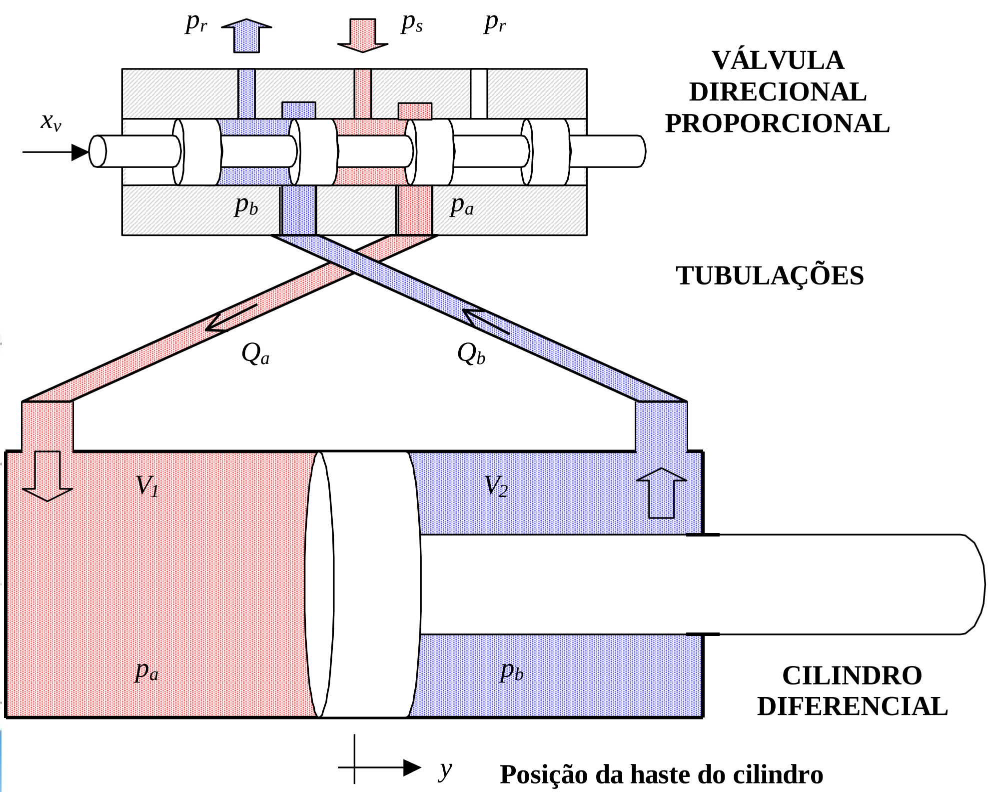
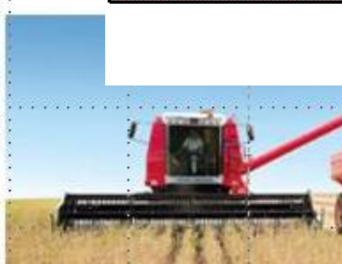
agricultural equipments

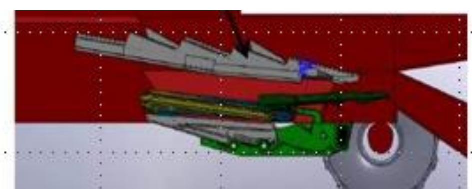




agricultural equipments







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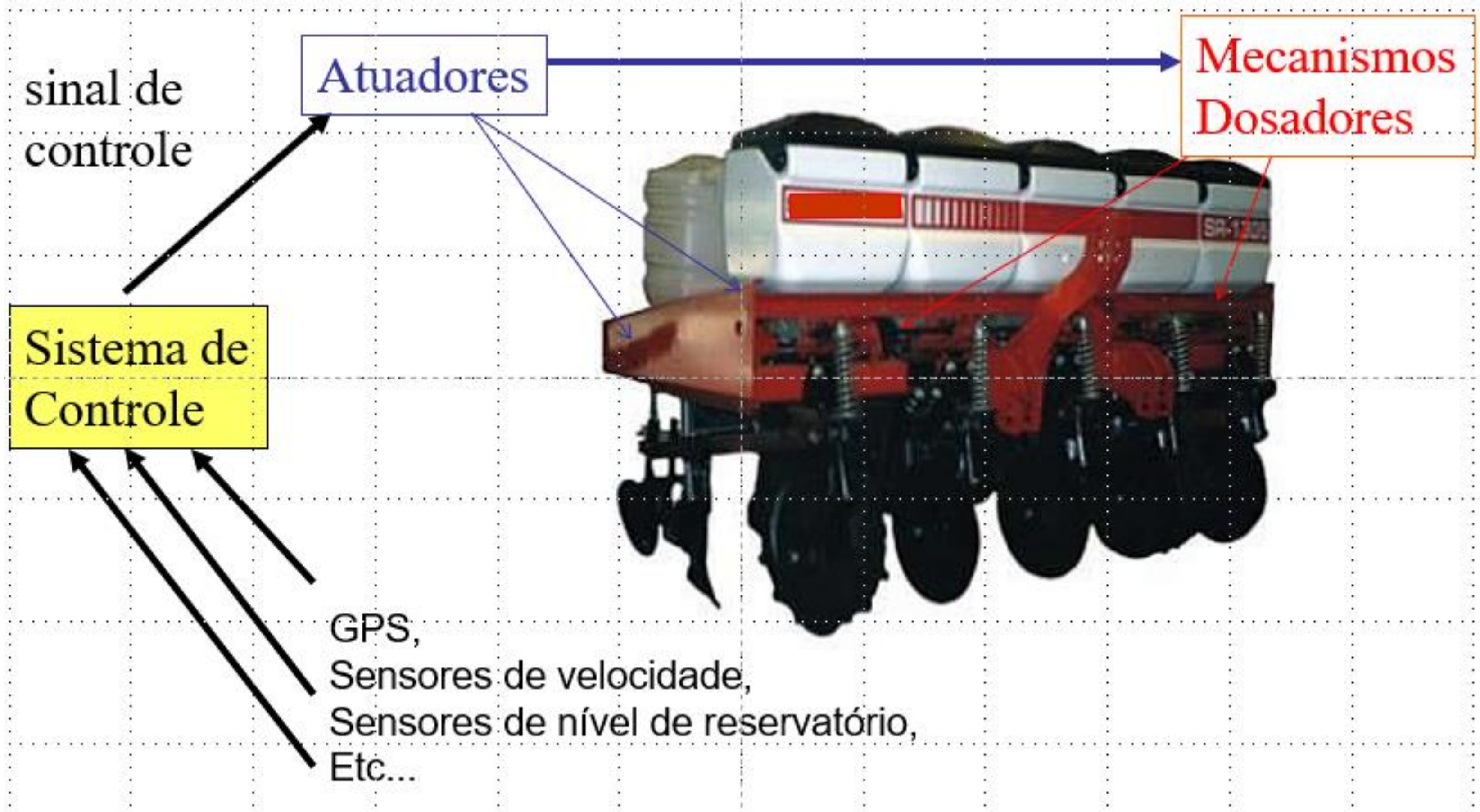
agricultural equipments



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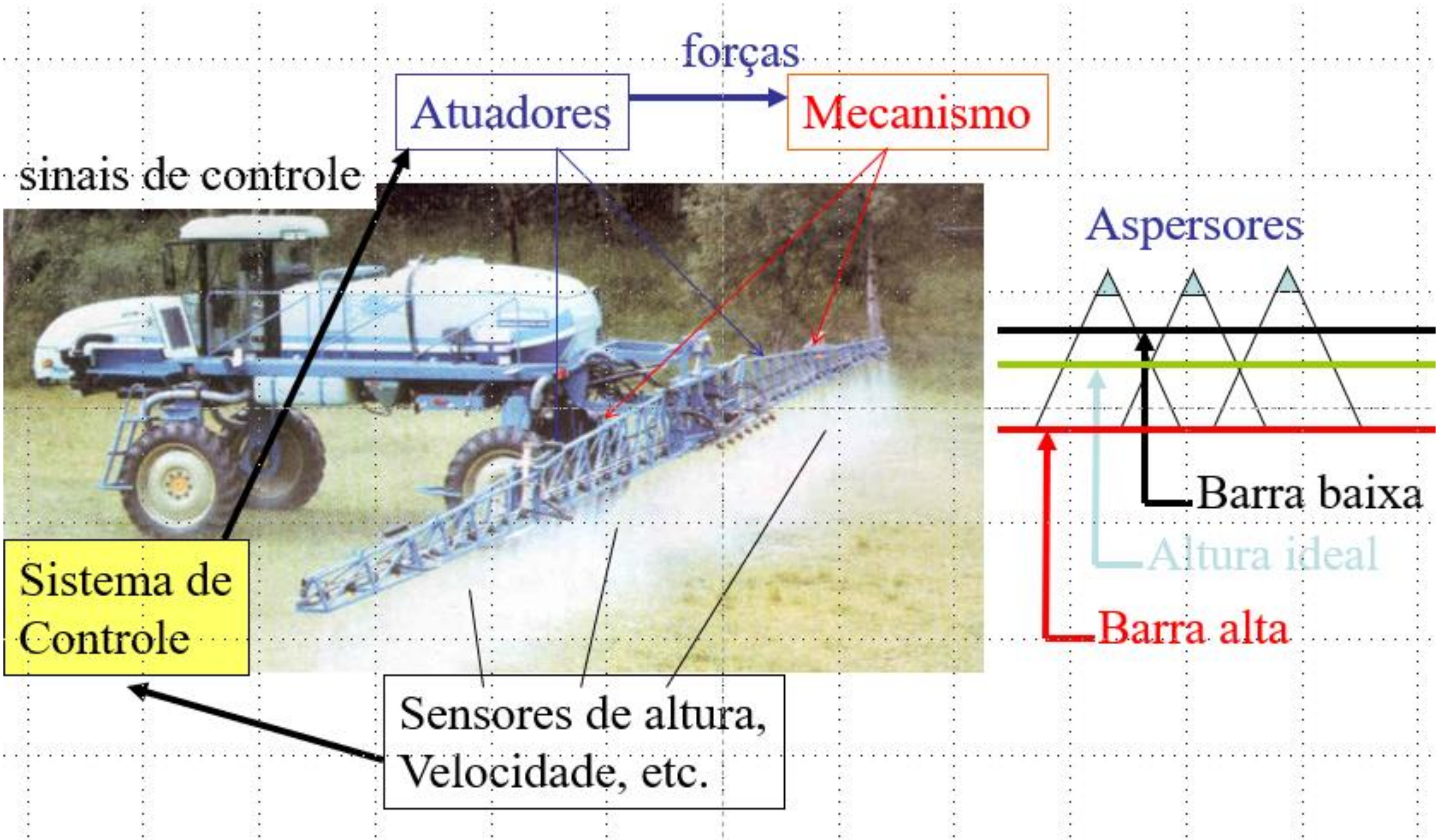
agricultural equipments



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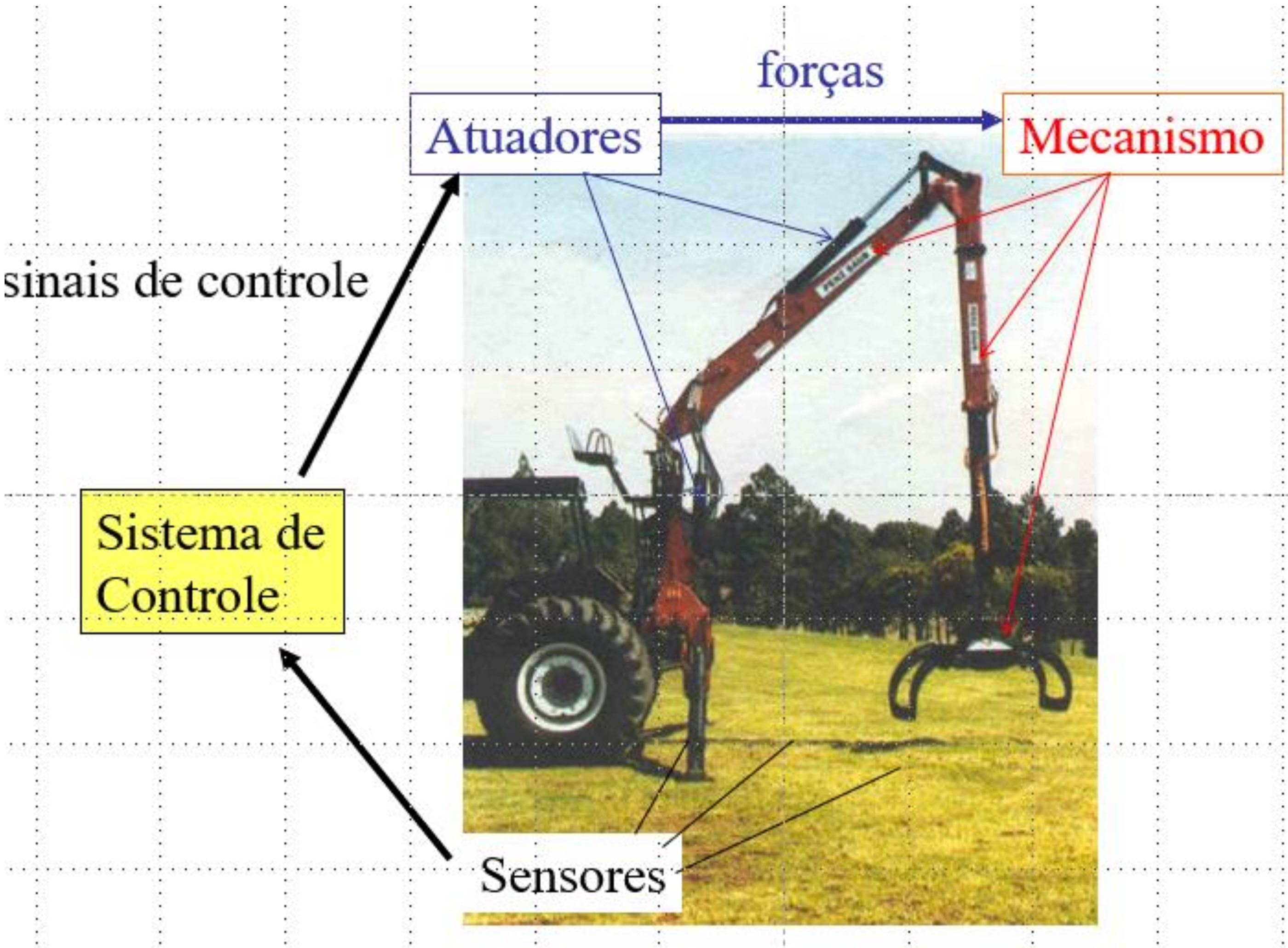
forestry equipment



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forestry equipment

NiMeP

Poda de Precisão

P&D ANEEL

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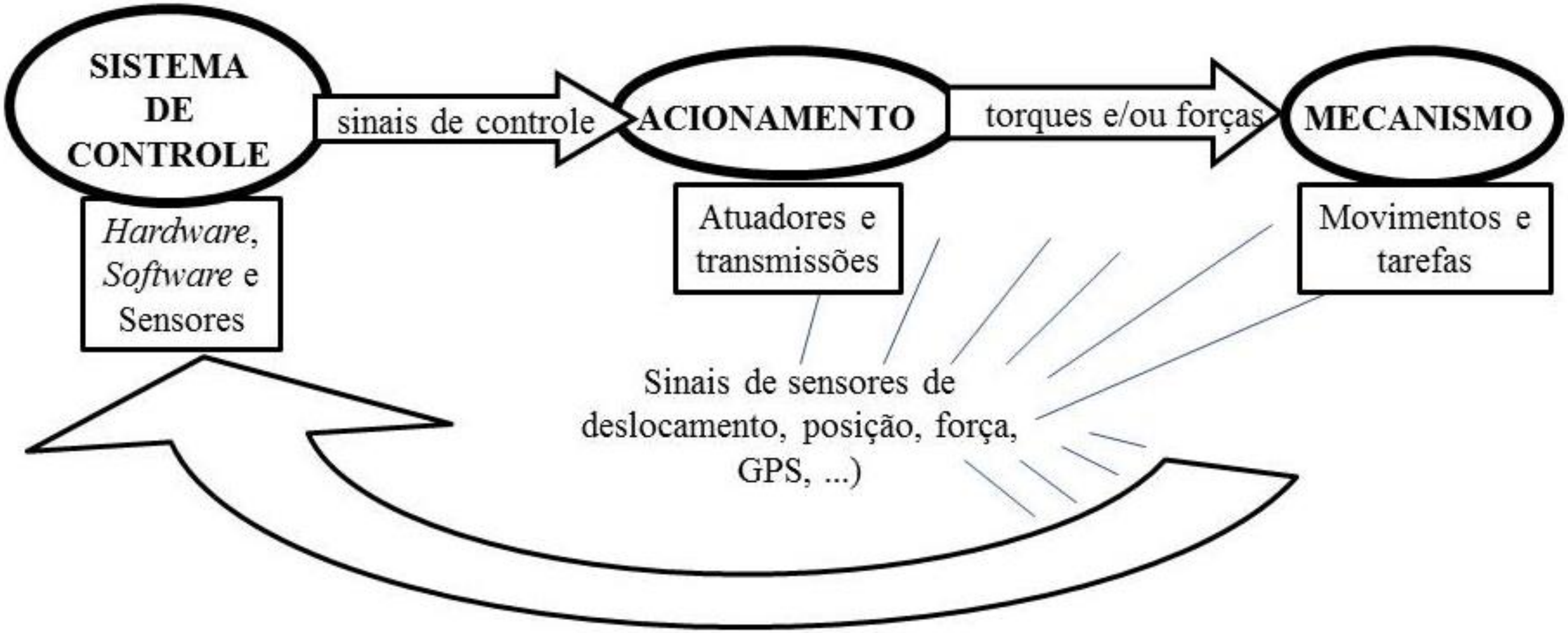
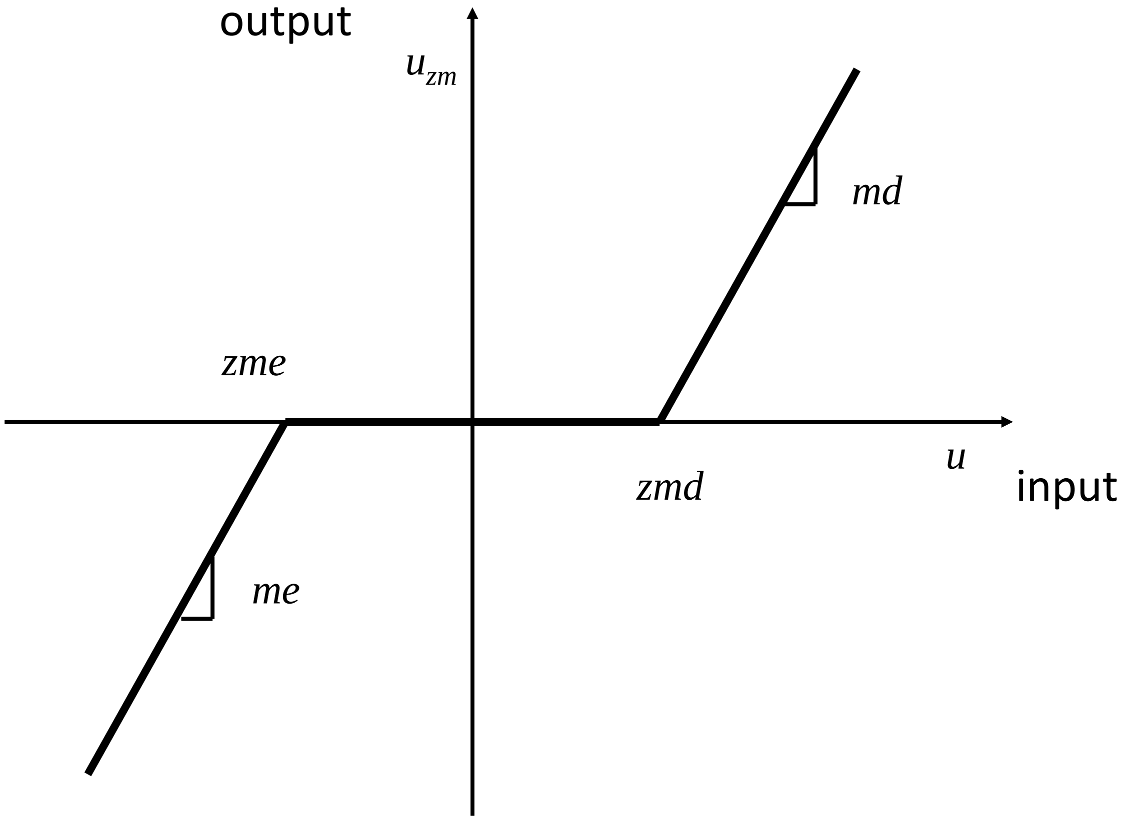
mechatronic system



Dead Zone Concept/ *Conceito de zona morta*

Dead zone is a static input-output relationship which for a range of input values gives no output/ *A zona morta é uma relação estática de entrada-saída que, para uma faixa de valores de entrada, não fornece saída*



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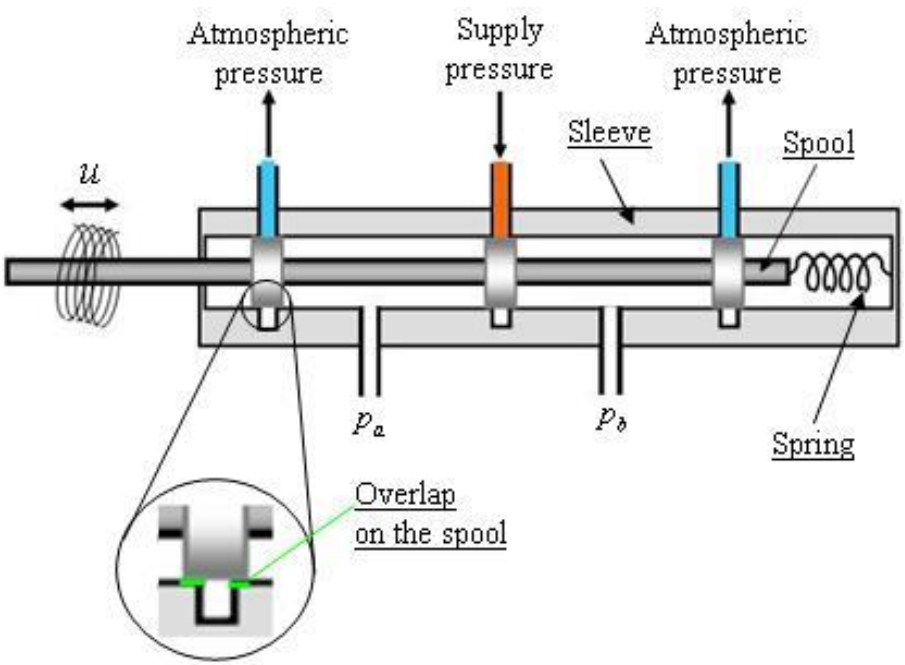
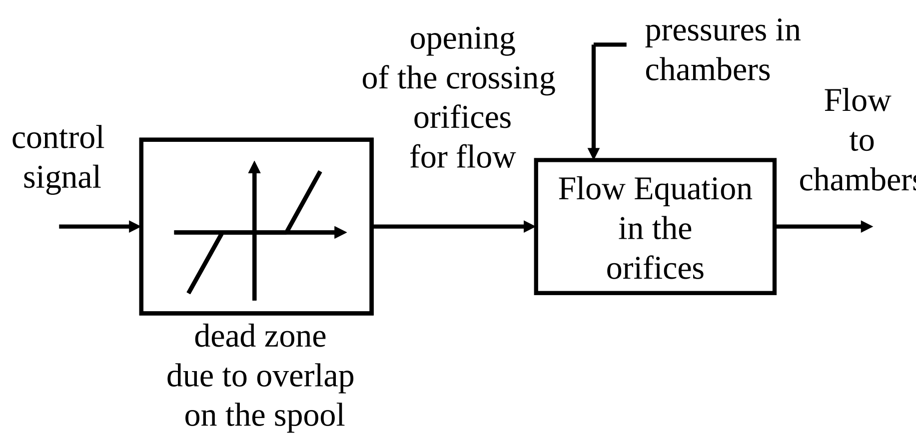
The dead zone nonlinearity is a common imperfection of mechanical system components and mainly of closed center valves when the land width is greater than the port width at neutral spool position (Virvalo, 1997)/ *A não linearidade da zona morta é uma imperfeição comum de componentes de sistemas mecânicos e principalmente de válvulas de centro fechado quando a largura do terreno é maior que a largura do orifício na posição do êmbolo neutro .*





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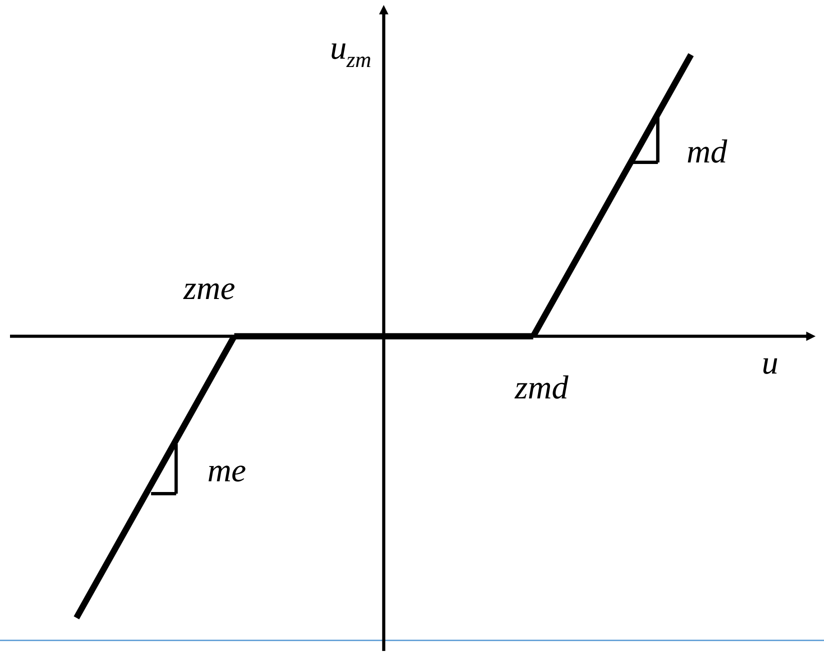
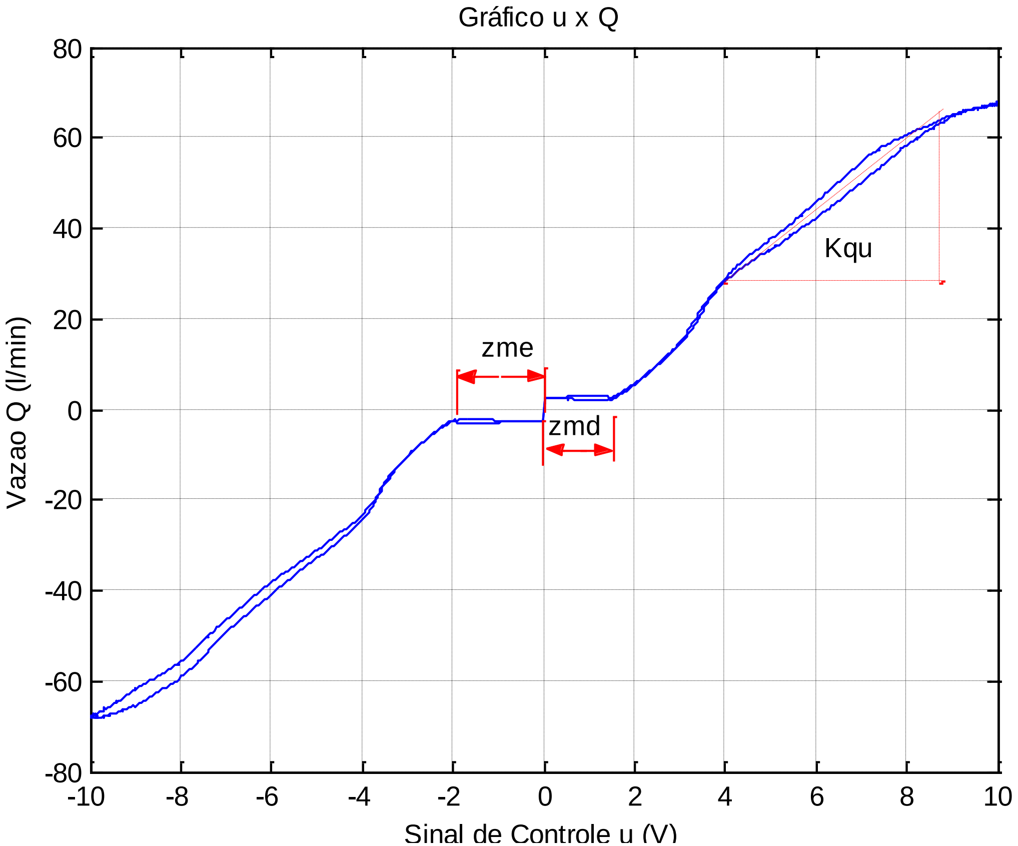
Dead zone is a static input-output relationship which for a range of input values gives no output.

$$u_{zm}(t) = \begin{cases} md(u(t) - zmd) & \text{if } u(t) \geq zmd \\ 0 & \text{if } zme < u(t) < zmd \\ me(u(t) - zme) & \text{if } u(t) \leq zme \end{cases}$$



Identification of the dead zone nonlinearity in valves/
Identificação da não linearidade da zona morta em válvulas

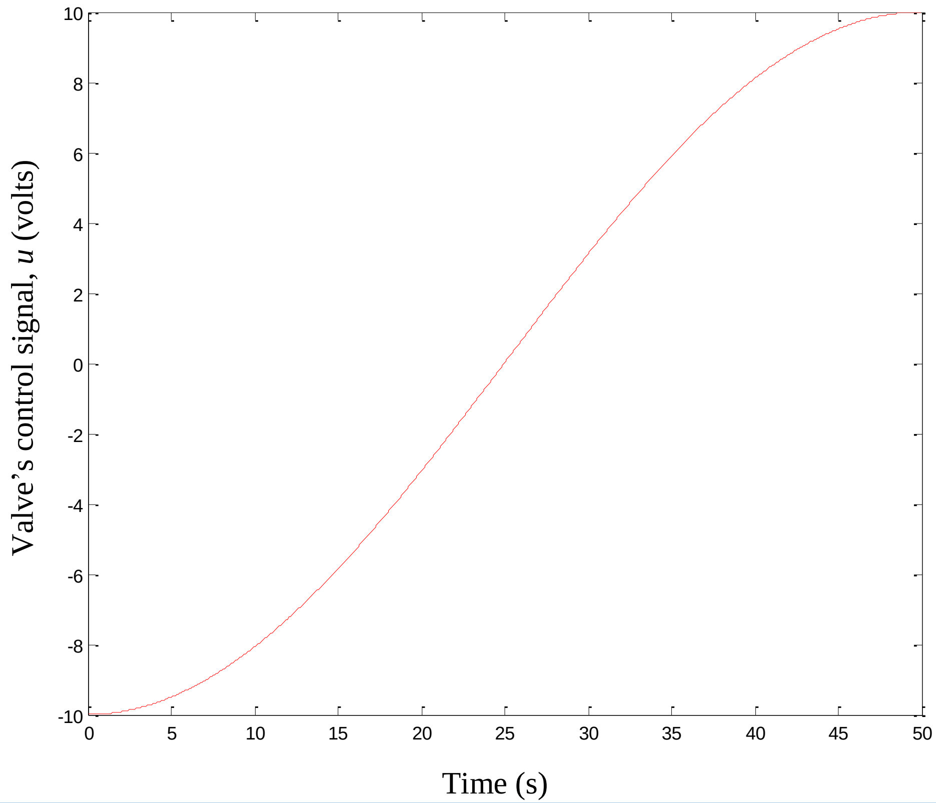
In classical procedure of the dead zone identification in overlapped proportional valves as ISO10770-1 standard (Iso, 1998), the dead zone identification in spool valves can be experimentally made in test installation with flow rate transducer, such flow rate transducer is expensive and these experimental tests can result in unacceptable cost for aspired application/ *Identificação da não linearidade da zona morta em válvulas*

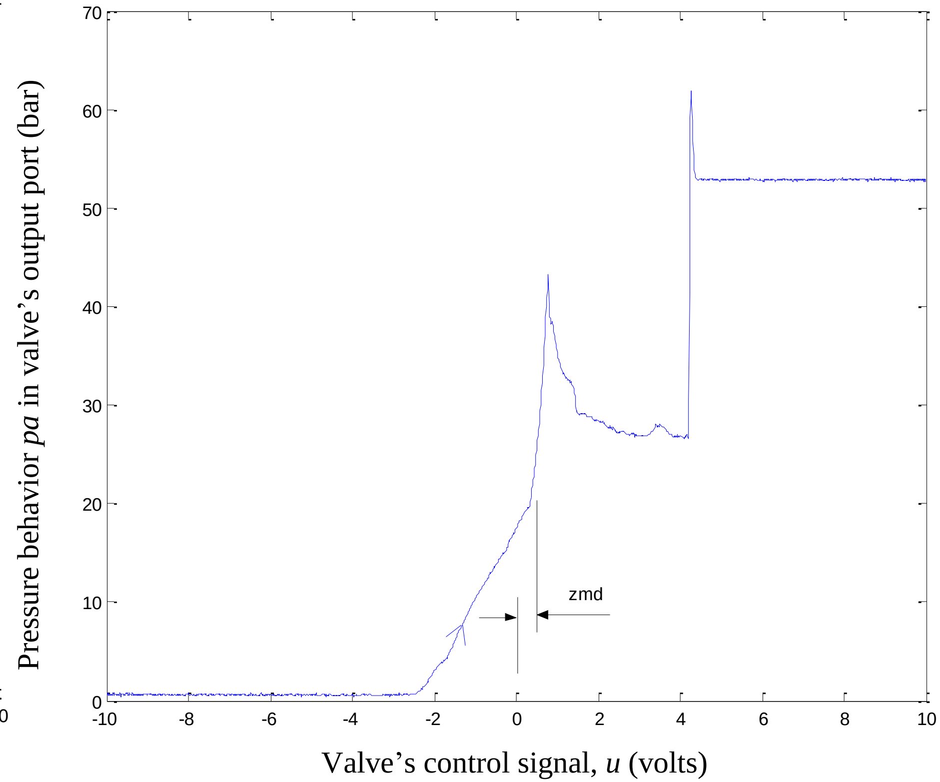


Proposed methodology/ *Metodologia proposta*

The proposed methodology is composed by open-loop's tests of actuator system (valve and actuator) with a slow sine control signal (10 volts amplitude and 100 seconds period), as for example it is shown in equation, pressure's measurements and analysis of their behavior as a function of the control signal.

$$u(t) = 10\sin(2\pi t/100)$$





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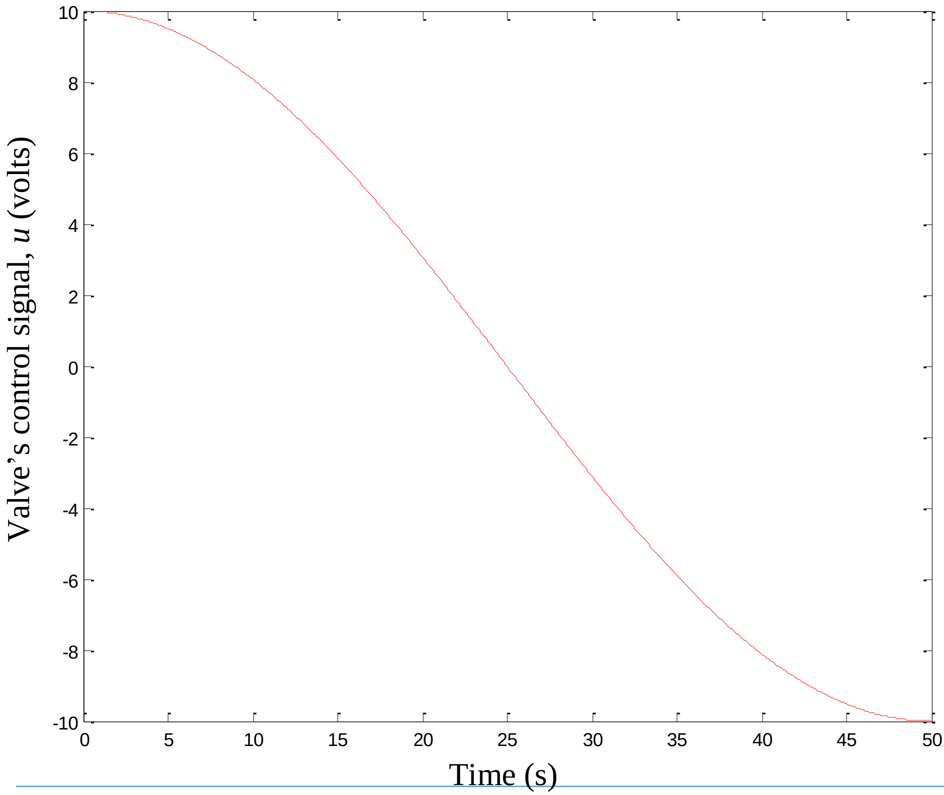
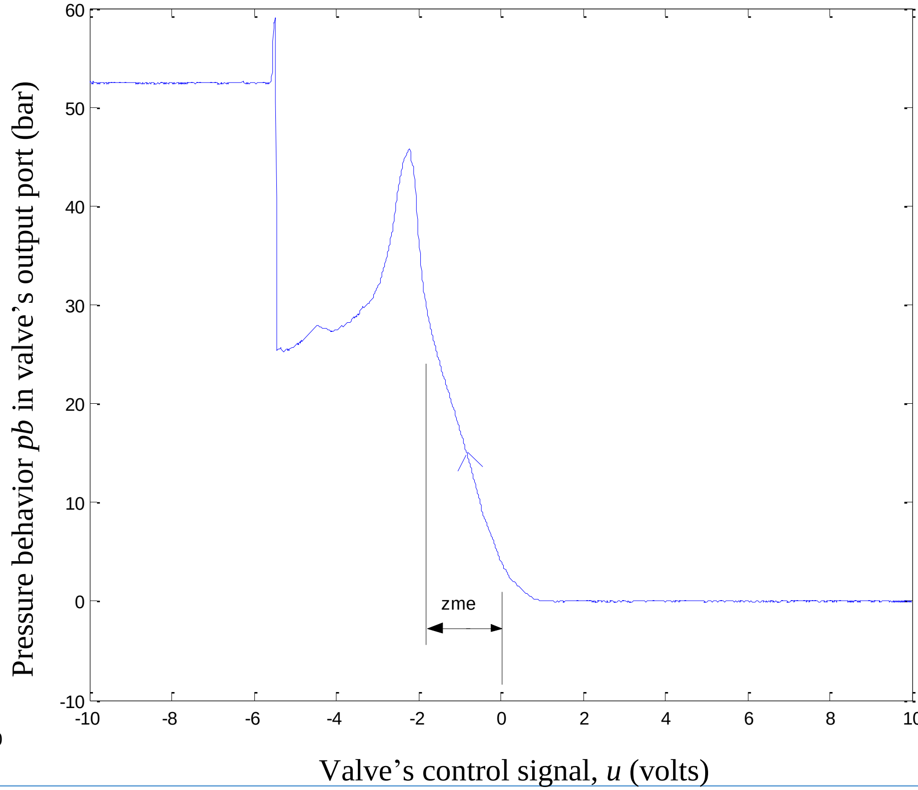
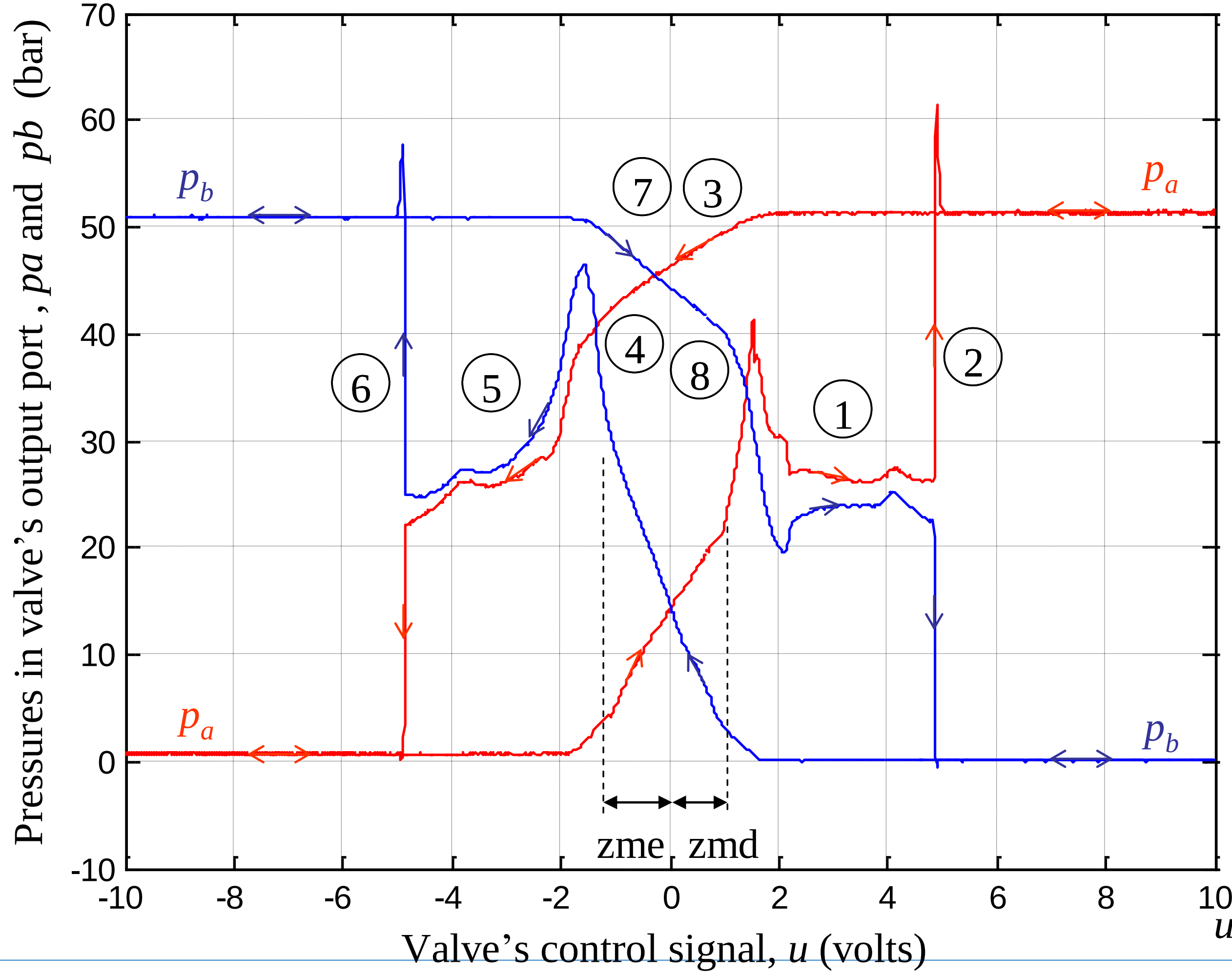
In the next step, the graphical of the p_b pressure is analysed in the valve gap for the u control signal range from 10 to -10 Volts (Fig. 8), as it is shown in Figure.

$$u(t) = 10\sin(2\pi t/100)$$





Both pressures behaviors as a function of control signal can be represented in only figure. In this graphical representation, the control signal value was added with the constant offset value such that the dead zone values (zmd and zme) are identical. The offset value can be important in some control applications.



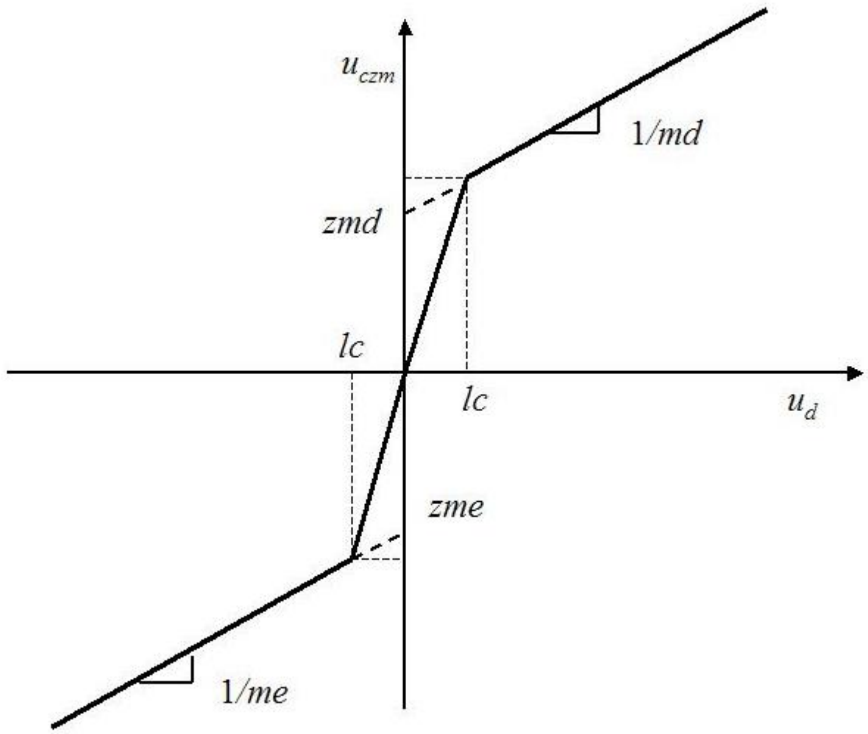
$u(t) = 10\sin(2\pi t/100)$

Proposed methodology/ *Metodologia proposta*

For the best comprehension, some pressure behavior branches are enumerated and commented in table. This table describes the behavior of the fluid power system's elements during experimental tests.

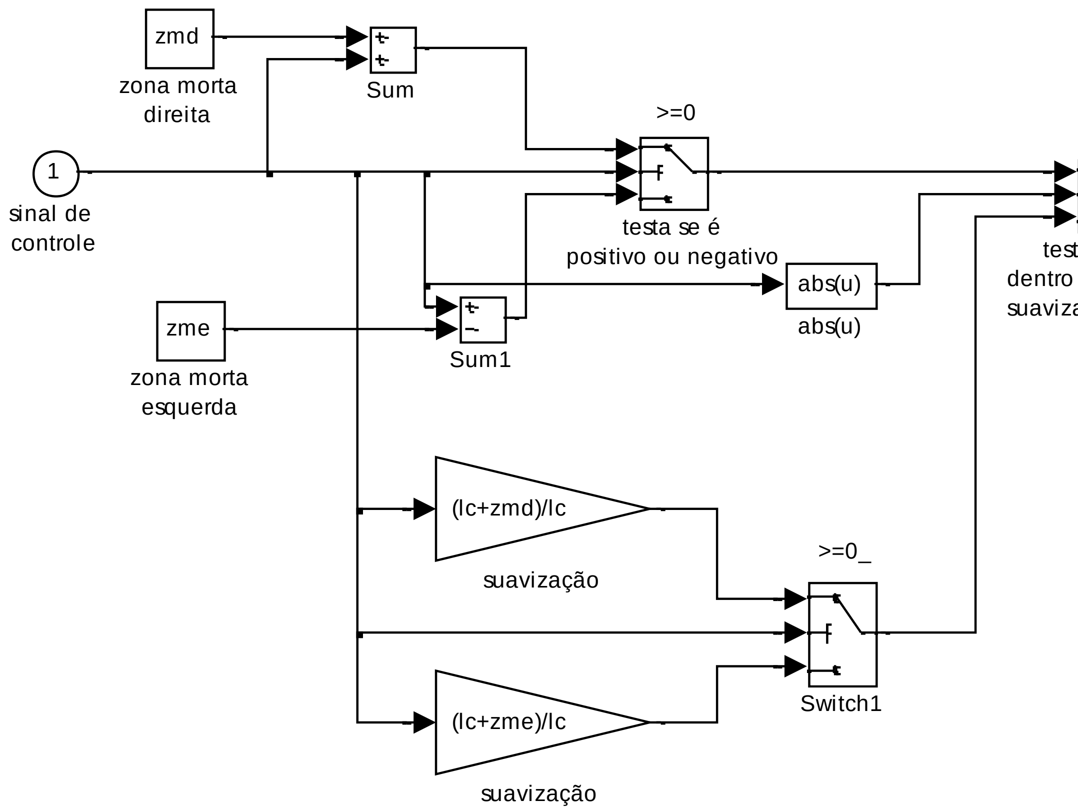
Branches	Control signal	Flow rates	Pressures	Cylinder's piston
(1)	$zmd < u < 4.85$	Cross cylinder chambers	Maintain necessary difference to movement	Travel to positive position
(2)	$4.85 \leq u \leq 10$ and $10 > u \geq 2$	There aren't flow rates to the chambers and the leakages aren't considerable.	Become quickly equal to tank's pressure and supply's pressure	Remain stopped at the end of its stroke.
(3) and (4)	$zmd > u > zme$	Leakages are considerable	Vary due to the leakages	Remain stopped
(5)	$zme > u > -4.85$	Cross cylinder chambers	Maintain necessary difference to movement	Travel to negative position
(6)	$-4.85 \geq u \geq -10$ and $-10 < u \leq -2$	There aren't flow rates to the chambers and the leakages aren't considerable.	Become quickly equal to tank's pressure and supply's pressure	Remain stopped at the end of its stroke.
(7) and (8)	$zme < u < zmd$	Leakages are considerable	Vary due to the leakages	Remain stopped

The control scheme with fixed and smoothed inverse compensation linearly close to the origin/ *Esquema de controle com a compensação baseada na inversa fixa e suavizada linearmente próxima da origem*



$$u_{czm}(t)=\begin{cases}\dfrac{u_d(t)}{md}+zmd & se \quad u_d(t)\geq lc\\ \dfrac{u_d(t)}{me}-|zme| & se \quad u_d(t)\leq -|lc|\\ \left(\dfrac{zmd+{lc}/{md}}{lc}\right)u_d(t) & se \quad 0\leq u_d(t)<lc\\ \left(\dfrac{|zme|+{|lc|}/{me}}{|lc|}\right)u_d(t) & se \quad -|lc|\leq u_d(t)<0\end{cases}$$

The control scheme with fixed and smoothed inverse compensation linearly close to the origin/ *Esquema de controle com a compensação baseada na inversa fixa e suavizada linearmente próxima da origem*



$$u_{czm}(t)=\begin{cases}\dfrac{u_d(t)}{md}+zmd & se \quad u_d(t)\geq lc\\ \dfrac{u_d(t)}{me}-|zme| & se \quad u_d(t)\leq -|lc|\\ \left(\dfrac{zmd+{}^{lc}/_{md}}{lc}\right)u_d(t) & se \quad 0\leq u_d(t)<lc\\ \left(\dfrac{|zme|+{}^{|lc|}/_{me}}{|lc|}\right)u_d(t) & se \quad -|lc|\leq u_d(t)<0\end{cases}$$

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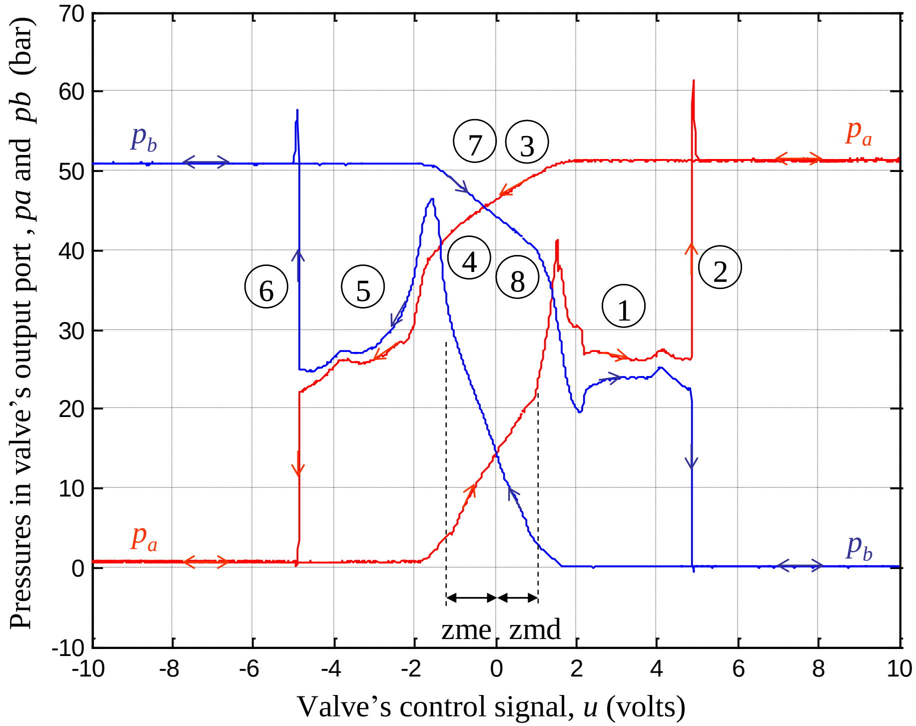
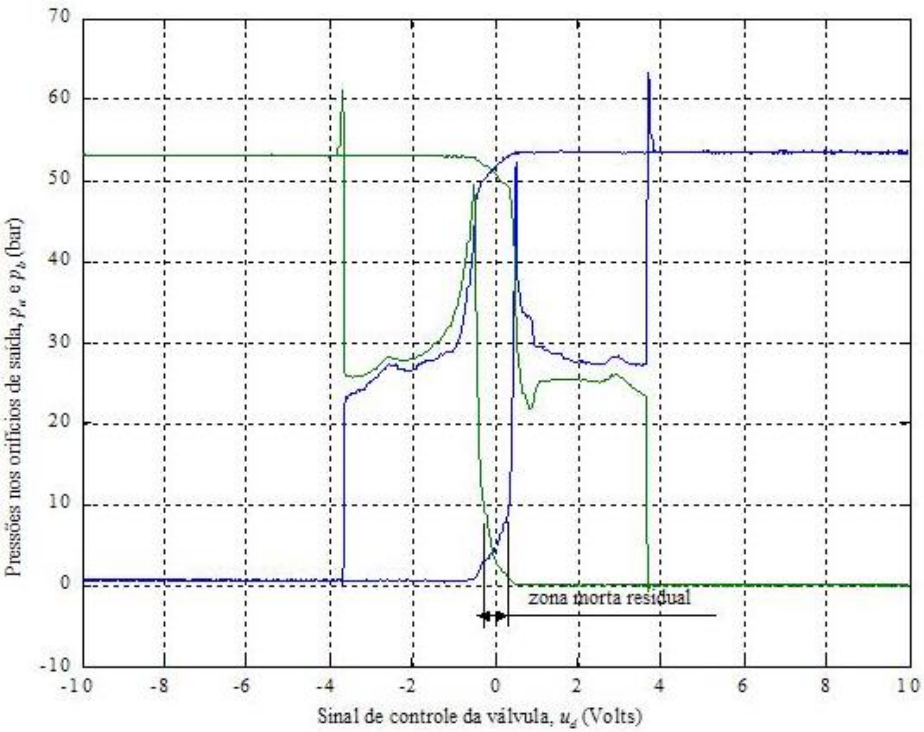
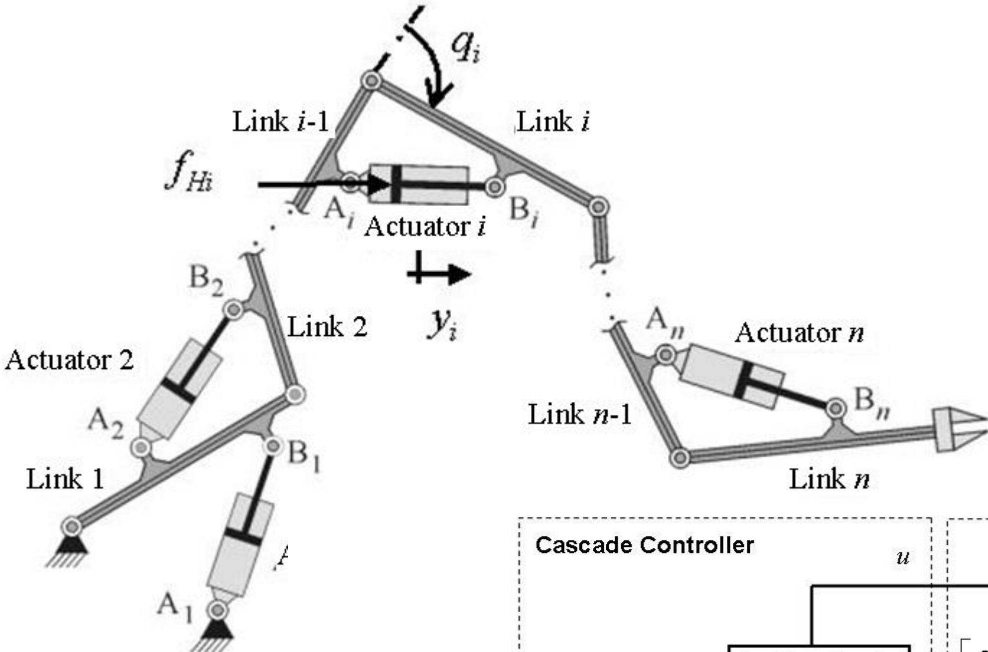
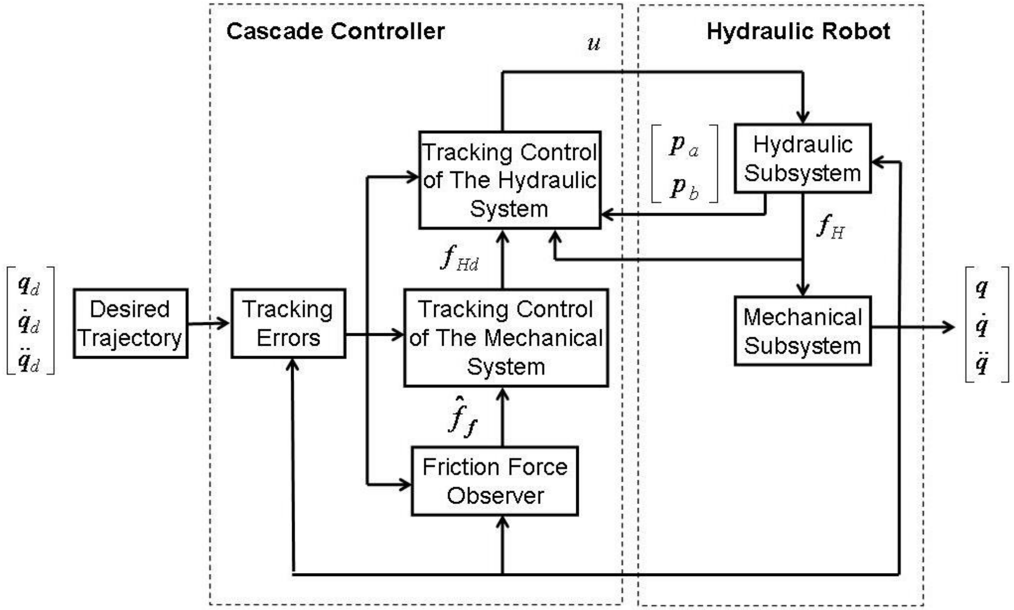
Graph of the pressures behavior in the test without and with the compensation of the dead zone / *Gráfico do comportamento das pressões no ensaio sem e com a compensação da zona morta*





Application in a hydraulic positioning system/ *Aplicação em um sistema de posicionamento hidráulico*



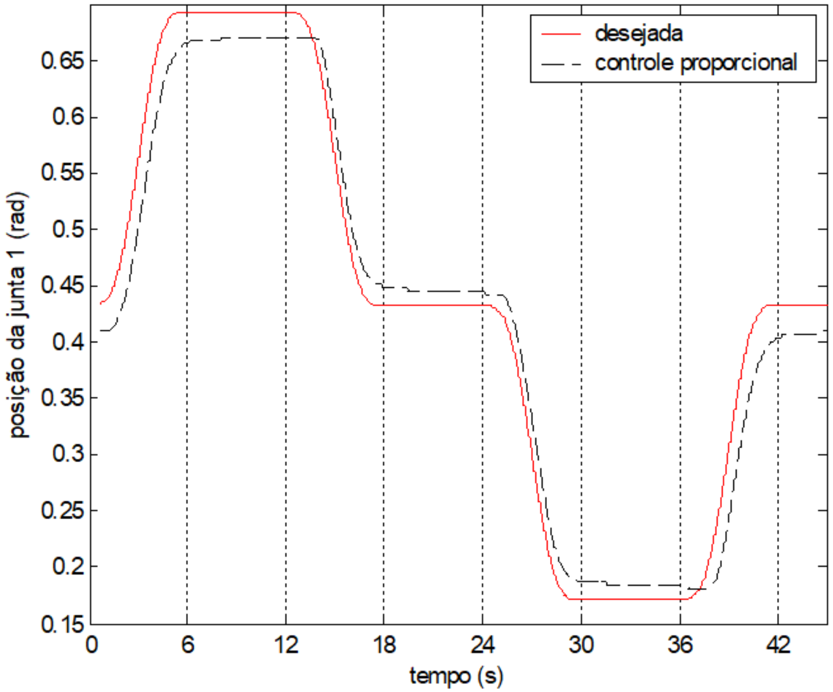


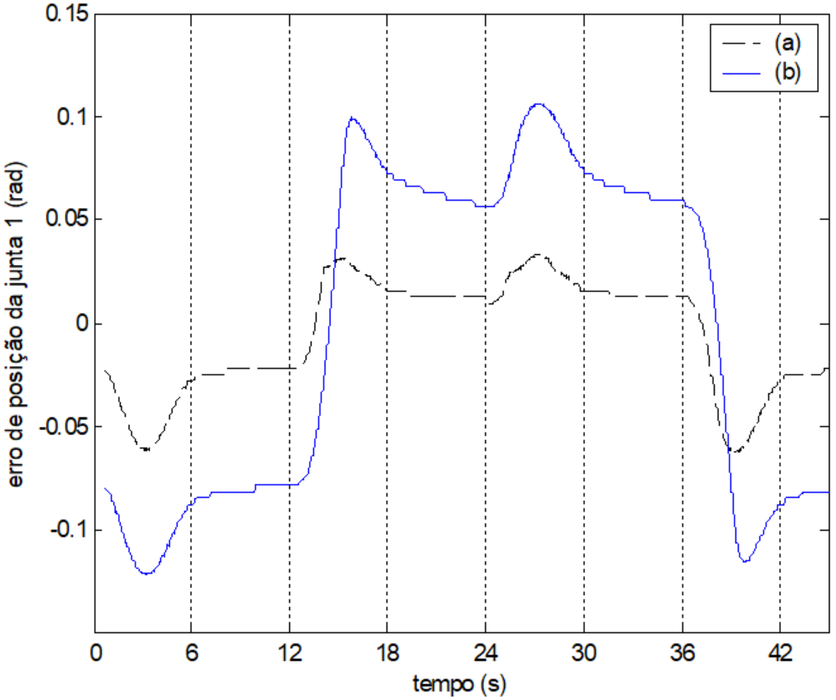
Application in a hydraulic positioning system/ *Aplicação em um sistema de posicionamento hidráulico*

Fabricante Modelo	BOSCH REXROTH 4WRE6E1-08-2X/G24K4/V(atuadores 1 e 2)
Coeficiente de vazão	$k_a = 2\,k_b = 2\text{x}10^{-8}\ \text{m}^3/\text{s/V/Pa}^{1/2}$ (veja procedimentos Apêndice A)
Zona morta	*offset* = 0,1 V, *zme* = -1 V, *zmd* = 1 V (veja metodologia de identificação no capítulo 5)
Vazão nominal com Δp = 10 bar Vazão máxima	8 litros/minuto $Q_b = Q_a/2$ (válvula assimétrica) 80 litros/minuto
Sinal de controle	± 10 V
Tensão de Alimentação	24 VDC
Sinal LVDT carretel	± 10 V
Cartela eletrônica amplificadora	VT-VRPA2-1-1X/V0/T1
Placa de ligação TN6	Tipo G 341/01 (G¼) (furação conforme DIN 24 340 / ISO 4401)

Application in a hydraulic positioning system/ *Aplicação em um sistema de posicionamento hidráulico*

Curva (a) tracejada representa o erro de seguimento do controle com compensação da zona morta e a curva (b) sem tal compensação





Application on a pneumatic servo positioner/ *Aplicação em um servoposicionador pneumático*

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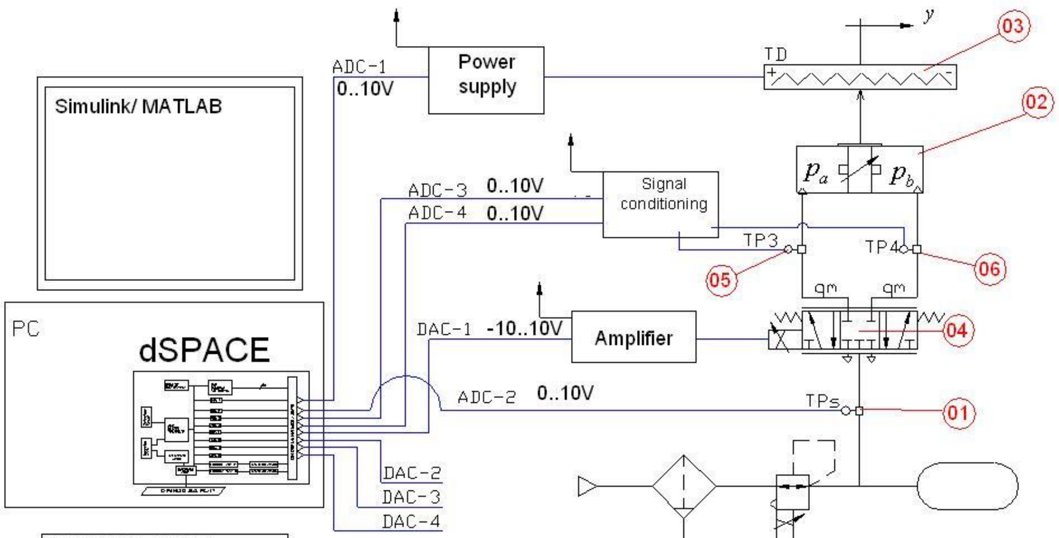

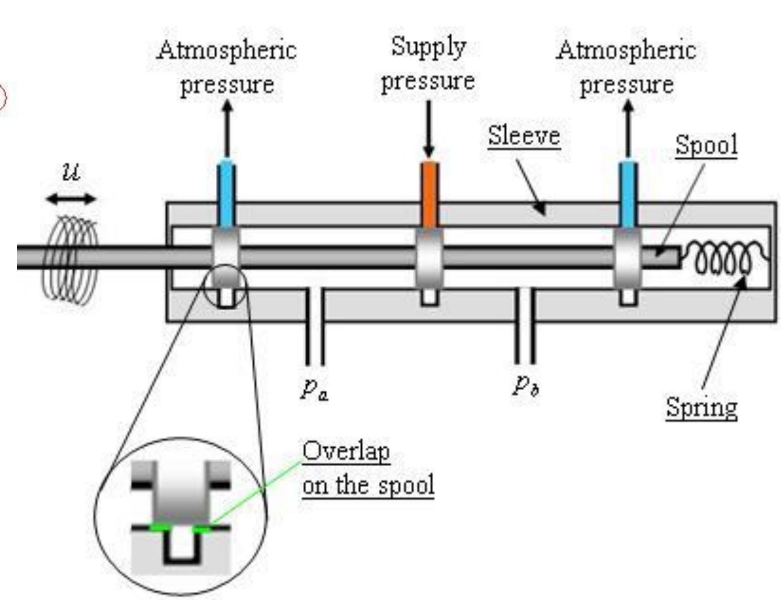

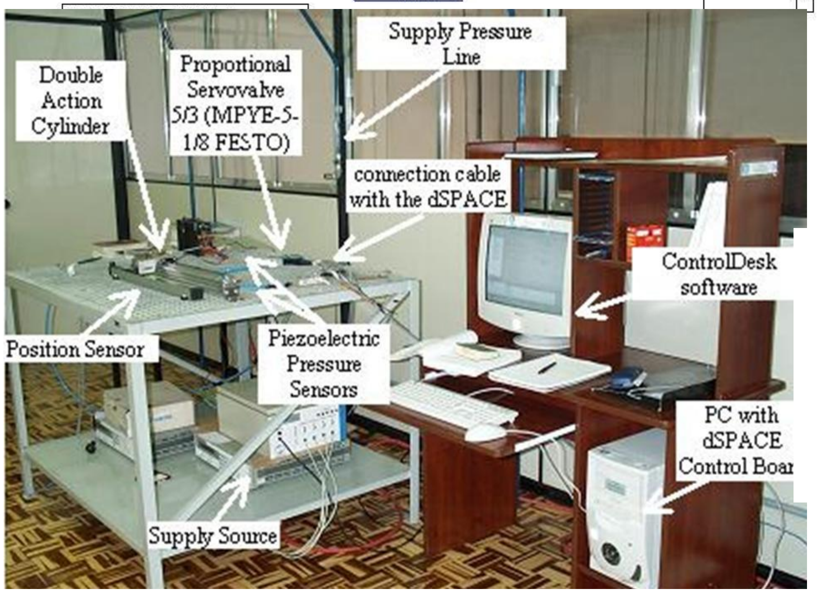

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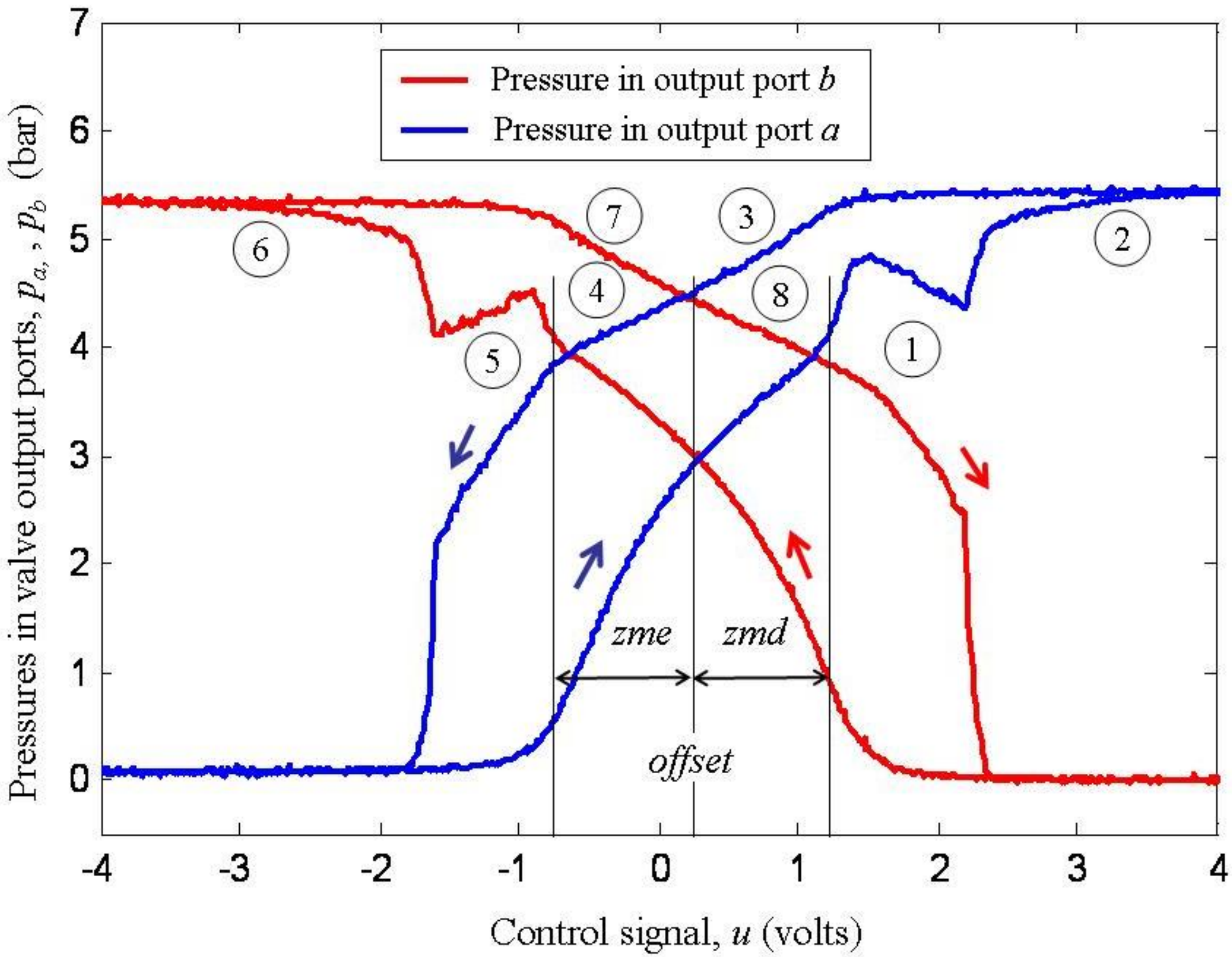
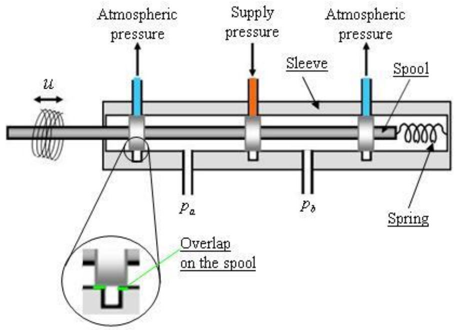
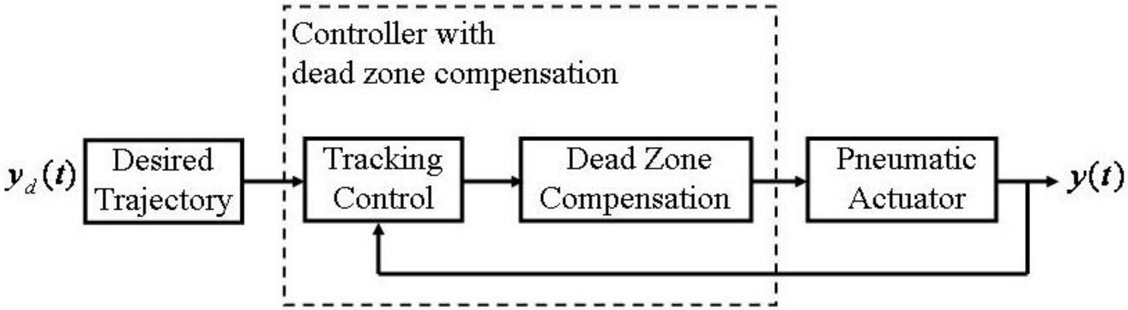
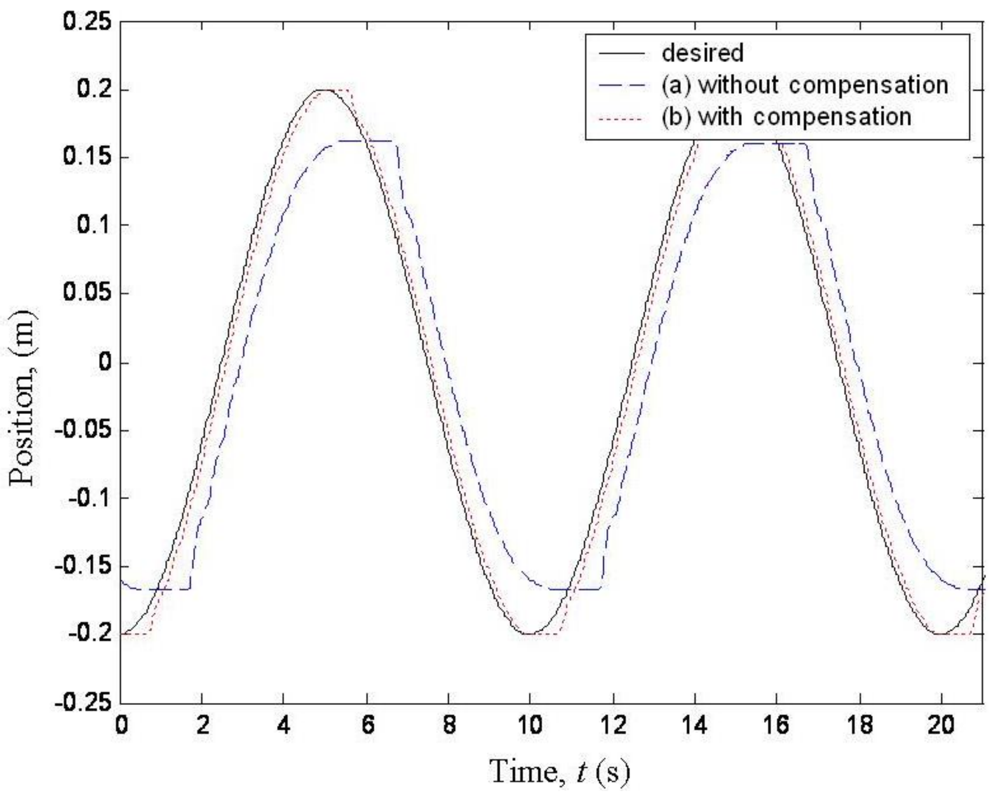
Application on a pneumatic servo positioner/ *Aplicação em um servoposicionador pneumático*

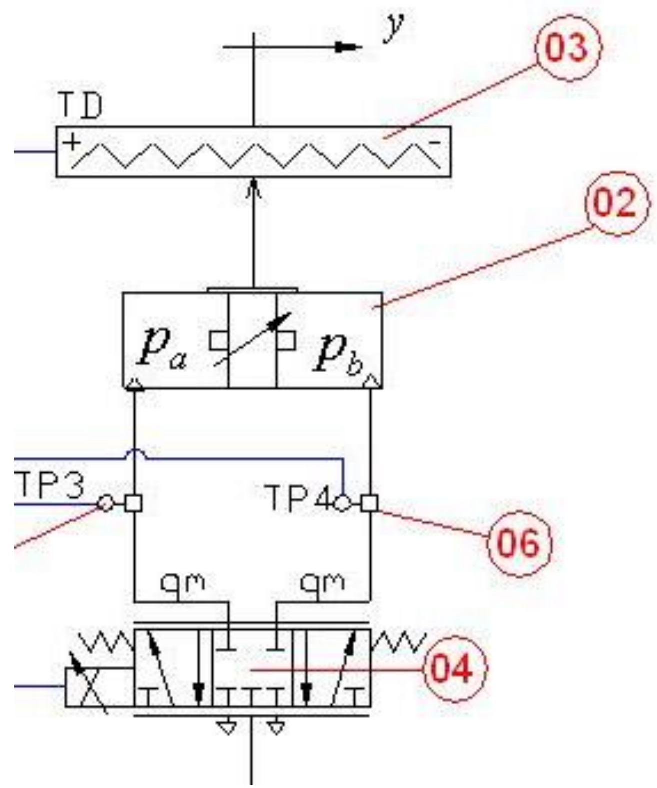




Application on a pneumatic servo positioner/ *Aplicação em um servoposicionador pneumático*







Advantages of the proposed method/ *Vantagens do método proposto*

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- Dead zone is a typical nonlinearity in proportional directional valves and it is treated as imperfection of mechanical components.
- The dead zone analytical model is characterized by set of parameters and the main aspect considered is its identification. The results of this paper show that is possible to obtain the parameters to dead zone model, in a simpler and easier way, based on observing the dynamic behaviour of the pressure in the valve gaps. These results were confirmed experimentally by a study case with actuator.
- This methodology is cheaper than the conventional ones because it needs only pressure transducers. With this method, the author intend to contribute in the study and research of advances in fluid power servo position control to open the doors to new industrial applications for these systems.

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