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NON INTEGER ORDER SYSTEMS

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Abstract : The novelty in this working is the suggested class of astatic control systems. The article proposes: DASCRONE and DASCRONE_GSC structures; synthesis algorithm; robast analysis. The synthesis is based on the wave disturbances absorbing principle, non integer differentiation, gain scheduled control, parametric and structure independence of the stability margin.

Keywords: robast control, non integer order disturbance absorbing systems, robast analysis.

Introduction, Basic Relations. The robust features of the *CRONE* (Commande Robuste d'Ordre Non Entier) systems [13-15,17,19] are achieved by the parametric invariance of the stability margin. For example, for a linear parametric non-disturbed (nominal) system and for the corresponding parametric disturbed system in the multitude Π (1): G^*, $G^{[]}$ are the nominal and the disturbed at the highest level models of the plant G; R^* - is the corresponding to G^* optimal controller; β^{nom}, β^{rep} - are models of the open-loop nominal disturbed in (1) systems; ω_u^{nom}, $\omega_u^{rep}=\omega_u^{nom}+\Delta\omega_u$ - are frequencies, corresponding to $\left|\beta^{nom}\right|=1$ and $\left|\beta^{rep}\right|=1$; $\Phi_m^{nom}(\omega_u^{nom})$, $\Phi_m^{rep}(\omega_u^{rep})$ - are the phase margins; ω_π^{nom}, $\omega_\pi^{rep}=\omega_\pi^{nom}+\nabla\omega_\pi$ - frequencies, corresponding to $arg\,\beta^{nom}=-\pi$, $arg\,\beta^{rep}=-\pi$; $B_m^{nom}(\omega_\pi^{nom})$, $B_m^{rep}(\omega_\pi^{rep})$ - are gain margins; $\Delta\omega_u,\nabla\omega_\pi$ - frequency variations, ℓ_a, ℓ_m - reparametrization ξ. The variations $\Delta\Phi_m$, ΔB_m of the disturbed in (1) system are (2), (3), as $\Delta\phi_p$ and $\Delta\phi_r$ - are the fluctuations in the plant and controller phases (4),(5).

$$\Pi=\left\{\begin{matrix}\ell_a=G^{[]}(j\omega)-G^*(j\omega),\left|\ell_a\right|\le\bar{\ell}_a(\omega)\\ \ell_m=\ell_a(j\omega)(G^*(j\omega))^{-1},\left|\ell_m\right|\le\bar{\ell}_m(\omega)\end{matrix}\right\} \quad (1)$$

$$\Delta\Phi_m=\Phi_m^{rep}(\omega_u^{rep})-\Phi_m^{nom}(\omega_u^{nom}),(\Delta\phi_p+\Delta\phi_r) \quad (2)$$

$$\Delta B_m=B_m^{rep}(\omega_\pi^{rep})-B_m^{nom}(\omega_\pi^{nom}),(\left|\beta^{nom}_{\omega_\pi^{nom}}\right|-\left|\beta^{rep}_{\omega_\pi^{rep}}\right|) \quad (3)$$

$$\Delta\phi_p(\Delta\omega_u,\ell_{a,(m)})=arg\,G(j\omega_u^{rep})-arg\,G^*(j\omega_u^{nom}) \quad (4)$$

$$\Delta\phi_r(\Delta\omega_u)=arg\,R^*(j\omega_u^{rep})-arg\,R^*(j\omega_u^{nom}) \quad (5)$$

$$\left\{\Delta\Phi_m=\Delta\phi_p+\Delta\phi_r\underset{\{\Delta\phi_r=-\Delta\phi_p\}}{=}0\right\} \quad (6)$$

The solutions [13-15,17, 19] for the achievement of the parametric and structure invariance of Φ_m and/or of B_m to $\left|\ell_i(j\omega)\right|\le\bar{\ell}_i(\omega)$ in (1) are in the synthesis of a controller R^{CRONE}, minimising (6). The criterion (7) of the synthesis is a definite shape (8) of β^{CRONE} (fig.1) in the range from 0 to $-\pi$ for all

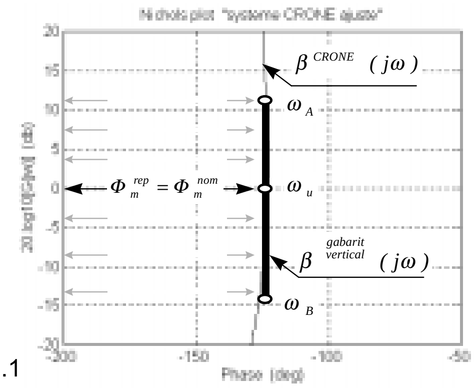


fig.1

the frequencies $\omega_u^{rep}=f(\bar{\ell}_a,\bar{\ell}_m)$, named *gabarit vertical* $\beta^{gabarit}_{vertical}$. When β^{CRONE} accepts the shape of $\beta^{gabarit}_{vertical}$, (6) is satisfied, and ω_A,ω_B are the limit values of the frequency range of $\beta^{gabarit}_{vertical}$ (fig.1). For the achievement of (7) and (8), R^{CRONE} is definite on the basis of (9), where: n - order of G^* (an whole number); n', $(1<n'<2)$ - non integer order of R^{CRONE}_{approx} (non whole number); m', $(0<m'<1$; $m'>1)$ - non integer order of *CRONE* (non whole number). For the realisation of (9) in *CRONE* is used the non integer differentiation *DNE* (Dérivation Non Entière), realised by approximating DNE_{approx} derivator $R^{CRONE}_{approx}\equiv R^{CRONE}_N$ (10), (11),

$$\beta^{CRONE}(j\omega)\equiv\beta^{gabarit}_{vertical}(j\omega),\forall\,\omega\in\left[\omega_A,\omega_B\right] \quad (7)$$

$$\beta^{gabarit}_{vertical\,(j\omega_u)}=\left(\frac{\omega_u}{j\omega}\right)^{n'},\ arg\ \beta^{gabarit}_{vertical\,(j\omega_u)}\equiv\Phi_m^{nom}\equiv-n'\frac{\pi}{2} \quad (8)$$

$$arg\ R^{CRONE}=m'\frac{\pi}{2},\ \forall\,\omega\in\left[\,\omega_A,\omega_B\,\right] \quad (9)$$

where: k_0 - is a static coefficient; ω_b - is the lower limit of $\Delta\omega_u$ in DNE_{etalon}; ω_h - is the upper limit of $\Delta\omega_u$ in DNE_{etalon}; N - an order of DNE_{approx} (whole number); ω_i,ω_i' - are the cut-off frequencies of the polynomial approximation DNE_{approx} with N zeros ω_i' and N poles ω_i. The approximation (10), (11) is based on (12) in the range $(\omega_A \div \omega_B)$ and satisfied (9), where α , η are the recursive coefficients of DNE_{approx} . By the values of N , ω_i , $\omega_i^{'}$, α , η , the characteristic β^{CRONE} is constructed in a way, achieving *gabarit vertical* , and (6) as well. The robust analysis demonstrates the robust stability and performance of the *CRONE* - systems, their advantages in comparison with the classical systems, the presence of an error in the steady-state regime under control of static plants.

The models of the perturbations $\xi(t)$ [7-12,17,18] expressed by semi-determinate equations (13) are known. They are with given (chosen) $f_i(t)$ of the basis $\left\{ f_i \right\}$ and with unknown parameters c_k , changing on

$$k_0 = \begin{cases} \left\{ a \left(\dfrac{1+\left(\dfrac{\omega_u}{\omega_h}\right)^2}{1+\left(\dfrac{\omega_u}{\omega_b}\right)^2} \right)^{\frac{m}{2}} \right\} , a = \dfrac{1}{\left| G^*(j\omega_u) \right|} \\ (0 < m^{'} < 1) \\ \left\{ a \left(\dfrac{1+\left(\dfrac{\omega_u}{\omega_h}\right)^2}{1+\left(\dfrac{\omega_u}{\omega_b}\right)^2} \right)^{\frac{m_e^{'}}{2}} \prod_{i=1}^{N} \left[\dfrac{1+\left(\dfrac{\omega_u}{\omega_i}\right)^2}{1+\left(\dfrac{\omega_u}{\omega_i^{'}}\right)^2} \right]^{\frac{1}{2}} \right\} \\ \left(m^{'} > 1 \; ; \; m_e^{'} + m_n^{'} = m^{'} \right) \end{cases} \tag{10}$$

$$R_N^{CRONE} = \begin{cases} \left\{ k_0 \prod_{i=1}^{N} \dfrac{\left(1+\dfrac{j\omega}{\omega_i^{'}}\right)}{\left(1+\dfrac{j\omega}{\omega_i}\right)} \right\} \\ (0 < m^{'} < 1) \\ \left\{ k_0 \left(\dfrac{1+\dfrac{j\omega}{\omega_b}}{1+\dfrac{j\omega}{\omega_h}} \right)^{m_e} \prod_{i=1}^{N} \dfrac{\left(1+\dfrac{j\omega}{\omega_i^{'}}\right)}{\left(1+\dfrac{j\omega}{\omega_i}\right)} \right\} \\ \left(m^{'} > 1 \; ; \; m_e^{'} + m_n^{'} = m^{'} \right) \end{cases} \tag{11}$$

$$\begin{cases} m^{'} \dfrac{\pi}{2} (\log \alpha + \log \eta) = \dfrac{\pi}{2} \log \alpha , \left(\dfrac{\omega_i}{\omega_i^{'}} = \alpha \; ; \; \dfrac{\omega_{i+1}^{'}}{\omega_i} = \eta \right) \\ R_{m^{'}}^{CRONE}(j\omega) \equiv R_N^{CRONE}(j\omega), \; \forall \omega(\overline{\ell}_a, \overline{\ell}_m) \in \left[\omega_A , \omega_B \right] \end{cases} \tag{12}$$

jumps their values under interval-permanent algorithm. The creation of (13) demands a choice of a suitable basis and the determination of its corresponding wave model of the state of This model is the differential equation, which solution is $\xi(t)$ (13). The determination of an unknown equation on its solution $\xi(t)$ is an inverse task. It is quite enough only one solution to be found. The convergence of the solving procedure is guaranteed by the next conditions execution.

$$\xi(t) = c_1 f_1(t) + c_2 f_2(t) + \ldots\ldots + c_M f_M(t), \; (M = L) \tag{13}$$

$$f_i(p) = L\left[f_i(t) \right] = P_{k_i}(p) Q_{l_i}^{-1}(p) , (0 \le k_i \le l_i \le \infty) \tag{14}$$

The necessary condition is - each element of the basis to respond to (14). If c_i are treated as a constants - (15) is valid. The sufficient condition is Q of the rank ρ to be

$$\xi(p) = L\left[\xi(t) \right] = \sum_{i=1}^{M} c_i \frac{P_{k_i}(p)}{Q_{l_i}(p)} = \frac{P(p)}{Q(p)} \tag{15}$$

$$Q(p) = p^{\rho} + q_{\rho} p^{\rho-1} + .. + q_2 p + q_1 , (\rho \le \sum_{i=1}^{M} l_i) \tag{16}$$

$$W(p) = Q^{-1}(p) \tag{17}$$

described by (16). Therefore, ξ . is presented as 'an output variable' of a fictitious linear dynamical system W *(17)* under initial conditions $\left\{ \xi(0), \dot{\xi}(0), \ddot{\xi}(0), \ldots \right\}$, that determine P . Thus (13) satisfies the solution of (18), where q_i are apriori known, do not depend on c_i and are

$$\frac{d^{\rho}\xi(t)}{dt^{\rho}} + q_{\rho} \frac{d^{\rho-1}\xi(t)}{dt^{\rho-1}} + .. + q_1 \xi(t) = 0 \tag{18}$$

$$\frac{d^{\rho}\xi(t)}{dt^{\rho}} + q_{\rho} \frac{d^{\rho-1}\xi(t)}{dt^{\rho-1}} + .. + q_1 \xi(t) = \vartheta(t) \tag{19}$$

$$R^{DAS}(p) = \frac{P_c(p)}{Q_{C1}(p) Q_{C2}(p)} \tag{20}$$

determined by $\left\{ f_i \right\}$. This is the solution of the inverse task. It gives an account of the changes of c_i under interval-permanent algorithm if in (18) is added external generating function $\vartheta(t)$. So, the wave model of the state of ξ is (19). Disturbance Absorbing System (*DAS*) use the model of the apriori uncertainty (19), given in the process of the *DAS* -design by suitable processing, approximation and wave modelling of a representative trend of a functioning industrial system. In *DAS* [7-12,17,18] is used the principle of the wave structured disturbances absorbing. For the scalar case it determines the controller $R^{DAS}(p)$ in *DAS* as (20). The polynomials P_{C1}, Q_{C1} are designed according to desired control plant function. Received from the industrial trend approximation, Q_{C2} (16) forms the feature of R^{DAS} to absorb ξ , defines the absorber (an integrator of a high non integer order *INE*) in *DAS* and corresponds to the characteristic polynomial (15).

Gain scheduled control systems *GSCS* [1-6,16,17], are designed for planned parametric changes in the controller, in conformity with the changes of measurable regime factors (under apriori known plant parameters dependence on the factors). For some *GSCS* the criterion for the synthesis is the stabilization of the system gain coefficient $k_{SYSTEM}(\xi , s) = const$, as the regime factor is the loading of the control valve $s = \left(\Delta P_{lin} \; \Delta P_{vanne}^{-1} + 1 \right)^{-1}$. The methods of the parametric balance for *GSCS* synthesis are known as well.

The aim of the article is: The merger of the features of *CRONE* - systems, *DAS* and *GSCS* in a new astatic class of robust systems – *DASCRONE* (Disturbances Absorbables Systèmes de Commande Robuste d'Ordre Non Entier) [17,20] and $DASCRONE \cdot GSC$ (Disturbances Absorbables Systèmes de Commande Robuste d'Ordre Non Entier type Gain Scheduled Contrôle), and proposing algorithms for their design.

Task's formulation. Given (21)-(29) or known are (Tabl.1): G^*, $G^{[]}$, Π, the cut-off frequency ω_c^{nom} of G^*, the local performance criterion Φ_m and the exploit change ranges of the set point - y^o, the loading - s and the reparametrization - $\overline{\ell}_a$, $\overline{\ell}_m$. It is necessary astatic non integer order control systems $DASCRONE$ and $DASCRONE \cdot GSC$ to be designed.

Tabl.1

given / results			algorithm for synthesis		
(21)	$G^*(p)$	$1{,}239\, e^{-2p}(10p+1)^{-1}$	(30)	$N \geq 5$	(DNE)
(22)	$G^{[]}(p)$	$4.96\, e^{-14p}(10p+1)^{-1}$	(31)	$\omega_u > 250\, \omega_c^{nom}$	(DNE)
(23)	ω_c^{nom}	$0.08775 \ \ rad/sec$	(32)	$\omega_A = 0.1 \omega_u$	(DNE)
(24)	n	3	(33)	$\omega_B = 10\, \omega_u$	(DNE)
(25)	Φ_m	50^o	(34)	$\omega_b = 0.2\, \omega_A$	(DNE)
(26)	$y^o(t)$	$10\% \leq y^o(t) \leq 90\%$	(35)	$\omega_h = 1{,}2\, \omega_B$	(DNE)
(27)	$s(t)$	$10\% \leq s(t) \leq 90\%$	(36)	$n' = 2(1 - \pi^{-1} \Phi_m^{nom})$	(DNE)
(28)	$\overline{\ell}_a$	$4.96\, e^{-14p}(10p+1)^{-1} - 1{,}239\, e^{-2p}(10p+1)^{-1}$	(37)	$m' = n - n'$	(DNE)
(29)	$\overline{\ell}_m$	$\dfrac{4.96\, e^{-14p}(10p+1)^{-1}}{1{,}239\, e^{-2p}(10p+1)^{-1}} - 1$	(38)	$\alpha = \left(\omega_h\, \omega_b^{-1}\right)^{(1.1+m')}$	(DNE)
(44)	$R^{PID}(p)$ CLASS	$0{,}13(5p+1)(5p)^{-1}(2p+1)(0{,}4p+1)^{-1}$	(39)	$\eta = \left[\left(\omega_h\, \omega_b^{-1}\right)^{\frac{1}{N}}\right]^{(-0.1-m')}$	(DNE)
(45)	R_N^{CRONE} DNE	$0.006 \begin{bmatrix} \left(\frac{1+0.0009\,p}{1+0.5696\,p}\right)\left(\frac{1+0.8666\,p}{1+0.1042\,p}\right) \times \\ \times \left(\frac{1+0.2411\,p}{1+0.0289\,p}\right)\left(\frac{1+0.0670\,p}{1+0.0080\,p}\right) \times \\ \times \left(\frac{1+0.0186\,p}{1+0.0022\,p}\right)\left(\frac{1+0.0052\,p}{1+0.0006\,p}\right) \end{bmatrix}$	(40)	$\left\{ \begin{matrix} \omega'_{i+1} = (\alpha\, \eta)^i . \eta^{\frac{1}{2}} \omega_b \\ \omega_{i+1} = (\alpha\, \eta)^i . \alpha . \eta^{\frac{1}{2}} \omega_b \end{matrix} \right\}$	(DNE)
(46)	$R^{DAS}(p)$ INE	$\dfrac{0.0000845}{(p^3 + 2p^2 + p)}$	(41)	$k_0 = \begin{cases} k_{01}, (0 < m' < 1) \\ k_{02}, \left(m' > 1\, ;\ m'_e + m'_n = m'\right) \end{cases}$	(DNE)
(47)	$\nabla \ell$ GSC	$0.5\left(e^{2n(1-l)} - 1\right)\left(0{,}99\, n\, s\, e^{2n(1-l)}\right)^{-1} \nabla s$	(42)	$\nabla \ell = -\, k_{s_0^*}\, k_{l_0^*}^{-1}\, \nabla s$	(GSC)
(48)	∇a GSC	$k_{SYSTEM}^{optim} \left(k_p^{optim}\right)^{-1} \Delta l \left(\Delta y\right)^{-1}$	(43)	$\nabla a = k_{SYSTEM}^{optim} \left(k_p^{optim}\right)^{-1} \Delta l \left(\Delta y\right)^{-1}$	(GSC)

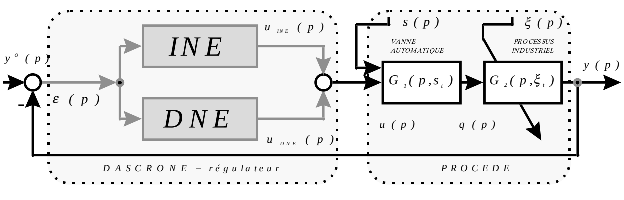


fig.2

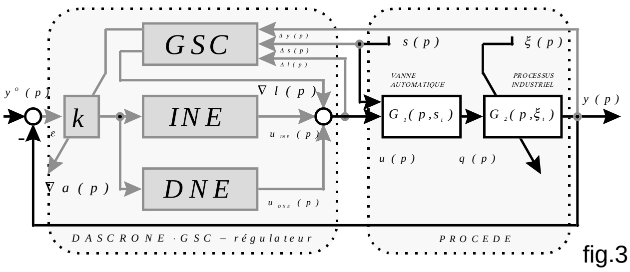


fig.3

Method for solving the task. Proposed are**:** **A.** Structures of $DASCRONE$ (fig.2) and $DASCRONE \cdot GSC$ (fig.3)**; B.** Methods for: the parametric and structure invariance of the stability by a polynomial recursive approximation of DNE; the wave structured disturbances absorbing by INE; the parametric balance in GSC for $DASCRONE$ and $DASCRONE \cdot GSC$ synthesis**; C.** Algorithm (30)-(41) for DNE_{approx}-component design (fig.4) under criterion $gabarit\ vertical\ U$ - $contour$, guaranteeing (fig.5) the invariance of Φ_m and B_m to $\xi \in \left| \ell_i(j\omega) \right| \leq \overline{\ell}_i(\omega)$**; D.** Algorithm for INE-component design, based on the determination of the model of ξ (13), by analysis and a trend approximation $y_t(\varepsilon_t)$ in the system with DNE_{approx}-component under exploit conditions**;**

E. Algorithm for INE-synthesis as a systematisation of character wave models (Tabl.2). Among them, by a visual analysis and comparison, is chosen suitable $\{f_i\}$ for modelling of ξ in the trend. In Tabl.2 are determined the corresponding models ξ^* (19), and the absorbers of the INE-

component; **F.** Algorithm [16,17] for GSC - component design, that determines the compensating variables as (42)-(43), knowing the kind of the valve.

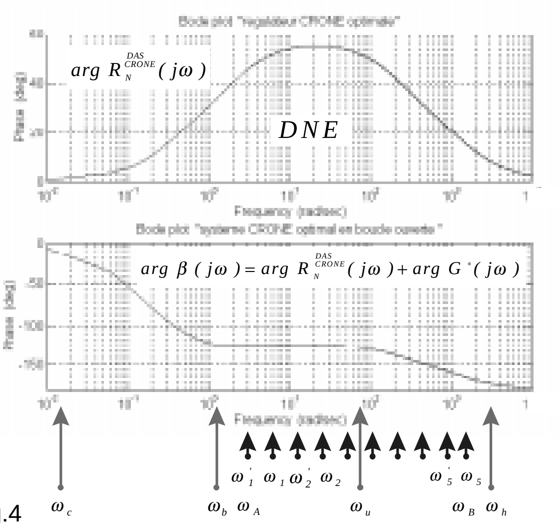


fig.4

Numerical example. A numeral example according to the data shown in Tabl.1 is solved (21)-(29) using the proposed methods and algorithms. The solution is illustrated by (44)-(48).

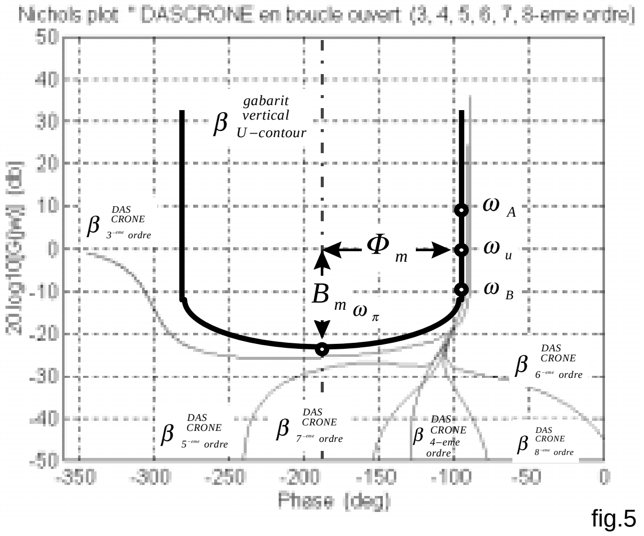


fig.5

Tabl.2

trend & ξ (t) ⇒ model	$Q_{C2}^{DAS}(j\omega)$ INE	trend & ξ (t) ⇒ model	$Q_{C2}^{DAS}(j\omega)$ INE
$\xi(t) = c_1 + c_2 t$; $\{f_i(t)\} = \{1, t\}$	$\frac{d^2\xi}{dt^2} = v(t)$	$\xi(t) = (c_1 + c_2 t)e^{-\alpha t} + (c_3 + c_4 t)e^{-\beta t}$; $\{f_i(t)\} = \{e^{-\alpha t}, te^{-\alpha t}, e^{-\beta t}, te^{-\beta t}\}$	$\frac{d^4\xi}{dt^4} + \alpha^2\beta^2\frac{d^3\xi}{dt^3} + (\alpha^2+\beta^2)\frac{d^2\xi}{dt^2} + \alpha\beta\frac{d\xi}{dt} + (\alpha+\beta)\xi(t) = v(t)$
$\xi(t) = c_1 + c_2 t + c_3 t^2$; $\{f_i(t)\} = \{1, t, t^2\}$	$\frac{d^3\xi}{dt^3} = v(t)$	$\xi(t) = c_1 + c_2(1 - e^{-t})$; $\{f_i(t)\} = \{1, (1 - e^{-t})\}$	$\frac{d^2\xi}{dt^2} + \frac{d\xi}{dt} = v(t)$
$\xi(t) = c_1 + c_2 t + c_3 t^2 + c_4 t^3$; $\{f_i(t)\} = \{1, t, t^2, t^3\}$	$\frac{d^4\xi}{dt^4} = v(t)$	$\xi(t) = c_1 + c_2(1 - e^{-t}) + c_3 te^{-t}$; $\{f_i(t)\} = \{1, (1 - e^{-t}), te^{-t}\}$	$\frac{d^3\xi}{dt^3} + 2\frac{d^2\xi}{dt^2} + \frac{d\xi}{dt} = v(t)$
$\xi(t) = c_1 + c_2 e^{-\alpha t}$; $\{f_i(t)\} = \{1, e^{-\alpha t}\}$	$\frac{d^2\xi}{dt^2} + \alpha\frac{d\xi}{dt} = v(t)$	$\xi(t) = c_1 + c_2(1 + (\alpha - 1)e^{-t}) + c_3((1 - \alpha)t + \alpha)e^{-t}$; $\{f_i(t)\} = \{1,\ 1 + (\alpha - 1)e^{-t},\ ((1 - \alpha)t + \alpha)e^{-t}\}$	$\frac{d^3\xi}{dt^3} + 2\frac{d^2\xi}{dt^2} + \frac{d\xi}{dt} = v(t)$
$\xi(t) = c_1 + c_2 e^{-\alpha t} + c_3 e^{-\beta t} + c_4 e^{-\gamma t}$; $\{f_i(t)\} = \{1, e^{-\alpha t}, e^{-\beta t}, e^{-\gamma t}\}$	$\frac{d^4\xi}{dt^4} + (\alpha+\beta+\gamma)\frac{d^3\xi}{dt^3} + (\alpha\beta+\alpha\gamma+\beta\gamma)\frac{d^2\xi}{dt^2} + \alpha\beta\gamma\frac{d\xi}{dt} = v(t)$	$\xi(t) = c_1 + c_2 te^{-\alpha t} + c_3 te^{-t} + c_4 e^{-\alpha t} + c_5(t - 2 + (t + 2)e^{-t})$; $\{f_i(t)\} = \{1, 2, te^{-\alpha t}, (t + 2)e^{-t}, e^{-\alpha t}\}$	$\frac{d^5\xi}{dt^5} + (2+\alpha)\frac{d^4\xi}{dt^4} + (1+2\alpha)\frac{d^3\xi}{dt^3} + \alpha\frac{d^2\xi}{dt^2} = v(t)$
$\xi(t) = c_1 + c_2 t + c_3 t^2 + c_4 t^3 + c_5 e^{-\alpha t} + c_6 e^{-\beta t} + c_7 e^{-\gamma t}$; $\{f_i(t)\} = \{1, t, t^2, t^3, e^{-\alpha t}, e^{-\beta t}, e^{-\gamma t}\}$	$\frac{d^7\xi}{dt^7} + (\alpha+\beta+\gamma)\frac{d^6\xi}{dt^6} + (\alpha\beta+\beta\gamma+\alpha\gamma)\frac{d^5\xi}{dt^5} + \alpha\beta\gamma\frac{d^4\xi}{dt^4} = v(t)$	$\xi(t) = c_1 + c_2 \sin(\alpha t) + c_3 \cos(\alpha t) + c_4 \sin(\beta t) + c_5 \cos(\beta t)$; $\{f_i(t)\} = \{1, \sin(\alpha t), \cos(\alpha t), \sin(\beta t), \cos(\beta t)\}$	$\frac{d^5\xi}{dt^5} + (\alpha^2+\beta^2)\frac{d^3\xi}{dt^3} + \alpha^2\beta^2\frac{d\xi}{dt} = v(t)$

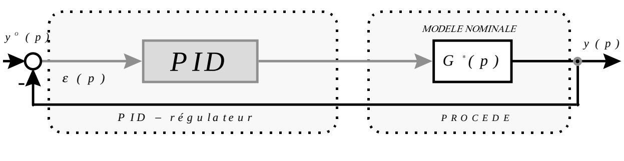


fig.6

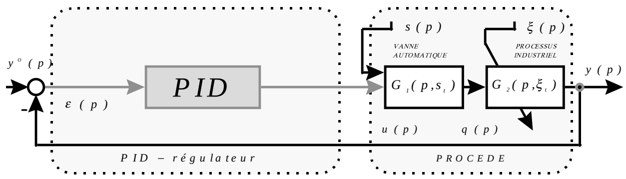


fig.7

fig.8.a

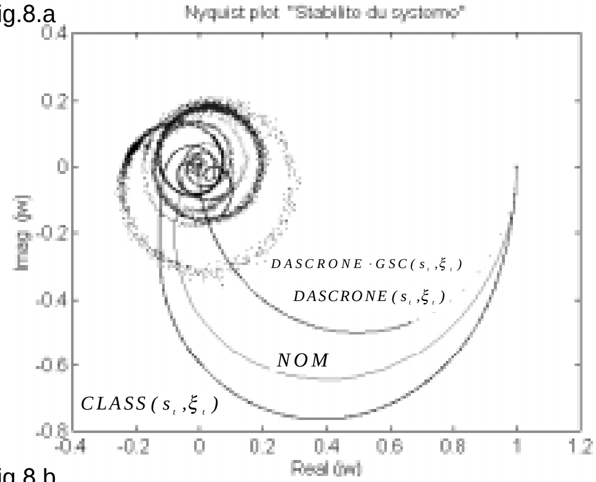


fig.10.a

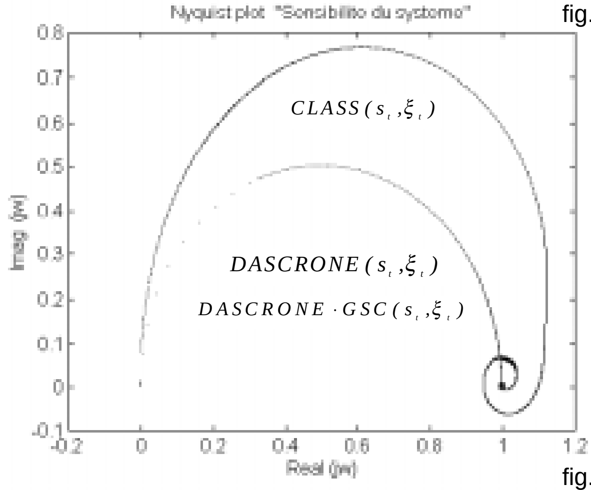


fig.8.b

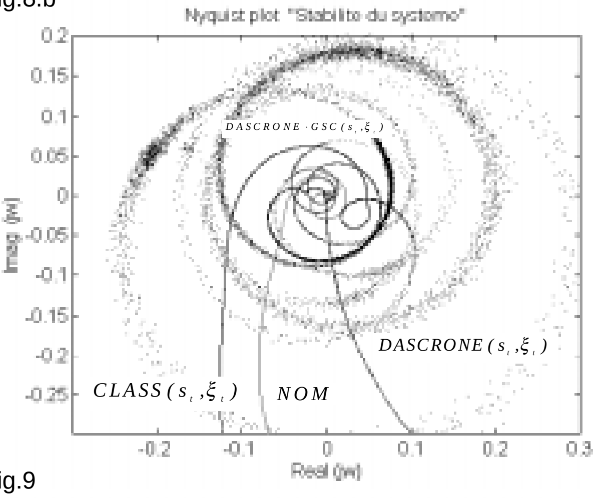


fig.10.b

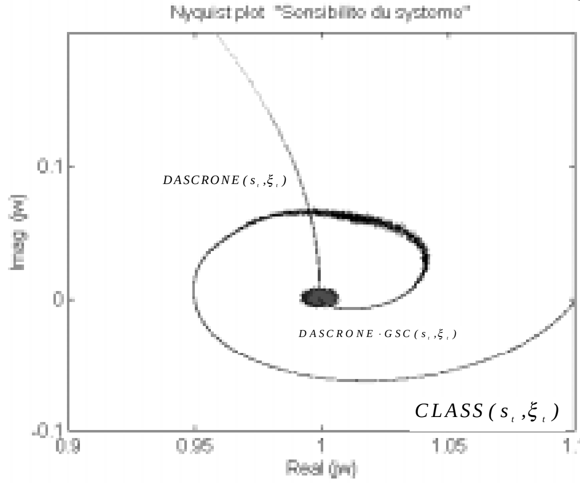


fig.9

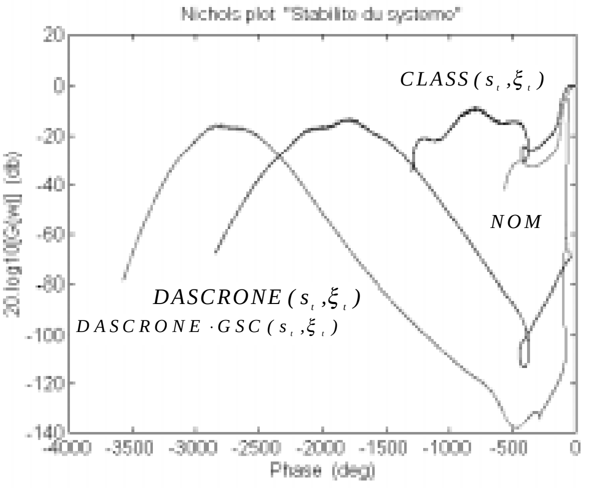
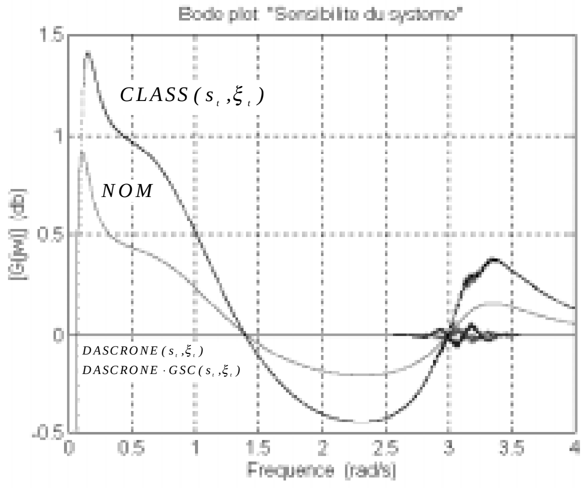


fig.11



Modelling. Robust analysis. The nominal NOM (fig.6), the classical $CLASS$ (fig.7), $DASCRONE$ (fig.2) and $DASCRONE \cdot GSC$ (fig.3) systems are modelled. The results of the simulations, functions of ω, ξ_t, s_t and functions of t, y_t^o, ξ_t, s_t, demonstrate: the stability (fig.8, fig.9); the rejector features, the astathysm and the zero sensitivity (fig.10, fig.11); the robust stability and robust performance (fig.12) of $DASCRONE$ and $DASCRONE \cdot GSC$ for the multitude Π (21)-(29).

Results based on the simulation analysis. The simulation results (44)-(48), functions of ω, ξ_t, s_t and functions of t, y_t^o, ξ_t, s_t, for the numerical example (21)-(29), confirm the reduced (fig.13) hydro-dynamical losses (49) [21] and the increased (fig.14) dynamical precision (50) [17] of $DASCRONE$ and $DASCRONE \cdot GSC$ in comparison with $CLASS$ in the principle and for the multitude Π (21), (22), (26)-(29) as well.

(49) $\left[\Delta \hat{E}\right] = a\, s\,(1 - s\,(1 - e^{2n(1-l)}))^{-0.5}, \left(a = const\right)$

(50) $\left[\hat{e}(t)\right] = \left[1 - \left(\int_0^t \left| \widehat{\varepsilon}^{\,DASCRONE,\ DASCRONE \cdot GSC}_{(t, y^o, s, \xi)} \right| dt \Big/ \int_0^t \left| \widehat{\varepsilon}^{\,CLASS}_{(t, y^o, s, \xi)} \right| dt \right)\right]$

Conclusions. The proposed in the article principally new astatic class systems $DASCRONE$ and $DASCRONE \cdot GSC$**:** merge effectively the features of DAS, $GSCS$ and $CRONE$ - systems**;** they are systems possessing proven robust features and confirmed high effectiveness under industrial conditions.

fig.12.a

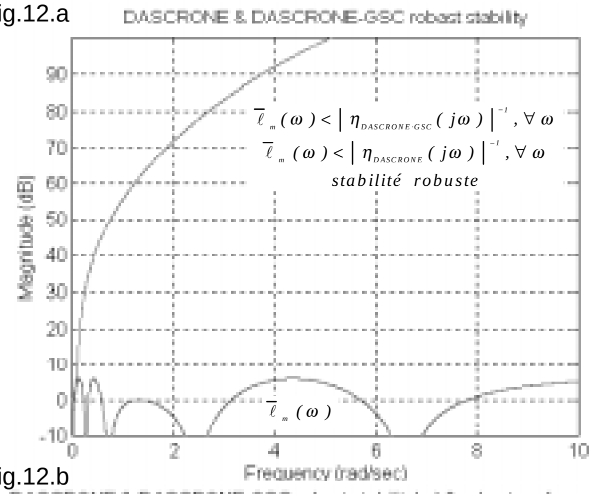


fig.14.a

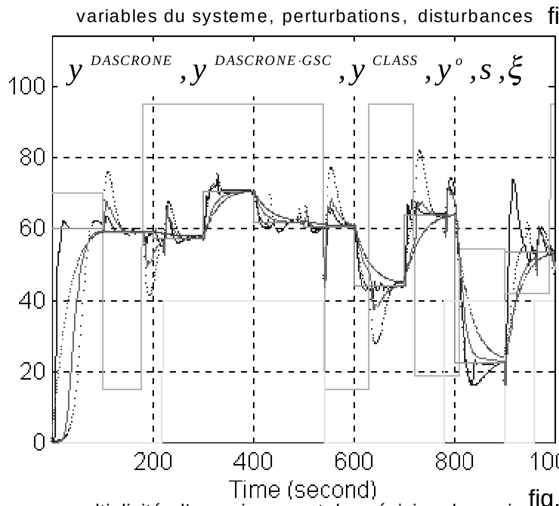


fig.12.b

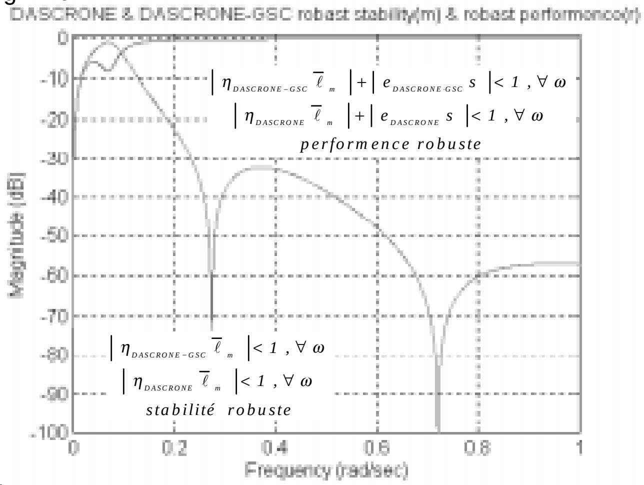


fig.14.b

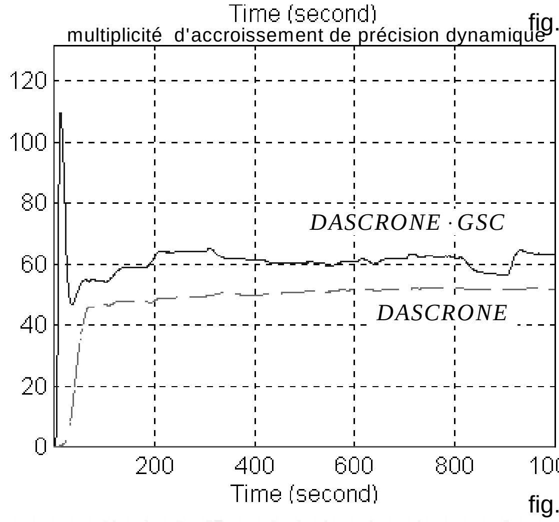


fig.13.a

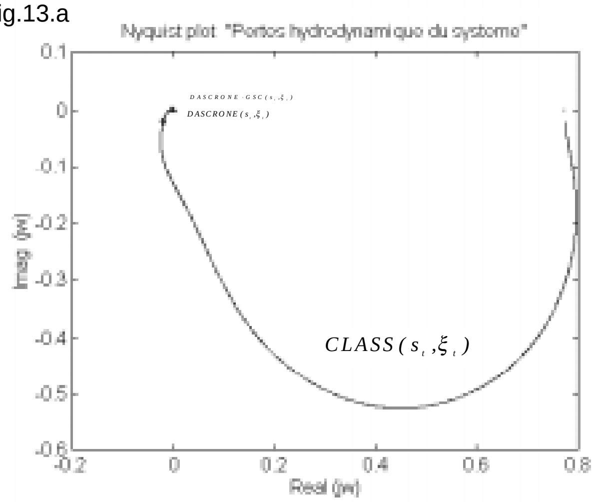
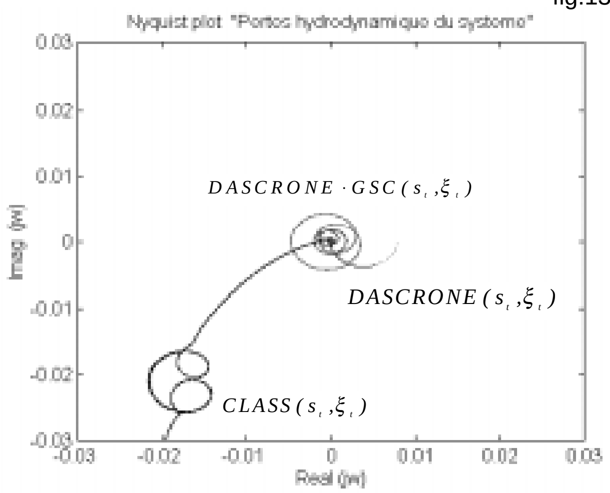


fig.13.b



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