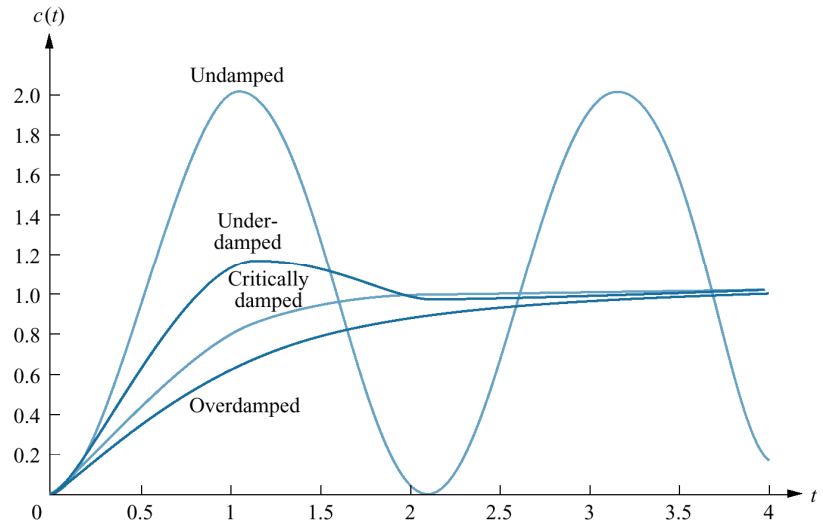
- **The various cases of the output responses discussed above can be compared as follows,**

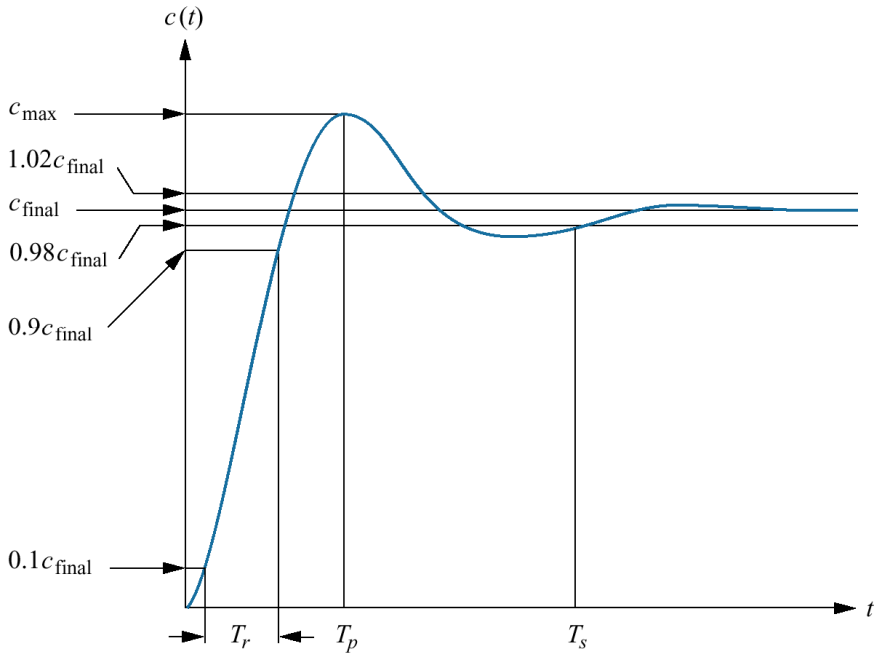


- **Time domain response specifications**

  - **A second order underdamped response is usually obtained in most analysis.**

  - **Hence, it is important that we know some standard specifications from the response.**

  - **Those specifications are defined as follows,**



- **Delay time, T_d : the time needed for the output response to reach 50% of the final output value.**

- **Rise time, T_r : the time taken for the output response to go from 10% to 90% of its final output value.**

- **Settling time, T_s : the time taken for the output response to reach, and stay within 2% of its final output value, or,**

$$T_s = \frac{4}{\zeta \omega_n}$$

- **Peak time, T_p : the time required for the output response to reach the first, or maximum, peak, or,**

$$T_p = \frac{\pi}{\omega_n \sqrt{1-\zeta^2}}$$

- **Percentage overshoot, *%OS* : the amount of the output response overshoots the steady-state, or the final, value at the peak time, expressed in percentage of steady-state value, or,**

$$\%OS = \frac{c_{\max} - c_{final}}{c_{final}} \times 100\%$$

or,

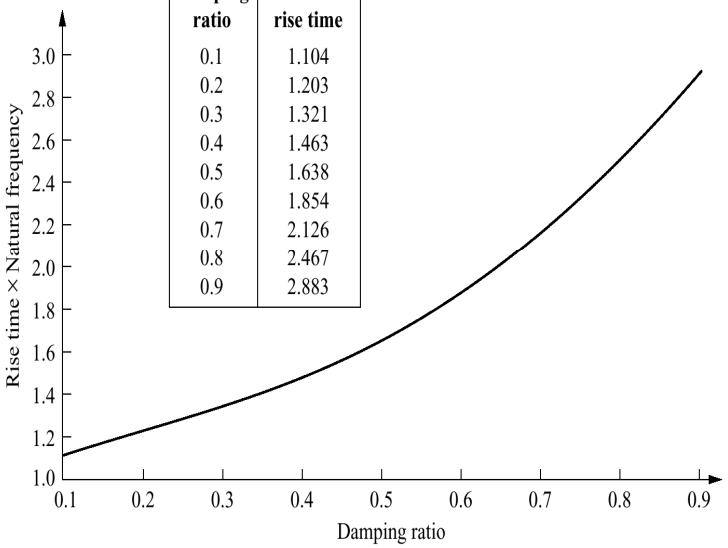
$$\%OS = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} \times 100\%$$

- **Example: Given a system with the transfer function,**

$$G(s) = \frac{100}{s^2 + 15s + 100}$$

Find T_p, T_s, *%OS* and T_r of the system. The following relationship is also given,

Damping ratio	Normalized rise time
0.1	1.104
0.2	1.203
0.3	1.321
0.4	1.463
0.5	1.638
0.6	1.854
0.7	2.126
0.8	2.467
0.9	2.883

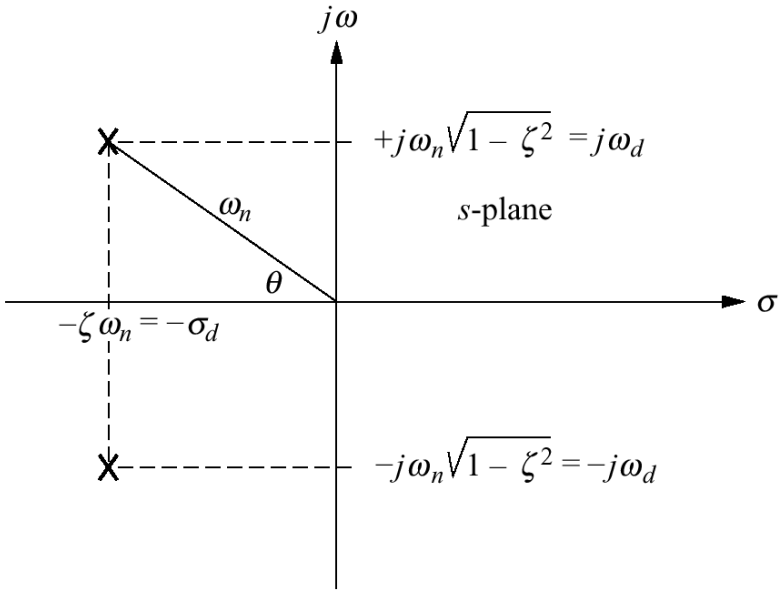


- **Relationships between the poles location and the system performance:**

  - **Consider a second order system with poles,**

$$s_{1,2} = -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}$$
$$= -\sigma_d \pm j\omega_d$$

  - **The poles location on the *s*-plane can be plotted as follows,**



  - **Hence, from the poles location, we can determine the system response, ie ζ , ω_n , T_s, T_p and *%OS***

  - **Example: The poles location of a second order system is given at $s_{1,2} = -3 \pm j7$. Determine the system performance.**

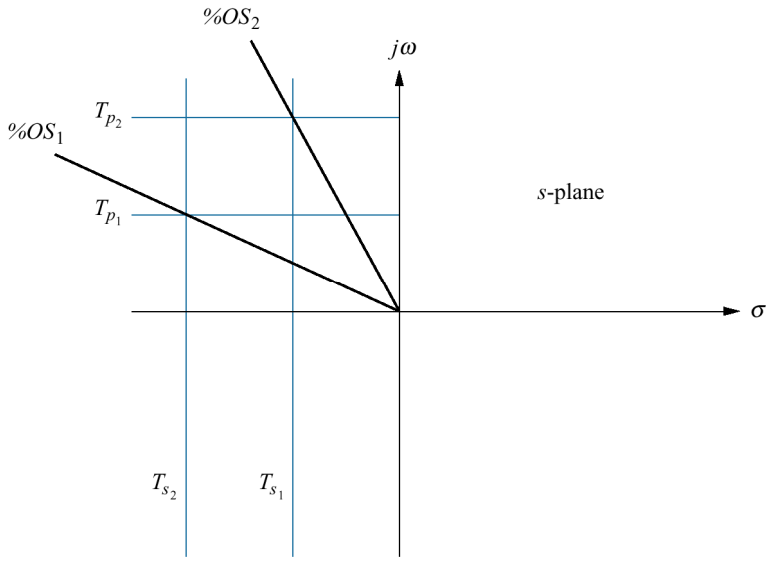
- **The different locations of system's poles will give different system performances.**

- **For example,**

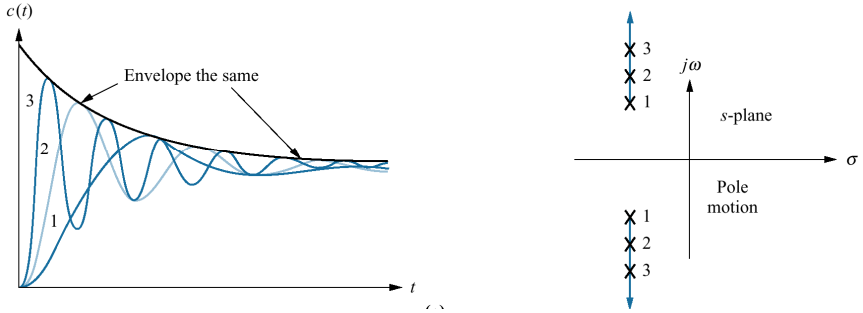
  - **T_s : can be determined from the real part of the pole**

  - **T_p : can be determined from the imaginary part of the pole**

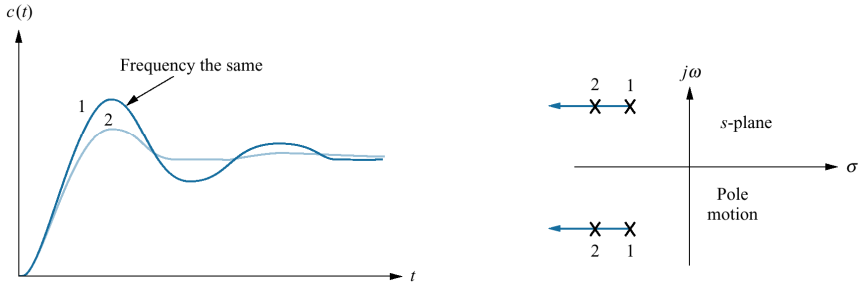
  - ***%OS* : can be determined from the angle of complex pole**



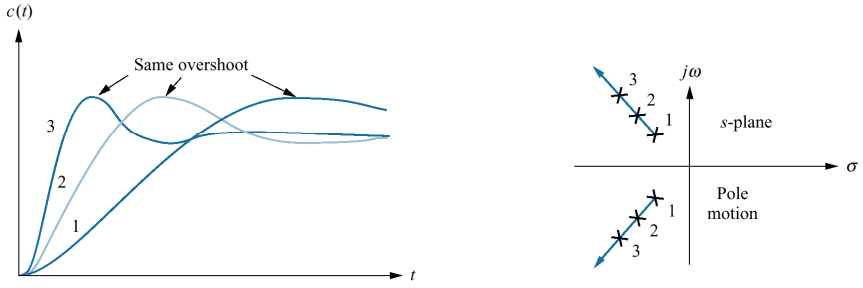
  - **Also, as the imaginary part is varied,**



- **As the real part is varied,**



- **As both the real and imaginary parts are varied simultaneously while keeping the pole angle constant,**



E) <u>Higher order systems</u>

- **The system order is determined by the number of poles a system has.**

- **The number of poles a system has, determines the system response.**

- **In most cases, we could assume a system response by considering the poles closest to the imaginary axis on the *s*-plane.**