4.2 Well and aquifer pressure

To see the overpressure caused by different heterogeneities, we compare cases for their average pressure and well pressure elevation. Average aquifer pressure 2.4 hours after the start of injection is plotted for all cases in Figures 10a and 10c; the corresponding histograms are shown in Figures 10b and 10d. In the rate-constrained scenario, high ranges of average pressure are observed (Figure 10a). Effects of aggradation angle, progradation and faulting are visible in the plot. Three clusters can be identified in the histogram of Figure 10b with medium, high and extreme pressure values. In Figure 10d, a small group of cases show lower pressures, while most of cases are distributed around the mean value ($\approx$ 300 bar).

We define the average elevation in the well pressure at time t_c as the temporal average of the difference between the bottom-hole pressure P_w and the average aquifer pressure $\bar{P}_a$:

$$\overline{\Delta P} = [\int_0^{t_c} (P_w - \bar{P}_a)\, \mathrm{d}t]/t_c. \tag{1}$$

The average well-pressure elevation is plotted for all cases in Figures 11a and 11c and histograms are shown in Figures 11b and 11d. Higher values imply a poor injectivity of the medium. For the rate-constrained scenarios, we see that maintaining the target rate will in many cases require a huge pressure elevation (up to 1400 bar in the worst cases) that would not be feasible nor possible to obtain. Pressure control on the injector reduces the range of pressure elevation variation below 170 bar.

Two regions can be identified in the medium, the region near the injection point; and the part of aquifer which is far from the injection point. The well-bore pressure is effected directly by heterogeneities in the near well-bore region, while the larger-scale region influences the average aquifer pressure. Pressure elevation variations in Figures 11a and 11b are influenced by the heterogeneity near the well-bore, where the reaction to injecting a fixed amount of CO_2 starts by a local pressure buildup. Heterogeneity on the scale of aquifer plays a considerable role in the range of variations in Figures 11c and 11d. In the pressure-constrained scenario, local pressure is controlled by putting a constraint on the well. Hence, the pressure elevation variations are controlled by the average aquifer pressure.

As we see in Figure 11a, low aggradation angle and down-dip progradation result in a poor injectivity and high pressure buildup in the injector. In particular, vertical transmissibility drops dramatically for low aggradation angles [2]. This restricts the pressure transfer within the injection layer, and therefore the pressure builds up locally around the well. Moreover, in cases with down-dip progradation the low permeability rocks surrounding river branches near the injector result in a local pressure buildup.

A group of cases in Figure 11c have a relatively low pressure elevation of less than 50 bar. These cases have a good injection quality, and the pressure is released through open boundaries easier than other cases. The rest of the cases show higher pressure elevation because of the heterogeneities in the larger scale, far from the injector. These results are obtained for a fixed injection location and one may observe different results, if one chooses to drill and complete the injector in the best formation with highest possible injectivity.

Faults influence both local pressure buildup near the injector as well as the average aquifer pressure. Therefore, they have a visible trend in many cases in Figures 11a and 11c (for example, see the three cases denoted by red circles in the right end of Figure 11a). This is specially more apparent in cases with high level of barriers.