

# Adequacy versus complexity of mathematical models for engineering an adsorbed natural gas device

Carlos A. Grande\*, Ørnulv Vistad

SINTEF Industry, P.O. Box 124 Blindern, N0314, Oslo, Norway



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## ABSTRACT

Deploying affordable and sustainable energy storage devices is one of the major pillars for changing the current energy systems. Natural gas (NG)/bio-methane storage for vehicle transportation is an existing technology where the gas is pressurized up to 250 bar. One possibility to reduce the compression and infrastructure costs of new installations is to use tanks filled with porous solids that can selectively adsorb and release methane. This is the so-called Adsorbed Natural Gas (ANG) concept, where pressure of storage is reduced to 30–60 bar while the energy density per tank volume is maintained.

Many publications have focused on the development of a suitable material with pre-defined specifications on amount of methane adsorbed. There are much less publications dealing with the testing of these materials in a current device and even less publications on the implementation of an entire system for ANG. This publication provides a modelling approach with the view of the different stages of development of the ANG concept, from materials to the system. An example of methane storage in a reference adsorbent material (high-surface area activated carbon) is used to validate existing phenomena in the different models used.

## 1. Introduction

Energy storage is one of the major pillars for improving the current energy systems [1]. One classical example of energy storage is the fuel tank in automobiles. In that regard, one of the largest contributors to emissions of greenhouse gases is transportation [2]. This industry sector is intensively looking for renewable and sustainable energy storage devices: batteries, hydrogen, renewable fuels, etc. Reducing the carbon emissions in transportation is very important to mitigate global warming and reduce climate change. In the case of renewable fuels, environmental performance improvements can come from more efficient automobiles, but also by reducing the environmental impact of the fuel conditioning, storage and distribution.

Vehicles moved by natural gas have proven that they have a better environmental performance than vehicles with traditional fuels [3]. This fuel is stored either as Liquefied natural gas (LNG) or as Compressed natural gas (CNG). Both options have already established markets. The energy consumption to condition natural gas to the required conditions is rather high and can be improved [4]. LNG requires large plants to be economically competitive and CNG requires compressing the gas to pressures in the range of 250 bar. On the implementation side, the investment costs of introducing these technologies in different markets were high and are supported on long-term

investments. In pioneering places where the options have already been taken, it may not be economically feasible to change them in the very near-term. What these technologies have shown is that is feasible and safe to store and use NG for vehicular transport. A possibility to further decrease the environmental impact and still use these technologies is to use bio-methane instead of natural gas [5,6]. Vehicles do not need additional changes and storage conditions can be done in a similar manner.

In new markets where methane or bio-methane can be considered as a vehicular fuel, there is a possibility of using mass-transfer agents for enhancing the capacity of storage tanks while reducing the pressure of loading. When the mass-transfer agents are porous adsorbents, such technique is termed Adsorbed natural gas (ANG). Despite being developed in the 1950's [7] major advances were made since 1980's, after the first oil crisis [8]. In ANG technology, a porous material prone to adsorb methane is loaded in the storage tank, allowing a much higher methane density than in the gas phase. Final pressure for ANG technology is lower than 60 bar. When the storage pressure is reduced to 30–60 bar, the compressor can be reduced to a 1–2 stages instead of the 4 or 5 stages currently used for CNG. This reduces the capital expenditure of building such infrastructure. Moreover, since the energy of compression is lower, this also reduces the operational expenditure, making the process more attractive in smaller applications or in

\* Corresponding author.

E-mail address: [carlos.grande@sintef.no](mailto:carlos.grande@sintef.no) (C.A. Grande).

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countries with lower incomes. Additionally, it results in less energy consumption, so it decreases the total carbon footprint of vehicular fuel [9].

The development and implementation of ANG technology requires developments in different scientific fields including material science, device manufacturing and system engineering. Different understanding of the involved phenomena and sometimes lack of proper communication between these fields makes the overall development slower and cumbersome.

The novelty of this publication is to provide a unified perspective about the entire ANG systems, showing different challenges on the entire pathway of developments and also how they can be overcome. The main objective is to demonstrate that several factors should be considered in order to achieve a final successful product. Moreover, we want to highlight that is only through symbiosis between novel materials and engineering developments that a final storage device for ANG technologies can be deployed to the market.

Our perspective is supported by mathematical models targeting developments in materials science and in engineering [10–13]. Models dealing with molecular interactions between the molecules and the adsorbent, molecular/structure prediction as well as grid models to interconnect different storage systems were not considered in this analysis. In order to demonstrate involved phenomena, the mathematical models were calibrated with ANG experiments made with high-purity methane adsorbed in a high surface area activated carbon.

## 2. Inter-disciplinary implementation of ANG

As the implementation of ANG systems is inter-disciplinary, different scientific fields see different solutions (and problems) to develop the technology. A non-comprehensive list of the effects is given in Fig. 1 for three different perspectives: the material, the storage device (tank) and the system.

### 3. Thermodynamic models for ANG

Major efforts to develop porous materials able to adsorb large quantities of methane started in the 1980's. Initially it was mostly driven by activated carbons [14–21]. Activated carbons with surface areas over 3000 m<sup>2</sup>/g are now available [22]. A common issue with activated carbons is that the increase of surface area is normally sustained by a higher burn-off of the structure, resulting in a lower material density. In recent years, the discovery of high surface area metal-organic frameworks had a significant impact in this field [23–31]. Unfortunately, a large portion of MOF materials with high gravimetric capacity towards methane also present low density.

Since the adsorbent is placed in a fixed finite volume, its gravimetric capacity is interesting, but its volumetric capacity is what really counts once that the material is contained in a tank with a fixed volume. In order to achieve competitive cost and to normalize the desired targets for the scientific community, the Department of Energy of United States established targets for ANG materials and devices. The current targets for the material are that the adsorbent must adsorb 0.5 g<sub>CH<sub>4</sub></sub> per gram of adsorbent (at 35 bar), which is equivalent to say that the adsorbent should have a methane capacity over 263 cm<sup>3</sup>/cm<sup>3</sup> of adsorbent [32] which corresponds to the methane density at 250 bar. Additionally, the device should have a capacity of 0.4 g<sub>CH<sub>4</sub></sub> per gram of adsorbent. This second specification is described as the effective loading for a shaped material. Within this value, the packing of the material should also be accounted for. Another specification of 12.5 MJ/L in the sorbent has further implications on the density of the material which should be then ~500 kg/m<sup>3</sup> (assuming a calorific power of 50 MJ/kg<sub>CH<sub>4</sub></sub>).

In order to evaluate the impact of the material in the device, the necessary mathematical model to describe the ANG tank is given by the isotherm, the packing and the density of the material. A mass balance taken at the end of the filling stage is given by:

$$\frac{\Delta n_{\text{tank}}}{V_{\text{tank}}} = \frac{\Delta P}{Z \cdot R \cdot T} \cdot [\varepsilon_c + (1 - \varepsilon_c) \cdot \varepsilon_p] + (1 - \varepsilon_c) \cdot \rho_p \cdot \Delta q_{\text{CH}_4} \quad (1)$$

Where  $\varepsilon_c$  is the porosity of the tank for gas transport,  $\varepsilon_p$  is the porosity of the adsorbent material,  $\rho_p$  is the particle density (shaped density) of the adsorbent and  $V_{\text{tank}}$  is the volume of the tank. The number of moles of methane stored in the tank ( $\Delta n_{\text{tank}}$ ) is thus depending on more variables than the amount adsorbed ( $\Delta q_{\text{CH}_4}$ ). To comply with the specifications, the desired result is to have 11.74 mol<sub>CH<sub>4</sub></sub>/L<sub>tank</sub>. This number should be multiplied by 22.414 L/mol to obtain the result in other common units for material scientists (cm<sup>3</sup>/cm<sup>3</sup> or cc/cc). One example (for a fictitious material) that in principle achieves all the adsorption capacity targets is shown in Fig. 2. In this figure, the amount of gas for an ANG and for the CNG concepts are displayed. For the case of CNG, a comparison between ideal gases and real gas is given [33]. This comparison means that for ANG concept, assuming ideal gas will not have an important impact and will help in simplifying the calculations (meaning that  $Z = 1$  in Eq. (1)). For this example, the density of the material is fixed at 500 kg/m<sup>3</sup> and the porosity of the tank to 10% ( $\varepsilon_c = 0.1$ ). Since this model is only thermodynamic, no diffusional limitations are considered. The problem with this approach is that the isotherm is enough to render the target in terms of methane adsorbed, but there will be a certain amount of gas that will remain adsorbed at the delivery pressure. Setting up a delivery minimum pressure of 1.5 bar (reasons for this value will be given afterwards) will render in the "desorbed gas" curve which still is far from the target.

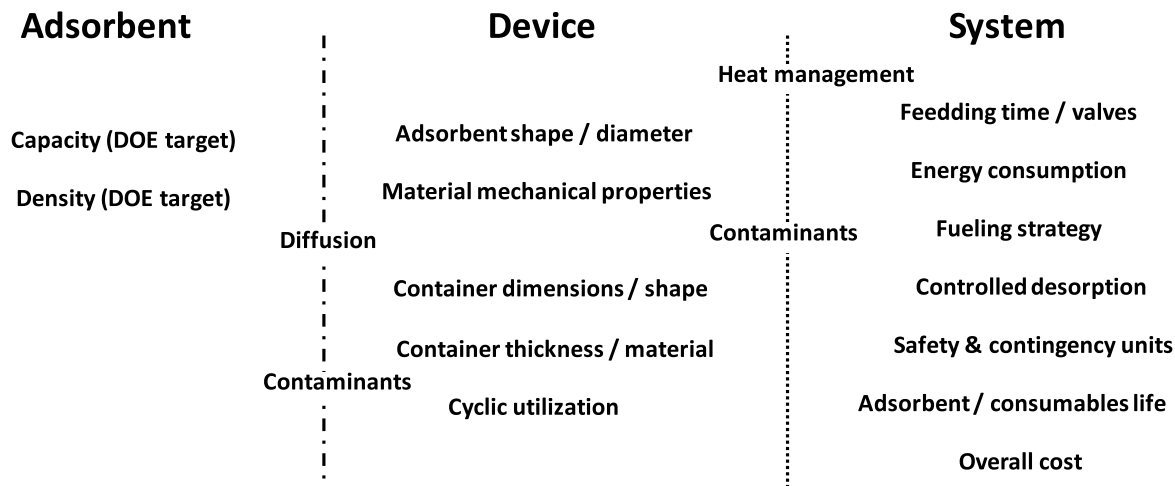


Fig. 1. Inter-disciplinary views & specs that should be satisfied to implement ANG into the market.

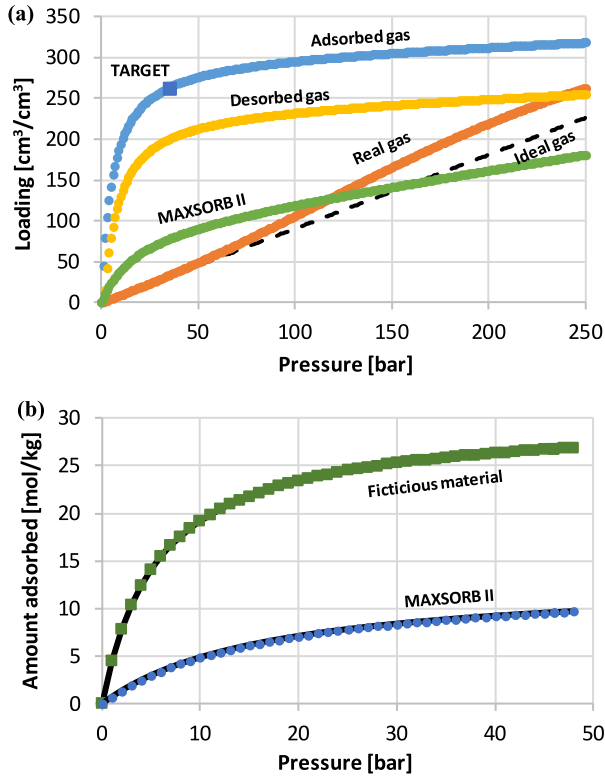


Fig. 2. (a) amount of gas adsorbed and desorbed and as CNG per volume of tank and (b) isotherm at 298 K that was used for such calculations and comparison with the isotherm of activated carbon used in this study.

The comparison of the fictitious material in Fig. 2(a) with a MAXSORB II activated carbon is also shown. As shown in Fig. 2(b), this carbon adsorbs 3 times less than the fictitious material at 35 bar and cannot also be packed at the same efficiency (pellets). This means that to meet the DOE targets, a material with a very high capacity towards methane but also with a low porosity should be available.

The importance of this modelling approach is that knowing the properties of the material (isotherm at 298 K and density) with a simple equation is possible to assess what can be expected from it. In this equation is important to pay attention to the packing of the material which plays a major role in the overall performance. Packing pellets can result in porosities of approx. 40% which will not render good results. The adsorbent material with the desired capacity should be shaped into honeycombs or other structured adsorbents where the overall porosity can be controlled should be used [34–36].

It is important to mention that the approach given by Eq. (1) also works with isotherms that are not Type I although the obtained curves will look different from the ones shown in this example.

As will be shown later, this approach represents the "maximum" values of what can be expected from a given material; only thermodynamic variables are considered. To get into more real performance, more complex models should be used as will be discussed in the following sections.

#### 4. Dynamic models for ANG

Adsorption is a dynamic and generally exothermic process. Several other phenomena are taking place when filling (and discharging) a tank with ANG. The gas takes some time to reach adsorption equilibrium due to different type of resistances that it may find, including diffusional effects in the pores of the material. In some cases, this effect can be neglected but in some other cases is very important to take it into account. Furthermore, adsorption is an exothermic process and when

large amounts of methane are getting adsorbed, there is an important release of energy that should be considered [37–42]. This effect is more important in the filling stage because the filling time is much faster than the consumption of the fuel.

To account for these effects, a more detailed mathematical model should be used [43–44]. The model has to be unsteady state. The model can be 1D, 2D or 3D in spatial coordinates. The model can also comprise the inner part of the vessel with gas and adsorbent material, the column wall (as a sink of heat) and the surroundings. Alternatively, in some cases it can just be modelled itself with a heat flux condition on the walls. In this work we will not consider any device for extracting heat from the tank but if there is one, it should also be included in the model either in the form of a heat exchanger or as a sink in the energy balance.

The mathematical model used in this work comprises mass, energy and momentum balances given by:

$$\frac{\partial}{\partial t} [\varepsilon_c \rho_g + (1 - \varepsilon_c) \rho_p M_w q_{CH_4}] + \nabla \cdot (\rho_g u) = 0 \quad (2)$$

$$\begin{aligned} & [\varepsilon_c \rho_g C_{p,g} + (1 - \varepsilon_c) \rho_p C_{p,p}]_{eff} \frac{\partial T}{\partial t} + \rho_g C_{p,g} u \cdot \nabla T + \nabla \cdot (-k_{eff} \nabla T) \\ & = (1 - \varepsilon_c) \rho_g \Delta H_{CH_4} \frac{\partial q_{CH_4}}{\partial t} + \varepsilon_c R_g \rho_g \frac{\partial T}{\partial t} \end{aligned} \quad (3)$$

$$\frac{\partial q_{CH_4}}{\partial t} = K_{LDF} (q_{eq,CH_4} - q_{CH_4}) \quad (4)$$

where  $\rho_g$  and  $\rho_p$  are the gas and adsorbent densities, respectively,  $M_w$  is the molecular weight of methane,  $C_{p,g}$  and  $C_{p,p}$  are the heat capacity of methane and of the adsorbent, respectively,  $k_{eff}$  is the effective thermal conductivity and  $K_{LDF}$  is the linear driving force (LDF) micropore diffusional constant ( $15D_c/r_c^2$ ) is a ratio of the micropore diffusion constant ( $D_c$ ) and the "crystal" radius ( $r_c$ ). The amount adsorbed ( $q_{CH_4}$ ) is limited by the amount in equilibrium ( $q_{eq,CH_4}$ ) at a given conditions (pressure and temperature). A simple approach to solve the momentum equation is to use the Darcy approach for calculating the velocity given by:

$$u = -\frac{k}{\mu_g} \nabla p \quad (5)$$

where  $k$  is the permeability and  $\mu_g$  is the viscosity of the gas.

The external boundary conditions were selected as no flow ( $\rho_g u = 0$ ), and constant heat flux for the external boundary. In this work, the walls were not modelled and the boundary condition used in the wall is:

$$q = h \cdot (T_{ext} - T) \quad (6)$$

where  $h$  is the heat transfer coefficient and  $T_{ext}$  is the temperature of the wall. In our experiments, the tank was inserted in a water bath to control the temperature, so it is assumed that the heat transfer is controlled in the inner part of the tank. The evaluation of the heat limitation is very important in defining the system and should be done carefully. In many cases, it should be evaluated if the tank wall should be described in the model once that the amount of metal/solid can act as an important local heat sink.

The mathematical model was solved in COMSOL Multiphysics. The solver was PARDISO with  $10^{-4}$  absolute tolerance and  $10^{-3}/t_{feed}$  as an initialization for the backward Euler algebraic solver when the solution was integrated from time zero to the end of the filling of the tank ( $t_{feed}$ ). Two and three-dimensional spatial coordinates were used in solving the model. For simple configurations, as the one used in this initial experiment, there is no substantial difference in using a 2D and 3D approach. However, if more advanced thermal management devices are applied, a more realistic (3D) system should be used.

In order to validate the mathematical models, experiments were made in a 150 ml tank (Swagelok, UK) where extrudates of activated carbon MAXSORB II were filled. Adsorption isotherms of methane and properties of this material were already available in literature [45]. Properties of the cylinder are also available [46]. The tank porosity was

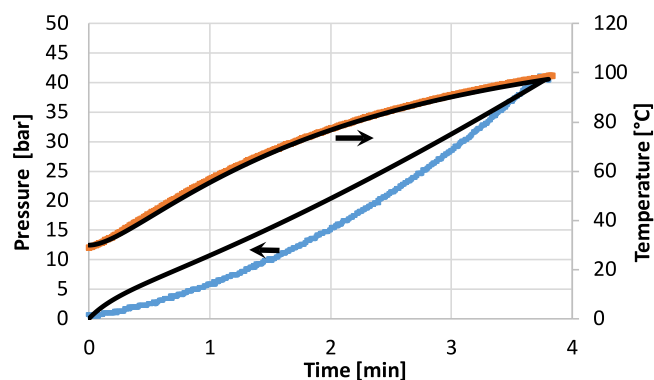


Fig. 3. Temperature and pressure evolution while filling a 150 ml tank filling filled with MAXSORB II activated carbon. The solid lines represent the results of the 2D spatial unsteady model.

0.53. Feed time proceeded for 228 s until the pressure of the tank was 40 bar. The fast feed time represents the market need once that the filling should not take very long time to be comparable with current systems with other liquid fuels.

The experimental result of a fast filling is displayed in Fig. 3. The increase of pressure in an empty tank should be linear if the amount of gas fed is constant. In the ANG tanks, due to a higher capacity of the adsorbent at lower pressures, the pressure does not increase linearly. Moreover, the pressure increase is accompanied by a large release of energy due to adsorption. This results in a temperature increase of almost 70 °C in the thermocouple inserted in the tank. The thermocouple is located in the centre of the tank, both in radial and axial directions.

In order to achieve an acceptable description of the system, the Darken equation had to be used to describe the diffusion coefficient in the micropores. This equation is given by:

$$D_c = D_c^0 \frac{\partial \ln P}{\partial \ln q_{CH_4}} \quad (6a)$$

where  $D_c^0$  is the diffusion coefficient at zero loading and the derivative is determined from the adsorption isotherm.

The only fitting parameter of this equation is the heat transfer coefficient. In our system, the overall heat transfer was determined to be 12 W/(m<sup>2</sup>K). Targeted experiments can be done in order to determine this value and make this model fully predictive, preferably using non-adsorbing gases like helium.

In Fig. 4, the temperature profile of the tank at the end of the filling is shown, together with the pressure (to show the pressure drop inside the tank) and the methane loading. The lines in Fig. 4 are the temperature and pressure evolution obtained with the 2D mathematical model used. One important point in the obtained results is that the pressure drop in the tank is small. This is because the volume of the tank is small but also because the overall velocity inside the tank is small. Indeed, after the first 6 s, the gas velocity is already at values lower than 0.2 m/s and decreasing while the pressure increases. In the initial moments there may be a deviation between the real behaviour and the one predicted by the Darcy law because the velocity of the system starts at ~1 m/s.

This model confirms what many researchers have pointed out regarding the thermal effects. A strong temperature increase is observed due to methane adsorption. However, when the tank achieves the target pressure, the initial portion of the tank is cooled down by the incoming gas, displacing the thermal front to the "rear" of the tank. This is potentially important if a device for thermal management is implemented. Using this activated carbon material, in the initial moments of the filling, the diffusional effects are important. This is related to the higher gas velocity but also to the slow diffusion for smaller loadings that is given by the Darken equation.

It should be noted that the standard settings for the COMSOL solvers

result in non-satisfactory results for this simulation. Indeed, as mentioned, the initialization of the simulation, as well as the overall tolerance should be tailored in order to achieve results that are thermodynamically consistent.

Using the same equations and a 3D scheme of the tank, small differences arise in terms of temperature. The temperature profile at the end of the filling stage is shown in Fig. 5. The predicted temperature with the 3D model (using the same heat transfer coefficients) is slightly lower. The main reason for that is that in the 3D model, there is more area available for heat transfer with the external environment than in the 2D model.

Nevertheless, the results are very comparable in terms of pressure, temperature and loading. It should be noted that in this work, only 1/8 of the volume of the tank was simulated. This is possible because the problem is very symmetric. However, the computational time of the 3D model is significantly higher than the 2D model. The reason for the longer computational time is that the mesh used for the simulations has approximately 10 times more elements. For this reason, this model is only recommended in case of having devices for thermal management that can result in loss of symmetry or for the last fine tuning in terms of development.

## 5. System model for ANG

The multi-dimensional models presented in the previous section are very important for the design of the tank and to evaluate how to minimize thermal excursions. However, they are computationally expensive. Indeed, the 3D model takes approx. 17 min to be solved and the 2D model approximately less than 3 min. Only methane was considered as adsorbate in this study. In order to fully understand the performance of the tank when other gases are adsorbed but also to evaluate several adsorption/desorption cycles, such models can take really long to render results.

Indeed, it has been shown that the presence of contaminants can result in severe reduction of capacity of methane during several fillings [47–50]. In the activated carbon used, carbon dioxide for example adsorbs strongly than methane so if this gas comes as impurity in the fuel, it will tend to accumulate in the tank for the next fillings, decreasing the methane capacity continuously. The combined effects of contaminants and heat transfer [50–52] may require simpler models to optimize the entire system and understand if external actions can be taken to mitigate such effects.

For this reason, a 1D unsteady model can be used. This mathematical model assumes that the properties changes only in the axial axis and do not change in other coordinates (radial) and is extensively used in modelling of adsorption processes. An additional and significant advantage of this approach is that it gives the possibility of modelling the entire filling system and not only the storage tank. The system used in this work is shown in Fig. 6. A similar unit arrangement has already been used for the description of gas separation using pressure swing adsorption processes. The mathematical model of the storage tank is similar to the one used in pressure swing adsorption (PSA) units for gas separation and has already been used in many different systems [53–55]. Indeed, during the conditioning of a PSA unit, there is a "pressurization" step that operates like the filling of a tank. The 1D mathematical model of the system has been solved in gPROMS software (PSE Enterprise, UK).

Given that the same thermodynamic conditions (ideal gas law and same isotherms) and also that the same boundary conditions are used, the differences between the models cannot be very large. The modelling results are shown in Fig. 7 where the temperature and pressure history are shown and compared with the 2D and 3D models. One of the main differences between the experimental data collected in our system and the prediction of the mathematical models is the initial uptake. While the mathematical models predict that the pressure should increase very fast, this is not observed experimentally. The main reason for that is

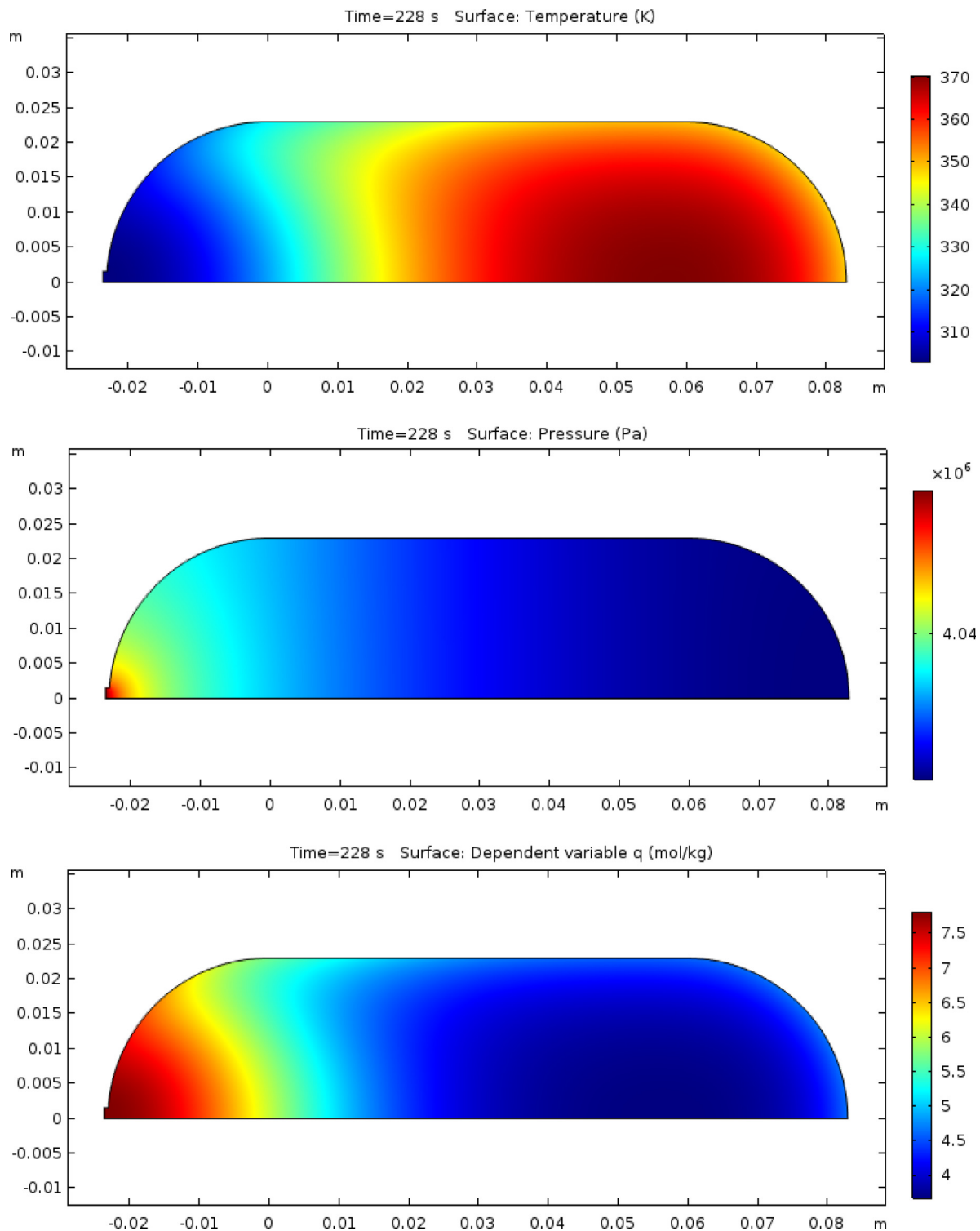


Fig. 4. Temperature, pressure and methane amount adsorbed at the end of the tank filling obtained with the 2D unsteady model.

that the volumes of the tubes attached to the tank are not negligible and for this reason, the pressure response of our system is slower than the one in the mathematical models. This 1D system model is able to take into account such volumes and this is the reason why the experimental data fits better to this model than to other more complex models.

An important difference between the different models is the evolution of the temperature in the system. Once that the surface area available for heat transfer is different (in this model, an equivalent to a cylinder is considered), the evolution to the final temperature is

different. In order to "fit" the final temperature with the one really obtained, a heat transfer coefficient of  $h = 15 \text{ W/m}^2\text{K}$  was used. For this reason, comparing the temperature and the loading between the 1D and the 2D models, several differences can be observed.

The major advantage of this modelling strategy is that modelling the filling of the entire system took only 5 s. Using this model, it will not be very time consuming to simulate other gases and several cycles to evaluate capacity decay. If other strategies like gas recirculation are used to mitigate thermal effects [56], this type of modelling can provide

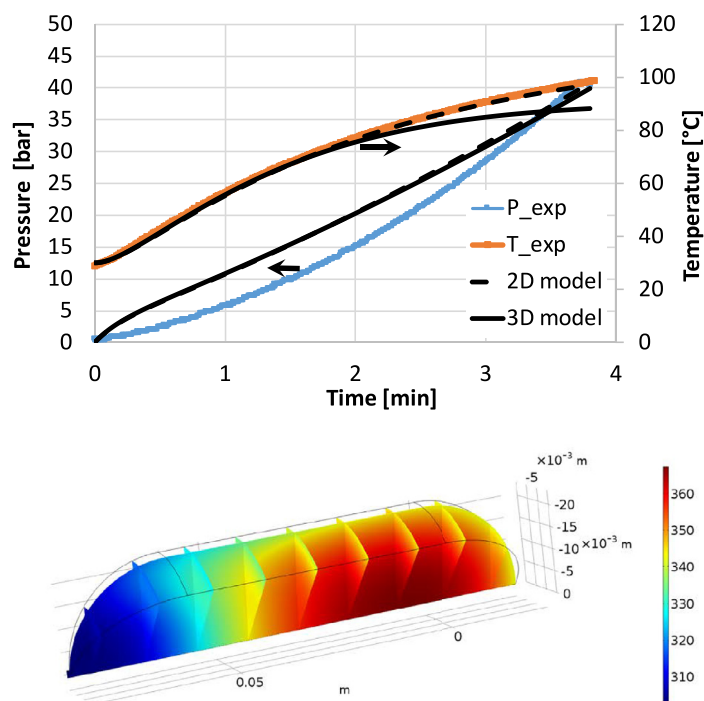


Fig. 5. (a) Temperature and pressure history comparing the results of the 2D model and the 3D model. (b) temperature profile at the end of the filling.

insight of the additional energy of compression that is required and of the size for additional equipment that should be used.

### 6. Discussion

The different types of modelling used in this work can serve as a basis to understand the different needs that should be considered when designing an ANG system. Although the material properties are of unique importance, they are not the only factor to be considered.

So far, the only material that can achieve the DOE targets is the metal-organic framework HKUST-1. Indeed, the target was settled by considering adsorption of methane and HKUST-1 crystallographic density. Shaping this material by standard techniques without severe

loss in methane capacity has not yet been demonstrated. Furthermore, the material must be efficiently packed to keep the volumetric capacity of the tank. Results in this direction has already been reported [57]. Unfortunately, a trade-off between packing and diffusional resistances should be made. Indeed, is with such models that these ratios can be established, minimizing the number of experiments with expensive materials that are under development. Another important consideration is that the endothermic nature of desorption will result in a temperature decrease inside the tank, reducing the overall delivery capacity. For this reason, the good thermal management of the tank should also be thought as necessary for the desorption step.

The models presented here can be used for different functionalities. The simple thermodynamic model can be used to qualify materials as

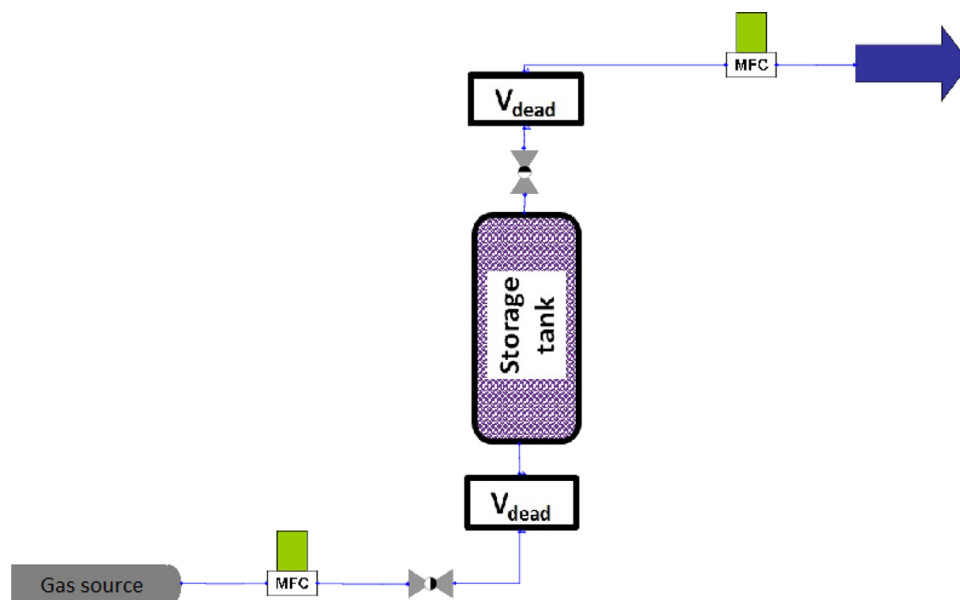


Fig. 6. System model of the unit used for methane storage with a 150 ml tank filled with MAXSORB II activated carbon including the storage tank, valves and dead volumes.

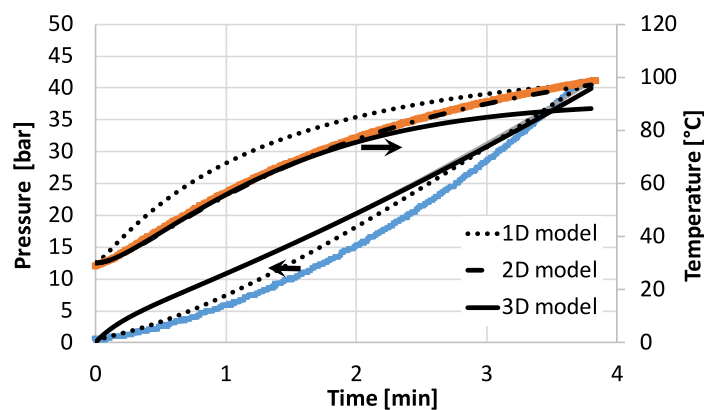


Fig. 7. Comparison of temperature and pressure history using a 1D model of the system and a 2D and a 3D model for the tank only.

potential candidates for this application. The steepness of the isotherms is also important for defining how much of the gas can be desorbed to a standard minimum delivery pressure for automobile applications that is set at 5 bar for most automobile manufacturers. Other techniques like localized heating can be used for decreasing that value (at higher temperatures, the amount of methane adsorbed is smaller and thus more gas can be desorbed).

However, the DOE targets are for storage of methane in automobiles. In the case of stationary storage of methane, the DOE specifications are desirable but not as important as a cheap material. For stationary applications, the thermal management can also be done with less volumetric restrictions so other assumptions may apply.

The more advanced unsteady tank models in 2D and 3D can be used for designing heat transfer devices to enhance the overall capacity of the tank with minimal effect in the volume and weight of the device. Evaluation of the symmetry of such elements should be done in order to decide if the 2D or 3D models should be used.

Once that the tank is optimized, the entire system can be evaluated using a system model that treats the tank in a simplified way. For the case of larger tanks, the inlet and outlet effects shown in this work will be much smaller resulting in less impact in the results. The simplicity of this model is adequate to model the assembly of the necessary units that compose the system, like compressors, coolers and eventually recycling. This model allows also to model the cyclic performance and to evaluate the effect of contaminants in the overall time evolution of the methane storage capacity. The system model has the potential to be used for sizing all components of the entire system that will lead to cost estimations.

## 7. Conclusions

In this work, a modelling approach is used to understand the different needs for designing a device for methane storage using porous adsorbents. The different models allow to identify interfaces between inter-disciplinary areas ranging from materials science to system engineering. The thermodynamic models are normally used for identifying and ruling out materials for methane storage. It is necessary to identify their methane isotherm until a loading at 35 bar but also the density of the material and how can be packed in the tank.

Thermodynamic models do not take into account the dynamic nature of adsorption as well as the thermal effects involved in the adsorption and desorption processes. To take these phenomena into account, more detailed and unsteady models should be used. In this work we have made a 1D, 2D and 3D models of the storage tank and they were compared to new experimental data of methane storage in a 150 ml tank filled with activated carbon. The 2D and 3D models are more appropriate for design of devices for thermal management. The 3D model is computationally intensive and it takes much longer than a 2D equivalent if the problem has symmetry.

The 1D model of the tank can also involve the entire filling system and is computationally much more efficient (seconds for a solution compared to minutes) and can be used to evaluate the effect of contaminants in the long-term cyclic capacity of the tank. This system model has also the potential to be used for sizing all components of the entire system that will lead to cost estimations.

Such multi-step modelling approach can be used to accelerate the development of an economically feasible technology for methane or bio-methane storage based on porous adsorbents.

## CRediT authorship contribution statement

**Carlos A. Grande:** Conceptualization, Software, Formal analysis, Validation, Writing - review & editing. **Ørnulv Vistad:** Conceptualization, Data curation, Writing - original draft.

## Declaration of Competing Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by the two authors and that there are no other persons who satisfied the criteria for authorship but are not listed.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property.

We understand that the corresponding author is the sole contact for the Editorial process (including the Editorial manager and direct communications with his office). He is responsible for communicating with the other author about the stages of the manuscript.

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## Supplementary materials

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