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Implementing An Integrated Solution For Dynamic Choke Control Modelling During Well Restart In OLGA

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Abstract
Restart and shut down sequences for oil and gas wells occur over a long duration in order to maintain sand production control integrity, by avoiding pressure shocks that may destabilise sand packing. To accommodate, well opening sequence (bean-up) guidelines often use dynamic hold periods between choke steps dependent on well production rate. Accurate well restart modelling therefore necessitates prior knowledge of the required choke opening to achieve the targeted production rate profile. However, the complexitiy of the profile considering changing reservoir and varied downstream conditions of the well, often result in the determination of these values becoming a computational prohibitive exercise. This leads to simplified bean-up profiles being utilised that may be conservative resulting in longer ramp up periods, or overly aggressive leading to potential damage of the completion. This paper introduces a novel control system within OLGA that dynamically adjusts well bean-up rate based on the in-situ simulated conditions, replicating the role of the operator.This system's implementation minimally impacts simulation speed, enhances the accuracy of the simulated bean-up profile and workflow efficiency, offering significant commerical and technical benefit. Further, the implementation of this system provides the operator with an advance knowledge of choke behaviour aiding in preserving completion integrity.

Keywords
Well Operation; Transient Simulation; OLGA; Ramp-up; Start-up; Ramp-down; Shutdown

Introduction
The process of beaning-up oil and gas wells is a complex operation, with multiple competing requirements that must be evaluated. Firstly, considering upstream (U/S) of the wellbore choke, the bean-up sequence is a crucial component of the overall sand management strategy to avoid ingress into the production tubing. Sand production can lead to premature equipment failure, reduced production, and well stalling in the event of a large influx of sand followed by a system shutdown [1]. Typical sand management strategies include completion screens to filter particles from production fluids, and inflow control devices to equalize pressure [1]. When opening the well choke, a near wellbore pressure gradient is induced by the increasing drawdown. If this pressure shock is substantial enough, particles will be entrained into the tubing [2], [3]. The most effective means of controlling sand ingress during bean-up is to allow for pressure across the sandface to stabilize between each choke step [4]. Therefore, to minimize sand mobilisation a slow bean-up profile is best suited.
However, slow bean-up poses significant operational challenges downstream (D/S) of the wellbore choke. Hydrate and wax formation propensity increases with a slower well bean-up as the flowline D/S of the well will operate at a lower temperature for a longer duration. This risk is heightened if the system is restarting into a shut-in and cooled down pipeline [5]. Well stall and slugging potential are also increased at low flowrate until a minimum stable rate (MSR) is achieved [6]. The competing philosophies U/S and D/S of the wellbore choke necessitate a balance between requirements to produce guidelines, typically resulting in an initial rapid bean-up to MSR which is then slowed over time as depicted in the example profile of Figure 1.

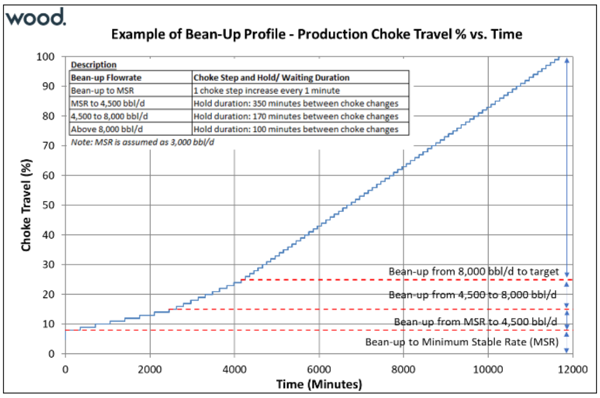

Figure 1. Example Bean-up Profile.

This example bean-up profile demonstrates four key flowrate criteria at which the choke hold

periods are altered. The hold periods have been selected to allow for sand pack stabilization in between each choke step and may vary between wells. The flowrate at any given choke opening will be influenced by both the U/S and D/S choke conditions, presenting a significant modelling challenge. The U/S conditions such as reservoir state and use of artificial lift may vary significantly over field life. Similarly, the D/S conditions may present a large range of operational scenarios, for example the well may be restarting into either a shut-in or a producing pipeline altering backpressure.
Traditionally, the approach to model this complex process has been through either parametric studies to obtain the correct profile, or the use of simplified bean-up profiles. However, these approaches can be either time prohibitive, or misrepresent the true dynamics of the system during bean up. The results of these studies are used for operational guidelines, and therefore to ensure the most reliable information is available it is crucial to accurately model this process.
This paper introduces a novel control system within OLGA that addresses these challenges, offering significant technical and commercial advantages for future modelling.
The next section will briefly describe the methodology utilised within the control system. Case study results will then be presented to benchmark the systems performance.

Control System

The control system has been designed as a general case which can be incorporated within any OLGA model via only two connections. Following the basic logic shown in Fig. 2, at the highest level the control system is simply reading in the D/S choke flowrate, determining the correct hold period specified, and then opening the choke one step after this period has elapsed. This process will recursively take place until the final specified conditions are met.

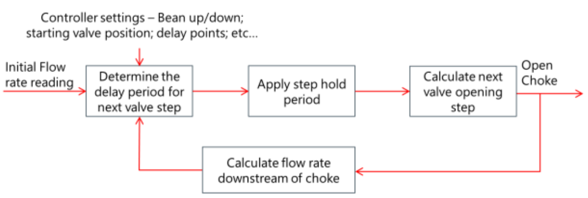

Figure 2. Control System Basic Logic.

A simplified representation of the control system is shown in Figure 3. This diagram captures the basic operation to bean-up the choke valve ignoring other operations such as extended hold periods, bean-down capability, and bean-up of other potentially dependent valves such as gas lift chokes. These additional operations have been included in the control system, but for brevity shall not be discussed in this paper.

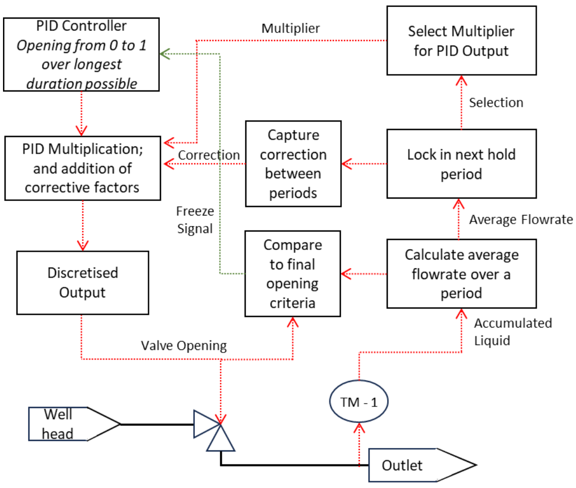

Figure 3. Simple Concept of System; dashed lines indicate controller connections.

The control methodology begins with the transmission of the accumulated liquid or gas content D/S of the choke valve via transmitter TM-1. This accumulated volume is used to capture the average flowrate D/S of the choke over a set period, allowing for the control system to deal with slugging and sudden surge of flow. This flowrate is then used to determine what hold period should be applied between choke steps. As each new hold period is reached the system will 'lock in' and not allow for previous hold periods to be considered. This is important as typically when the bean-up rate slows down a temporary drop in flowrate is observed. From here the signal is then split to two different operations, firstly to multiple the PID controller output, and secondly to capture the final valve opening at the last hold period to be applied as a corrective factor.
The PID controller serves as the central control of the system, driving the opening of the choke. The controller opening time from a value of 0 to 1 is set over the longest possible duration that it could take for the valve to open. Each hold period can be represented as a linear choke opening (y) over time (t), as shown in Eq. (1). The gradient (m) of the line is dependent on the hold period and choke characteristics and can be determined using Eq. (2). The multiplier on the algebraic controller (β), corrects the curve position as we enter each hold period to have the correct opening. As β is changed this will result in the choke opening suddenly rapidly changing, the corrective factor c is introduced to capture the last valve opening prior to the new hold period, this is either added or subtracted to maintain the last valve opening.

$$y(t) = \beta m t + c \quad (1)$$
$$m = 1/((\text{hold period x No. of steps}) + \text{Stroke time}) \quad (2)$$

The formation of Eq. (1) takes place within algebraic controllers as shown in Figure 3. The output of y is then read by a table controller with discrete bins for opening and maintaining a constant valve opening between set ranges. An example of these discrete ranges can be seen in Table 1.

Table 1. Example Discretisation Table

y	Valve Opening
0	0
0.009	0
0.01	0.01
0.0199	0.01
0.02	0.02
…	…

This control system will continue to ramp up from the set start point of the PID controller until fully open unless a freeze signal is sent to the PID controller. This freeze point can be based on valve opening, flowrate D/S of the choke or any number of criteria the user may set.

Development of the overall control system required an integration of over 140 individual controller components per well in OLGA, however as a significant amount of these controllers served as static memory the overall impact in the execution time was typically observed to be less than 10%.

Control System Performance

The system has been implemented for numerous studies and shown to reduce both model setup and computational simulation overheads. A typical performance impact of less than 10% increase in execution time has been observed, which is significantly less than the parametric studies required to obtain the bean-up profile to the same accuracy. The model setup to produce an accurate bean-up profile is straightforward, requiring only a few inputs to each controller such as the multiplier values, and hold setpoints.

As shown in the single well example in Fig. 4, the control system is correctly adjusting the hold period as each flow setpoint is met. In this example a flowrate freezing setpoint of 12,500 bbl/day was prescribed. As the D/S flowrate reaches this target, the system ceases beaning and maintains a constant flowrate until the end of the simulation.

Figures 5 and 6 shows valve opening for the cold restart of a well considering three different bean-up profiles and 0% watercut (WC) and 30% WC respectively. The fastest profile considers a constant hold period irrespective of the flowrate D/S of the choke, whilst the remaining profiles consider different hold periods that have been prescribed based on sand management and hydrate management requirements. The use of this control system allowed for a fast turn around of these results and highly accurate representation. Simulation time to produce the full cold restart for each WC scenario required a week of execution time, considering the second WC scenario likely would have not occurred without the use of this system.

Figure 7 shows the control systems implementation for the simultaneous bean-up of multiple wells into the same flowline, with varied final D/S flowrate setpoints. The resultant bean-up profile for this study accurately captured the correct hold periods for each well, and the final targeted flowrate. This scenario would have been challenging to model accurately without the control system due to the constantly changing D/S choke conditions.

The final example shown in Fig. 8 was part of a study investigating the potential to kick off a well using only the inventory of the gas lift system (GLS) in the event the compression system on the FPSO is offline. In this study multiple different reservoir conditions and well depths were considered as part of the parametric study to understand if a well could be restarted for long enough to restart the gas compression system. In the scenario shown the well was unable to kick off. The control system enabled a larger parametric study than would have otherwise been possible, providing significantly more insight into the problem. This example includes the annulus choke valve (ACV), demonstrating the additional capability of the control system to control two chokes with different criteria.

All examples discussed in this section also included a section of the control system for the Gas Lift choke valve control that, as mentioned in the methodology section, have not been discussed in this paper.

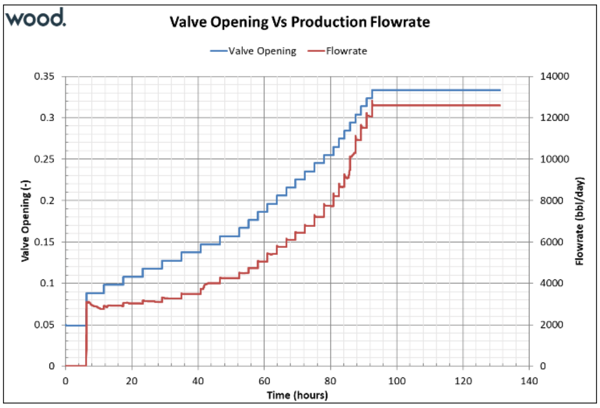

Figure 4. Valve Opening vs D/S Flowrate

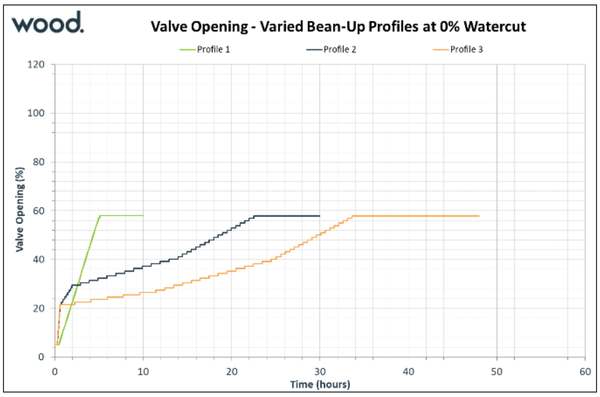

Figure 5. Cold Restart Valve Opening: 0% WC.

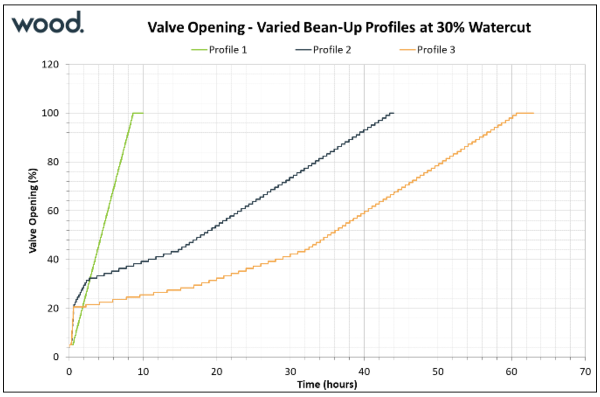

Figure 6. Cold Restart Valve Opening: 30% WC

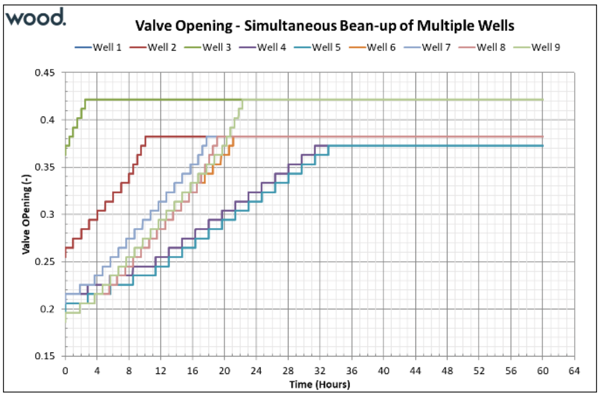

Figure 7. Simultaneous well bean-up.

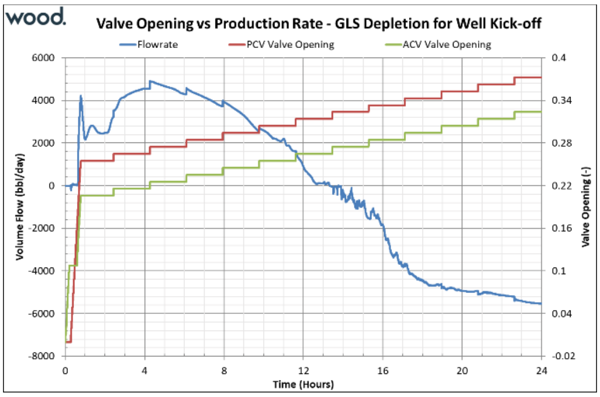

Figure 8. Well bean-up Considering Gas Lift System Depletion.

Conclusions

A control system has been constructed within OLGA that is capable of dynamically adjusting well bean-up rates based on the in-situ simulated conditions, replicating the role of the operator. The use of this system in multiple studies have proven it to reduce both model setup, and simulation overheads required. This provides a technical and commercial advantage when studying transient events considering well bean-up, allowing for more information to be provided to the operator in the same amount of time, with a more accurate representation of the transient event. The simple setup of the model furthers this advantage as only small modifications are required to setpoints to capture field modifications to the bean-up profile. The use of this dynamic control system will provide precise valve opening details to the operators for each step of the ramp-up/ram-down operations. The control system has been made as a general addition to any OLGA model, requiring minimal connection points. In future there is interest in further modularization of this control system within an OLGA OPC environment for fast turnaround of well bean-up information.

Responsibility Notice

The authors are the only responsible for the paper content.

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