Tuning loops quickly at start-up

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ABSTRACT
Traditional methods for PID tuning require several hours or sometimes days to complete, because they rely on steady-state process response or on continued oscillation. Furthermore, at start-up it is not always possible to ask operation people to make bumps. To ensure the start-up will go smoothly, the tuning parameters for each loop should be estimated accordingly to the loop type. This paper presents methods to tune control loops quickly: in minutes, not hours.

INTRODUCTION
With traditional methods, way too much emphasis is put on bump tests needed to tune loops. This paper will demonstrate that this can be overcome by focusing on the short-term dynamics of the process. Also, an automated frequency-response tuning method will be demonstrated. If it is possible to collect data from all loops during start-up then, with the appropriate tools, the models will automatically be obtained; hence tuning parameters will be obtained on the fly.

DEFAULT VALUES
Before the start-up, a good practice is to enter acceptable values for tuning parameters. For example, most flow loops require a low proportional gain and an integral time smaller than 10 seconds.

START-UP VALUES [EXCEPT PARALLEL CONTROLLERS]

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>I</th>
<th>D</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$K_P$</td>
<td>$T_i$ [s]</td>
<td>$T_d$ [s]</td>
<td>$T_F$ [s]</td>
</tr>
<tr>
<td>Flow</td>
<td>0.1</td>
<td>5</td>
<td>0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Pressure (liquid)</td>
<td>0.1</td>
<td>5</td>
<td>0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Pressure (gas)</td>
<td>1</td>
<td>60</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Level</td>
<td>5</td>
<td>300</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Temperature</td>
<td>1 to 5</td>
<td>60 to 600</td>
<td>0 to 20</td>
<td>5</td>
</tr>
<tr>
<td>Analysis</td>
<td>.1</td>
<td>600</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>
\( p \text{H} \text{ (should be characterized) } \) 

<table>
<thead>
<tr>
<th></th>
<th>.001 to .1</th>
<th>300</th>
<th>0</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 ( \frac{\tau}{5 t_d \cdot G_p} )</td>
<td>5( t_d )</td>
<td>0</td>
<td>( \frac{t_d}{5} )</td>
</tr>
</tbody>
</table>

The last line in the table requires having an estimate for the dead time and processing gain. Good design practices are to select process gain (Gp) close to 1 and to reduce as much as possible the dead time. Most piping design are done with liquid flowing at 1 to 3 m/s; this value can be used to estimate dead time where transportation time is an issue: \( t_d = \frac{\text{length}}{1 \text{ m/s}} \). Each piece of equipment corresponds at least to 1 s. Most valve travel time is also 1 to 2 s. Finally, thermowell will add 10 s to 1 minute in most cases. Using these rules of thumb, an estimate of dead time will help to calculate tuning parameters.

These values will ensure a smooth start-up. Using these values will give acceptable results and will guaranty robustness. However each loop will have to be tuned accordingly to obtain expected results.

TRADITIONAL METHODS TO TUNE LOOPS

Traditional methods to tune loops and find a model for them have been known for decades. It can be done by hand or using a tuning software package.

METHOD

- First step is to ensure that all the equipment is working properly.
- Second step is to stabilize the process, then bump the controller output and let the process stabilize again. It is preferable to repeat the bump in the opposite direction since many processes behave differently according to the direction.
- The third step consists to determine the process model then compute tuning parameters considering:
  - set-point response or load response
  - performance criterion selected
  - controller structure and units.

For example, a temperature process with a long time constant is used to compare tuning and identification method.

This method is time consuming and if an upset happens during the test, it will have to be redone. Also, during the test, the loop is not in automatic mode and it could be impossible to do.
The model identified for this process is:

\[ e^{-1.8s} \]

\[ 0.95 + 3.4s + 13s^2 \] minutes

<table>
<thead>
<tr>
<th>Gain</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead time</td>
<td>1.8</td>
</tr>
<tr>
<td>1st Time constant</td>
<td>32</td>
</tr>
<tr>
<td>2nd Time</td>
<td>0.43</td>
</tr>
</tbody>
</table>

This method where the analysis is done in the frequency domain is at the origin of the following method. Any signal producing low frequencies (stable) and high frequencies (fast change) will give good results.

**NEW METHOD PROPOSED**

The new method is based not on a bump test but on a short pulse test. This pulse test can be applied on the controller output or on the set point if the actual tuning parameters can stabilize the loop. In fact, any change will do if three conditions are respected:
1. begin stable (measurement and controller output),
2. quick change on controller output,
3. fairly stable at the end.

This method is quick, includes dynamics when increasing and decreasing. We assume the equipment has been verified or tested before which should be the case at start-up.

First step is to stabilize the process then bump the controller output (or the set-point) and wait enough time to see the process variable change by a sufficient amount; a sufficient amount is usually 3 to 5 times more than the noise band.

In manual mode, note the time that the controller output had to be maintained to observe a sufficient change and bump the controller output in the opposite direction by twice the first change. Maintain the controller output at this value during the same time it was initially; finally go back to the original value.

![Manual mode pulse test](image)

![Automatic mode pulse test](image)

**Figure. 3 Pulse tests in manual and automatic mode**

In automatic mode, bring back the set-point value at its original value.

Using this pulse test, the software can now determine:
- a process model
- tuning parameters accordingly to a performance criterion
- performances expected
- simulation of different tuning parameters

The third step consists to determine the process model then compute the tuning parameters considered. An example is presented using the same process.
A short pulse is applied on the set-point change. After 15 minutes, the process is stable. This data is fed to the software, which determines the process model and the tuning parameters.

### Identified Process Model

\[
\text{e}^{-1.1 \text{s}} \quad 1.1 \div 35 \text{ s} + 33 \text{ s}^2
\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain</td>
<td>0.94</td>
</tr>
<tr>
<td>Dead time</td>
<td>1.1</td>
</tr>
<tr>
<td>1st Time constant</td>
<td>32</td>
</tr>
<tr>
<td>2nd Time</td>
<td>0.98</td>
</tr>
</tbody>
</table>

**Figure 4** Pulse test in automatic mode

A similar procedure was used to find the process model using a double pulse test in a manual mode.

### Identified Process Model

\[
\text{e}^{-7.56 \text{s}} \quad 0.9 \div 32 \text{ s} + 48 \text{ s}^2
\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain</td>
<td>1.1</td>
</tr>
<tr>
<td>Dead time</td>
<td>0.76</td>
</tr>
<tr>
<td>1st Time constant</td>
<td>34</td>
</tr>
<tr>
<td>2nd Time</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**Figure 5** Real process and model, pulse test in automatic mode

**Figure 6** Real process and model, double pulse test in manual mode
MODEL IDENTIFICATION

For process identification, this method gives quick results and does not disturb the process too much. This is useful to calculate mass balance, uses model predictive control and multivariable controls. Both methods give similar results but the pulse test is a lot quicker.

Bump test lasts 3 hours  
Pulse test lasts 15 minutes  
Double pulse test lasts 12 minutes

The results are slightly different but the differences are acceptable.

The tuning parameters in each case are similar for the same criterion (tuning for load rejection).

USING CHANGES AND ACTIONS FROM OPERATION PEOPLE

During a start-up, operators generate a lot of changes. If all data is collected, it is easy to search for changes if the three conditions are present:

1. begin stable (measurement and controller output),
2. quick change on controller output,
3. fairly stable at the end.

If a performance monitoring software is installed, the software will detect the best model in the last 14 days and calculate the tuning parameters corresponding to the goal for the loop.

CONCLUSION

A fast method to tune loops at start-up has been presented. It is also possible to use this method to determine the process model. This method gives excellent results and can be applied on most processes.

Advantages of this method:
- Quick, reliable, easy to do
- Can be done in manual or automatic mode
- Reduce the risk of having load change during the tests
- Can be done during normal production while the process is running
- Ensure fast start-up
- With the model found, it is possible to test control strategies and tuning parameters off-line

All the figures in this article were derived from ExperTune software from ExperTune Inc.

REFERENCES

ABOUT THE AUTHOR
Michel Ruel is a registered professional engineer, university lecturer and author of several publications and books on instrumentation and control. Michel has 28 years of plant experience including these companies: Monsanto Chemicals, Domtar Paper, Dow Corning, Shell Oil, Abitibi-Consolidated, Petro-Canada, Noranda, Degussa, Alcan, Smurfit Stone, Kruger, Pratt & Whitney and International Paper. He is experienced in solving unusual process control problems. Michel has presented process control lectures to over 4,000 engineers and technicians in 6 countries. He translates his experience in a very user-friendly presentation and teaching style. Michel speaks French and English. He is president of TOP Control Inc. Michel is as well, an ISA Fellow member.