Application Note

FESTO

Servo press kit YJKP - force control function

This Application Note describes characteristics, mode of operation, parameters configuration and application examples of the force control function of the servo press kit YJKP.

YJKP

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1 Utilised components/software

Type/name	Software/firmware version	Date of manufacture
Servo press kit YJKP	General	--
Application software YJKP (GSAY-A4-F0-Z4-1.3.3)	V1.3.3	--
Controller firmware (CECC-X)	V3.4.6	--
Motor controller firmware (CMMP-AS)	V4.0.1501.2.4	--

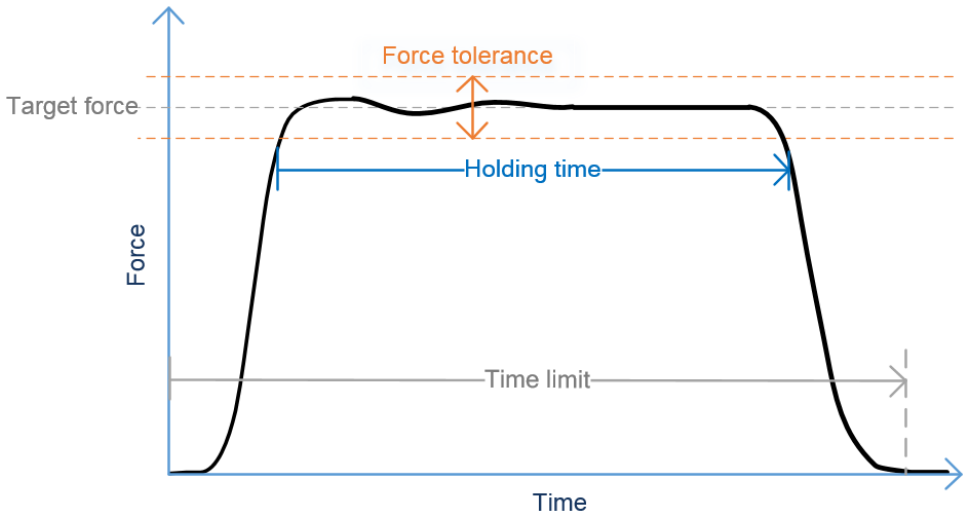
Table 1.1: Utilised components/software

2 Characteristics

The force control function makes it possible to maintain a specific target force over a defined period of time.

Force control demonstrates the following characteristics:

- Continuous regulation
- Positive and negative force fluctuations can be compensated.
- Can be selected as a function in the sequencer
- Multiple instances of the force control function can be used in a program within the sequencer.
- A holding time of the force is defined, which begins as soon as the force tolerance (±2% to ±100%) is reached.
- Limits which are monitored for the entire duration of force control include maximum position, maximum force and maximum time limit.



- Graphic representations of force-time and force-position are used to analyse control performance and evaluate the process. All available evaluation methods can be used.
- The force control function optionally includes a driving profile for *velocity switch*. This can be used to optimise process time.
- The respective speed limits for the various sizes of the servo press apply to force control as well.
- Maximum diagram recording time amounts to 45 minutes per function. Depending on recording time, sampling time varies from 1 ms to just less than 100 ms.

3 Parameters configuration

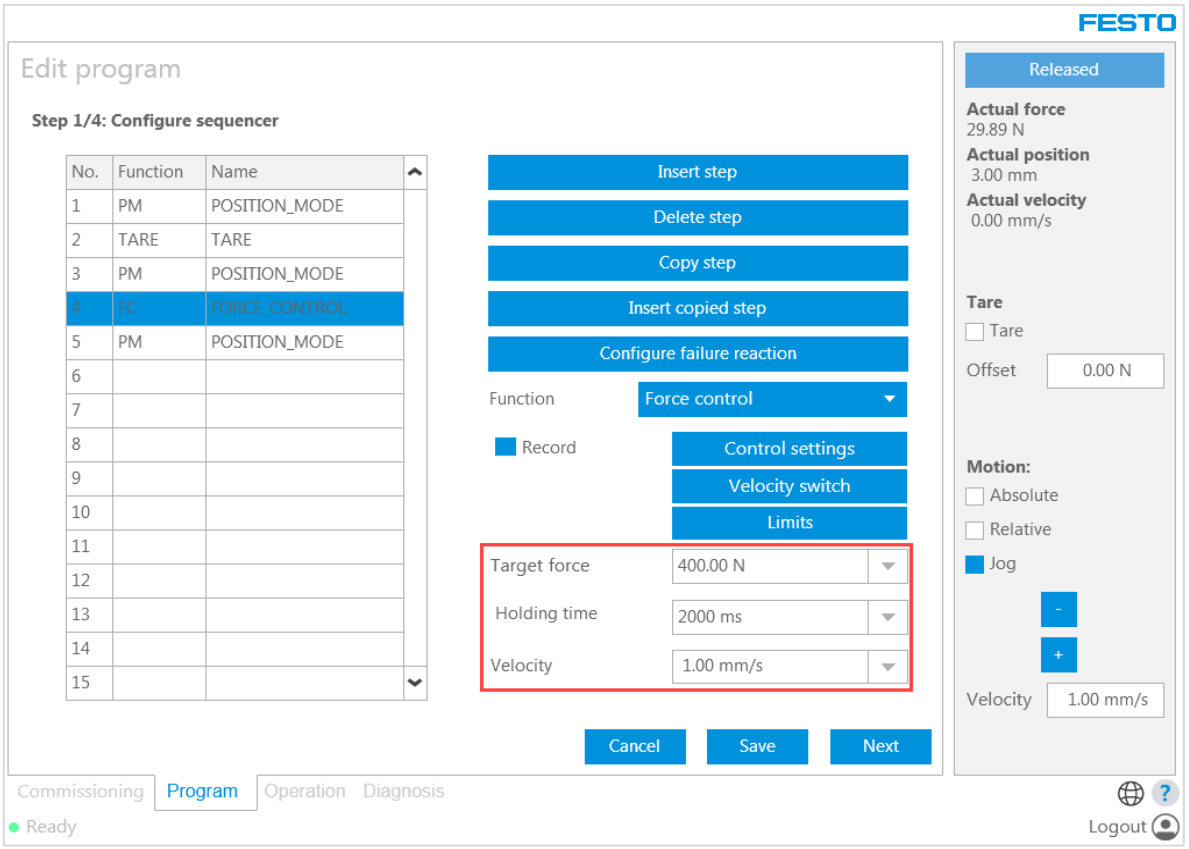
3.1 Influences

Various influences must be taken into consideration when configuring force control parameters:

- *Speed:* If speed is too great, the target force value may be exceeded and the object to be pressed or the servo press itself may be damaged.
- *Object to be pressed / frame:* Depending on the stiffness of the object to be pressed, the control parameters and/or speed must be adjusted.
- *Target force:* Depending on the target force, the control parameters and/or speed must be adjusted.

3.2 Press parameters

- *Target force* [N]: Pressing force
- *Holding time* [ms]: Duration of how long the force is maintained after it has reached the tolerance range
- *Speed* [mm/s]: Maximum possible speed during the pressing operation
  Note: Selected maximum speed is only complied with in the case of positive force build-up.



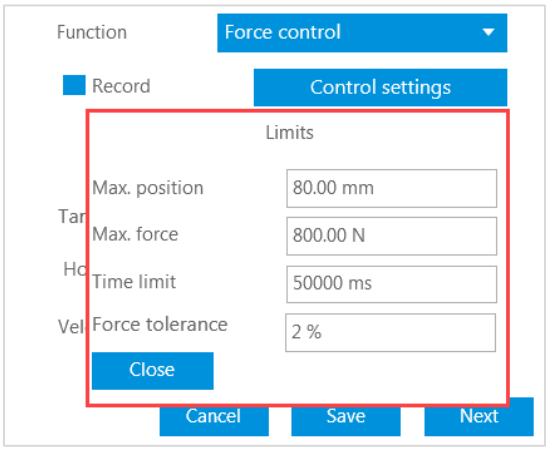
3.3 Limit values

If any of the limits is exceeded (other than the force tolerance), either the selected “failure reaction” is executed or the process is interrupted. **Note:** It’s advisable to activate “failure reaction” if this is possible within the application.

- *Max. position* [mm]: The process is interrupted if this position (absolute) is exceeded.
- *Max. force* [N]: The process is interrupted if this force value is exceeded.

Size	Up to 0.8 kN	Up to 1.5 KN	Up to 4 kN	Up to 7 kN	Up to 12 kN	Up to 17 kN
Max force limit [kN]	0.84	1.575	4.2	7.35	12.6	17.85

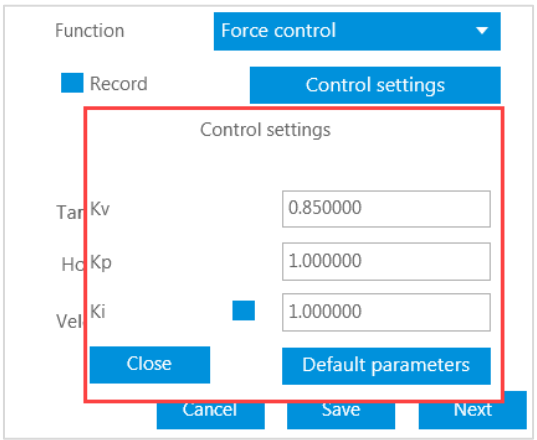
- *Time limit* [ms]: Specifies the maximum permissible duration of force control. If the selected duration is exceeded, force control is interrupted.
- *Force tolerance* [%]: Maximum deviation from target force as of which the tolerance is deemed complied with and holding time begins. Later non-compliance with the specified tolerance range has no effect.
  Note: No evaluation method! If applicable, compliance with a tolerance range must be tested separately.



3.4 Control parameters

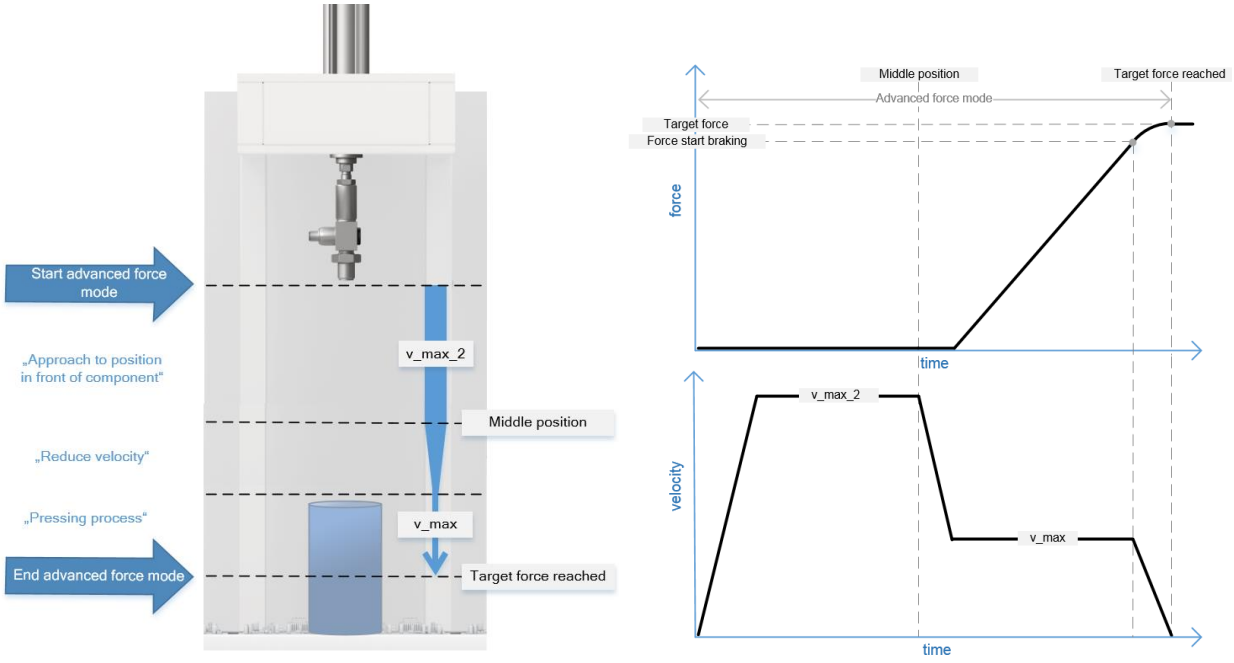
Force control is based on a precontrol with a PI controller. Only the I controller can be deactivated. Further information on parameters configuration is included in the next section.

- *Kv*: Precontrol gain
- *Kp*: Proportional gain
- *Ki*: Integrator gain
- *Act_I*: Activation of the integrator
- *Default parameters:* Standard control parameters apply to each servo press size. These are only intended as benchmarks.



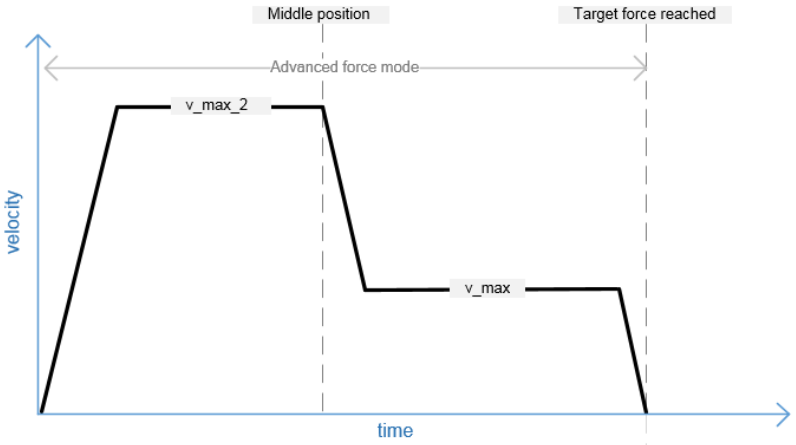
3.5 Velocity switch (optional)

Velocity switching can be activated optionally in the force control function. Using this function, an intermediate position (e.g., position shortly upstream of the pressing) can be approached at high velocity (v_max_2). From there, the system brakes to the set velocity (v_max) without stopping.

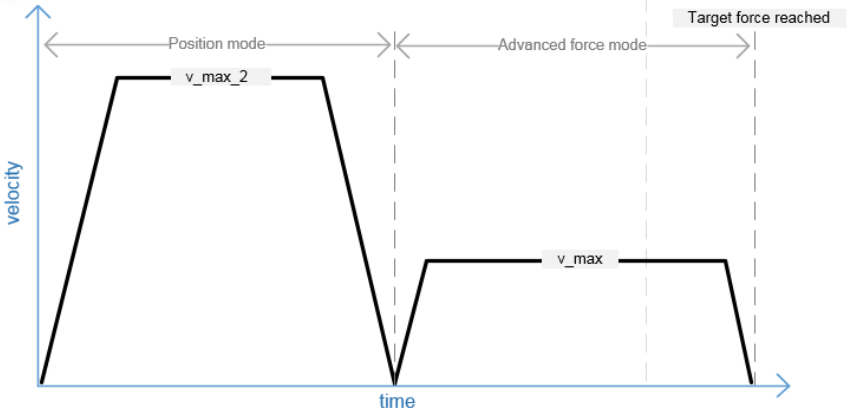


With this switching of the speed, the cycle time can be reduced in contrast with a separate positioning step. This is illustrated in the following diagrams:

With approach velocity:

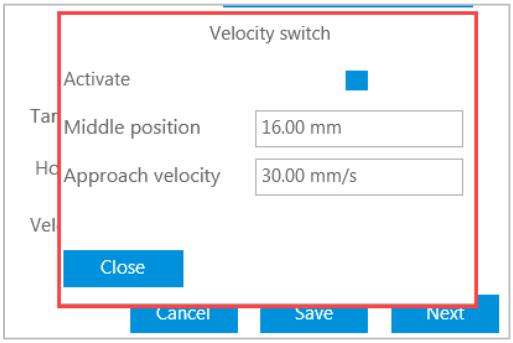


Without approach velocity:



Parameter

- *Act*: Activation of velocity switch
- *Middle position* [mm]: At this position, the velocity starts to be reduced from v_max_2 to v_max.
- *Approach velocity* [mm/s]: Velocity from the start of force control up to the middle position (v_max_2)



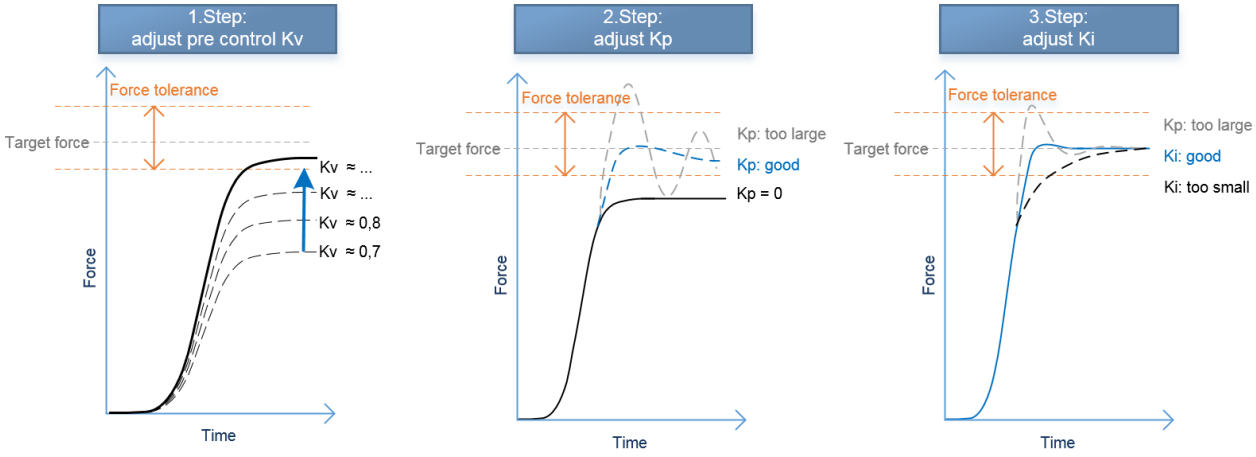
Note: The velocity is not reduced until the middle position is reached.
When determining the middle position, you must ensure that it is not too close to or on the pressing. Otherwise an excessive approach velocity (v_max_2) can lead to damage to the press and/or part.

3.6 Parameterisation procedure

Depending on the size of the Servo press, there are various standard parameters which serve as approximate values. If the desired results are not obtained with these values, the controller can be optimised with the help of the following three steps.
The Kv, Kp and Ki parameters are adjusted, one after the other, to this end. They can be adapted on the basis of the force-time diagram. A reference curve is repeatedly recorded with adjusted values until the desired results are obtained.
If target force doesn't lie within the tolerance range, which may be the case in particular at the beginning of parameters configuration, waiting is required until the time limit has elapsed, or the process can be stopped manually.

If possible, processing speed should be selected such that it's as close as possible to the desired cycle time. Subsequent changes to control parameters can be reduced or avoided in this way.

The following three steps are repeated until the control parameters are satisfactory. An application example is included in section 4.



- Step 1:
  Target current is calculated internally on the basis target force. This is boosted or diminished with the help of precontrol parameter Kv. As a rule, this value should be between 0.5 and 1.5.
  Parameters should initially be set as follows: Kv = 0.5, Kp = 0, Ki = 0. Kv is then slowly increased until a value of just less than target force has been reached. It should be avoided that the target force is only reached with the precontrol. Control parameters Kp and Ki must otherwise be set too low which can result in poor control performance.
- Step 2:
  Kp is an slowly increased from 0. Nearly no overshooting should occur.
- Step 3 (optional):
  Continuous deviation from target force remains when only precontrol and the P controller are used. The I controller can also be used in order to compensate for this. The I controller is activated and slowly increased from 0.
  Note: The I controller is not activated until 99% of target current is reached for precontrol.

4 Application examples

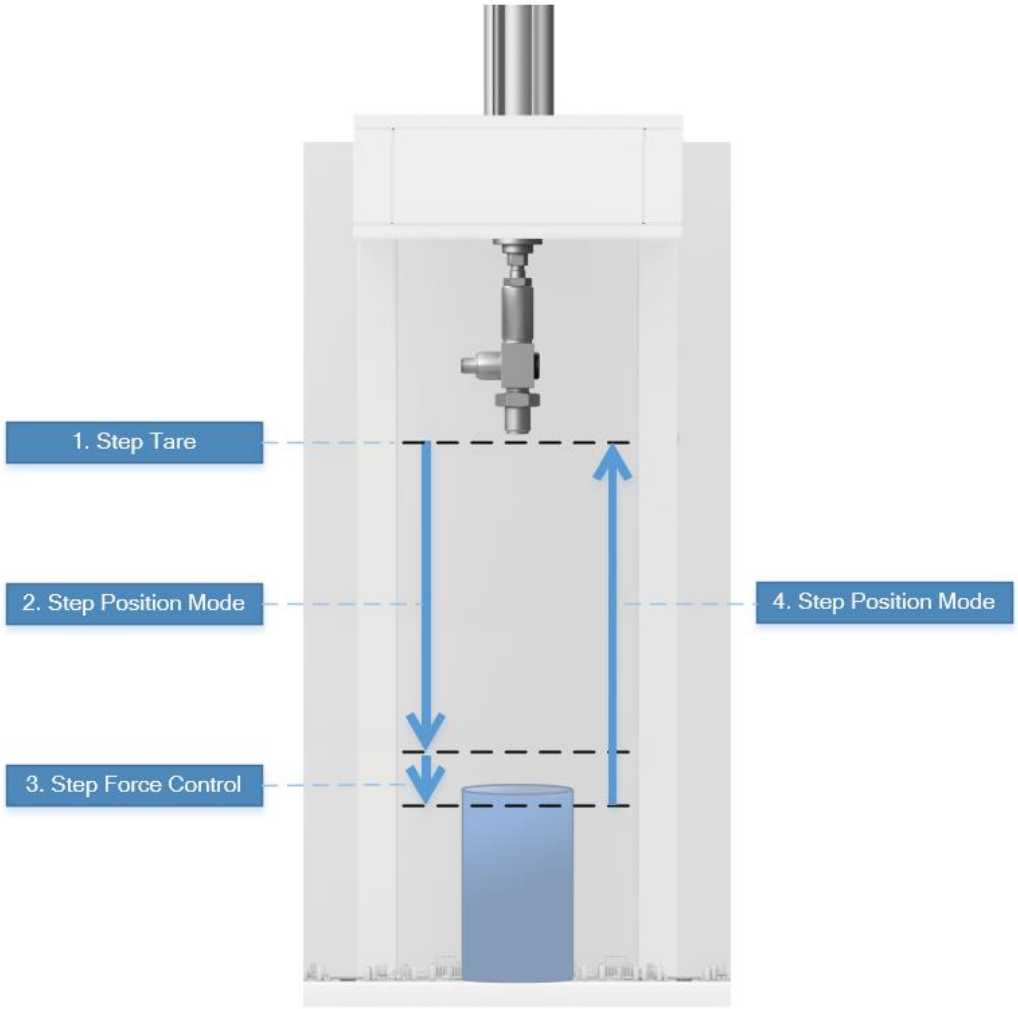
Various possibilities are pointed out below for configuring and improving the pressing process with a force control function.

4.1 Determining control parameters

4.1.1 Sample application

A servo press of the size up to 800 N will be used to apply a force of 400 N to a metal block. Force should be maintained for a duration of 2000 ms.

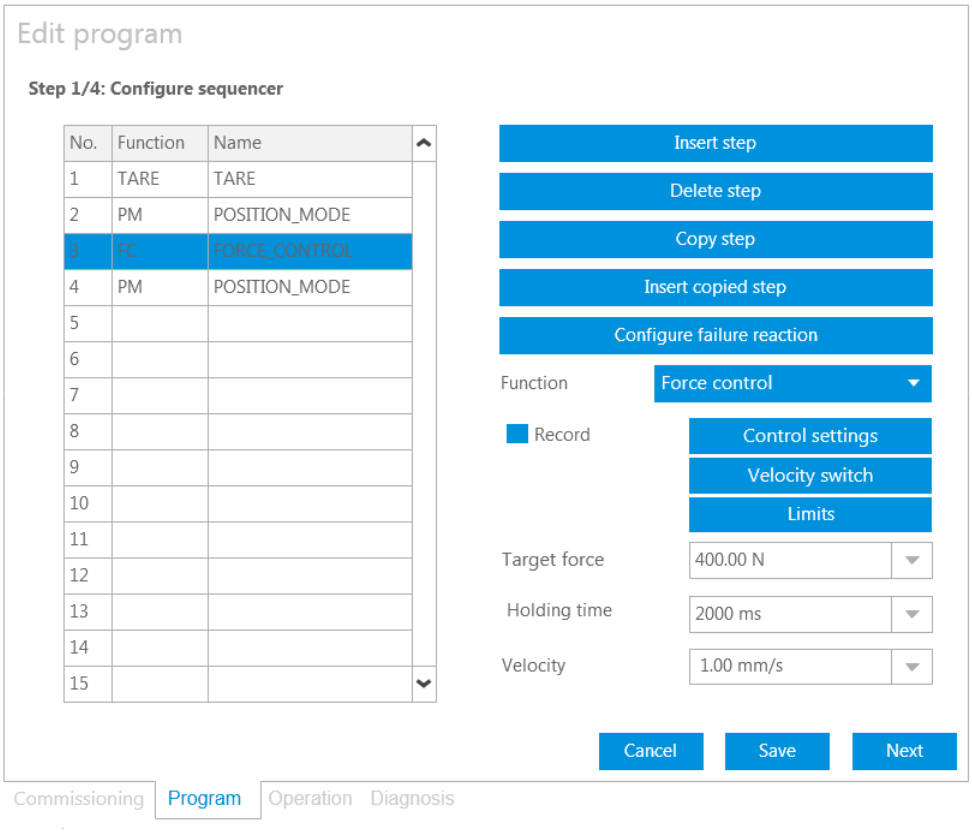
A simple program consisting of 4 steps will be prepared in order to determine the control parameters.



The force sensor is tared to an initial value at the initial position. That is positioned in front of the component and is pressed using force control. When the pressing operation has been completed, retraction to the initial position takes place.

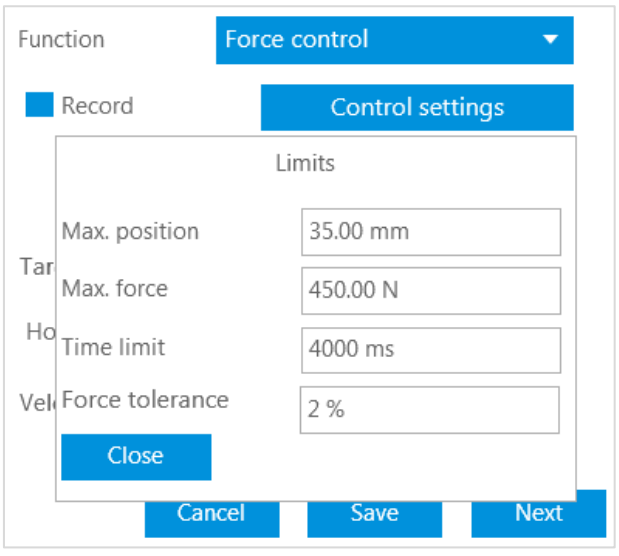
4.1.2 Adjusting press parameters

- The parameters for the force control function are configured in “Step 1/4: configuring sequencer”:



- Recording of the force control step must be activated in order to be able to subsequently adjust the control parameters on the basis of the recorded curve.
- A target force of 400 N and a holding time of 2000 ms are selected.
- At the beginning it’s advisable to set speed appropriately for the application and preferably a bit too low. This can be adjusted later on if necessary.

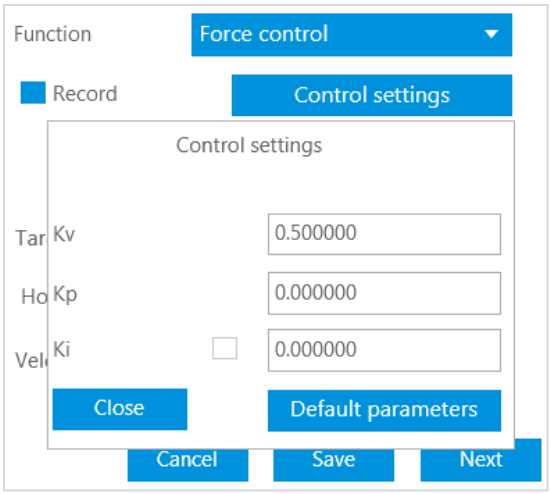
4.1.3 Adjusting limit values



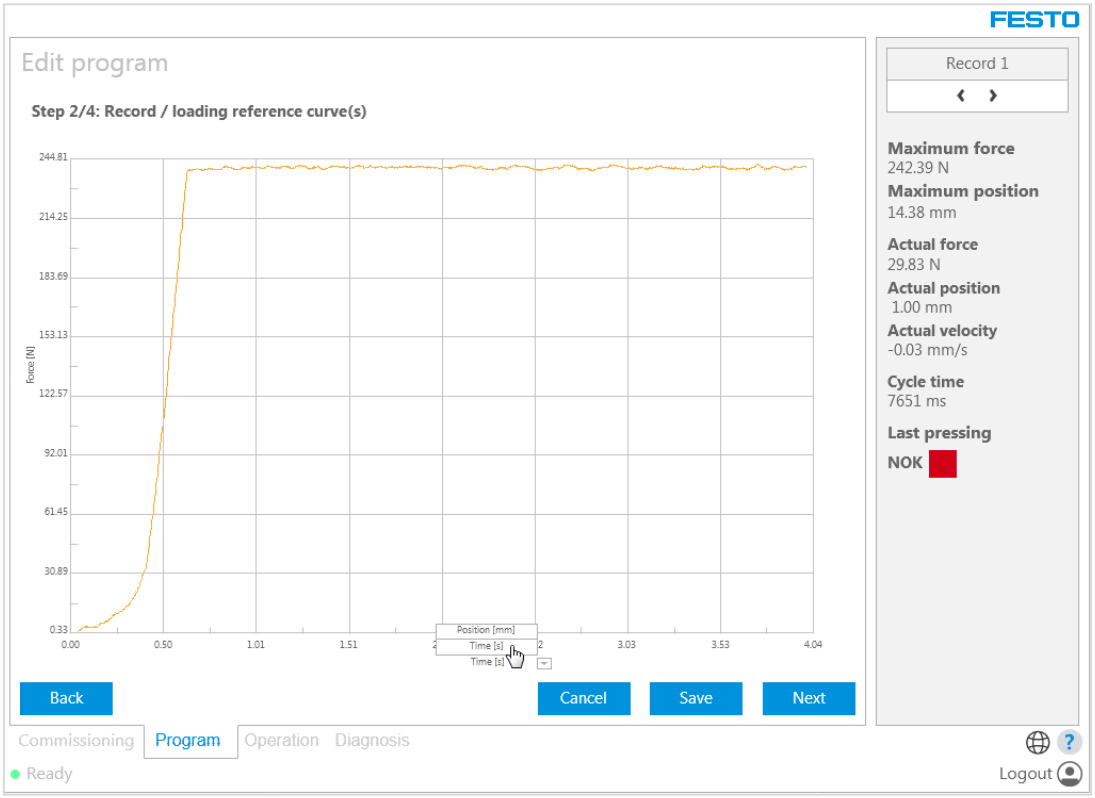
- The limit values need to be adjusted in accordance with the mechanical construction and the application.
- **Important**: The force tolerance only applies at the beginning of holding time. It’s not an evaluation method for the actual pressing process.

4.1.4 Adjusting control parameters with the procedure described in section 3.6

- Initially, only Kv is set to a value of 0.5:

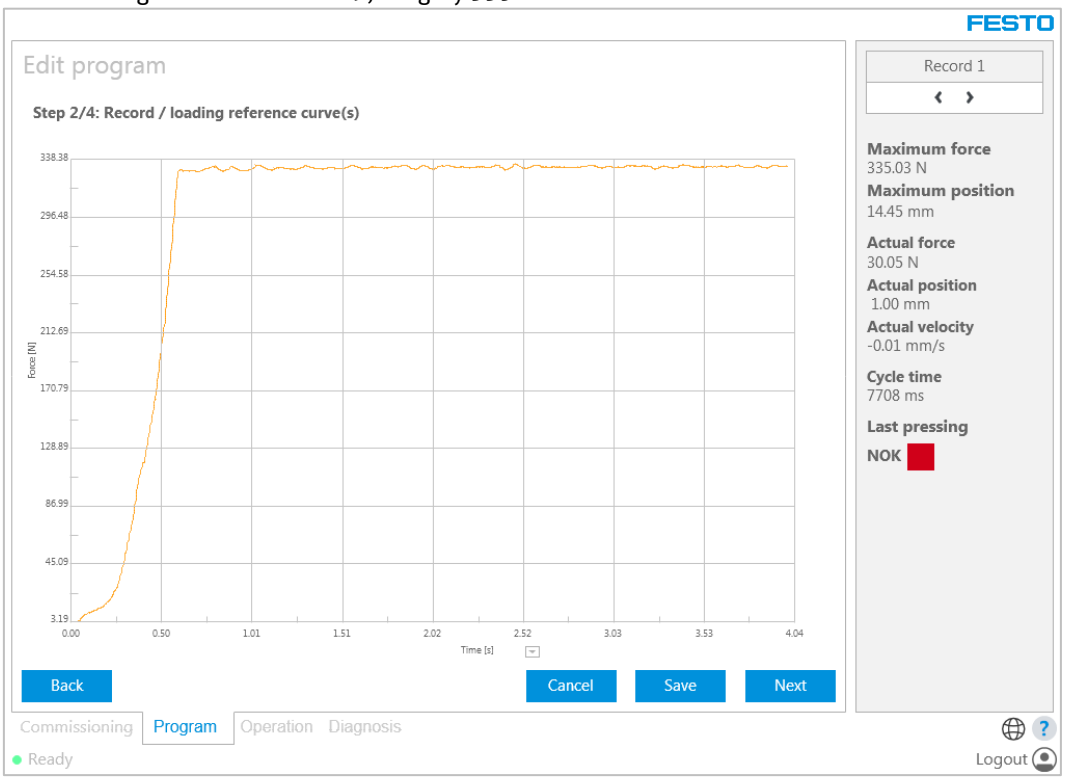


- All parameters have been set. A reference curve is then recorded in “Step 2/4: record/loading reference curve”. If target force is not reached, waiting is required until the time limit has elapsed, or the process can be stopped manually. The force-time diagram is reviewed for the purpose of analysis:



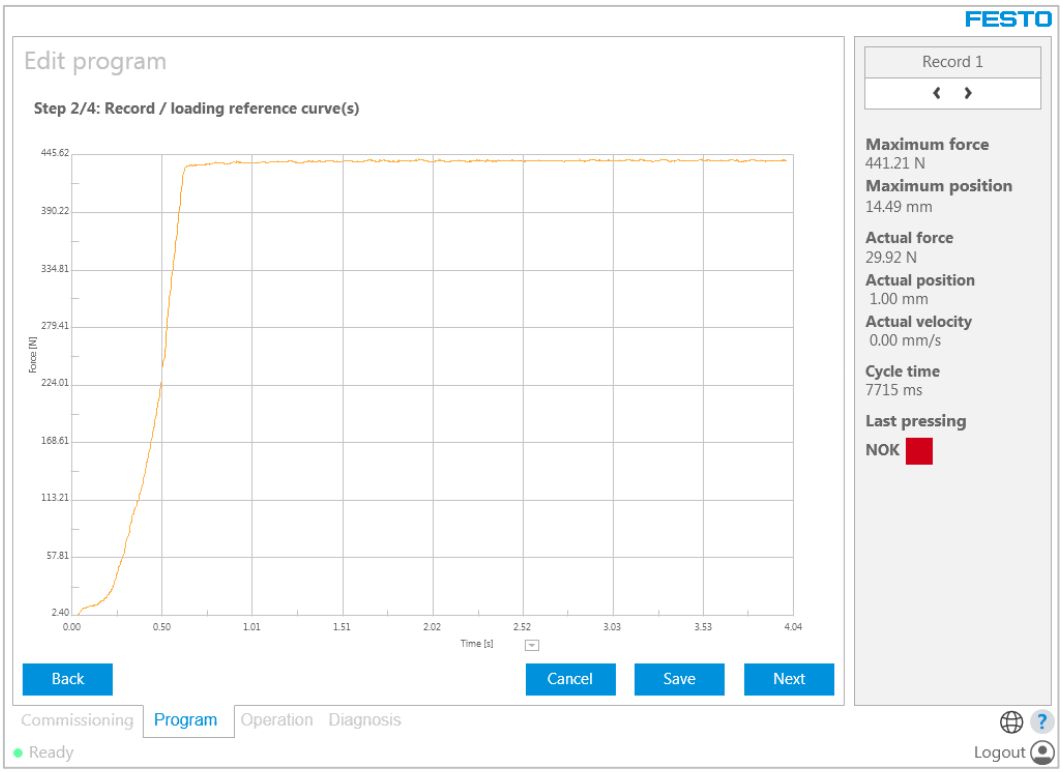
- The diagram shows that a force of approximately 242 N is reached. “Back” is then used to return to “Step 1/4: configure sequencer”, and the value for Kv is increased.
- This procedure is repeated until a force of just less than target force is reached while force is settling in.

- Force-time diagram where Kv = 0.7, roughly 335 N is reached:



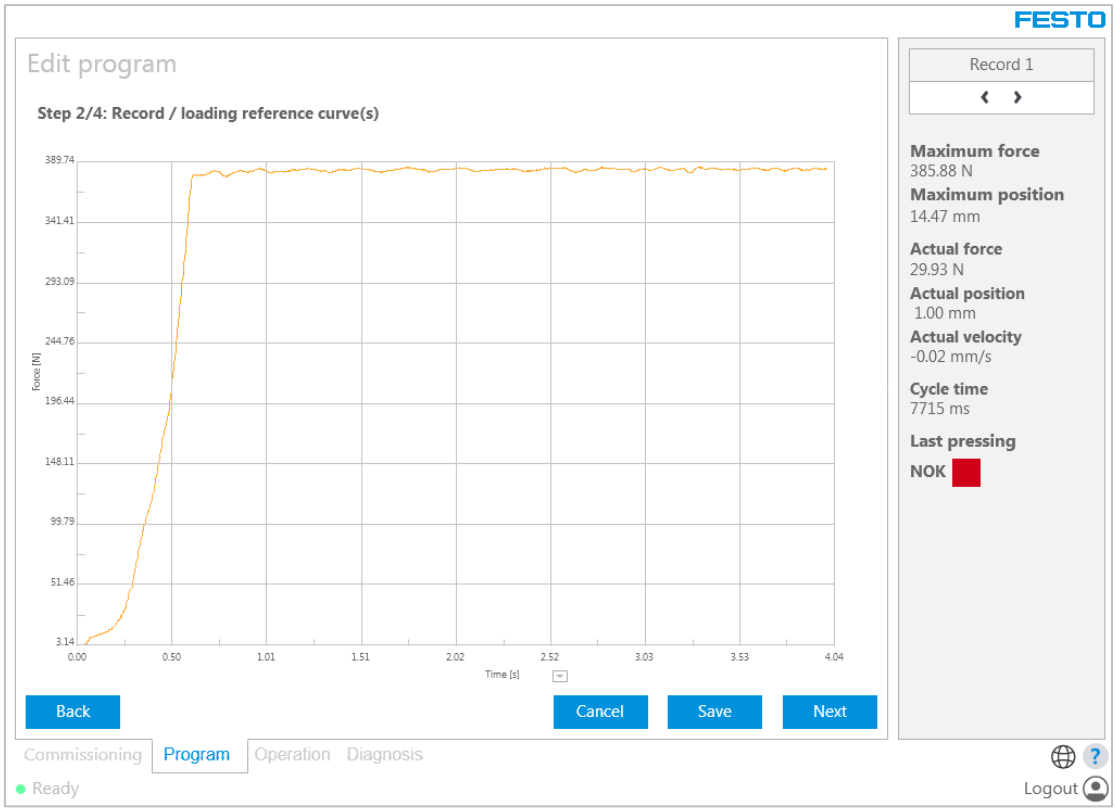
➔ Kv must be further increased.

- Force-time diagram where Kv = 0.9, roughly 441 N is reached:



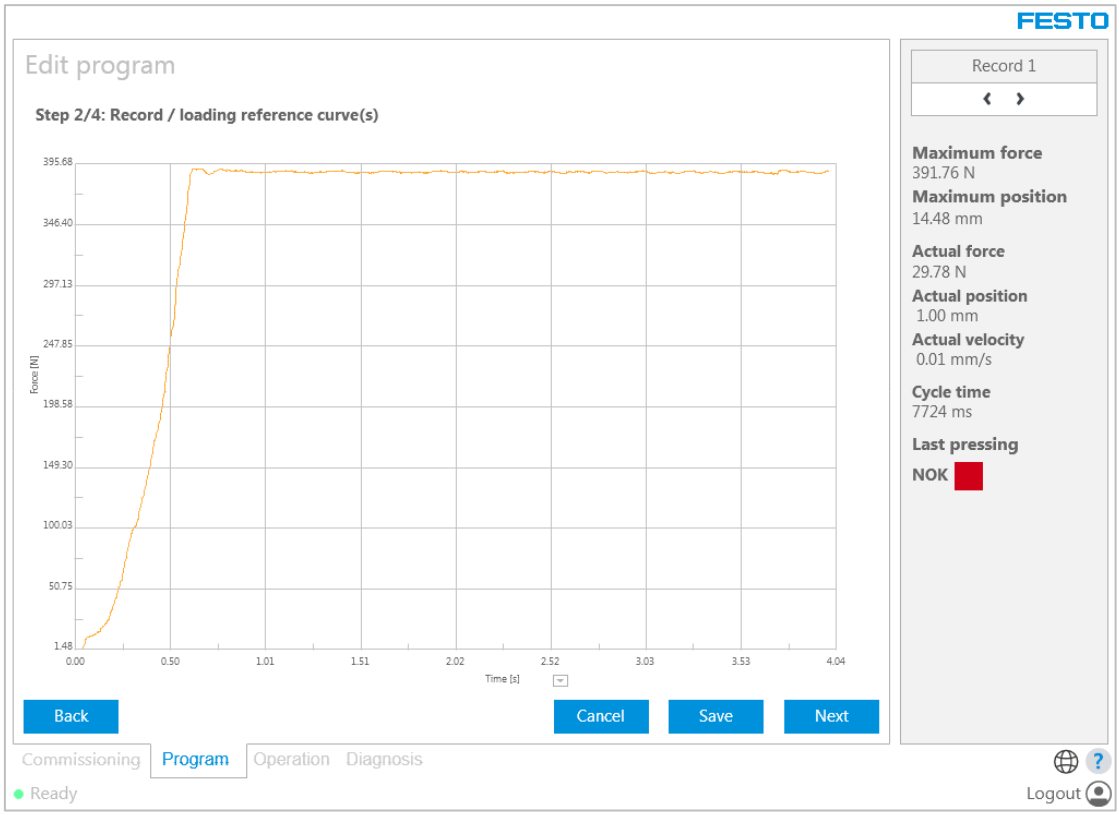
➔ Kv must be reduced.

- Force-time diagram where Kv = 0.8, roughly 385 N is reached:



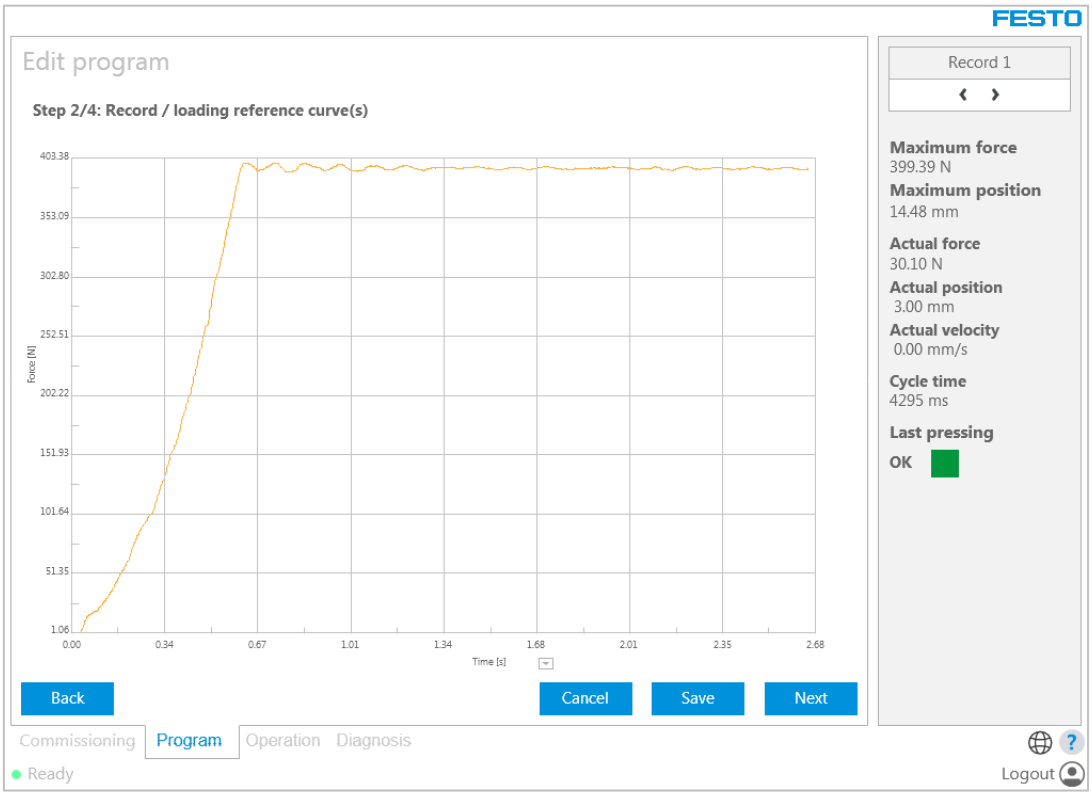
➔ Kv closely approaches target force. Kp can now be adjusted.

- Force-time diagram where Kv = 0.8 and Kp = 0.5, roughly 391 N is reached:



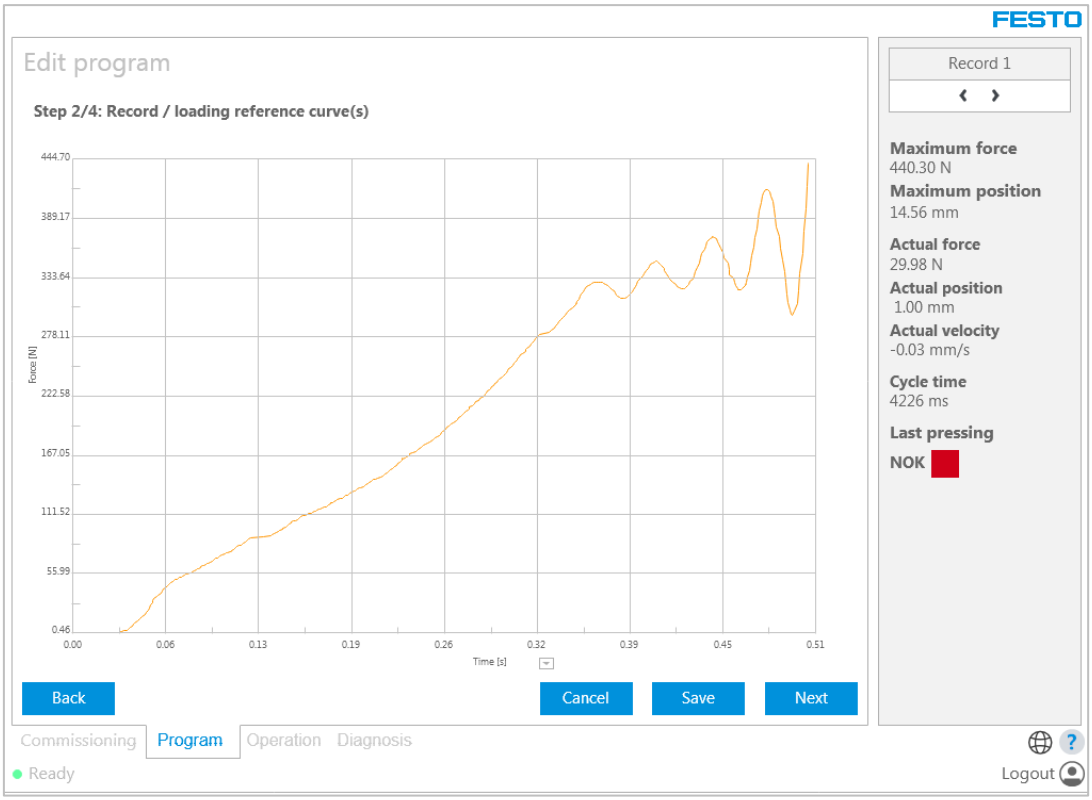
➔ Kp must be increased step by step.

- Force-time diagram where Kv = 0.8 and Kp = 1, roughly 399 N is reached:



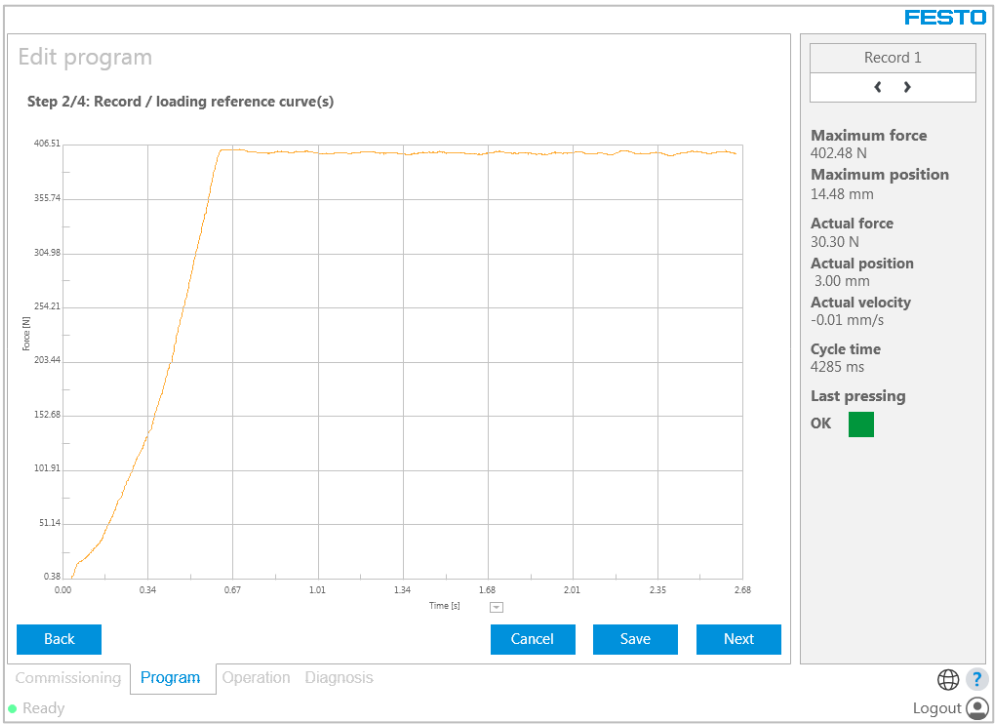
➔ Target force is reached with nearly no overshooting. As an option, Ki can now be adjusted as well. This helps to keep target force even more constant in the event of force fluctuation.

- Example of excessively high Kp:
  Force-time diagram where Kv = 0.8 and Kp = 6:



➔ The controller is rendered instable and starts to oscillate due to the excessively high Kp value. The “maximum force” limit value stops the process.

- Force-time diagram where Kv = 0.8, Kp = 2 and Ki = 5, roughly 402 N is reached:

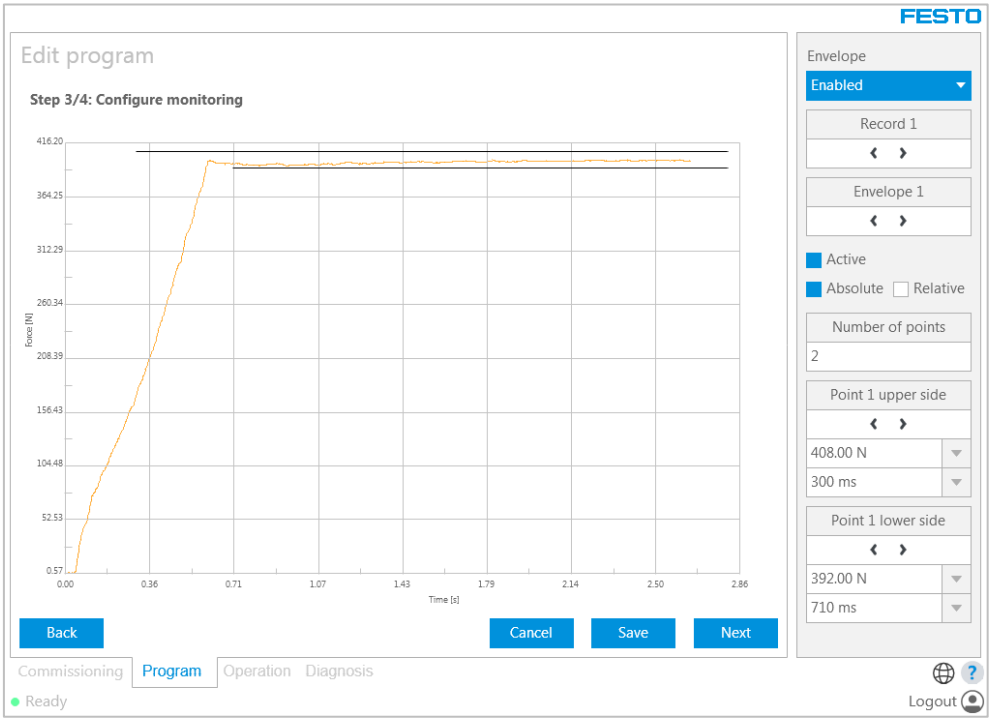


➔ Any remaining deviation can be compensated for with Ki. It should be increased slowly until the desired control performance is achieved.

4.2 Setting up evaluation methods

It’s possible to make use of evaluation methods in the force-position diagram or in the force-time diagram.

In order to monitor the achievement and maintenance of target force, the force-time diagram is used with the “envelope curve” evaluation method in the following example:



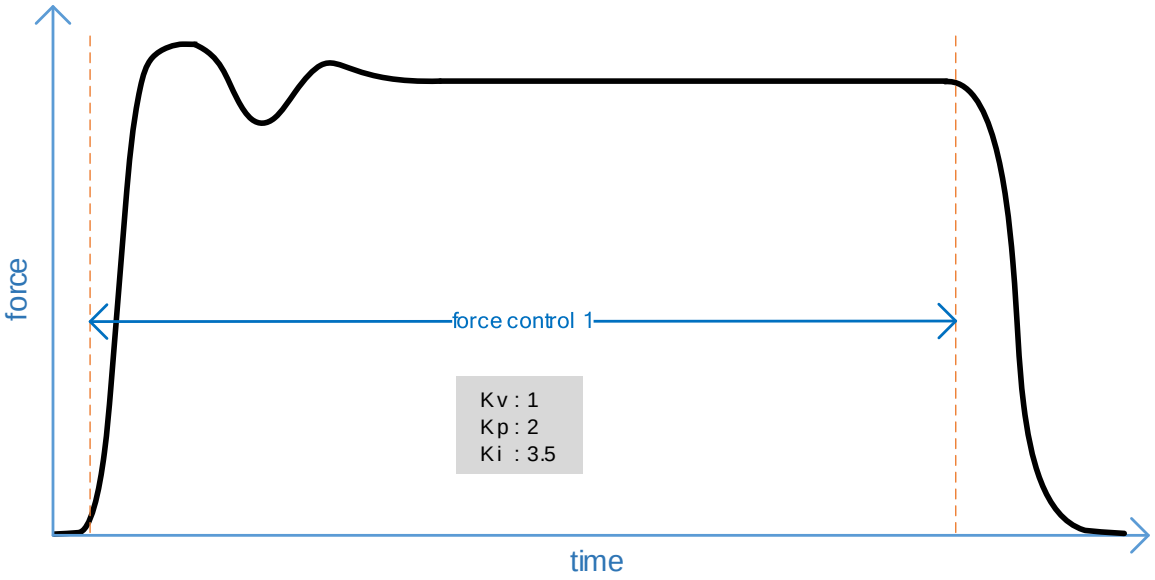
➔ The envelope curve is used to monitor whether or not a target force tolerance of ±2% is maintained.

➔ Other evaluation methods can be added and, if necessary, control parameters can be further optimised.

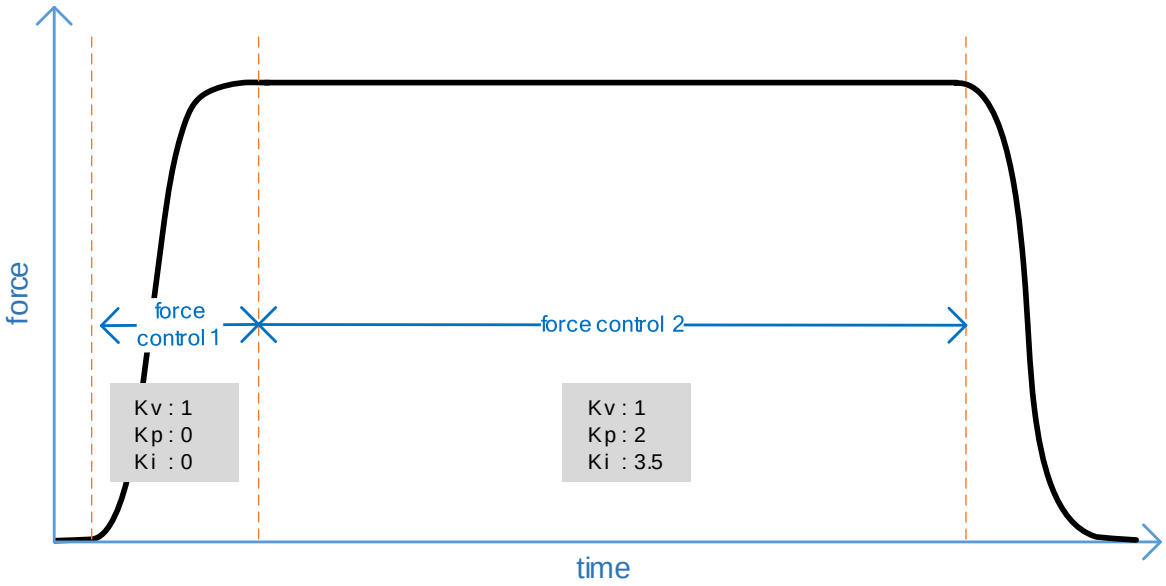
4.3 Additional improvement examples

4.3.1 Improved settling in

In order to fulfil press process requirements, the settling in process can be improved with a second force control function.

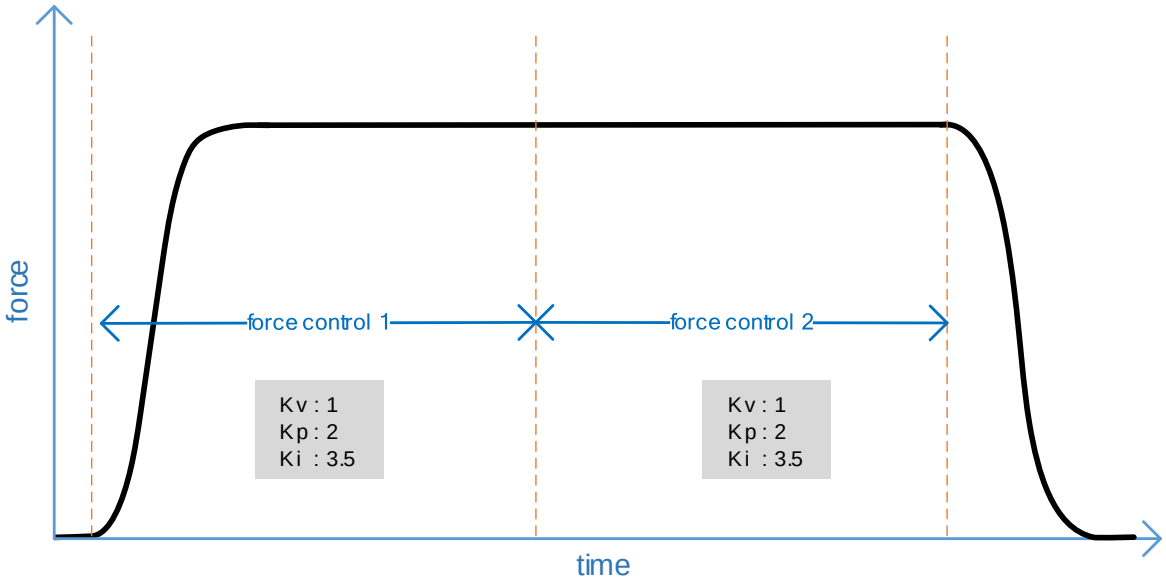


A force control function can be used with precontrol only and a very short holding time, in order to reduce overshooting. Kp and Ki are activated as required by means of the second force control function.
Alternatively, pressing at target force can be implemented by means of **"advanced force mode"** (instead of force control 1), after which switching to the force control function takes place.



4.3.2 Extending recording time

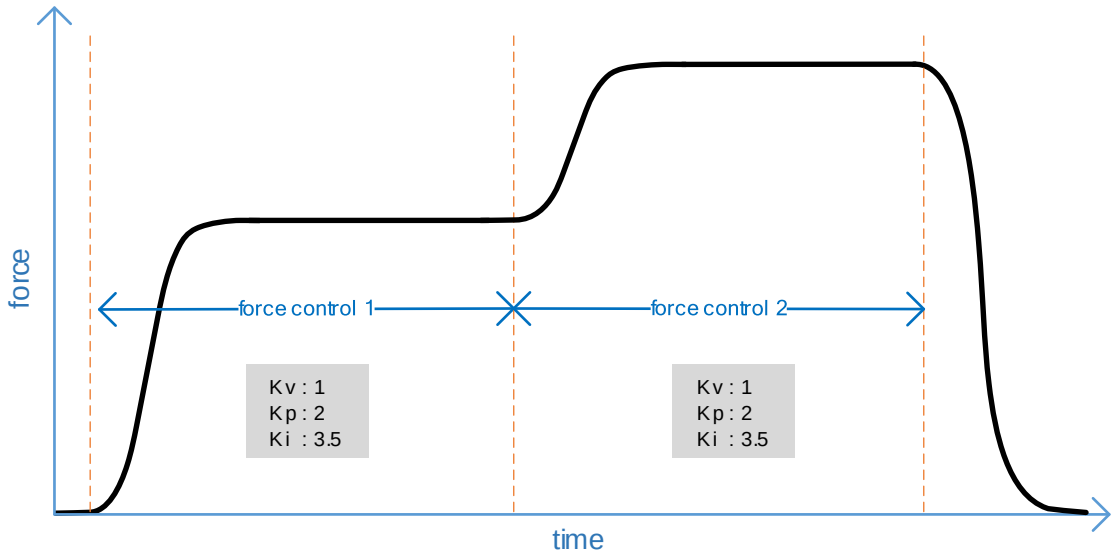
Holding time for any given step with a force control function is limited. In order to extend this time, several steps with a force control function can be used one after the other.
As a rule, the first force control function step can be used for the following steps as well. Velocity switch should be deactivated in the later steps.



4.3.3 Increasing force step by step

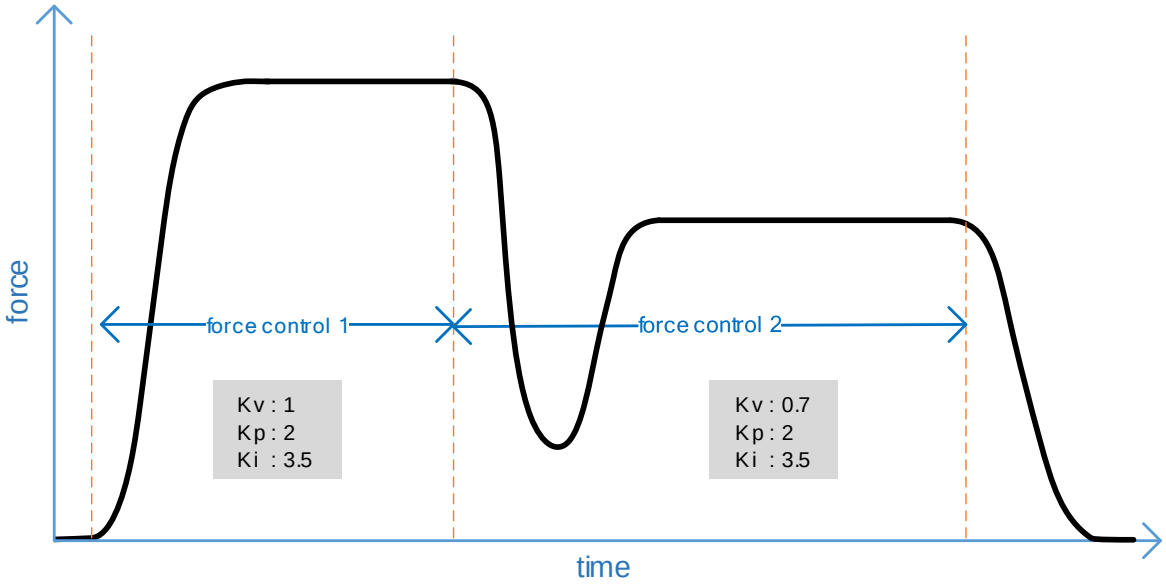
If force needs to be increased step by step, this can be implemented through the use of several force control functions arranged one after the other. The parameters of the force control functions in the following steps have to be adjusted as required to this end.

Alternatively, pressing at target force can be implemented by means of **“advanced force mode”**, after which switching to the force control function takes place.



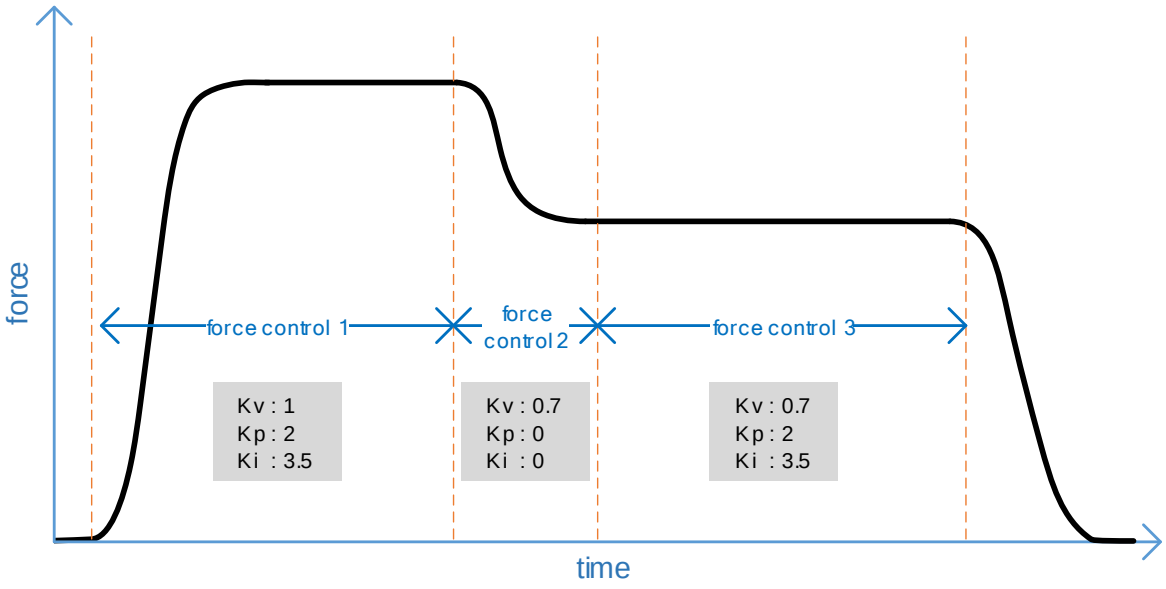
4.3.4 Reducing force step by step

If force needs to be reduced step by step, this can be implemented through the use of several force control functions arranged one after the other. However, force may be decreased excessively.



An additional force control function must be included in order to reduce this decrease in force. This function makes use of precontrol only, and thus prevents excessive decreases in force.
Force control function parameters have to be adapted individually in this case.

Alternatively, pressing at target force can be implemented by means **"advanced force mode"** (instead of force control 2), after which switching to the force control function takes place.



Note: Selected maximum speed is only complied with in the case of positive force build-up. In contrast, maximum speed is complied with even when force is reduced in the case of advanced force mode.