Spring Selection Tool (SST): README and Startup Guide

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August 13, 2025

Contents

Nomenclature

k_i Stiffness of individual spring i [$\mathrm{N\,m^{-1}}$]

k_{parallel} Equivalent stiffness of springs in parallel [$\mathrm{N\,m^{-1}}$]

k_{series} Equivalent stiffness of springs in series [$\mathrm{N\,m^{-1}}$]

N Number of springs in arrangement

ϵ Percentage error between the target and output stiffness of SST candidate

F_0 Initial force [N]

F_n Maximum load at L_n [N]

L_0 Unloaded length of spring [m]

L_n Maximum loaded length of spring [m]

R Spring constant (spring rate, stiffness) [$\mathrm{N\,mm^{-1}}$]

S_n Maximum travel of spring [m]

1 Introduction

The **Spring Selection Tool (SST)** assists in selecting appropriate spring configurations to represent the scaled elasticity of fibre mooring lines in hydrodynamic tank testing of offshore renewable energy (ORE) devices. The SST searches commercial spring catalogues and proposes arrangements that meet a target stiffness while balancing practical installation.

2 System requirements and distribution

2.1 Requirements

- Windows 10 or 11 (64-bit).
- No Python installation required (packaged application).
- Read/write access to a user folder for saving outputs.

2.2 What you receive

You will receive a ZIP file containing the SST application.

2.3 Unzip and first run

1. Right-click the ZIP → **Extract All...** and choose a location in your user folders (e.g. `Documents\SpringSelectionTool`).
2. Open the extracted folder and then open the app folder `SpringSelectionTool`.
3. Double-click `SpringSelectionTool.exe`.
4. On first run, Windows SmartScreen may warn about an unknown publisher. Click **More info** → **Run anyway** (if applicable).

2.4 Folder contents (after unzipping)

A typical layout is:

```
SpringSelectionTool\                    <-- Application folder
          SpringSelectionTool.exe       <-- The app you double-click
          catalogues\                   <-- Spring catalogues (editable)
                springs_catalogue.xlsx
                tank_springs_stock.xlsx   (optional)
          _internal                    <-- Runtime files (do not edit)
```

Important: The `catalogues` folder is *external to the executable* so that you can update the spreadsheets without rebuilding the app. The other runtime files are internal dependencies—please do not move or edit them.

3 What is in the catalogues (editable)

3.1 `springs_catalogue.xlsx`

This Excel file lists the commercial springs used for selection. **Columns:**

- `SKU` – supplier stock code (string; used for matching and reporting).
- `L0` – unloaded length [mm]
- `Ln` – maximum loaded length [mm]

- `Sn` – maximum travel [mm]
- `F0` – initial force [N]
- `Fn` – maximum load at `Ln` [N]
- `R` – spring rate [$\mathrm{N\,mm^{-1}}$]
- Optional housekeeping columns (e.g. `Supplier`, `Material`, `Range`) may be present; they are ignored by the tool.

Notes. The tool converts units internally (e.g. mm to m; N/mm to N/m) and sanitises numeric fields. Ensure `SKU` values have no trailing spaces and each row represents a single spring product.

3.2 `tank_springs_stock.xlsx` (optional)

This optional spreadsheet lists springs currently held in your local tank stock. If supplied, matching items in the global springs shortlist are highlighted as *in-stock* to prioritise procurement simplicity. Notably, these items must have previous been procured from one of the suppliers in the `springs_catalogue.xlsx`.

Why are these external?

Keeping catalogues outside the `.exe` allows you to:

- update supplier data or add new springs at any time;
- independently maintain your local stock list.

Notes. Currently, the tool does not support users importing their own supplier catalogues directly. However, a workaround is possible by swapping in a different catalogue to one of the supplier's sheets in `springs_catalogue.xlsx`, and updating the `All Springs` sheet accordingly. Notably this will update will not be reflected in the name of the spring suppliers presented in the tool GUI, but will allow the tool to search within alternative catalogues.

4 Using the SST

4.1 Quick start

1. Launch `SpringSelectionTool.exe`.
2. On the **Home** screen, click **Continue**.
3. Fill in the full-scale inputs (see Table 1) and choose whether to:
    - *Calculate axial stiffness* from `EA` and `L`, or
    - *Supply axial stiffness* directly as k.
4. Choose the catalogue source (*Industrial Springs*, *Lee Springs*, or *Both*).
5. Optionally tick **Include tank stock** and browse to `tank_springs_stock.xlsx`.
6. Set **Save files location** (an empty folder is fine).
7. Click **Run selection**.

4.2 Outputs

The SST creates the following files in your chosen save location:

- `parameters.xlsx` – full-scale inputs and scaled values.
- `shortlist.xlsx` – ranked spring candidates with dedicated sheets for:
  - `all_candidates` (scored and sorted),
  - `minimum_score` (overall optimum),
  - `minimum_error`,
  - `least_springs`,
  - `tank_stock_springs` (if applicable).
- `plot.png` – scatter plot of error vs number of springs.

4.2.1 Scatter plot interpretation

See Figure 1 for an example. The plot shows all shortlisted spring candidates against:

- `x-axis:` stiffness error (ϵ) from the target value,
- `y-axis:` total number of springs in the arrangement (N).

Each candidate is plotted as a marker, colour-graded so that the most attractive arrangements (low stiffness error and few springs) appear prominent, while less suitable arrangements fade into the background. The legend symbols highlight:

- $\star$: optimal solution(s) – best compromise of low stiffness error and few springs (lowest score from Algorithm 1).
- $\times$: minimum-error – regardless of spring count.
- $+$: fewest-springs – regardless of stiffness error.
- $\bigcirc$: in-stock items (if a stock list was provided)
- $\cdot$: other valid solutions.

How to use the plot:

1. First, check the $\star$ markers – these usually offer the best practical trade-off.
2. If absolute accuracy is critical, consider the $\times$ markers, but note they may require many springs (and therefore be harder to source or install).
3. If simplicity and ease of procurement are priorities, the $+$ markers may be preferable, even if the stiffness error is slightly higher.

For example, in Figure 1, the lowest-error solution ($\times$) has 18 springs per mooring line, which would require sourcing and installing 54 springs for a three-line system. In most cases, the $\star$ solution will be more practical for testing programmes.

5 Technical background (selection logic)

5.1 Tool objectives

1. Minimise error between target axial stiffness and the mechanical stiffness of the selected spring system.
2. Minimise total spring count to reduce tank model complexity and procurement challenges.

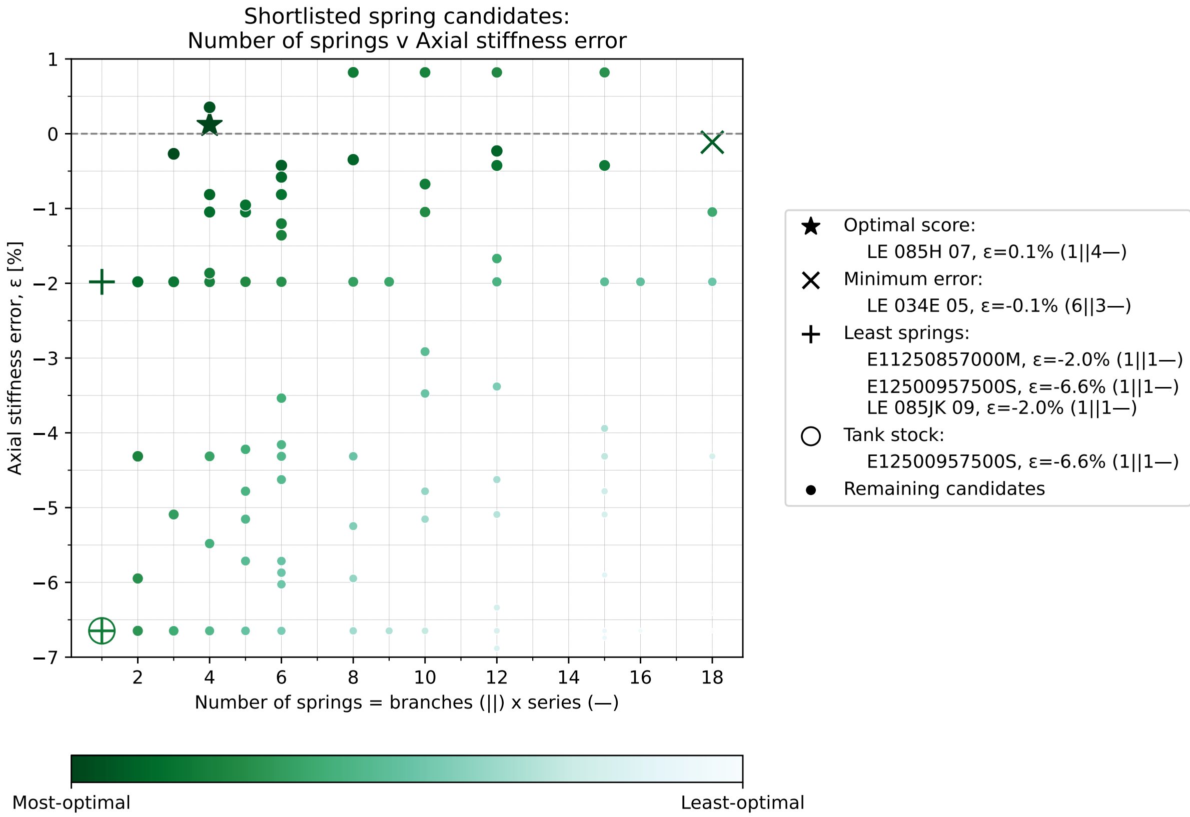


Figure 1: Example SST scatter plot. The most optimal arrangements are highlighted, while suboptimal candidates fade into the background.

5.2 Series and parallel arrangements

Arrangements and stiffness equations are shown in Figure 2 and Equations (1) and (2). Nomenclature is listed below.

$$\frac{1}{k_{series}} = \sum_{i=1}^{N} \frac{1}{k_i} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + ... + \frac{1}{k_n} \tag{1}$$

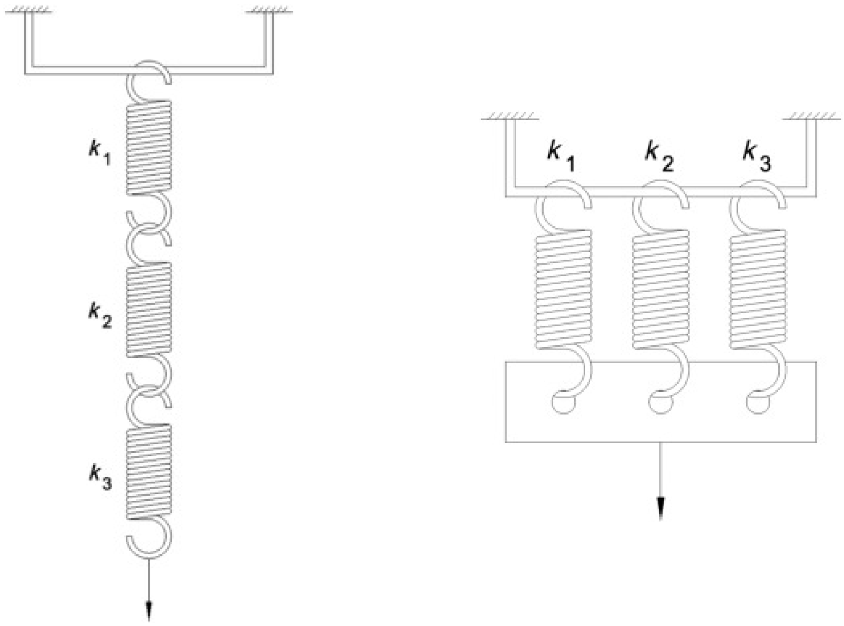
$$k_{parallel} = \sum_{i=1}^{N} k_i = k_1 + k_2 + k_3 + ... + k_n \tag{2}$$

6 User inputs

The user inputs are described in Table 1. Its likely better to be conservative with maximum travel and load, especially when survival testing is being done. The advantage of using springs is that their stiffness response is known and easy to replicate in a numerical model, however, that certainty is lost if the springs over-extend or are loaded beyond its limits.

7 Workflow overview

The automated workflow of the SST is outlined in Algorithm 1.



(a) Springs in series. (b) Springs in parallel.

Figure 2: Spring arrangements. Symbols relate to Equations (1) and (2). Reproduced from Childs (2021).

Table 1: Glossary of full-scale user inputs for the Spring Selection Tool (SST).

Symbol	Description	Units
λ	Froude scale (e.g., 20, 50). Converts inputs from full- to tank-scale.	–
x_{travel}	Maximum expected travel of the floating body under environmental conditions. Ensures spring extension is sufficient.	m
F_{tension}	Maximum expected mooring line tension under environmental conditions. Ensures the spring can withstand peak loading.	N
$F_{\text{pretension}}$	Mooring line pretension in static equilibrium. Prevents spring breakout.	N
EA	Rope axial stiffness. Used to calculate k.	N
L	Unstretched rope length. Used with EA to calculate k.	m
k	Target mechanical stiffness. Either user-defined or calculated as EA/L.	N/m

8 Recommended procedure to design tank-scale fibre moorings using the SST

The following step-by-step procedure is recommended when using the SST to design tank-scale fibre moorings.[1]

1. **Choose stiffness inputs** (see Figure 3). For polyester-based lines, use a *single* linear stiffness. For nylon-based lines, use *DLC-specific* linear stiffness values to get two solutions, each for different testing conditions.

2. **Run the SST** to select a spring type and arrangement that meets the target stiffness with acceptable error.

3. **Check robustness via trial and error.** If candidates are near extension or load limits, increase conservative inputs (e.g. maximum travel x_{travel} and maximum tension F_{tension}),

[1]DLC = Design Load Case.

Algorithm 1: Spring Selection Tool (SST) workflow. User input symbols refer to Table 1.

Input: λ, x_{travel}, F_{tension}, $F_{\text{pretension}}$, and either (EA, L) or k
Output: Shortlisted spring configurations and plots
Step 1: Initialisation
if *User provides* EA *and* L **then**
  $k = EA/L$
else
  Use user-provided k
Scale inputs using λ; load spring catalogues (Section 3).
Step 2: Selection Loop
Loop over possible parallel branches and series springs. For each arrangement:

1. Compute breakout force, maximum force, and maximum travel.
2. Filter out configurations that fail user constraints.
3. Calculate equivalent stiffness (Equations (1) and (2)) and error from target.
4. Store valid configurations.

Step 3: Post-processing
Score, rank, and shortlist configurations. Save outputs described in Section 4.2.

re-run the SST, and choose solutions that stay comfortably within limits. This mitigates the risk of springs over-extending during testing due to low-frequency drift and still-water calibration tests (free decay and static pull-out).

4. **Account for manufacturing tolerance.** Use the uncertainty-propagation approach in Section 10. If tolerances could push the system beyond limits or increase error unacceptably, adjust inputs or select an alternative candidate and re-run.

5. **Finalise on practicality.** Where multiple candidates meet the technical requirements, choose those with fewer total springs and/or items available in tank stock, provided the stiffness error remains acceptable.

9 Troubleshooting and FAQs

The app says it cannot find the `catalogues` folder.

Ensure a folder named `catalogues` sits next to `SpringSelectionTool.exe`, containing `springs_catalogue*.xlsx`.

Nothing happens when I double-click the `.exe`.

Right-click → **Properties** → **Unblock** (if present). Also ensure the folder is fully extracted from the ZIP and not read-only.

Where are my results saved?

In the *Save files location* you chose in the GUI. Look for `parameters.xlsx`, `shortlist.xlsx`, and `plot.png`.

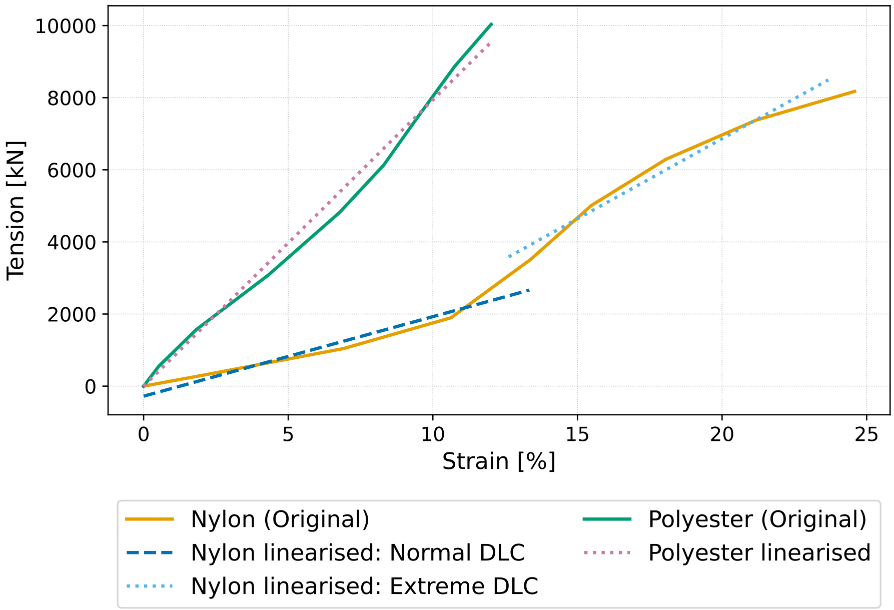


Figure 3: Representative linear stiffness choices used as SST inputs. DLC = Design Load Case.

10 Spring rate uncertainty (optional background)

In practice, springs are supplied with a manufacturer's stiffness tolerance. When springs are arranged in series or parallel, the overall uncertainty in the system stiffness can be estimated using the *propagation of uncertainty* method (Beckwith and Marangoni, 2006).

For a function f of several independent variables $(x, y, z, \dots)$, the relative uncertainty is:

$$\frac{\delta f}{f} = \frac{1}{f}\sqrt{\left(\frac{\partial f}{\partial x}\cdot \delta x\right)^2 + \left(\frac{\partial f}{\partial y}\cdot \delta y\right)^2 + \left(\frac{\partial f}{\partial z}\cdot \delta z\right)^2} \tag{3}$$

Here:

- x, y, z = stiffness values of each individual spring $(k_1, k_2, k_3, \dots)$,
- f = equivalent stiffness of the arrangement (either k_{series} from Equation (1) or k_{parallel} from Equation (2)),
- $\delta x, \delta y, \delta z$ = uncertainties in each spring's stiffness.

For quick reference, Figure 4 shows the *multiplication factors* for converting a single-spring stiffness tolerance into a total system tolerance.

10.0.1 Worked example

Suppose each spring has:

- Spring rate $R = 0.03$ kN mm$^{-1} \pm 10\%$,
- Maximum load $F_n = 16.30$ N $\pm 10\%$,
- Initial load $F_0 = 1.48$ N,
- Travel $S_n = 407.92$ mm.

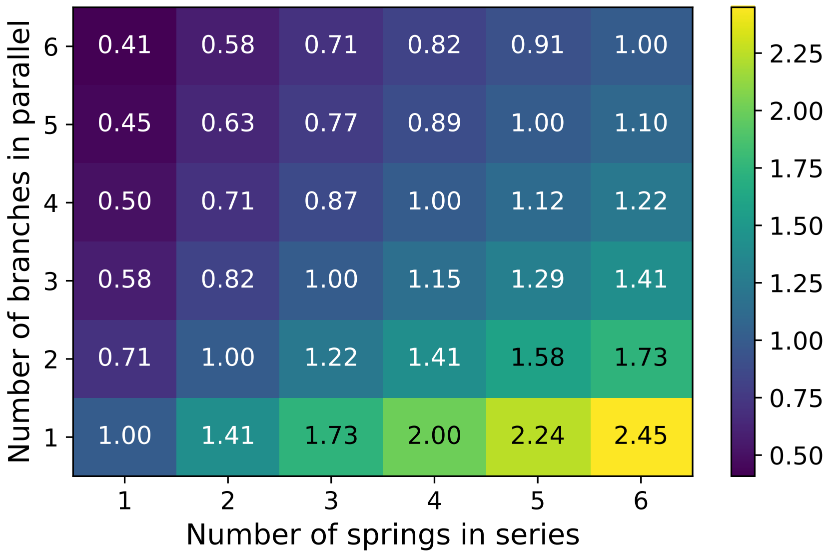


Figure 4: Multiplication factors for converting individual spring rate tolerance to total arrangement stiffness tolerance.

Arrange them as two parallel branches, each with three springs in series. Applying Equation (3), the system stiffness uncertainty is $\pm 12.3\%$, equivalent to a range of:

$$0.02631 \text{ to } 0.03369 \text{ kN mm}^{-1}.$$

This calculation is simplified using Figure 4. For example, in the above arrangement, the factor shown is 1.22, giving:

$$\text{System tolerance} = 1.22 \times 10\% = 12.3\%.$$

10.0.2 Direct calculation check

Alternatively, the spring rate can be calculated directly from:

$$R = \frac{F_n - F_0}{S_n} \tag{4}$$

If F_n is varied by $\pm 10\%$, this gives a maximum spring rate of 0.04033 kN mm^{-1}. This is higher than the propagated uncertainty result, likely due to rounding in catalogue values.
Therefore, the actual maximum spring rate of the system may be higher than the propagated maximum due to rounding. This analysis also assumed that the manufacturing tolerance was the same for all six springs in the arrangement, which in reality would like differ between springs.

References

Thomas Beckwith and Roy Marangoni. *Mechanical Measurements*. Pearson, 6th edition, 2006. ISBN 9780201847659.

P.R.N. Childs. Chapter 9 - Springs. In *Mechanical Design*, chapter 9, pages 337–370. Butterworth-Heinemann, 2021. ISBN 978-0-12-821102-1. doi: 10.1016/B978-0-12-821102-1.00009-3.