AD FALCON API Manual

Explanation of Load Types in FALCON

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1 Explanation of Load Types in FALCON

This document provides detailed explanations of the various load types implemented in FALCON, along with their governing equations and behaviors.

1.1 Syntax (how to specify a load type)

Load types are used inside several input sections (for example: stress boundaries, discharge boundaries, prescribed values, point loads, rigid-body force control, and body forces).

Many sections specify a load type using a single **LoadType line** with key/value pairs:

```
LoadType <Immediate|Ramp|Sinusoidal|DampedSinusoidal|Tabular> Step
<StartStepId> [Frequency <f>] [PhaseLag <deg>] [DampingFactor <λ>]
```

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Notes:

- In this key/value LoadType line, key names are case-insensitive (recommended style: `LoadType`, `Step`, `Frequency`, `PhaseLag`, `DampingFactor`). A trailing `:` after a key is allowed (e.g. `LoadType:` is accepted).
- LoadType names are case-insensitive (recommended style: `Immediate`, `Ramp`, `Sinusoidal`, `DampedSinusoidal`, `Tabular`).
- `Step` is required.
- `Frequency` is required for `Sinusoidal` and `DampedSinusoidal`.
- `PhaseLag` is specified in **degrees** and defaults to `0` if omitted.
- `DampingFactor` controls exponential decay for `DampedSinusoidal` and defaults to `0` if omitted.
- For `Tabular`, an additional `TabularData ...` line is required in the sections that support tabular loads (see the relevant section page).

1.2 Immediate Load

1.2.1 Description

- The Immediate Load type applies a load instantaneously and maintains it at a constant value throughout the simulation.
- It is used to represent loads that are applied and held constant without any time-dependent evolution.

1.2.2 Governing Equation

The load at any time t is given by:

$$F(t) = \begin{cases} A, & \text{if } t \geq t_{\text{start}} \\ 0, & \text{if } t < t_{\text{start}} \end{cases} \tag{1}$$

where:

- A: Amplitude of the load.
- t_{start}: Time when the load is applied.
- t_{end}: End of analysis time.

1.2.3 Key Characteristics

- Instantaneous application.
- Load remains constant after application.

1.3 Ramp Load

1.3.1 Description

- The Ramp Load type increases linearly over time from zero to its maximum value during the specified duration.
- It is commonly used to represent gradual load applications.

1.3.2 Governing Equation

The load at any time t is given by:

$$F(t) = \begin{cases} \frac{A}{T}(t - t_{\text{start}}), & \text{if } t_{\text{start}} \leq t \leq t_{\text{end}} \\ A, & \text{if } t > t_{\text{end}} \\ 0, & \text{if } t < t_{\text{start}} \end{cases} \tag{2}$$

where:

- A: Maximum amplitude of the load.
- T: Duration over which the load ramps up $t_{\text{end}} - t_{\text{start}}$.

1.3.3 Key Characteristics

- Linear increase.
- Load stabilizes at maximum value after ramping period.

1.4 Sinusoidal Load

1.4.1 Description

- The Sinusoidal Load type varies sinusoidally over time, making it suitable for oscillatory or periodic loading conditions.

1.4.2 Governing Equation

The load at any time t is given by:

$$F(t) = \begin{cases} A \sin(2\pi f \, t + \phi), & \text{if } t \geq t_{\text{start}} \\ 0, & \text{if } t < t_{\text{start}} \end{cases} \tag{3}$$

where:

- A: Amplitude of the load.
- f: Frequency of oscillation.
- ϕ: Phase lag.

1.4.3 Key Characteristics

- Periodic and oscillatory.
- Amplitude and frequency control the intensity and oscillation rate.

1.5 Damped Sinusoidal Load

1.5.1 Description

- The Damped Sinusoidal Load combines oscillatory behavior with an exponential decay over time.
- It is often used to represent transient vibrations or dynamic loads that fade over time.

1.5.2 Governing Equation

The load at any time t is given by:

$$F(t) = \begin{cases} A \, e^{-\lambda t} \, \sin(2\pi f \, t + \phi), & \text{if } t \geq t_{\text{start}} \\ 0, & \text{if } t < t_{\text{start}} \end{cases} \tag{4}$$

where:

- A: Initial amplitude of the load.
- λ: Damping factor.
- f: Frequency of oscillation.
- ϕ: Phase lag.

1.5.3 Key Characteristics

- Oscillatory with a diminishing amplitude over time.
- Damping factor controls the rate of decay.

1.6 Tabular Load

1.6.1 Description

- The Tabular Load type allows the load magnitude to be specified as discrete values at specific times.
- Intermediate values are interpolated linearly between the specified points.

1.6.2 Governing Equation

The load at any time t is determined by linear interpolation between the tabular data points:

$$F(t) = F(t_1) + \frac{F(t_2) - F(t_1)}{t_2 - t_1}(t - t_1) \tag{5}$$

for $t_1 \leq t \leq t_2$, where:

- t_1, t_2: Time points bounding t.
- $F(t_1), F(t_2)$: Load values at t_1 and t_2, respectively.

1.6.3 Key Characteristics

- Highly customizable.
- Allows for non-linear or user-defined load variations.

1.6.4 TabularData source (inline vs external file)

- For standard load blocks that use `LoadType: Tabular` (e.g. `% Stress Boundary`, `% Body Force`, discharge boundaries, prescribed values), the tabular points must be provided **inline** in the input file using a `TabularData ...` line (time/value pairs separated by `;`).
- The TabularData file=<path> form is **not** supported for these standard load blocks.
- External tabular files via TabularData file=<path> are supported for **rigid motion equation strings** (see: Rigid Motion Constraints and Rigid Body).

1.7 Propagation Across Steps

1.7.1 Concept

- The formulas above define how a load varies with **global analysis time** t.

- In the input file you also choose one or more **simulation steps** on which this time history is active.
- The `Propagate` keyword tells FALCON to keep using the same time history in later steps instead of switching the load off at the end of the first step.
- The time variable is **continuous across all steps**: when a load is propagated, its underlying time law is *not* restarted at each step; the same global history is simply evaluated at later times.

  Typical places where `Propagate` appears:

- `% Stress Boundary` (edge pressures/tractions)
- `% Body Force`
- `% Prescribed Values`
- `% PointLoads`

In all cases the idea is the same: you give a `LoadType` with an associated step, then optionally tell FALCON how far in the step sequence that load should remain active.

1.7.2 Generic syntax

The precise syntax depends on the block, but the allowed options are:

- **Element / edge loads (stress boundaries, discharges, body forces)**

```
LoadType: Immediate Step: 1      # or Ramp / Sinusoidal /
DampedSinusoidal / Tabular
Propagate: Yes                   # active from step 1 to last simulation
step
```

  or

```
LoadType: Ramp Step: 2
Propagate: FinalStep 4           # active on steps 2, 3 and 4 only
```

  - `Propagate: Yes` → use this load on every step from its start step through the final simulation step.
  - `Propagate: FinalStep <N>` → use this load only on steps `StartStep ... N`.
  - For **body forces**, `StartStep <id>` must appear before `Propagate:`; see Body Force for full syntax.
  - For **discharge boundaries** there is **no explicit Propagate line**; they always behave as if `Propagate: Yes` from their start step to the last simulation step (see Discharge).

- **Prescribed nodal values**

```
@@LoadType: Tabular
@@StartStep: 1
@@Propagate: Yes
```

or

```
@@LoadType: Ramp
@@StartStep: 2
@@Propagate: FinalStep 4
```

The meaning of `Yes` and `FinalStep <N>` is identical to the element/edge-load case; see Prescribed Values for the complete list of `@@` parameters.

1.7.3 Special rule for Tabular loads

Tabular loads (Section 5) model an arbitrary time history $F(t)$, so they must remain active for the entire time interval on which the table is defined. For this reason:

- For **Tabular** load type you must use:

```
Propagate: Yes          # or @@Propagate: Yes for prescribed values
```

- `Propagate: FinalStep <N>` is **not allowed** for Tabular loads and will trigger:
  - `[IR-1214]` for stress/discharge boundaries.
  - `[IR-2833]` for body forces and prescribed values.

For all other load types (Immediate, Ramp, Sinusoidal, Damped-Sinusoidal), the load history is interpreted on a continuous global time axis, and `Propagate` selects on which simulation steps that time history is active:

- In the **first step inside** the propagation range, the load ramps on according to its type (instant jump for Immediate, linear rise for Ramp, oscillation for Sinusoidal/Damped).
- On **intermediate** steps inside the range, the load stays at its full value (or continues its oscillation).
- In the **first step after** the last propagated step (for example, step `N+1` after `Propagate: FinalStep N`), the solver performs a **linear ramp-down to zero over that entire step**:
  - At the beginning of that step the load starts from its current value.
  - By the end of the step the load factor has been reduced smoothly to zero.
- On all **subsequent steps** the load factor remains zero; the load does not re-activate or jump back on.

In other words, when propagation ends the contribution does **not** stop abruptly at a step boundary: it is reduced smoothly to zero over one full step, and then stays off.

1.8 Error Codes

The LoadApplication module uses standardized error codes with the prefix `[LA-XXXX]`. These errors may be encountered when:

- Specifying an invalid load type name
- Using Tabular load type without providing tabular data
- Internal load calculation errors

Common LoadApplication Error Codes:

Code	Description	Resolution
LA-0001	Unknown LoadType	Use one of: Immediate, Ramp, Sinusoidal, DampedSinusoidal, or Tabular
LA-0002	Unsupported load type	Internal error - contact developer if encountered
LA-0003	Tabular data is empty	Provide at least one time-magnitude pair in TabularData section

For a complete list of all FALCON error codes, see the Error Dictionary.

For input reader errors related to load type parsing (e.g., missing parameters, invalid propagation settings), see error codes: - **IR-1209**: Invalid or missing LoadType parameters in `% Stress Boundary` - **IR-1214**: Propagation must be enabled for Tabular load type in `% Stress Boundary` - **IR-1302**: Load type parameters missing or incorrect in `% Discharge Boundary` - **IR-1401-1407**: Prescribed value parameter errors