Instruction Manual

WP 121 Euler Strut Theory
Demonstration Unit

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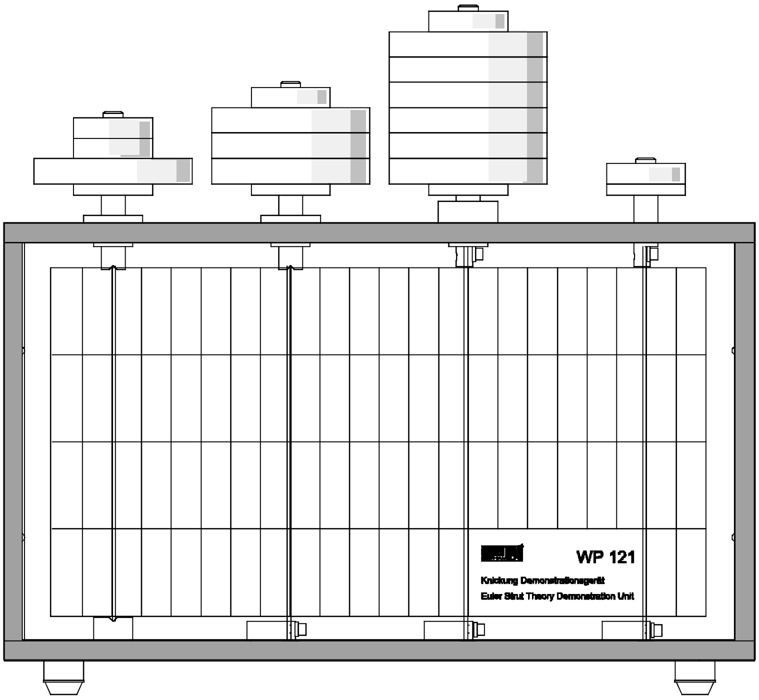

Instruction Manual

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1 Introduction

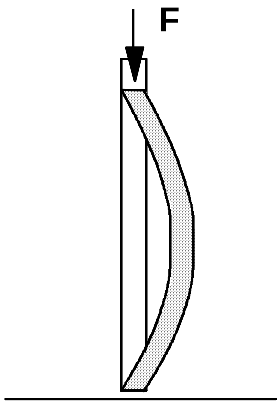

Fig. 1.1 Buckling of a slender column under axial load

The **WP 121 Euler Strut Theory Demonstration Unit** is a straightforward unit designed for clearly illustrating various forms of buckling.

In contrast to simple strength problems such as tension, compression or bending, buckling is a stability aspect.

Buckling plays an important part in virtually all areas of engineering, for example:

- Columns and supports in construction engineering and steel construction
- Piston rods in hydraulic cylinders
- Elevating screws in lifting gear
- Push rods and connecting rods in engine construction

The unit can be used both by the lecturer to demonstrate experiments and by trainees for practical laboratory work.

2 Unit description

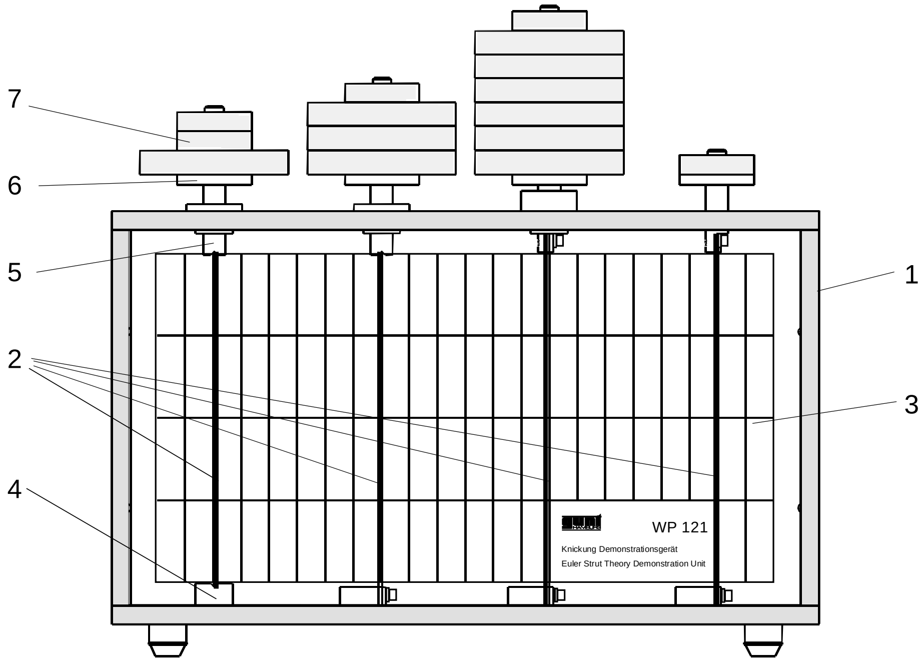

Fig. 2.1 Components of demonstration unit

The unit comprises a frame (1) to accommodate 4 buckling columns (2). The frame is provided with a white rear wall (3) with printed grid to highlight the buckling pattern.

The buckling column mounts are designed to permit illustration of all known *types of Eulerian buckling*. Whereas the lower mounts (4) are permanently connected to the frame, the upper mounts (5) can be vertically adjusted (for case 2 horizontally as well) and are provided with a holder (6) for fitting the weights. The columns are firmly clamped using a screw at the mount; for loose mounting, a lip fits into a corresponding groove of the mount.

The actual buckling columns (2) are made of stainless spring steel of size 0.5 x 12 x 180 mm.

Loading is achieved using a set of 5N and 1N weights (7).

Fig. 2.2 below shows the various types of *Eulerian buckling*.

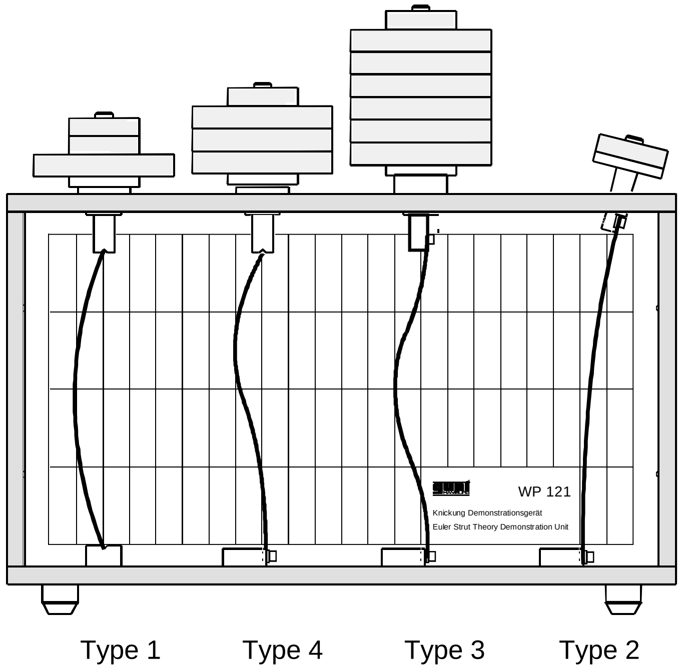

Fig. 2.2 Types of *Eulerian buckling*

3 Experiments

3.1 Theoretical principles

The so-called buckling length is responsible for the buckling load. The buckling length is governed by the method of mounting at the ends of the buckling column. Fig. 3.1 shows the buckling lengths for the various Euler cases.

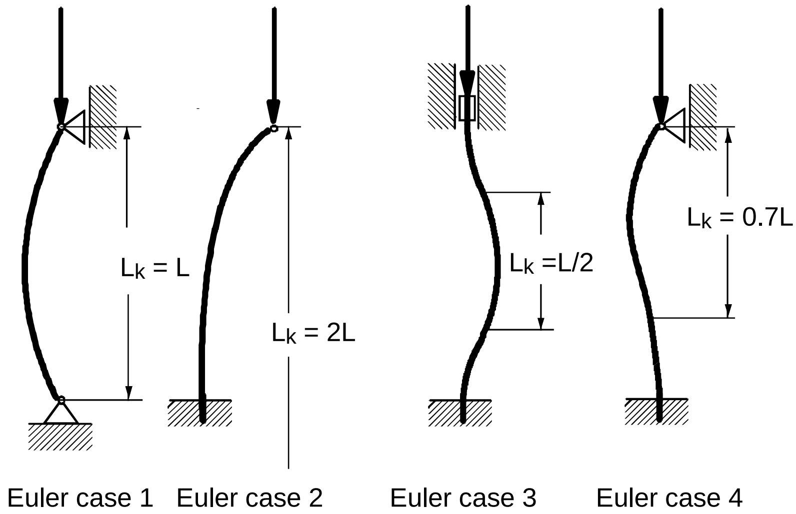

Fig. 3.1

The buckling load F_{crit} to be expected for the various Euler cases can be calculated on the basis of the following formulae

- Euler case 1:

$$F_{crit} = \frac{\pi^2 E I_y}{L^2}$$

- Euler case 2:

$$F_{crit} = \frac{\pi^2 E I_y}{4L^2}$$

- Euler case 3:

$$F_{crit} = \frac{\mathbf{4}\,\pi^2\,E\,I_y}{\boldsymbol{L^2}}$$

- Euler case 4:

$$F_{crit} = \frac{\pi^2\,E\,I_y}{(\,\mathbf{0.7}\,\boldsymbol{L})^2}$$

The modulus of elasticity E of steel is 210000 N/mm^2. For the rectangular cross section of 0.5 x 12 mm of the buckling column, the area moment of inertia I_y is

$$I_y = \frac{b\,h^3}{12} = \frac{12 \cdot 0.5^3}{12} = 0.125\ mm^4.$$

The theoretical buckling forces for a length of *L*=180 mm are thus

- For Euler case 1:

$$F_{crit} = \frac{\pi^2\,E\,I_y}{L^2}\} = \frac{\pi^2 \cdot 210000 \cdot 0.125}{180^2} = 8.0\ N$$

- For Euler case 2:

$$F_{crit} = \frac{\pi^2\,E\,I_y}{4\,L^2} = \frac{\pi^2 \cdot 210000 \cdot 0.125}{4 \cdot 180^2} = 2.0\ N$$

- For Euler case 3:

$$F_{crit} = \frac{4\,\pi^2\,E\,I_y}{L^2} = \frac{4\,\pi^2 \cdot 210000 \cdot 0.125}{180^2} = 32.0\ N$$

- For Euler case 4:

$$F_{crit} = \frac{\pi^2\,E\,I_y}{(\,0.7\,L)^2} = \frac{\pi^2 \cdot 210000 \cdot 0.125}{(\,0.7\ \ 180\,)^2} = 16.3\ N$$

The relationship of the buckling loads must therefore be 1 to 1/4 to 4 to 2.04.

Given equal length and rigidity, the buckling loads can only vary as a function of the end mounting method by a factor of 16.

3.2 Performance of experiment

In the course of the demonstration the load due to weight is gradually increased. On approaching the calculated buckling load it is appropriate to only increase the weight in small stages (1N weights) to be able to clearly witness the sudden attainment of instability, i.e. the buckling point.

The vertical adjustment of the upper mount is such that the buckling column is not damaged even when overloaded.

The experimental buckling loads are generally lower than those calculated. This is due to the inevitable slight pre-deformation of the column. Each column therefore also has a preferred buckling direction. Theory calculations cannot predict the direction in which the column will buckle.

When determining the buckling load, it should be remembered that the weight holder and upper mount already weigh 1N.

4 Technical data

Column length (mount/mount)	180	mm
Column cross section:	0.5 x 12	mm^2
Column material:	Steel 1.4310	spring-tempered

Euler cases:	Mounting:	
Euler case 1	Flexible	/ Flexible
Euler case 2	Clamped /	Free
Euler case 3	Clamped /	Clamped
Euler case 4	Clamped /	Flexible
Buckling loads:	approx. 2 ... 32	N

Set of weights:	10 x 5	N
	5 x 1	N

Dimensions (without weights):

L x W x H:	380 x 110 x 270	mm
Weight:	approx. 10	kg