POLYURETHANE SPRINGS

DESIGN GUIDE

Introduction

Among the traditional products of PEMŰ Plastic Industry Rt., polyurethane springs hold a prominent position. This design guide presents the possible uses of springs, application examples, calculation examples necessary for design, as well as information on the physical and mechanical properties and chemical resistance of the raw materials.

Applications

In deep drawing, stamping, and forming technology, especially in the manufacture of tools for stamping, tapered, disc, coil, and ring steel springs are widely used to hold or eject parts.

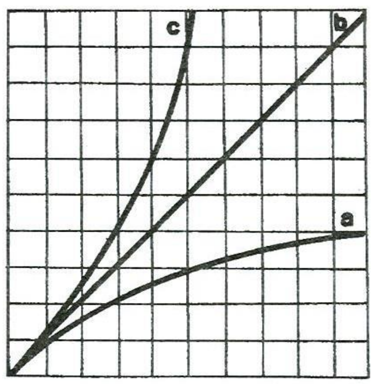
Fatigue fractures can cause spring rings to fall into the tool, causing significant costly damage. This was the main reason for trying to use elastic materials instead of steel springs. A material had to be found that provides the characteristics of steel springs but eliminates their disadvantages.

Such a suitable material is found among elastomers.

In practice, springs are characterized by their spring characteristics.

In a degressive characteristic, the spring force "P" decreases as the spring travel increases. The spring characteristic is linear if the spring travel and spring force are directly proportional.

In a progressive characteristic, the spring force increases more steeply than the spring travel (see Figure 1).



1) Figure: Comparison of spring characteristics

a) degressive (falling) characteristic
b) linear (straight)
c) progressive (rising)

When using elastomers as springs, the Shore hardness of the material determines whether the spring is designed for spring travel or spring force.

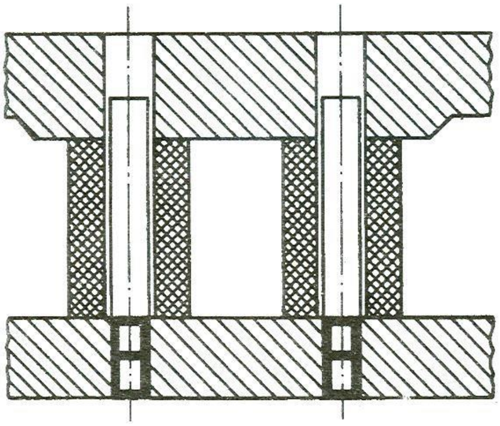
Based on practical experience, three Shore hardness levels can satisfy a wide range of applications

80 Shore A, 90 Shore A, and 95 Shore A.

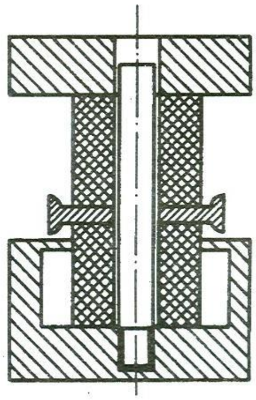
Unlike coil and disc springs, elastomer springs do not require a block length. For elastomer springs, 20-30% of the total unloaded spring length is allowed as spring travel.

A load higher than 30%—in special cases—does not damage the tool as steel springs do, but the elastomer spring will fatigue faster.

The preloading of elastomer springs must be calculated at 8-10% of the allowable spring force.



2. Figure Paralell connection

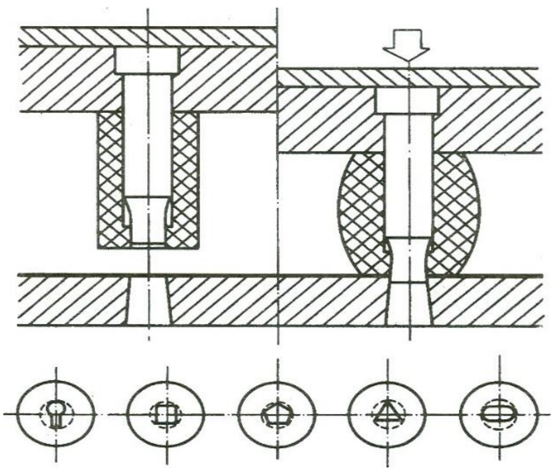


3. Figure Series connection

<u>Note</u>

In series connection of spring elements, the spring travels add up, but the spring force remains the same (Figure 3).

In parallel connection, the spring forces add up, but the spring travel remains the same (Figure 2)



Spring Guiding Methods

4. Figure

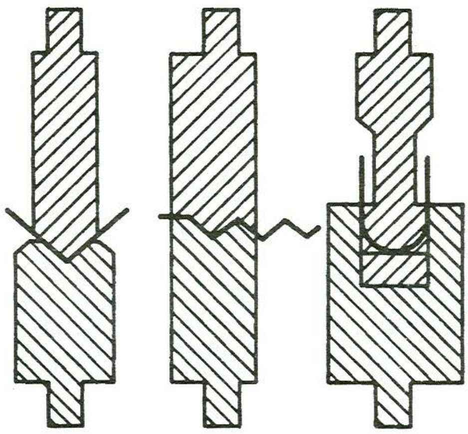
Sheet metal forming with PU elastomer die.

Practically every industry uses forming presses from decorative shaping of thin sheets to bending thick sheets.

PU elastomers used in pressing technology are considered relatively new structural materials.

Their unique combination of properties—excellent load resistance, minimal cracking under load, excellent resistance to crack propagation, wear resistance, oil resistance, and excellent elastic properties—make them ideal for use as dies.

Figure 5 shows the arrangement of the punch and die.



5. Figure

This tool is used for pressing the products shown in Figure 6.

6. Figure

Form Factor

The form factor is defined as the ratio of the loaded surface to the total free surface that can bulge under load. For example, a cube with 1 cm edge length has a form factor of 0.25 (1 cm^2 divided by 4 cm^2).

If the cube is cut into two parts with 1 cm^2 top and bottom surfaces but half the height, the form factor becomes 0.5 (1 cm^2 divided by 2 cm^2).

These examples clearly show the designer’s option: reducing the deformable free surface increases the form factor and the body's resistance to deformation.

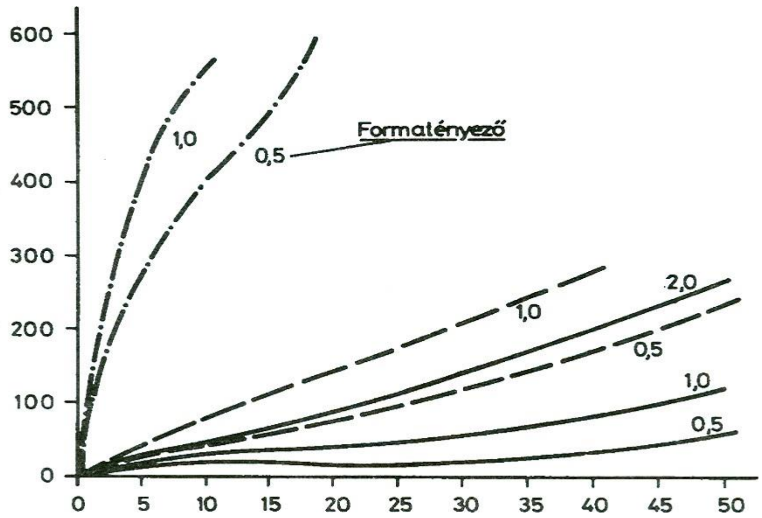
In other words, the compressive strength of PU elastomers increases if the free surfaces that can move under pressure are reduced.

Interestingly, the pressure deformation curves of different hardness types can be partially overlapped by modifying the form factor.

Punch Penetration Depth

Experience shows that the maximum deformation still providing reasonable service life is about 30%. A rough rule of thumb is that the die thickness should be at least three times the punch penetration depth.

The die's top surface should be twice the projected area of the punch at the deepest penetration plane. Figure 7's diagram confirms this practical rule.



nyomás hatására fellépő deformáció %

7. Figure

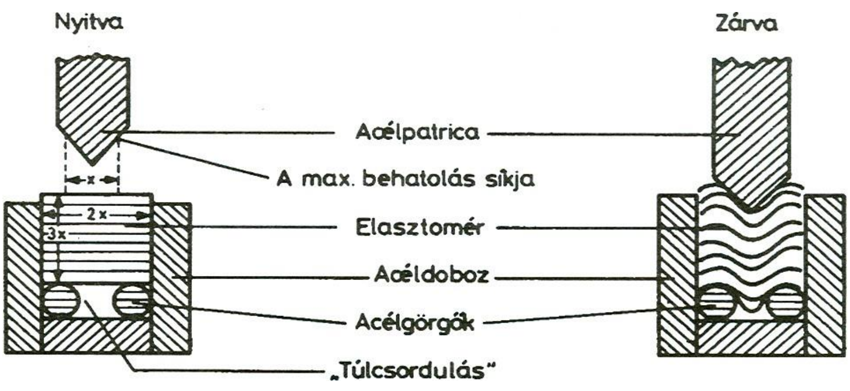
PU Elastomer Hardness

The harder the elastomer, the smaller the die deformation under punch pressure, increasing die life.

This is why elastomers used for this purpose are generally in the 90-95 Shore A hardness range.

Under punch load, elastomers behave like liquids under pressure. Therefore, the elastomer die must be held in a container—steel box. The steel box and elastomer pad construction allow achieving maximum forming factor.

It must be considered that some safety volume is left in the box to accommodate "overflow" if the punch loads it. Figure 8 shows this overflow and die relaxation.



8. ábra

Spring Element Size Table

- For 80 Shore A hardness springs: PUA 80A (red)
- For 90 Shore A hardness springs: PUA 90A (blue)
- For 95 Shore A hardness springs: PUA 95A or PUA 50D (green)
-

Orders should be made based on the product selection shown below.

D (mm)	16	20	25	32	40	50	63	80	100	125
d (mm)	6,5	8,5	8,5	13,5	13,5	17	17	20	21	27
h (mm)	340	340	340	500 és 340	500 és 340	500	500	500	500	500

Dimensional Tolerance: The dimensional tolerances of products are guided by the values of grade P3 in the DIN 7715 standard.

Order Example

A spring element with outer diameter D=16 mm,

inner diameter d=6.5 mm

length h=340 mm,

and material PUA 80A is ordered as:

Ø 16/6.5 x 340 mm PUA 80A spring.

PU stands for polyurethane, A is the abbreviation for Adiprene material, and the numbers indicate Shore hardness on the Shore A scale.

Springs are sold 90% in the given colors for easier material identification. Customers can request natural (colorless or translucent yellow) springs in any hardness.

Physical-Mechanical Properties of Different ADIPRENE Types

Test	*Standard*	*Unit*	***80 A***	***90 A***	***50 D (95 A)***
Shore Hardness (A or D scale)	*DIN 53505*	*Hardness Unit*	***80/31***	***90/38***	***95/50***
Density	*DIN 53479*	*Kg/m³*	***1070***	***1100***	***1140***
Abrasion Loss	*DIN 53516*	*mm³*	***48***	***50***	***65***
Tensile Strength at Break	*DIN 53515*	*N/mm²*	***65***	***70***	***87.5***
Elasticity	*DIN 53512*	*%*	***70***	***45***	***40***
Stress at 100% Elongation	*DIN 53504*	*MPa*	***2.8***	***7.6***	***12.5***
Stress at 300% Elongation	*DIN 53504*	*MPa*	***4.4***	***14.5***	***23.4***
Tensile Strength	*DIN 53515*	*kN/m*	***20***	***31***	***34.5***
Elongation at Break	*DIN 53504*	*%*	***600***	***400***	***300***

The table data is for information only

Chemical Resistance

Chemical	ADIPRENE (urethane)	NEOPRENE (rubber)	**Chemical**	ADIPRENE (urethane)	NEOPRENE (rubber)
Acetone	C	B	**Ethyl acetate**	C (50 °C)	C
Ethyl ether	C	C	**ASTM oil 1**	A (70 °C)	A
ASTM oil 3	B (90 °C)	B (70 °C)	**Gasoline**	B	B
Benzene	C (70 °C)	C	**Beer**	A	A
Butane	A	A	**Butyl acetate**	C	C
Calcium chloride solution	A	A	**Chloroform**	C	C
Cyclohexane	A	C	**Dioctyl phthalate**	C	C
Acetic acid (20%)	B	A	**Glacial acetic acid**	C	C
Hydrofluoric acid (48%)	C	A	**Furfural**	C	B
Formaldehyde (40%)	C	A	**Glycerin**	A	A (70 °C)
Isooctane	B	A	**Linseed oil**	B	A
Seawater	A	A	**Methyl alcohol**	C	A (70 °C)
Mineral oil	A	A	**Sodium hydroxide (20%)**	A	A

Sodium hydroxide (73%)	C	A	**Sodium chlorite (5%)**	C	A
Sodium hypochlorite (20%)	C	B	**Sodium hypochlorite**	C	C
Phenol	C	C	**Nitric acid (10%)**	C	B
Nitric acid (70%)	C	C	**Hydrochloric acid (20%)**	B	A
Silicone grease	A	A	**Hydrochloric acid (37%)**	C	A

A = slight effect

B = moderate effect

C = strong effect

Data for 80 Shore A Hardness Springs

d1 mm	*d2* mm	*h0* mm	*hv* mm	*fa* mm	*Pressure* kp	*d3* mm
16	6,5	12,5	11	3	115	~21
		16	14,5	4	110	
		20	18	5	106	
		25	22,5	6	104	
20	8,5	16	14,5	4	175	~28
		20	18	5	170	
		25	22,5	6	165	
		32	28,5	7,5	162	
25	8,5	20	18	5	280	~35
		25	22,5	6	275	
		32	28,5	7,5	270	
		40	36	10	268	
32	13,5	32	28,5	7,5	440	~42
		40	36	10	430	
		50	45	12;5	425	
		63	56	15	420	
40	13,5	32	28,5	7,5	745	~52
		40	36	10	735	
		50	45	12,5	730	
		63	56	15	725	

Explanation of the calculation example:

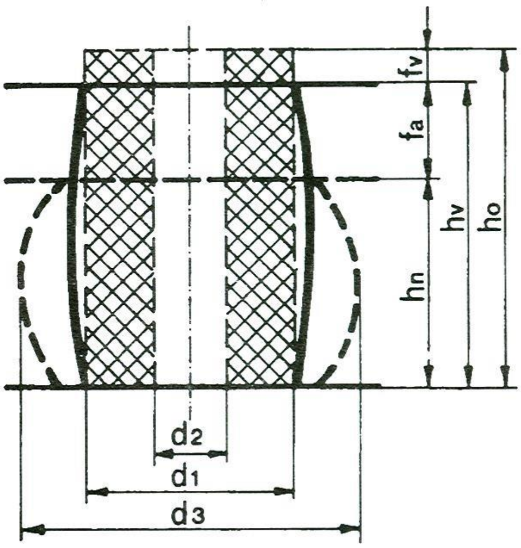
The figure shows a bushing in three states: unloaded (length h0*h0*), preloaded (length hv*hv*), and loaded (length hn*hn*).

Plastic springs generally tend to "creep" (relaxation under load) — polyether-based polyurethane springs exhibit this phenomenon only to a very small extent — therefore, they must be installed with some preload (tv*tv*).
A 10% preload relative to the resulting height (h0*h0*) is sufficient.

For simplicity, the table shows not only the resulting height (h0*h0*) but also the preloaded size (hv*hv*). It also provides the usable spring travel (fa*fa*), which corresponds to the difference between the preloaded spring height (hv*hv*) and the compressed spring height (hn*hn*).

If the force per spring and the spring travel are already given, the appropriate combination of force and usable spring travel must be found in the "pressure" and "fa" columns.
From this, the measurable height in the preloaded state (hv*hv*) and the resulting height (h0*h0*) can be determined.

This data also provides the required spring height. The outer diameter of the spring is found in the "d1" column.



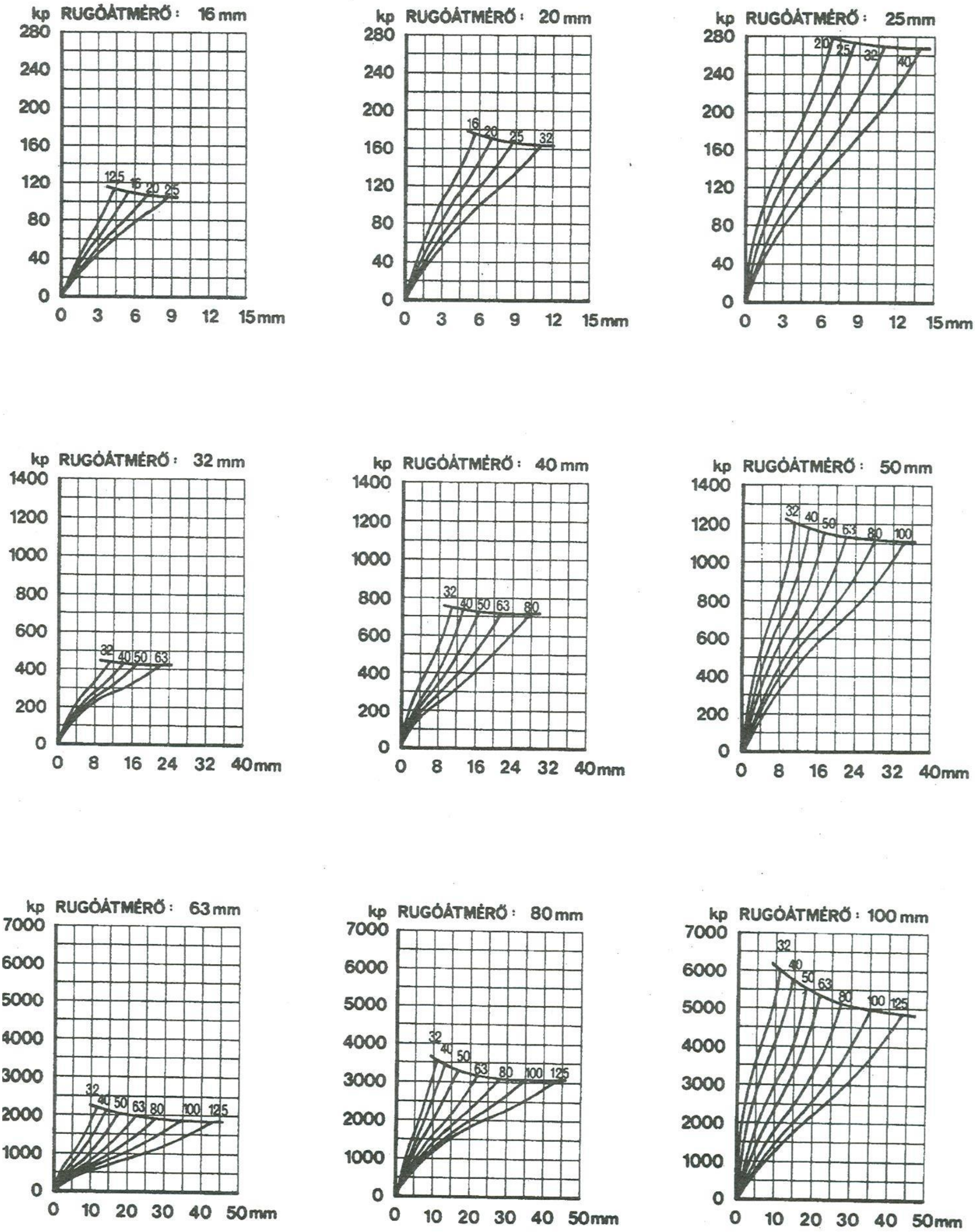
Calculation example:

Force per spring: 3000 kp
Required spring travel: 18 mm

In the "pressure" and "fa" columns, find the closest values, in this case: 3100 kp and 20 mm.
From this, it can be determined that the preloaded height is 72 mm, and the resulting height is 80 mm.

Therefore, in this example, a spring with an outer diameter of 80 mm and height of 80 mm must be installed.

Characteristic Curves of 80 Shore A Hardness Springs



Data for 90 Shore A Hardness Springs

d_1 mm	*d_2* mm	*h_o* mm	*h_v* mm	*f_a* mm	*Nyomás* kp	*d_3* mm
16	6,5	12,5	11,5	2	158	~20
		16	14,5	3	153	
		20	18	4	150	
		25	22,5	5	148	
20	8,5	16	14,5	3	235	~27
		20	18	4	230	
		25	22,5	5	228	
		32	28,5	6	226	
25	8,5	20	18	4	398	~32
		25	22,5	5	390	
		32	28,5	6	386	
		40	36	8	382	
32	13,5	32	28,5	6	595	~39
		40	36	8	585	
		50	45	10	580	
		63	56	12	575	
40	13,5	32	28,5	6	1020	~49
		40	36	8	1000	
		50	45	10	995	
		63	56	12	990	

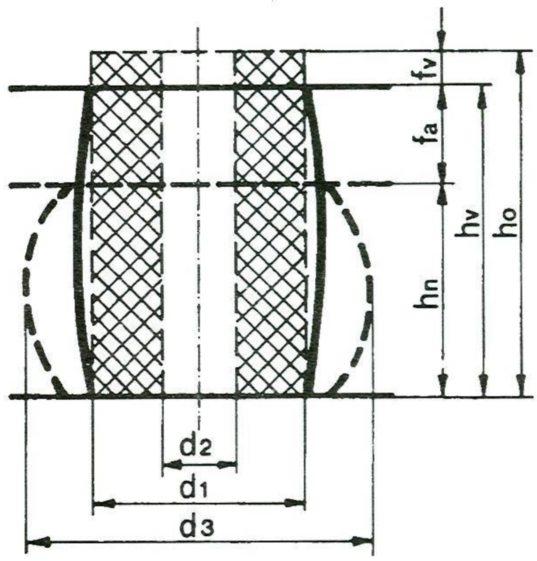
Explanation of the calculation example:

The figure shows a bushing in three states: unloaded (length h0*h*0), preloaded (length hv*hv*), and loaded (length hn*hn*).

Plastic springs generally tend to "creep" — polyether-based polyurethane springs exhibit this phenomenon only to a very small extent — therefore, they must be installed with some preload (tv*tv*).
A 10% preload relative to the resulting height (h0*h*0) is sufficient.

For simplicity, the table shows not only the resulting height (h0*h*0) but also the preloaded size (hv*hv*). It also provides the usable spring travel (fa*fa*), which corresponds to the difference between the preloaded spring height (hv*hv*) and the compressed spring height (hn*hn*).

If the force per spring and the spring travel are already given, the appropriate combination of force and usable spring travel must be found in the "pressure" and "fa" columns. From this, the measurable height in the preloaded state (hv*hv*) and the resulting height (h0*h*0) can be determined. This data also provides the required spring height. The outer diameter of the spring is found in the "d1" column.



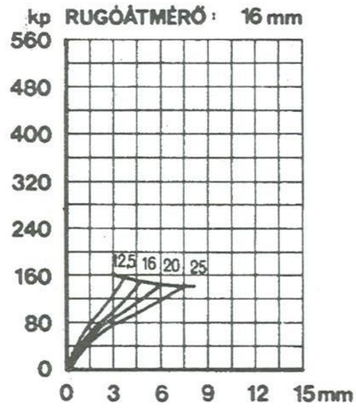
Calculation example:

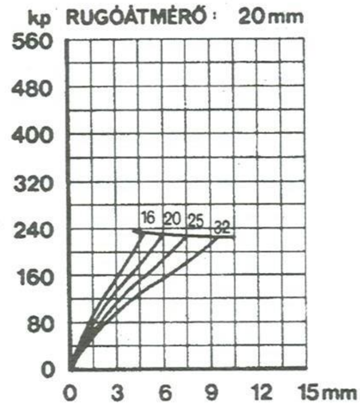
Force per spring: 6000 kp
Required spring travel: 22 mm

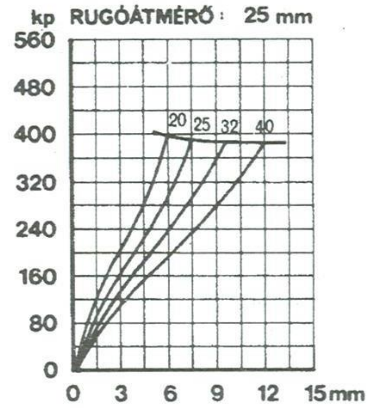
In the "pressure" and "fa" columns, find the closest values, in this case: 6520 kp and 24 mm.
From this, it can be determined that the preloaded height is 112 mm, and the resulting height is 125 mm.

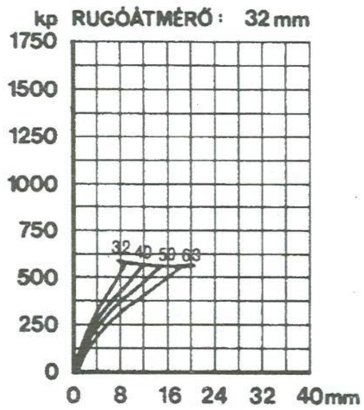
Therefore, in this example, a spring with an outer diameter of 100 mm and height of 125 mm must be installed.

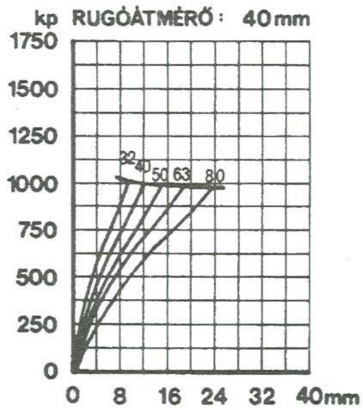
Characteristic Curves of 90 Shore A Hardness Springs

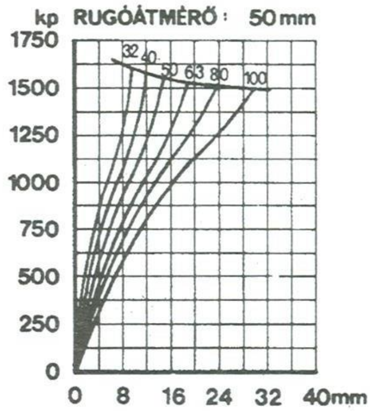


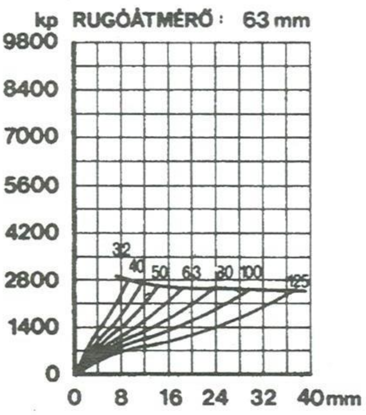


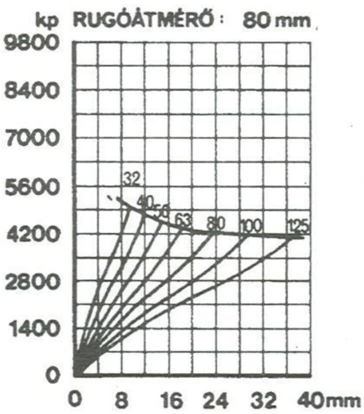


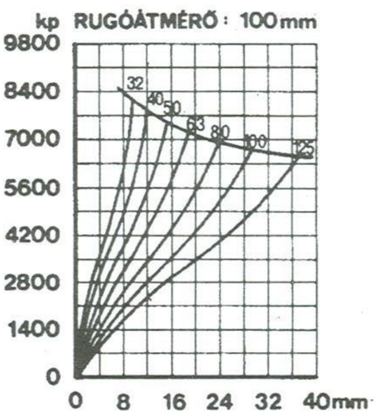












Data for 95 Shore A (50D) Hardness Springs

d, mm	d_2 mm	h_o mm	h_v mm	f_a mm	Nyomás kp	D_3 Mm
16	6,5	12,5	11	1,5	192	~19,5
		16	14,5	2	188	
		20	18	3	185	
		25	22;5	4	182	
20	8,5	16	14,5	2	290	~25
		20	.18	3	285	
		25	22,5	4	282	
		32	28,5	4,5	280	
25	8,5	20	18	3	490	~30
		25	22,5	4	480	
		32	28,5	4,5	475	
		40	36	6	470	
32	13,5	32	28,5	4,5	730	~38
		40	36	6	718	
		50	45	7,5	708	
		63	56	9	700	
40	13,5	32	28,5	4,5	1250	~46
		40	36	6	1230	
		50	45	7,5	1225	
		63	56	9	1215	

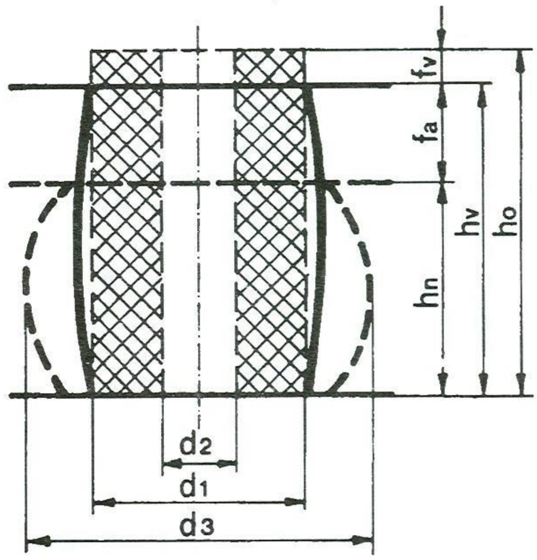
Explanation of the calculation example:

The figure shows a bushing in three states: unloaded (length h0*h*0), preloaded (length hv*hv*), and loaded (length hn*hn*).

Plastic springs generally tend to "creep" — polyether-based polyurethane springs exhibit this phenomenon only to a very small extent — therefore, they must be installed with some preload (tv*tv*). A 10% preload relative to the resulting height (h0*h*0) is sufficient.

For simplicity, the table shows not only the resulting height (h0*h*0) but also the preloaded size (hv*hv*). It also provides the usable spring travel (fa*fa*), which corresponds to the difference between the preloaded spring height (hv*hv*) and the compressed spring height (hn*hn*).

If the force per spring and the spring travel are already given, the appropriate combination of force and usable spring travel must be found in the "pressure" and "fa" columns. From this, the measurable height in the preloaded state (hv*hv*) and the resulting height (h0*h*0) can be determined. This data also provides the required spring height. The outer diameter of the spring is found in the "d1" column.



Calculation example:

Force per spring: 1800 kp
Required spring travel: 8 mm

In the "pressure" and "fa" columns, find the closest values, in this case: 1900 kp and 9 mm.
From this, it can be determined that the preloaded height is 112 mm, and the resulting height is 63 mm.

Therefore, in this example, a spring with an outer diameter of 50 mm and height of 63 mm must be installed.

Characteristic Curves of 95 Shore A (50D) Hardness Springs

sssss