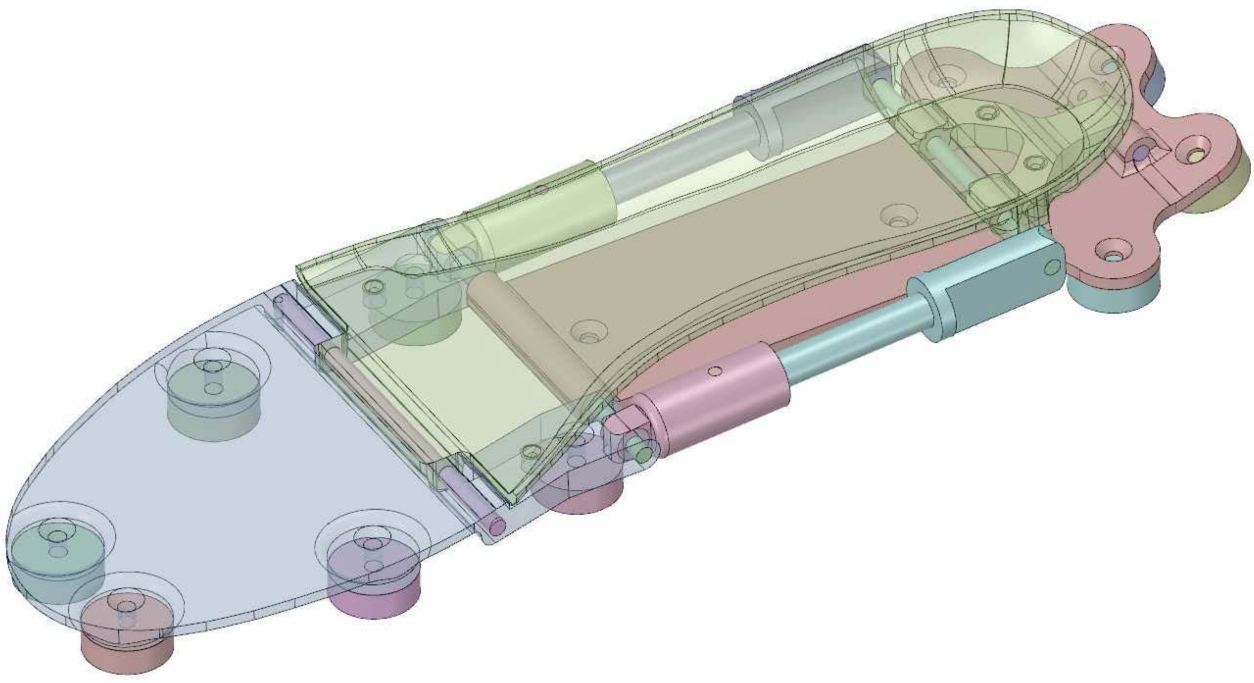
STUDY AND DESIGN NOTES FOR THE CONCEPT OF

“ENKO Running Shoes”

This shoe utilises mechanical parts integrated into the sole, which provide it with significant cushioning (increased comfort) and energy release (increased performance). The innovative sole is equipped with two shock-absorbers, permitting a gentle release, at the right moment, of all the energy stored during cushioning of the stride.

We will evaluate in an analytical manner the quality of the cushioning and the increase in performance that the “ **Enko running shoes**” concept provides compared to a conventional shoe for a runner weighing 70kg running at different speeds.



- CAD of the sole and its mechanical parts -

A WORD ABOUT THE STRIDE

The stride can be defined as the bound made between two successive contacts with the ground. It consists of a period of support and a period of suspension. The period of support is the one that interests us in the context of this study, as it is during this period of time that the transfers of energy take place. It is the moment when the foot of the runner is in contact with ground.

According to this approach, this phase is divided into three successive steps (see illustration below).

- **Cushioning phase:** Begins the moment the foot makes contact with the ground and ends when the vertical projection of the centre of gravity coincides with the vertical of support.
- **Support phase:** This is the moment when the speed of the vertical displacement becomes zero. The centre of gravity is then approximately in line with the support on the ground.

- **Pushing phase:** From a mechanical point of view, the push phase begins at the moment of support and ends when the foot leaves the ground. So it is the driving-force moment *parexcellence*.

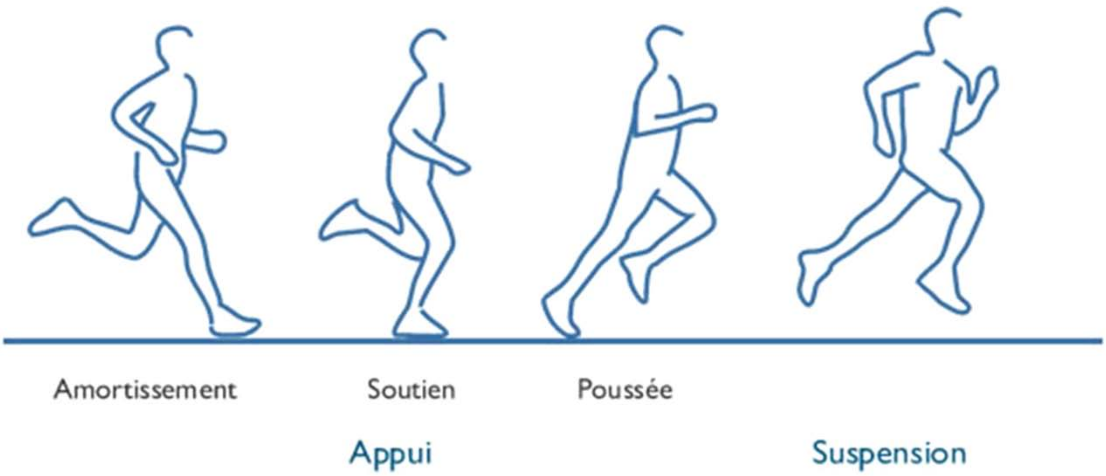


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Illustration of the different stride phases -

(*Translator's key to illustration: Amortissement* = Cushioning*; Soutien* = Support*; Poussée* = Pushing*; Appui* = Support*; Suspension* = Suspension*)*

DESCRIPTION OF ENERGY CALCULATIONS

To address the problem of the contribution of soles to the performance of the runner, we adopt an energetic approach. That is to say, we will estimate the amounts of energy stored and then 'restored' by the sole thanks to its shock absorbers and compare them with the amounts of energy involved during running for a runner weighing 70 kg with an average efficiency of stride.

These calculations are done for four different speeds - 9,12,15 and18km/h, and use the referenced average energy expenditure values and a stride of average capacity. The stride amplitudes considered are 1m,1.2m,1.5m and 1.75m for the four respective speeds while the components of the energy cost related to the runner, which are necessary for the calculations, will come from recognised scientific data.

ENERGY STORED AND RELEASED BY THE SYSTEM WITH EACH STRIDE

To calculate the energy stored and released by the shock-absorbers, we consider the system for the four successive phases summarised above.

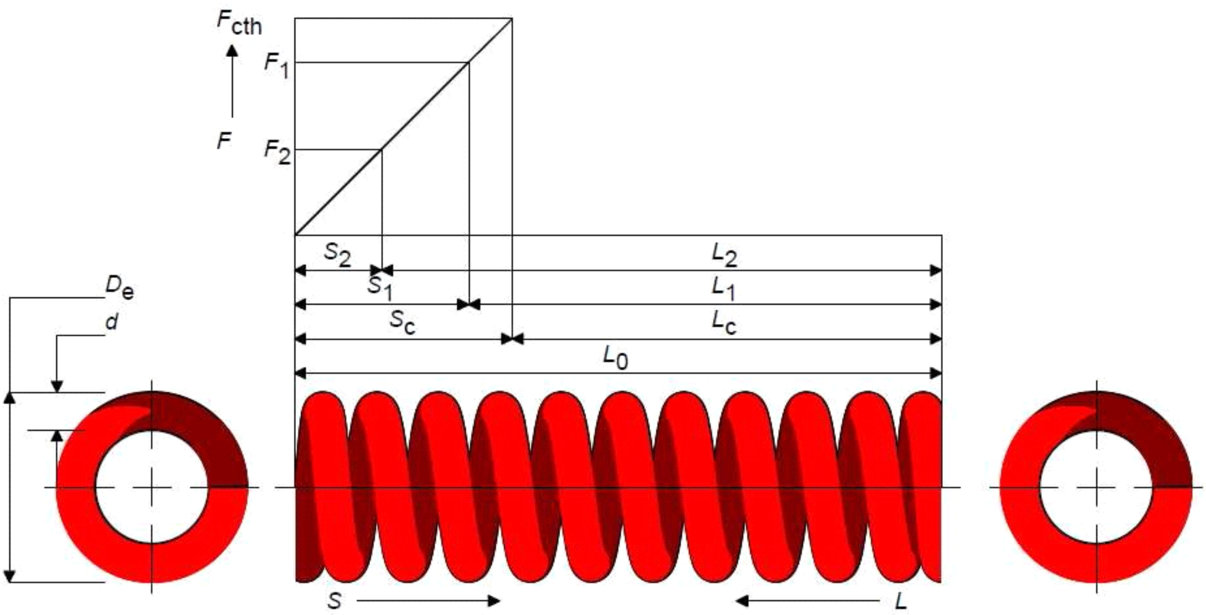
At the beginning of the cushioning, the springs are released and experience no constraint.

It has the a length of L*0*.

During the cushioning phase, they will compress and exert a resistance force, F*ressort*, which will help limit the energy collected by the sole and the leg of the runner.

This energy stored by the springs by compressing during the cushioning phase for a runner weighing 70 kg is as follows:

$$E_{emmag} = 2 \times E_{Ressort} = 2.\left(\frac{1}{2}.K.(L_0 - L_1)^2\right) = \boldsymbol{K.(L_0 - L_1)^2}$$



De = 15.2 mm
d = 3.1 mm
K = 52.8 N/mm (spring rate for a runner weighing 70kg)
L*0* = 52mm
L*c* = 40 mm

With the values obtained, we have:
Energy stored in the two springs:
$K.(L_0 - L_c)^2$ = 7.6 **J**

Analysis of the cushioning phase

What makes this shoe unique is that it is equipped with interchangeable springs chosen according to the weight of the runner, and that the cushioning phase takes place over 20 mm of the shoe's height, about ten times more than with a traditional shoe. The cushioning is always optimised, providing you with unparalleled comfort.

Energy cost of running

This energy cost is a factor widely studied in the field of running; it is estimated from energy balances from a large number of representative runners.

For a runner weighing 70 kg, this cost is:

- **1,036**kcal/kg/km(4,330.5J/kg/km) at 18km/h

- **1,028**kcal/kg/km (4,297J/kg/km) at15km/h
- **1,027**kcal/kg/km(4,292.9J/kg/km) at12km/h
- **1,037**kcal/kg/km(4,334.7J/kg/km) at9km/h

Mechanical output

To be able to estimate the real contribution of shoes, it is necessary to know the mechanical output *h* corresponding to the proportion of the energy cost used solely to in order to remain running.

The performance range for an average runner is between 18 and 24%. We have used the following values according to speed:

- *h=18% at 9 km/h*
- *h=20% at 12 km/h*
- *h=22% at 15 km/h*
- *h*=24% at 18 km/h

Energy cost adjusted

For a runner weighing 70 kg:

- **72752.1 J/km** at 18 km/h
- **66174.4 J/km** at 15 km/h
- **60100.0 J/km** at 12 km/h
- **54616.7 J/km** at 9 km/h

Gains made to the Energy Cost

To be able to compare the amount of energy provided by the springs, it is necessary to relate it to running for one kilometre. The stride amplitudes (*L*) considered for this are as follows:

1m at 9 km/h
1.2m at 12 km/h
1.5m at 15 km/h
1.75m at 18 km/h

The spring energy $E_{spring/km}$ provided by one kilometre of running is then deducted from the energy provided to each stride by: $E_{spring/km} = E_{spring} . \frac{1000}{L}$

Gains provided by the “Enko Running Shoes” shoe as a percentage of energy cost

SPEED	9km/h	12km/h	15km/h	18km/h
Total energy cost of running	303426 J/Km	300500 J/Km	300792 J/Km	303134 J/Km
Mechanical output of running	18%	20%	22%	24%
Adjusted energy cost	54616.7 J/km	60100.0 J/km	66174.4 J/km	72752.1 J/km
Energy provided by the springs $E_{ressort}$ / *km*	7603.2J/km	6336.0J/km	5068.8J/km	4344.7J/km
Energy gain provided by “Enko Running Shoes” as a percentage of energy cost	**13.92 %**	**10.54 %**	**7.66 %**	**5.97 %**

We can see that the gains provided by the shock-absorbers in terms of mechanical energy is between 6% and14% depending on the speed considered, and this is a significant advantage.

It is also interesting to note that the contribution of shock-absorbers is greater for running at low speeds since the number of strides per kilometre is higher.

“Enko Running Shoes” are aimed at runners wishing to benefit from a significant amount of propulsion as well as cushioning gains providing a reduction in running-related injuries.