PowerOval®
Science extended

PowerOval® - Science based Premium Non-Circular Chainrings

1. Analysis of the pedaling process.

The moments ("torques") which are generated in the joints through the muscles are needed on the one hand to generate the force on the pedal (**non-kinetic** driving force) and on the other hand these moments have to accelerate and to decelerate the masses of the lower limbs (**dynamic or kinetic** force/moments).
In other words, the **total driving moment** in each of the joints of the lower limbs can be decomposed into a **kinetic moment** (intersegmental moment due only to the dynamic action of the leg links) and **a non-kinetic moment** (moment only due to pedal forces).

$$M_{total} = M_{non\text{-}kinetic} + M_{kinetic} \qquad \text{equation (1)}$$

This moments-equation is valid for ankle-, knee- and hip joint respectively.

Kinetic forces/moments **do not generate "external" crankpower**. They do not contribute to the propulsion but are only needed to move the legs. The kinetic force/moment component is due to gravitational effects acting on the masses of the moving legs and due to inertial effects (acceleration and deceleration of the legs) during pedaling.

2. Kinetic forces/moments.

The **non-kinetic** moment is only a consequence of the applied pedal forces and does not depend on the masses nor on the accelerations of the lower limbs.

The **kinetic** forces / moments are a function of the masses, the moments of inertia, the angular accelerations and linear accelerations (of the centre of gravity) of the foot, leg and thigh and also of the gravity acting on foot, leg and thigh.

These kinetic forces / moments acting on the joints at a given pedaling rate, **can** be **modified** by a **change** of the angular accelerations and the linear accelerations of the lower limbs.
However the non-kinetic moments remain unchanged.

3. Non-circular chainrings.

When cycling at constant speed with a **non-circular chainring**, the pressure point of the foot is describing a circular motion but the **crank angular velocity is varying** through one revolution (what is not the case with a circular chainring). This means there are angular accelerations and linear accelerations.

These angular accelerations, but also the linear accelerations of the lower limbs, **can be changed** by modifying the ovality and the shape of the chainring, the orientation of the crank relative to the major axis of the chainring and by varying the pedaling frequency.

4. Modification of the kinetic forces / moments in the joints.

By modifying the geometry (ovality, shape and position of the crank) and the rotation frequency of the oval chainring, other angular- and linear accelerations occur and cause **altered kinetic forces / moments in the joints.**

5. Optimization.

Through simulations with different ovalities, shapes and crank positions versus the major axis of the chainring, **an optimal non-circular chainring** can be found.

This **optimal** non-circular chainring **minimizes** the **kinetic** force-moment in the joints.
See also the equation (1).
When the total driving torque (total moment) remains the same, the muscles which have to generate the same total driving torque, will deliver **more non-kinetic moment with the same effort** (indeed, because they have to generate less kinetic moment) and consequently more pedal force and thus **finally more pedal power.**

That optimal non-circular chainring **(criteria for the optimization)**
-**minimizes** the peak-load (kinetic joint moment and -joint power) in the extensor muscles of the joints compared to a circular chainwheel.
-and thereby **maximizes** a kinetic crankpower gain compared to a circular chain wheel, at a given pedaling rate.

Both the unloading in the extensor muscles of the knee- and hip joints and the crank power gain increase more than proportionally with increasing pedaling cadences.

In cycling the extensor muscles are predominantly recruited and provide most of the forward drive (external crank power) for the bicycle movement.
Any "unloading" of the extensors is favourable regarding extensor muscle fatigue and allows the cyclist to keep a given level of crank power longer.

6. **PowerOval®** non-circular chainring.

The **PowerOval®** chainring is the result of the optimization study.
That optimal non-circular chainwheel is the best performing non-circular chainring selected from multiple (36) simulated and investigated geometries and crank orientations.
See "Performances".

The **PowerOval®** has the following "optimal" features:
ovality 30 %, four shape segments (round, a transition section to flat, a flat segment and a spiral of Archimedes for transition from flat to round) and the crank arm positioned at 68°, measured clockwise from major axis of the oval for the standard racing bike (seat tube angle about 73°).
However, the optimal crank offset is depending on the bike geometry and the seating position of the rider. Therefore the **PowerOval®** has also two additional mounting options: one at 76° for TT-bikes (seat tube angle about 80°) and one mounting possibility at 84° for extreme forward seating position (greater "virtual" seat tube angle).
For practical reasons (see "Product Description") the ovality is limited to 25%. This does not give a noticeable loss of performance.

7. References

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