Static and dynamic unbalance, off–the–car balancing, matching, optimization, finishbalancing ... - terms which are connected with tyre service routine and yet are not always quite easy to understand. That is why we want to explain those terms and present some fundamentals of balancing technology without going too much into technical details.

HOFMANN®

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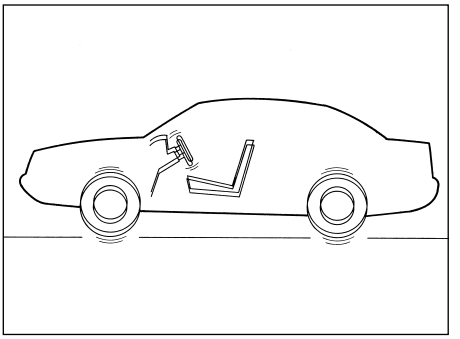
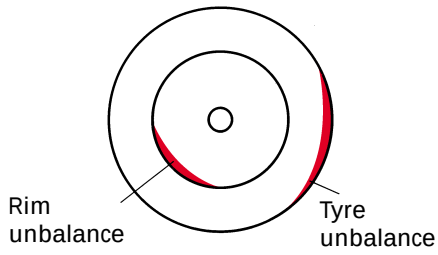


1. Static / dynamic unbalance

Steering wheel flatter, vibrations sensed in the passenger compartment ... - there is no one who would not have experienced such inconveniences someday or someway. Main causes for those vibrations sensed in the passenger compartment are the structures of tyre and rim and the combination of those negative effects, sometimes under most unfavourable conditions and on all four wheels. Before we are going to study the possible causes of those vibrations ...

Fig. 1

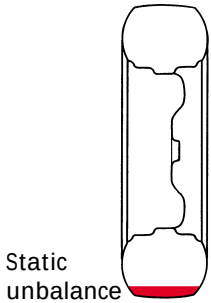


... let us first answer the question 'What does unbalance mean indeed?'.

Unbalance is the heavy spot in the tyre or rim structure which has been produced in manufacture (Fig. 1).

Those heavy spots (due to non–uniform mass distribution) make the wheel and steering system vibrate during the ride unless they are balanced.

Fig. 2

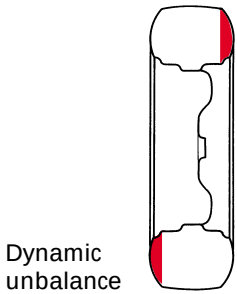


Basically we distinguish between **two types of unbalance:**

1. static unbalance
2. dynamic unbalance

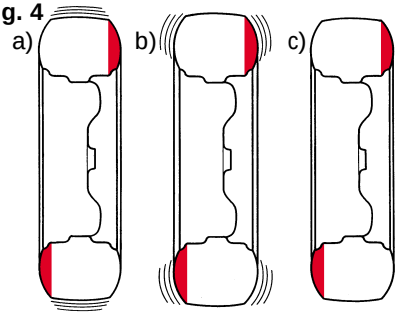
The difference is easily explained on the tyre. **Static unbalance** exists when the tyre has one heavy spot **(Fig. 2)**. When such a tyre is suspended the heavy spot will tend towards the bottom. This means static unbalance can be determined without rotation of the wheel.

Fig. 3



The contrary applies to dynamic unbalance. With **dynamic unbalance** the tyre has two heavy spots diagonally opposed **(Fig. 3)**. If such spots are equally heavy, they compensate for each other when the wheel does not rotate.

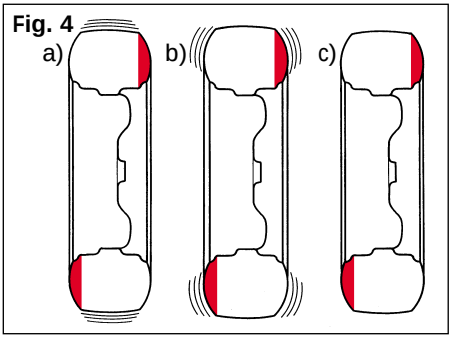
Fig. 4



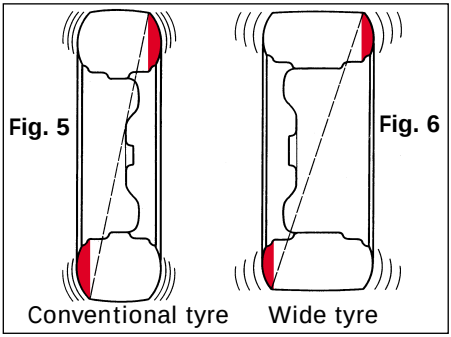
But what do you expect the wheel to behave like once set into rotation:

Fig. 4

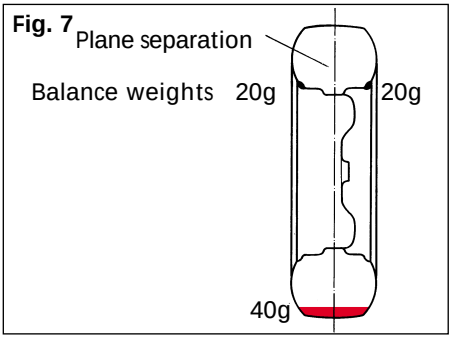
a) Will the wheel bounce?
b) Will the wheel wobble?
c) Will the wheel run smoothly?



re a): The wheel would bounce if it had static unbalance. Dynamic unbalance makes the wheel wobble (hence b is correct).
re b): **You are right.** A wheel with dynamic unbalance tends to wobbling once set into rotation.
re c): As the two heavy spots are diagonally opposed the wheel will never allow smooth ride, but tends to wobbling when set into rotation (hence b is correct).

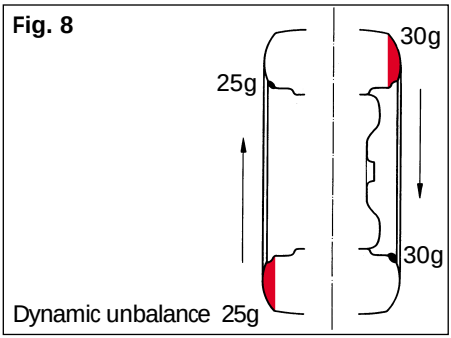


Important:
Dynamic unbalance is **only** recognized when the wheel is set into rotation.
The wider a tyre, the more increases the effect of dynamic unbalance, that is the more wobbling is noticeable during the ride. **Fig. 5 and 6.**



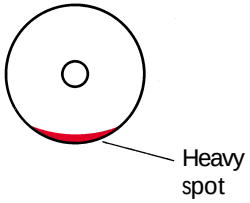
In this context let us consider the question of how and where static or dynamic unbalance can be eliminated.

Important for your understanding:
State–of–the–art wheel balancers divide the wheel into two halves, the so–called planes **(Fig. 7)**.
If the wheel possesses static unbalance (one heavy spot of , say, 40 g) that unbalance is compensated for by attaching each one balance weight of 20 g left and right at the diametrically opposite sides of the wheel **(Fig. 7)**.



If the wheel possesses **dynamic unbalance** (two heavy spots diagonally opposed) the so–called plane separation feature is applied: Each wheel plane (wheel half) is considered separately; the dynamic unbalance portion can only be compensated for diametrically opposed, that is at the same wheel side, because otherwise there would another unbalance.
In our example the unbalance of 25 g of the left wheel plane is compensated for by a balance weight of 25 g attached to the diametrically opposed (left) wheel position. The same procedure is applicable to the right wheel side (unbalance of 30 g) - **Fig. 8.**

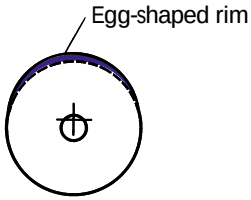
Fig. 9



2. Possible causes of unsmooth ride

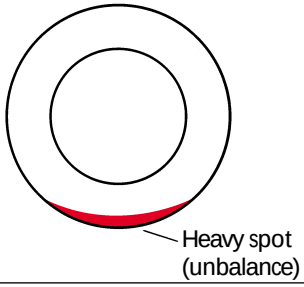
In their structure tyres and rims possess a variety of properties that might cause unsmooth ride:
First possibility:
The **rim** possesses unbalance, that is a heavy spot, which adversely affects smooth ride **(Fig. 9)**.
When the wheel is perfectly balanced, this defect of the rim is completely compensated for.

Fig. 10



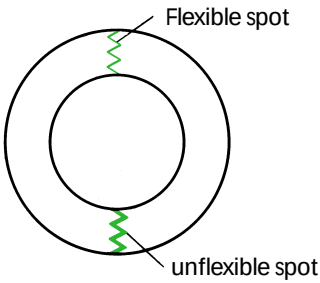
Second possibility:
The **rim** possesses admissible deformat-ion caused in manufacture - the so–called egg–shape **(Fig. 10)**.
The unsmooth ride will be noticed despite of perfect balancing of the wheel (balanced 'egg').

Fig. 11



Third possibility:
The **tyre** possesses unbalance, that is a heavy spot **(Fig. 11)**.
When the wheel is perfectly balanced this defect of the tyre is completely compensated for.

Fig. 12



Fourth possibility:
The internal **tyre** structure presents more and less flexible parts which means tyre deflection will vary over one revolution of the wheel, hence during ride **(Fig. 12)**.
The unsmooth ride will be noticed despite of perfect balancing of the wheel.

3. How to remedy unsmooth ride

What are now the techniques to remedy unsmooth ride on a vehicle?

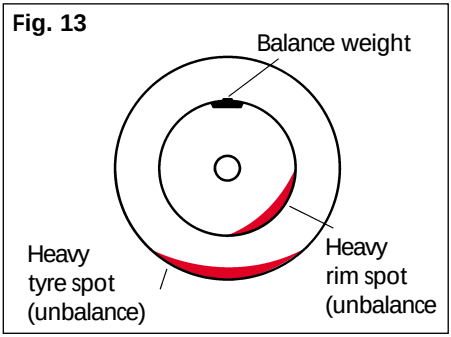


Fig. 13

1. Balancing

Tyre and rim unbalance is determined during the measuring run and compensated for using balance weights **(Fig. 13).**

Mind:
Unsmooth ride - due to deformation of rim and non–uniform tyre deflection - is still possible after balancing.

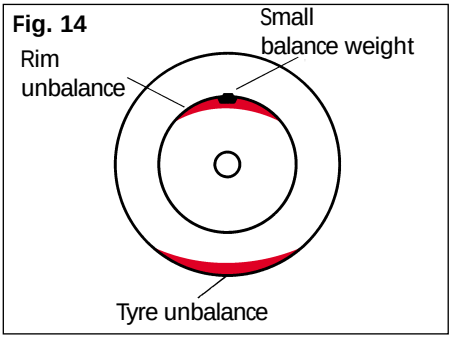


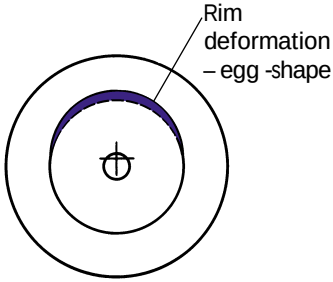
Fig. 14

2. Matching

With this technique nowadays used in garages and motor–vehicle workshops the tyre is readjusted relative to the rim until tyre unbalance and rim unbalance are opposed and then - at least partly - compensate for each other **(Fig. 14)**. The small residual unbalance thus achieved will be compensated for with balance weights.

Mind:
If the position of rim unbalance does not coincide with the position of rim deformation (which is very likely with alloy rims), unsmooth ride will still be possible after matching.

Fig. 15

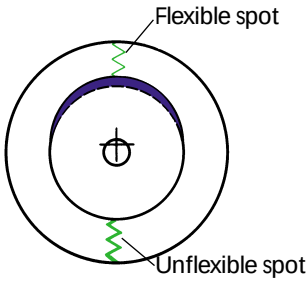


3. HOFMANN opto–ride technique

The most important target of this optimization procedure is to determine rim deformation, or more precisely the highest rim spot **Fig. 15.**

Why this takes three measuring runs - please see overleaf.

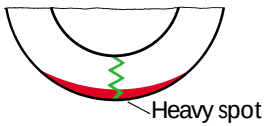
Fig. 16



How can rim deformation as determined be compensated for?

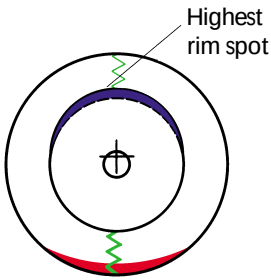
Rim deformation can only be compensated for by non–uniform tyre deflection (unflexible tyre spot - in technical terms radial force variations) **Fig. 16.**

Fig. 17



As exact determination of those unflexible tyre spots is only possible with expensive and highly sophisticated industrial machines.
HOFMANN follows the law of probability:
In most cases the unflexible tyre spot is also its heavy spot - Fig. 17.

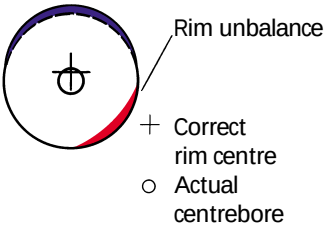
Fig. 18



With the opto–ride technique the unflexible heavy spot of the tyre is opposed to the highest spot on the rim **Fig. 18.**

Residual tyre and rim unbalance is then compensated for with balance weights.

Fig. 19

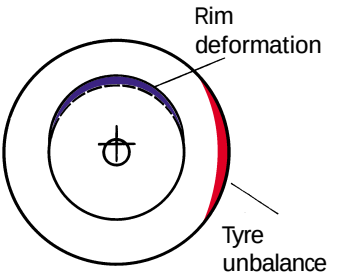


First measuring run

What will happen in the individual measuring runs?

Important: The rim must have the same position before every measuring run (e g valve in top vertical position).
In a **first measuring run** the rim alone, that is without tyre, is measured and the unbalance determined is compensated for electrically (will be added again after the last measuring run). What is left after the first measuring run is the effect of deformation of the rim, which is still unknown **(Fig. 19).**

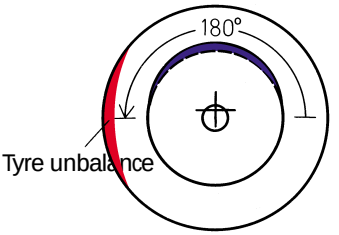
Fig. 20



Second measuring run

In order to determine amount and position of rim deformation another two measuring runs are necessary:
For a **second measuring run** the tyre is fitted on the rim and the whole tyre/rim assembly is measured on the balancing machine.
The measured result is composed of tyre unbalance and rim deformation **(Fig. 20)**.

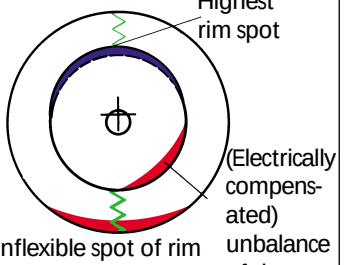
Fig. 21



Third measuring run

In order to exactly determine rim deformation, that is the highest spot on the rim, the tyre has to be readjusted by 180 degrees relative to the rim before the **third measuring run** - **Fig. 2.**

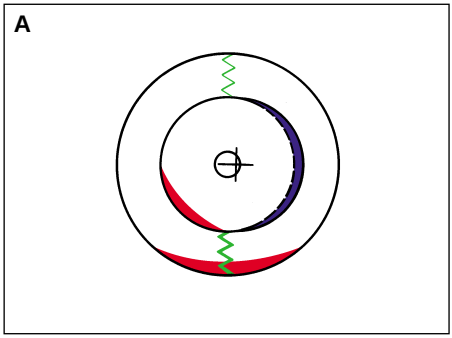
Fig. 22

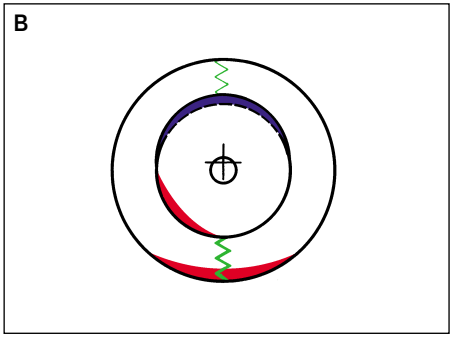


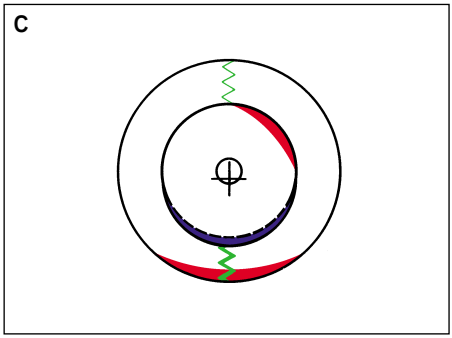
Optimization

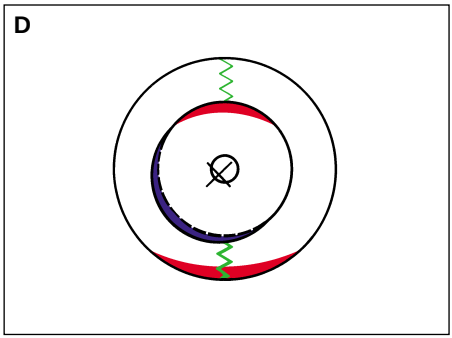
This means the highest spot on the rim is opposed to tyre unbalance, which mostly is the unflexible spot on the tyre **(Fig. 22)**.

In the **final measuring run** the rim unbalance previously compensated for electrically is added again and read out together with the residual unbalance of the tyre **(Fig. 22)**.







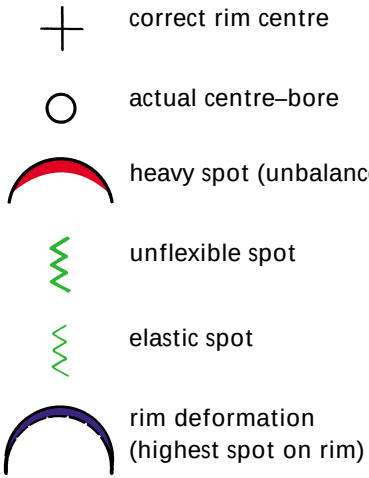


Let us sum up:

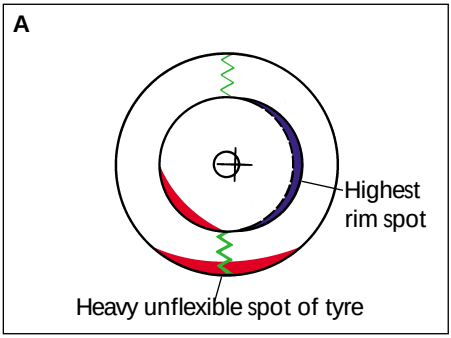
The patented HOFMANN opto–ride system does not only determine the unbalances of tyre and rim, but also rim deformation due to manufacture.
Rim deformation is compensated for by opposing the highest spot on the rim to tyre unbalance (where mostly the most unflexible tyre spot is located).
With the opto–ride technique HOFMANN offers the optimum smooth ride as achievable with garage equipment and is, therefore, able to satisfy even most sensitive customers with respect to driving comfort.
Do you think you now have correctly understood the fundamentals of optimization?

4. Test your understanding of optimization

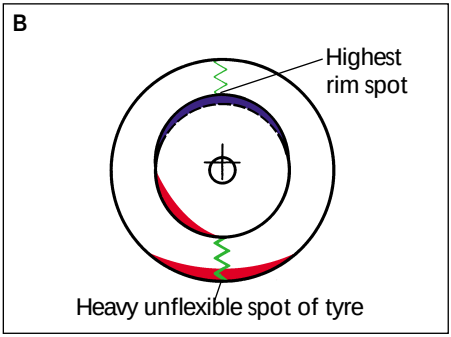
Which of the four examples given (A - D) shows the wheel in optimized condition?



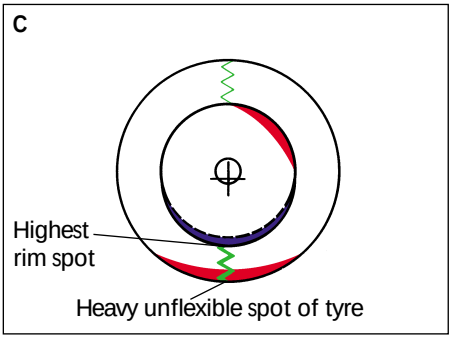
For the solution see overleaf!



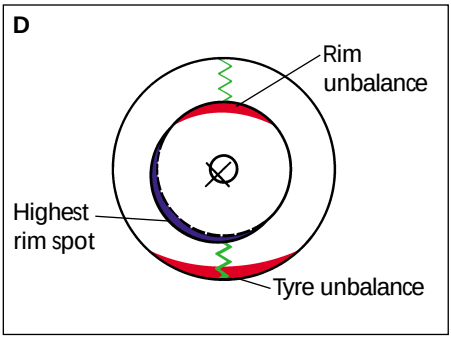
A: Either you did not look at the figure properly, or you have not understood the optimization procedure correctly. In figure A the highest spot on the rim (deformation) is not opposed to the heavy unflexible spot on the tyre - hence B is correct.



B: Congratulations! You have the correct understanding of what optimization is like.
Only in this example is rim deformation (highest spot on rim) opposed to the heavy unflexible spot of the tyre.
The position of rim unbalance does not import at all for optimization because it can easily be balanced.



C: May–be you simply made a slip.
When you look at the figure more closely you will see that rim deformation (highest spot on rim) and the heavy unflexible spot of the tyre coincide - whereas they have to be opposed with an optimized wheel. Hence B is correct.



D: By opposing tyre and rim unbalances (matching) residual unbalance can be reduced.
But rim deformation, which is not compensated for, will continue to adversely affect smooth ride.
Wheel optimization is shown in Fig. B.

Fig. 23

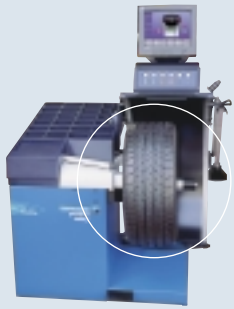
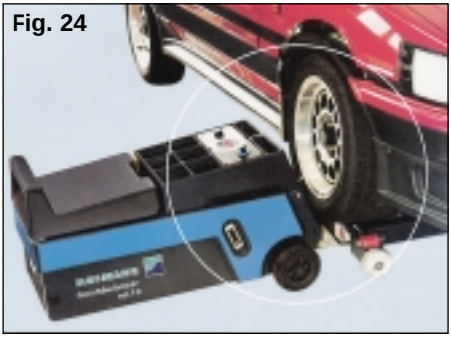


Fig. 24



5. On–the–car balancing

In this last chapter we would like to study the question why the **finishbalancer** (for on–the–car balancing) is an indispensable tool to achieve optimum ride of every vehicle despite of previous off–the–car balancing and optimization of the wheels.

The fundamental difference:
Both off–the–vehicle balancing and the HOFMANN opto–ride technique are "only" able to optimize ride as related to the wheel - **Fig. 23**.

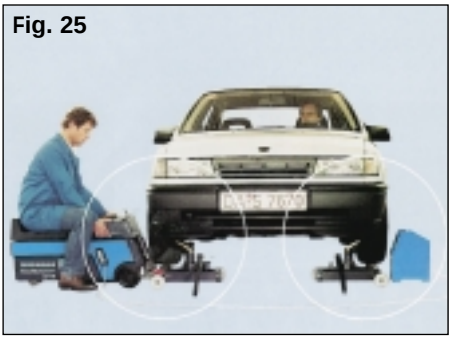
The finishbalancer, however, handles wheels and vehicle as one unit - Fig. 24.

Even a perfectly optimized wheel mostly presents new unbalance when fitted on the vehicle.
It is caused by added manufacturing tolerances of the vehicle components such as:

- manufacturing tolerances of wheel hub
- residual unbalances of hub
- unbalances in brake drum or brake disc

The HOFMANN finishbalancer determines the effects of such manufacturing tolerances of vehicle components, which might be transmitted to the wheel and produce new unbalance.

Fig. 25



With the selective measurement technique at different speeds HOFMANN ensures that even with driven wheels every wheel is considered singly and unaffected by influences of the opposite wheel - **Fig. 25.**

If you are interested in details on this measurement technique, please see our separate brochure "Precision balancing on the vehicle at different speeds".

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