HIGH SPEED WHEELS FOR AGRICULTURAL TRACTOR

The purpose of this document is to give some information that clarify the needs of European tractors, where in the last years the utilization speed have been increased from 40 to 50 kph and more, and how Titan Italia has faced and sorted out the problems of safety, comfort and strength.

MARKET DEVELOPMENT

In the past, in Europe the tractor was considered a means dedicated to the pure agricultural mechanization. Starting from the beginning of 1900 it had replaced the animal use in all operations mainly concerning the work of the ground until it had become the multi-funcional means supporting the farmer during the daily working life.
Only in the last ten years the use of the tractor has seen a deciding change; the request of performances always more specific and faster has brought to the creation of services companies in the agricultural economy. Following the increase of road transports, these companies have pushed the manufacturers of tractors to increase the power of the machines in order to minimize the working operation time and satisfy the need of driving at a higher speed.
While in Italy and France the local law admits the increase of the speed up to 40 kph, at the beginning of 1990 the new ranges up to 50 kph come up in the German market.
The first manufacturers are Fendt and Deutz, whom with Titan Italia develops and put on the market the new range of fixed track wheels, which are suitable for the use at high speeds thanks to particular process modifications.
At the end of 1998 the problem of high speed has been reviewed with a different method, that is the possibility to cancel the geometrical errors, although minimum, both of the rim and the tyre.
This new and fascinating challenge has been brilliantly faced and sorted out with the introduction on the market of a new range of wheels and tyres, where Titan Italia has shown itself as the winner again.

THE NEW FRONTIER

We have seen the development of the agricultural market and which are the new frontiers towards which the research and the components development should be addressed.
Also the characteristics of the tractor, as in all other vehicles, are influenced by the speed, in particular as far as the loads on wheels are concerned and which follow exponentially the increase of the same. In fact, moving from 40 to 50 kph there is an increase of the dynamic stress of more than 50% and it explains why until today there was not much interest in the control of vibrations caused by the geometrical unevenness of tyres and wheels. This is because the unbalance generates, with the rotation, strengths which modify the normal behaviour of the wheel. Such strengths are as higher as the speed increases and this problem was not remarkable when the tractors ran at 30 kph.

We all know that the wheels of our cars are equipped with counterweights in order to eliminate the unbalance of the assembly wheel-tyre and therefore this would make us consider operating in the same way for the agricultural wheels.
But if we look at the new cars we can notice that very rarely counterweights are added although the wheel and the tyre are not at all different from those that will replace them after wear.
This is due to the fact that tyres manufacturers have agreed with the wheels manufacturers on the marking of the point corresponding to the minimum and maximum values of the first harmonic, respectively. Therefore, coupling opportunely rim and tyre the overall unevenness is brought within acceptable limits.

Also for the agricultural tractors it has been taken the way of the development of a new range, that using what has been already applied in the field of car OEM equipment allows to minimize the vibrations thanks to the right coupling wheel-tyre.
It is to remind that for agricultural tractors the task to minimize the vibrations is very hard since normally they are not fitted with suspensions, except from some series which have been already studied expressively to reach the speed of 50 kph and more and which are fitted with a suspension system, although on the front axle only.

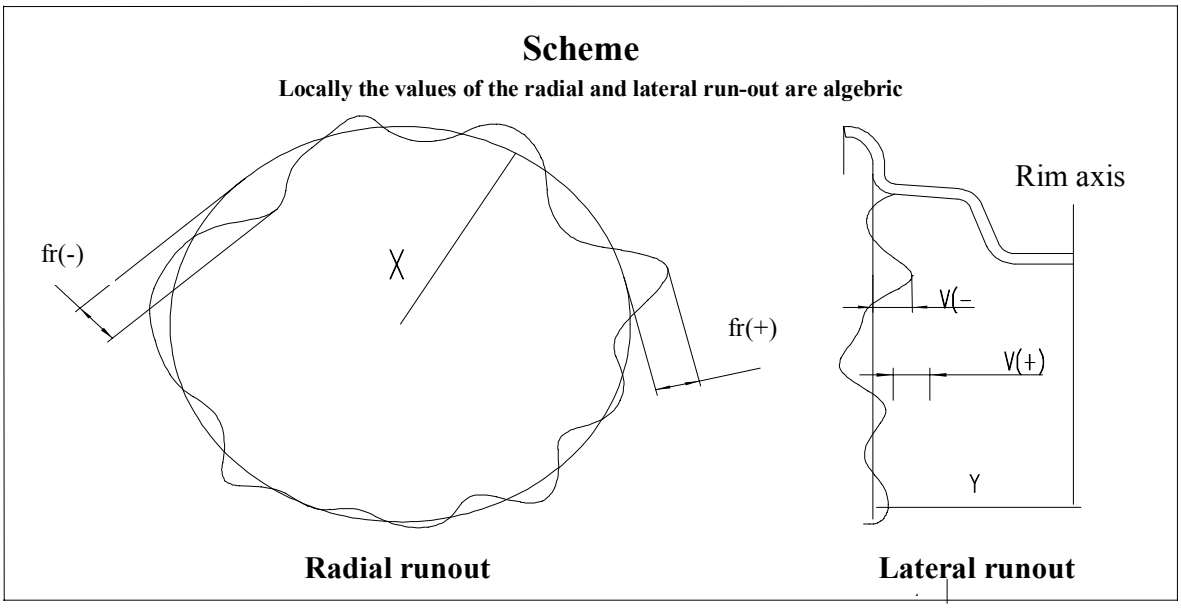
FIRST HARMONIC ON AGRICULTURAL WHEELS.

Purpose of this brief document is to explain some concepts about the uniformity and lack of uniformity in a wheel, without using as more as possible mathematics concepts and the science of vibrations.

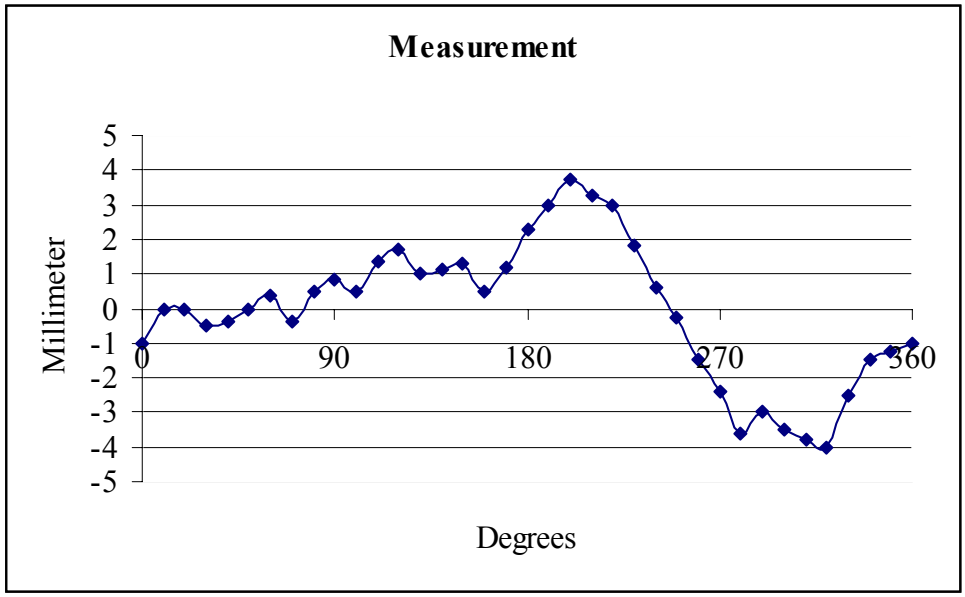
1. Definitions

1.1. The notion of Radial run-out, ”fr”, corresponds, for each of the wheel bead seats, to the variation over one complete revolution of the wheel, of the distance x of the bead seat vs the axis of rotation of the wheel. It is measured in mm.

1.2. The notion of Lateral run-out, "V", corresponds, for each of the rim flanges, to the variation over one complete revolution of the wheel of the distance Y of the rim flange vs. the mean plane of the rim (plane perpendicular to the axis of rotation of the wheel and equidistant from the 2 rim flanges). It is measured in mm.



Note: Radial run-out and lateral run-out relate to the mechanical notion of angular displacement (radial and axial). If we start with the measurement in a certain position, valve hole normally, and we read the run out value every 10°, for example, we record 36 values linked to a certain angular position, that we can put in a diagram like this:



Each value is linked to an angular position.

1.3. Uniformity implies that any characteristic of the wheel is constant in phase and magnitude both in static and in dynamic conditions around the circumference. It is related with asymmetry of mass distribution, geometry and forces generated when the solid is in motion.
Lack of uniformity in a wheel, when it is rotating around its axis, causes variation of forces, which may vary with the angular speed and are applied to the said axis.

1.4. Peak to peak (total) is the difference between the maximum and the minimum values of measurement signals, with a specific band width, during one revolution (in our case, the scale is in mm and the peak to peak value TIR= 7.75 mm (3.75 + 4), where TIR means total indicator reading).

1.5. First harmonic is the peak to peak amplitude of the fundamental frequency component of the Fourier series representing the variation. Its frequency is equal to the frequency of rotation.

1.6. Second (and higher order) harmonic is the peak to peak amplitude of the second (or higher order)frequency of the Fourier series representing the variation.

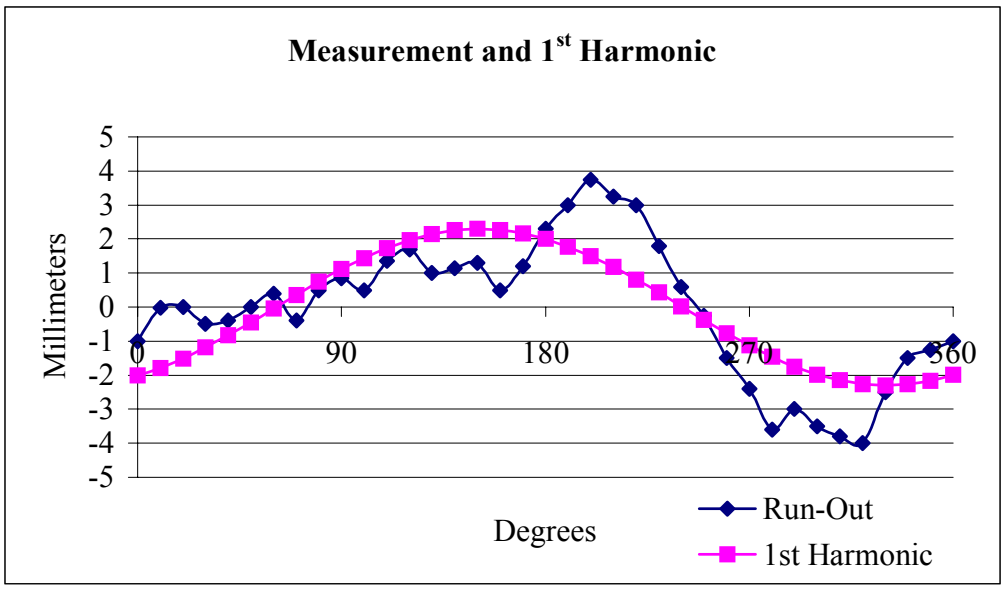
2. Mathematical series

All these definition are easy to understand except, of course, the first harmonic and the Fourier series. So, each variation can be represented (under certain conditions that in our case are satisfied) from an envelope of curves said harmonics.

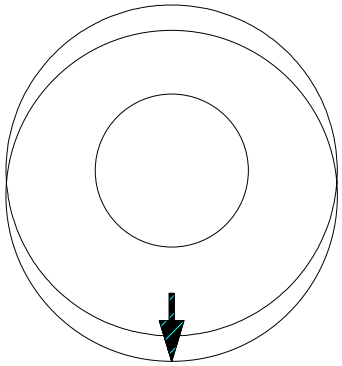
Fourier Series

$$Fx = a0 + a1\cos x + b1\sin x + a2\cos 2x + b2\sin 2x + \ldots\ldots\ldots + an\cos nx + bn\sin nx.$$

The first factor is the average value of our variation (sum of the 36 values divided by 36), the second (a1cosx+b1sinx) is the first harmonic, the last (an cosnx+bn sinnx) is the n-harmonic. These curves have a regular development and can be associated to a precise geometrical mean. So, the first harmonic of the variation (our example, see above) is:

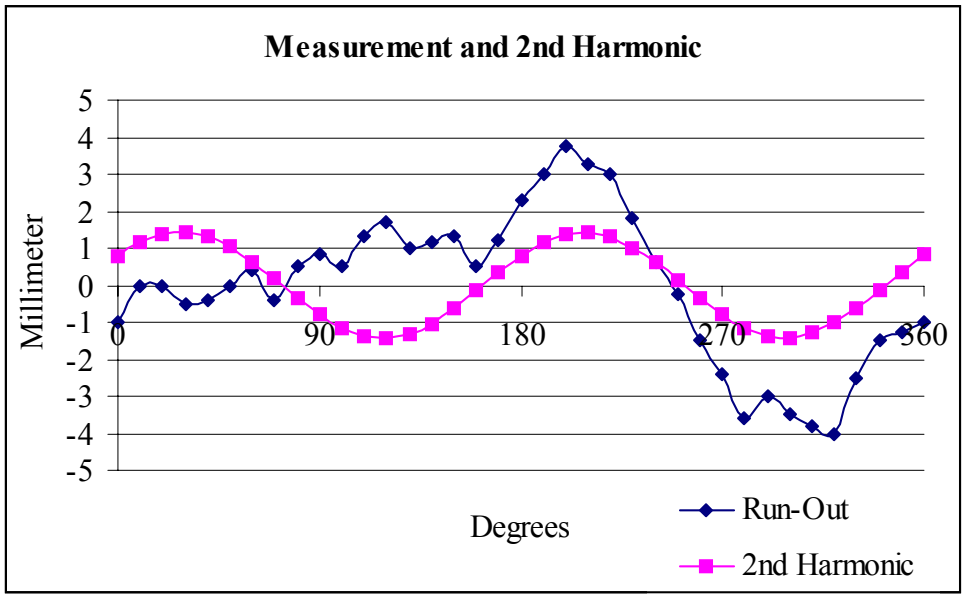


And its meaning is:

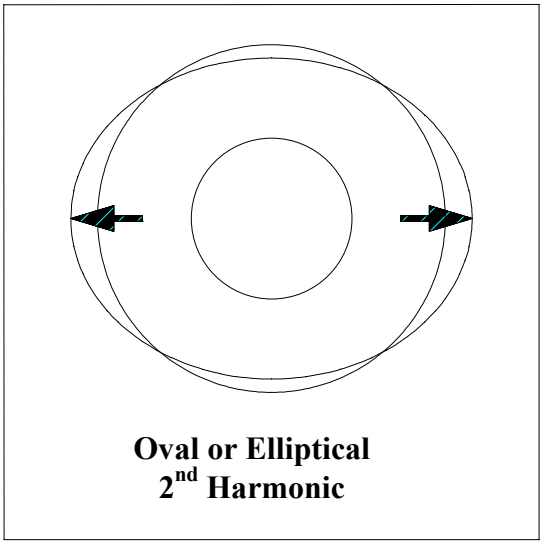


Eccentric 1st Harmonic

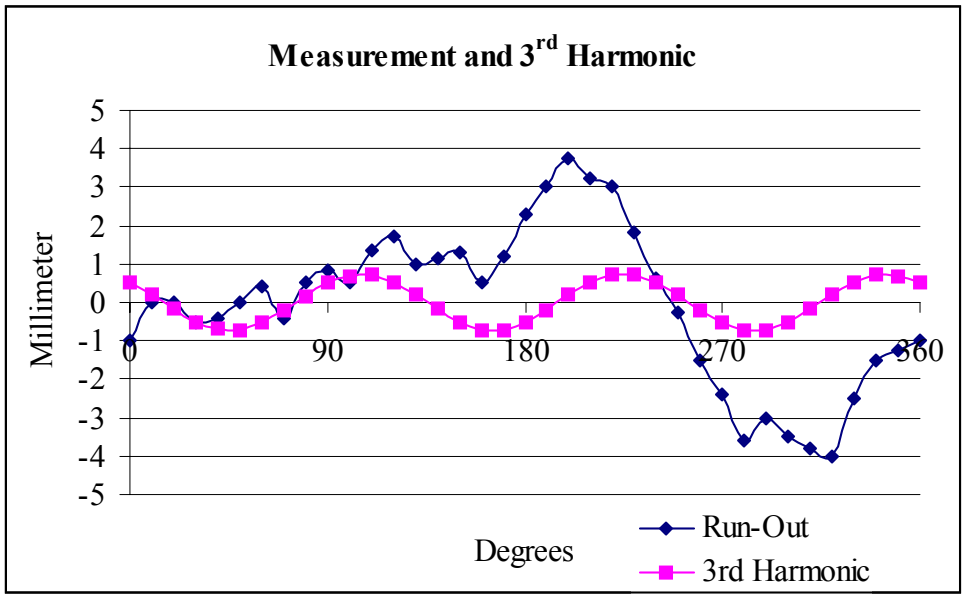
The second harmonic of the variation is:



And its meaning is:



The third harmonic of the variation is:



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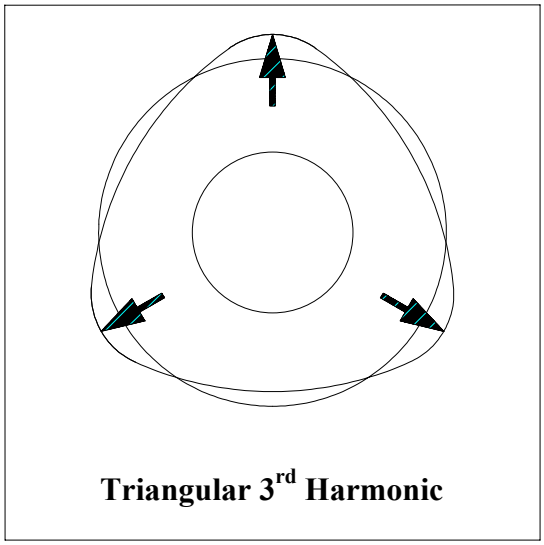
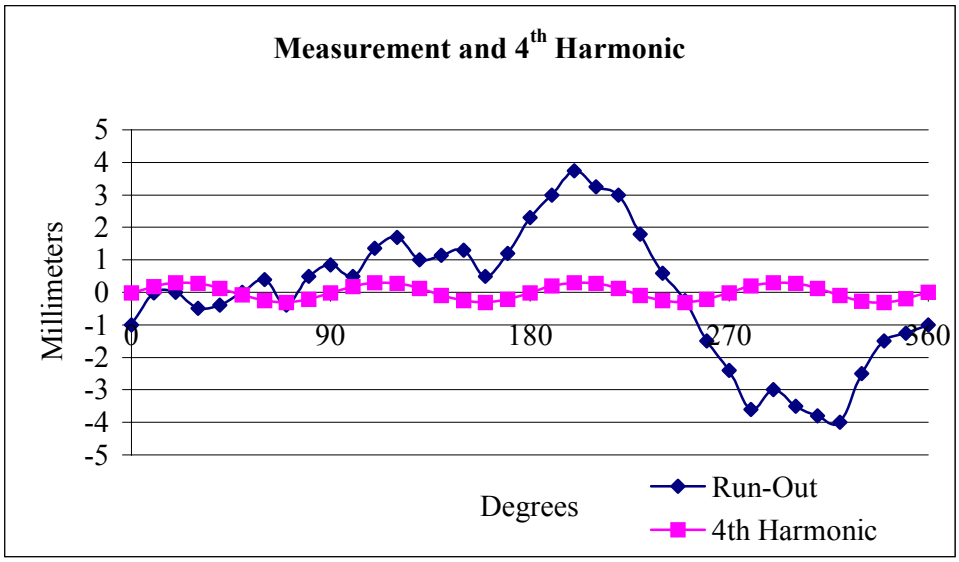
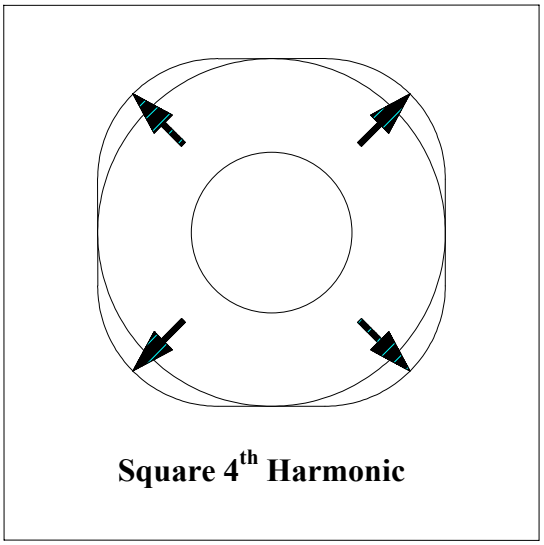


The fourth harmonic of the variation is:

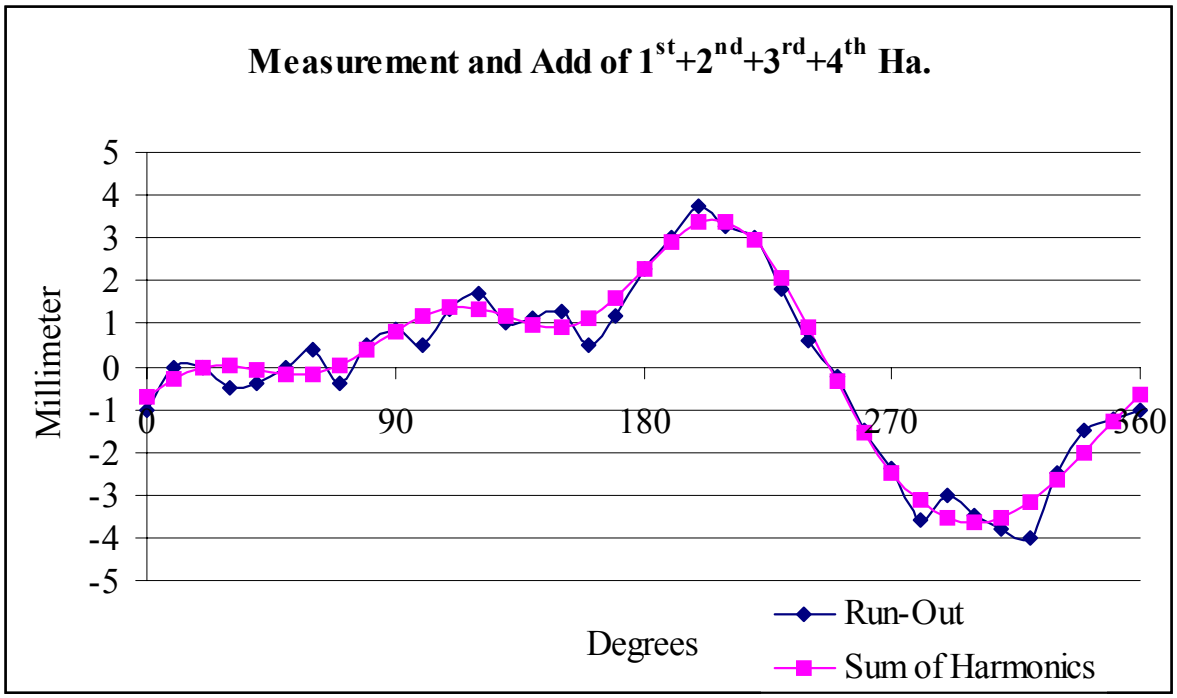


And its meaning is:



and so on.

It is easy to demonstrate that the sum of all the factors in the Fourier series is the original variation. In our example, if we do the sum of the first, second, third and fourth harmonic we have:



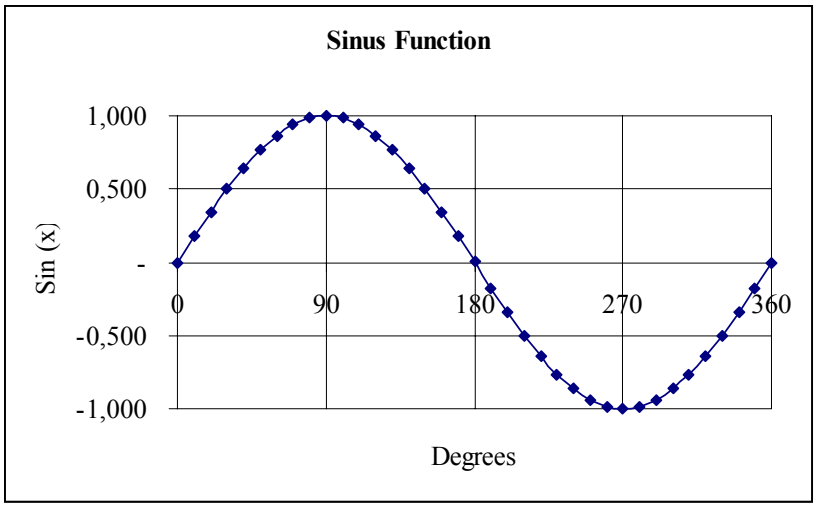
This gives us the possibility to analyse more in depth, from the technical point of view, what is the influence of each part of the original curve on the driver's comfort. So if we have an eccentric wheel, the wheel is round but it turns with its center in different position than the natural, and at each revolution the vehicle goes up and down.
We can easily understand the effect on the vehicle and on the driver and his ability to drive correctly and safely. The higher the first harmonic value the worse the driver's condition, and the higher the speed the worse the driving ability of the vehicle.
For the other harmonics, the reader can do similar considerations...

We remark, then, another important issue:
The first harmonic is the most important in terms of value. That means that engineers can concentrate their attention on the first harmonic and omit the other harmonics. That is true on 50 Km/h agricultural tractors, that is the subject of our interest.

Note: In the past, on agricultural wheels the word “first harmonic” was unknown and the designer defined the accuracy of the wheel in terms of uniformity, fixing run-out values only. Now, the very important changes in max road speed call for a different analysis of the lack of uniformity and the first harmonic becomes very important.

An other important thing is that, as we said above, the curve of the first harmonic is a sinusoidal curve. That means that on 360° it has one maximum and one minimum with the same absolute value, and that the angular position between the two is 180 degrees.

The sinus function has the following representation:



Our first harmonic has not these values, obviously, but it has this regular shape, even if the phase is not the same, that is if the zero value is not at 0° degree. On our diagram (see page. N°5.) at 0° the value was –2 mm, but the max and the min, approx. 2.3 mm were at 150° and 330° respectively. That is interesting for the reason that we will see later.

3. The fitted wheel

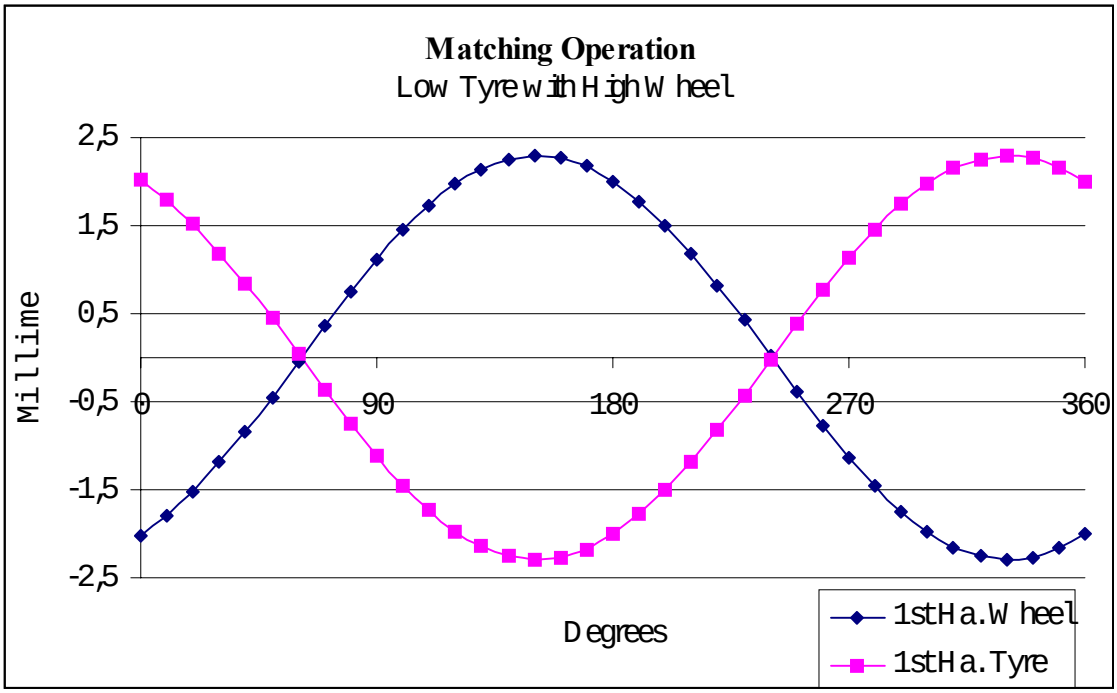
Other components influence the riding wheel.
The agricultural tyre has the same problem of lack of uniformity of the wheel. Using the same methods, the tyre manufacturers can measure the run out and then calculate the first harmonic.

At this point we can imagine what happens if we make the fitting (assembly of tyre & wheel) at random.
If we are lucky, we can have the low point of the first harmonic of the tyre in the same position where there is the high point of the first harmonic of the wheel. In this case we minimize the lack of uniformity of the wheel & tyre assy We may however be unlucky and match the high point of the wheel with the high point of the tyre maximizing therefore the geometric errors. This is the situation we had in the past, and that was not so dangerous because the speed of the tractor was low.

4. Solution

Now it is more and more needed to mark the high spot value of the first harmonic of the wheel and the low of the tyre for matching them during the fitting operation.

For easier understanding, if we suppose that the tyre has the same first harmonic of the rim, it is sufficient, referring to the 0°degrees point, to rotate the tyre of 180° (half revolution) for having the two diagrams in the condition shown below:



The total first harmonic is in this case zero! Actual cases, this is very unlikely, but we can minimize the total first harmonic value for having the best possible driver's comfort.
The last possible cause of lack of uniformity can be originated from the assembly clearance between the hub of the axle and the pilot hole of the wheel. The more the clearance, the more the eccentricity error. In some cases when assembling with care the wheel and centering the pilot hole on the hub, we can reduce the possible increase of the lack of uniformity on the wheel assembly.

THE PROCESS

The measurement and marking of the first harmonic has been considered as final objective, but the main characteristics of wheels for agricultural tractors produced with the standard production process make its achievement rather difficult.

After several studies and improvements of the production process of every single wheel component, Titan Italia has obtained the minimization of the single errors on shape that guarantees the continuity and a drastic reduction of the final geometrical unevenness at the point to guarantee a maximum run out of 2 mm for front wheels and 3 mm for rear wheels.

The wheels produced in this way are the bases to allow to proceed with the marking of first harmonic, which must be kept under 1.5 mm also for wheels of big dimensions. On this subject we wish to remind that for the road lorries, whose road speed is over 100 KPH, the more restrictive requests fix the maximum of first harmonic at 1.2 mm.

Titan Italia, in order to propose on the market a reliable and competitive solution, has developed and built an automatic equipment which is able to find and mark the angular position of the first harmonic maximum value.
This tool can control directly on the production line the range of wheels up to a diameter of 42” used by the most important tractors manufacturers.

The complete measurement and calculation system is controlled by a software expressively developed which guarantees the precision and continuity of the measures, reducing the human intervention to the minimum essential.
After having found the angular coordinate whom to the maximum of first harmonic make reference, the machine proceeds in marking indelibly the rim.
In case the customer mounts the tyres using an automatic tooling, an adhesive black stamp is placed for an easy identification by the optical devices.

NEW TITAN ITALIA WHEELS

For Titan Italia the previous observations have been the basis for developing a new range of wheels with values of geometrical unevenness, and therefore of first harmonic, extremely low, which are automatically marked in correspondence of the first harmonic maximum value.
These wheels matched with tyres produced, on purpose which are marked in correspondence of the first harmonic minimum value, are the best solution that can be achieved in terms of safety, comfort and strength without influencing drastically the costs.

The new range of 'High Speed Wheels' has sorted out the problem of vibrations and bouncing, allowing safe driving on road even at high speeds.

Presently it is available in the market a range of fixed wheels, front and rear, suitable for usage on agricultural tractors 80 through 300 HP.

For further information, please contact us.

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