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TECHNICAL MEMORANDUM 1391

REDUCTION OF THE SHIMMY TENDENCY OF·TAIL AND NOSE-WHEEL

LANDING GEARS BY INSTALLATION OF SPECIALLY

DESIGNED TIRES

By H. Schrode

Translation of "Verminderung der Flatterneigung von Sporn- und Bugwerken
durch Einbau besonders geformter Reifen," Bericht
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REDUCTION OF THE SHIMMY TENDENCY OF TAIL AND NOSE-WHEEL LANDING GEARS BY INSTALLATION OF SPECIALLY DESIGNED TIRES*

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ABSTRACT

Shimmy of tail and nose wheels may be eliminated by installation of dampers and use of large trail; however, this produces construction and operational disadvantages. It is more favorable to employ, instead of the customary tail-wheel tires, tires with lesser shimmy tendency. A description of the best possible form for these tires follows; furthermore, a few general concepts regarding the effects of the condition of the tire, of the type of rolling motion, and of the loading, are discussed.

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I. INTRODUCTION

Wheel shimmy is a phenomenon which is connected with the elastic properties of the tire and with its adhesion to the ground; it may therefore be influenced by modification of the tire elasticities and of the friction coefficient between tire and ground. Whereas a significant variation of the friction coefficient by means of structural modification

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of the tire is hardly possible, and for reasons of maintaining the
tracking characteristics is indeed not even desirable, the tire elastic-
ities may be varied within wide limits (ref. 1).

A desirable tire would have so little shimmy tendency that shimmy
would be with certainty avoidable even without use of artificial damping
if a trail still acceptable with respect to the bending stress on the
fuselage and to the danger of veering-off were chosen. Thereby the dis-
advantages would be abolished which are caused by the installation of
powerful dampers and by use of a very large trail for complete elimina-
tion of shimmy.

The question arises how a pneumatic tire[1] must be designed in order
to have minimum shimmy tendency while favorable springing properties per-
pendicular to the runway are maintained. According to the existing
theoretical work (refs. 2 and 3), a high lateral stiffness of the tire
favors the stability of a swivellable wheel, which is in agreement with
the results of shimmy tests with rigid rollers and solid-rubber rollers;
knowledge regarding the significance of further tire constants will have
to be gained by calculation of a number of examples.

However, the most favorable tire cannot be accurately calculated
since these theoretical reports are based on simplifying assumptions,
since, above all, the influence of the skidding effects is not sufficiently
clarified and since, moreover, for instance, the deceleration or acceler-
ation of the rolling motion and several additional tire constants affecting
the shimmy tendency have not been taken into consideration. However, if
one influences the deformations chiefly appearing in shimmy, namely the
lateral curvature of the flattened tire running surface, the lateral
deflection of the flattened tire region, and the twist of the tire about
the existent or imaginary vertical axis, then the effects of such measures
may be determined directly by shimmy tests, and criteria for the most
favorable design of tires may be obtained.

A brief report on a few partial results follows; the investigations
on tires of various form are being continued.

II. TEST TIRES AND TEST SETUP

The means available for influencing the tire elasticities, compared
to the customary balloon tires, are:

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[1]One could visualize employment of solid-rubber rollers which are
not subject to shimmy for tail and nose-wheel landing gears; however,
this is not possible because of the unfavorable springing properties
and the low durability at high rolling speeds.

Thickening and flattening of the tire running surface (like in automobile tires). Thereby the running surface in itself becomes stiffer, the curvature of the running surface in the flattened region under the action of a side force is reduced. Simultaneously, the area of contact between tire and runway decreases and adhesion of the tire to the runway (interlocking forces) is somewhat reduced.

Selection of a wide or low tire cross section and reinforcement of the side walls and of the bulge section of the tire for increase of the lateral and torsional stiffness.

The following pneumatic tires[2] are investigated:

(a) Balloon tail-wheel tires of different sizes, conventional design.
(b) Balloon tail-wheel tires with flat running surface (thickness in tire center about the same as in the conventional design).
(c) Balloon tail-wheel tires with flat running surface, thickened by 3 mm.
(d) Wide-rim tires (smooth contour tires).   ⎫ (Compare fig. 1
(e) Elliptic tires.   ⎬   from ref. 1)
(f) Spherical tires.   ⎭

The test setup is schematically shown in figure 1. The wheel runs on a drum of 1,600-mm diameter. The wheel fork is bolted to a vertical swivel axis with conical roller bearings; trails of -25 to +400 mm can be adjusted. A friction damper built into the swivel axis permits adjustment of a frictional moment up to approximately 4 mkg. The loading takes place by putting weights into the freely swivellable weight pan.

The drum is driven by a asynchronous-alternating-current motor. In the tests, the velocity range of 0 to 205 km/h was traversed in forward and return travel in 30 sec each so that the rolling conditions corresponded approximately to those in take-off and in landing of an airplane. At short time intervals, the swivelling system was struck with a rod, and every time the velocity was determined for which the shimmy no longer was damped. The results were represented in velocity-trail diagrams.

The shimmy deflection was limited to approximately ±4° by a stop. The friction moment of the swivelling axis due to the roller-bearing friction, for a loading of 600 kg and a trail of 300 mm, amounted to approximately 1.25 mkg. During the tests, the condition of the bearings, of the clamping, and of the damper mounting was checked continuously. Even slight play or elasticity would lead to a considerable increase in shimmy.

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[2]The balloon tires with flat running surface and the wide-rim tire were developed in cooperation with the Continental Company which graciously put them at our disposal free of charge. The elliptic and spherical tire were developed in cooperation with the Phoenix Company.

The influence of the drum curvature (compared to a plane runway) on shimmy is very small, according to Dietz and Harling (ref. 4). The friction conditions on the steel drum correspond approximately to those on firm runways with improved surface.

III. TEST RESULTS

A. General Concepts

1. Condition of the tire.- A tire is, to a large extent, a product of manual labor and, for this reason as well as for reasons of manufacturing technique, it cannot be as uniform as, for instance, a turned metal part. Somewhat uneven distribution of material, unequal stretching of the cords, and uneven wear cause, together with the nonuniformity of the inner tube, unbalances, lateral flapping, and faulty concentric running of the tire. These phenomena, often hardly noticeable in new tires, usually are intensified during the "time of growth" of the tire; moreover, the tire becomes "softer" with increasing use. All this causes a considerable increase of shimmy tendency, as has been already pointed out by Fromm (ref. 5) in his investigation of automobile tires. Figure 2 shows, for comparison, the range-of-shimmy curves of a new 290 × 110 balloon tail-wheel tire with flat and reinforced running surface, and those of the same tire after 200 km endurance run.[3] The difference is relatively large; above all, the speed range within which shimmy occurs, is considerably extended for the tire that has been used for a longer time. This finding is particularly important for dimensioning the shimmy damper since an increase of the area within the closed curve signifies an increase in the required damping. (Compare ref. 3.)

All further shimmy tests were, therefore, performed with tires which already had completed an endurance run of 200 km.

2. Rolling condition.- The type of rolling motion - whether the motion is accelerated or decelerated - also is of considerable importance. The shimmy ranges are displaced with respect to one another and of unequal magnitude. (See fig. 3.) For accelerated motion (take-off), that is, when the revolving drum transmits energy to the wheel, shimmy sets in only at higher speeds than those at which it ends again for decelerated motion (landing). The tangential forces transferred from the drum to the tire exert a stabilizing effect, in the sense of a brake. In the case of decelerated motion, shimmy appears again only at lower speeds. The speed range is considerably smaller in landing than in take-off. Below we have indicated, in comparisons of different tires, the shimmy ranges for accelerated motion. Tires which show a favorable behavior in accelerated motion are more favorable than others also in decelerated motion, and vice versa.

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[3]After having run such a distance, the tire usually has essentially completed its "growth."

3. Influence of the loading.- According to general opinion, increasing wheel loading increases the tendency toward shimmy. However, tests with various loadings showed that this is predominantly true only in the range below normal loading and is, moreover, different for different tires. It may happen that a tire which, for smaller loading, had been superior to another tire, proves inferior for higher loadings. For the standard 290 × 110 balloon tire, the shimmy tendency increases approximately up to a loading of 90 percent of the normal loading of $P_r = 450$ kg which is customary at present. In the case of a further increase in loading, the trail range within which shimmy occurs will be smaller again. (See fig. 4.) In figure 5, the trail q_0 required for freedom from shimmy is given as a function of the loading. For small loadings, the curves of the shimmy range within the first quadrant are closed; for higher loading, the curves are opened toward the abscissa like those calculated by Dietrich (ref. 3).

In order to evaluate two different types of tire design with respect to their shimmy behavior in flight operation, one must perform shimmy tests at the normal loading.

B. Influence of the Main Dimensions and of the Tire Form

1. Main dimensions.- If one has, in the borderline case, the choice between two tire sizes, installation of the smaller tire is advisable. Figure 6 shows the shimmy ranges of the 290 × 110, 350 × 135, and 380 × 150 tail-wheel tires, each for 400 kg loading and an inflation pressure of 4.5 atmospheres gage. For the 290 × 110 tire the range of shimmy is only about two-thirds as large as for the 380 × 150 tire. This difference is maintained also for higher and lower loadings.

By increasing the load capacity of tires now in use, it could in some cases become possible to install the next smallest tire and thus to produce a reduction in shimmy tendency. On the other hand, one may conclude from this result that it is favorable to keep the loading of tail- and nose-wheel landing gear as low as possible.

2. Form of tire.- An essential reduction of the tendency toward shimmy may be obtained by the simple means of reinforcing and flattening the tire running surface of a balloon tire. Figures 7(a) and 7(b) show, for comparison, the ranges of shimmy of a customary 290 × 110 balloon tire, furthermore, of a tire of the same size with flattened running surface, and of a tire with flat and, in addition, reinforced running surface for loadings of 200 and 400 kg (in flight operation, the loads on tires probably lie mostly within this range). As shown in figure 8, the maximum of shimmy tendency occurs approximately at a trail $q = 0.25D$. (D = tire diameter.) The damping required for complete elimination of

shimmy is considerably smaller for the tire with flattened and reinforced running surface than for the standard tire (see fig. 8) and for a trail of 0.5D and a loading of 300 kg still amounts to 0.7 mkg instead of 1.05 mkg. This amount can usually be supplied by the sliding friction of the swivel-axis bearing. On the other hand, if a larger amount of friction is present, a smaller trail may be selected.

Increase in lateral stiffness by widening of the rim likewise causes, as had been expected, a reduction in shimmy tendency compared to the balloon tire. Figure 9 shows the shimmy ranges of a 380 × 150 balloon tail-wheel tire and, for comparison, those of a 390 × 155 wide-rim tire for 600 kg loading. The lateral stiffness of the wide-rim tire is about 2.5 times as high as that of the balloon tail-wheel tire; the reduction in range of shimmy is, therefore, not proportional to the stiffness. The lesser shimmy tendency of the wide-rim tire is maintained throughout a loading range of 200 to 800 kg. The total-friction moment (including bearing friction) required for elimination of shimmy for a trail of 220 mm = 0.56D is for the balloon tail-wheel tire approximately 1.9 mkg and for the wide-rim tire, in contrast, only 1.3 mkg.

Elliptic and spherical tires also show less tendency toward shimmy than the balloon tail-wheel tire which is customary at present.

The investigations are being continued with the aim of producing a pneumatic tire with minimum shimmy tendency.

IV. SUMMARY

The investigations made so far resulted in the finding that it is possible to produce tires of considerably lesser tendency toward shimmy than the balloon tail-wheel tires now in use by means of a special shaping of the tire cross section and of the running surface. Small main dimensions, very stiff running surface, high lateral and torsional stiffness, small area of contact between tire and runway are favorable. In many cases, it will be possible to eliminate the shimmy of swivelling wheels, without installation of artificial dampers, solely by an arrange- ment of tires of low shimmy tendency. It will be expedient not to forego the damping effect of the friction of bushings of the swivel-axis mounting.

The tire industry has the task of contributing to the solution of the problem of shimmy by the development of small and particularly uniform tires of low shimmy tendency.

Translated by Mary L. Mahler
National Advisory Committee
for Aeronautics

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3. v. Schlippe, B., and Dietrich, R.: Das Flattern eines bepneuten Rades. Bericht 140 der Lilienthal-Gesellschaft für Luftfahrtforschung.

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5. Becker, G., Fromm, H., and Maruhn, H.: Schwingungen in Automobillenkungen. M. Krayn, Berlin 1931.

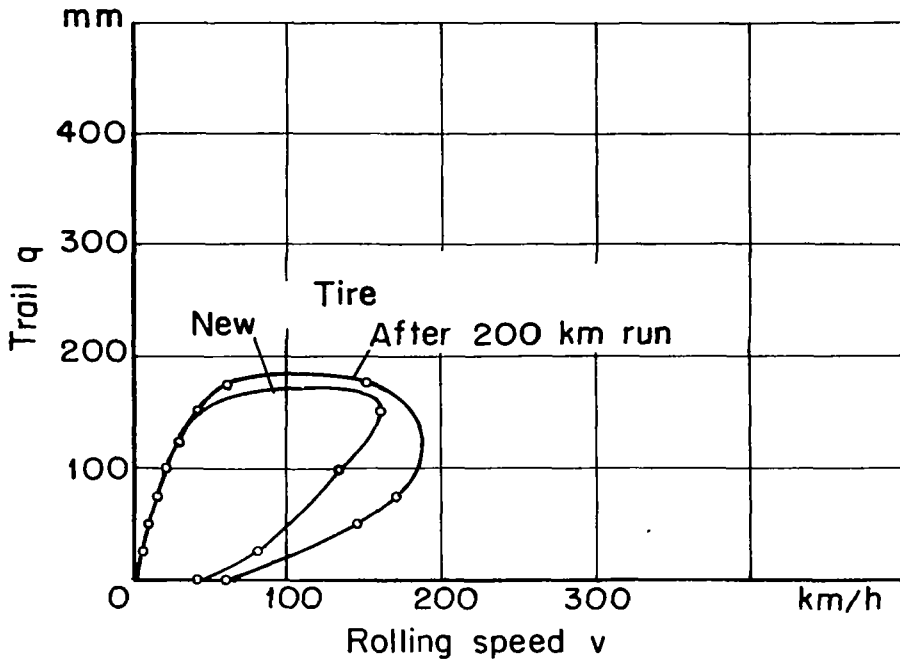Figure 1.- Diagram of the shimmy setup.

Figure 2.- Ranges of shimmy of tires of equal load capacity but different length of use. 290 x 110 tire with flattened and reinforced running surface. Loading $P_r = 400$ kg, air pressure $p_i = 4.5$ atmospheres gage.
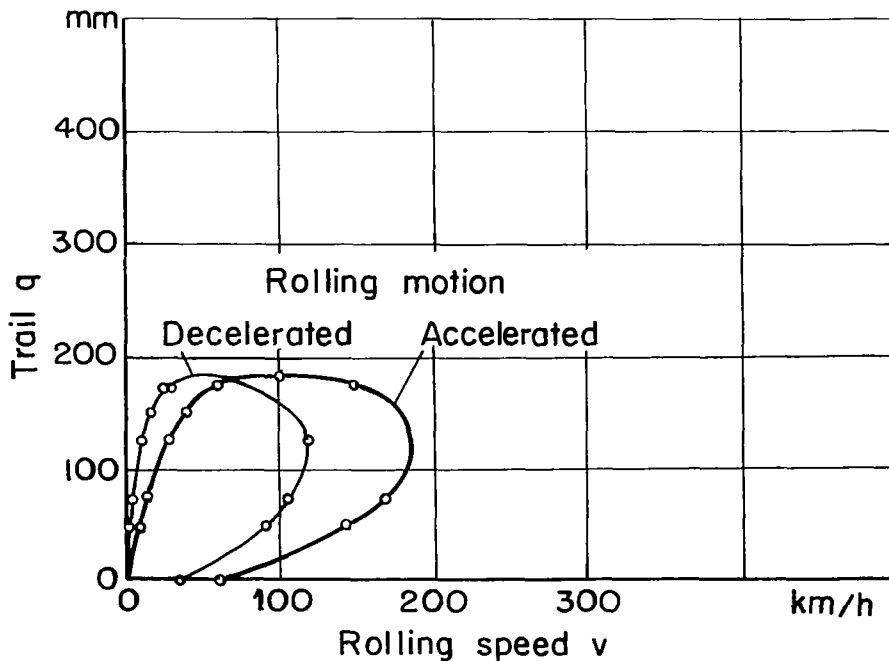

Figure 3.- Influence of the type of rolling motion on shimmy. 290 x 110 tire with flattened and reinforced running surface. Loading $P_r = 400$ kg, air pressure $p_i = 4.5$ atmospheres gage.
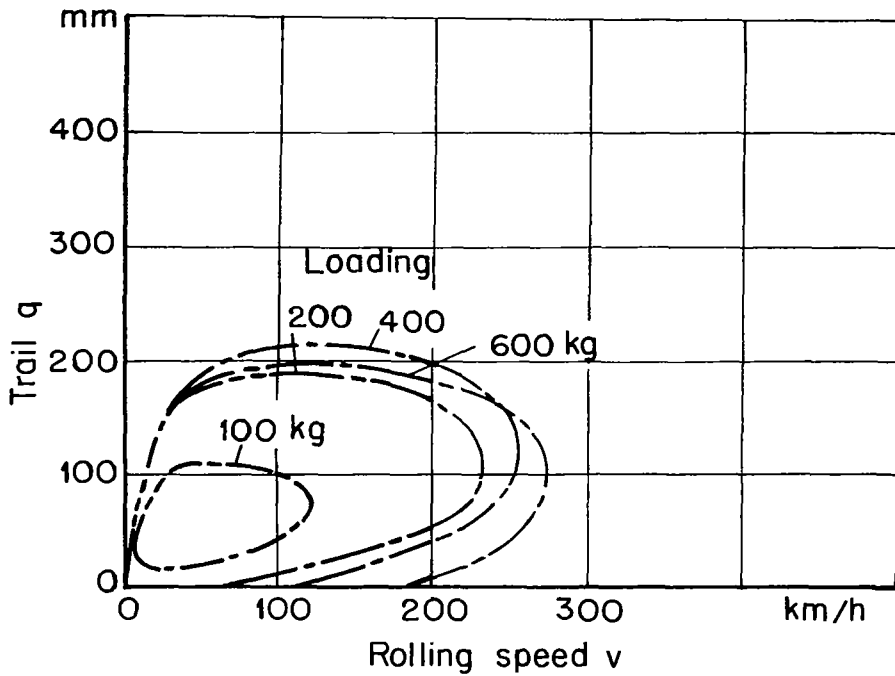
Figure 4.- Influence of the loading on the tendency toward shimmy.
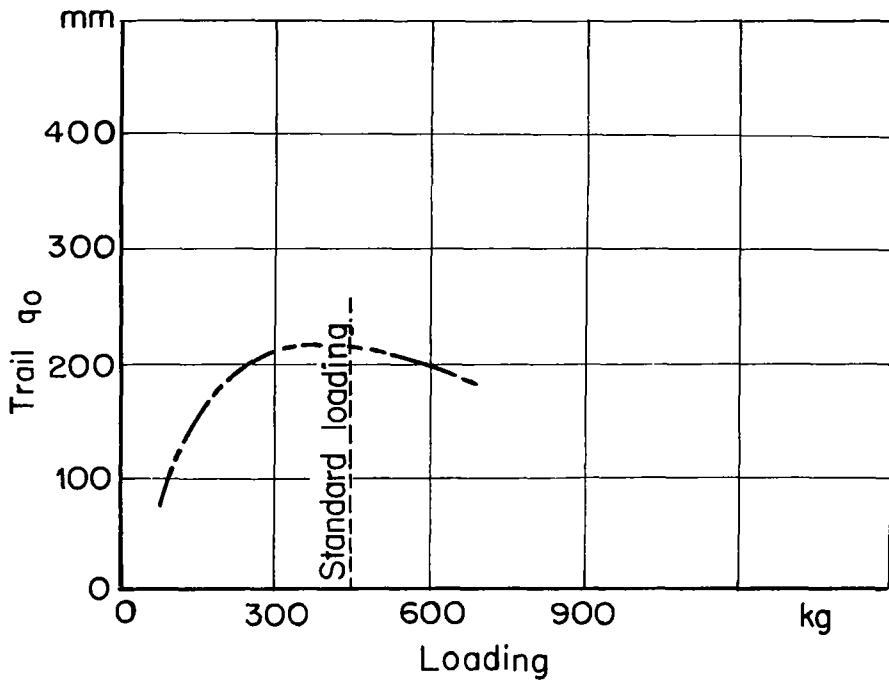290 x 110 balloon tire. p_i = 4.5 atmospheres gage pressure.

Figure 5.- Trail required for freedom from shimmy as a function of
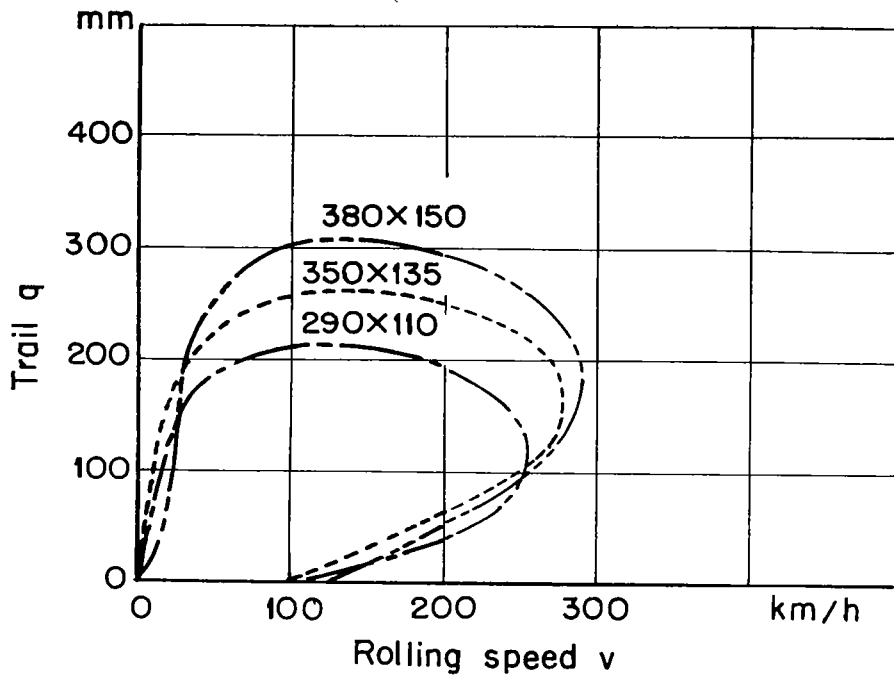the loading. 290 x 110 tire, air pressure p_i = 4.5 atmospheres gage.

Figure 6.- Influence of the tire size on shimmy. Loading $P_r = 400$ kg, air pressure $p_i = 4.5$ atmospheres gage.