National Advisory Committee
for Aeronautics
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AUG 15 1935

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 537

A PRELIMINARY DETERMINATION OF NORMAL ACCELERATIONS ON RACING AIRPLANES

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Washington
August 1935

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SUMMARY

Rules and methods for insuring safe structural strength of racing airplanes used in the major air meets in this country have recently been considered. Accelerometer records made in racing airplanes during actual air races were therefore considered desirable, and the National Advisory Committee for Aeronautics undertook the measurement of accelerations during races as a part of an investigation of loads on airplanes during all conditions of flight.

Accelerations were measured on four airplanes at the Miami All-American Air Races in January 1934 and January 1935. The airplanes were representative of the fastest limited and unlimited displacement racing airplanes in current use in this country. Records during two races, or flights, on the race course were obtained with each airplane. The maximum normal acceleration recorded was 6.2g and the minimum was -1.2g.

INTRODUCTION

Within the past year there has been a movement toward the adoption of regulations establishing minimum requirements for the structural strength of racing airplanes used in the major air meets in this country. In order to carry this objective forward, the Professional Racing Pilots' Association, which includes in its membership all the active racing pilots of the country, has been considering recommendations regarding rules and methods for insuring safe structural strength adaptable to the conditions under which racing airplanes are designed and built.

One of the first requirements for formulating rational design rules is a knowledge of the maximum loads to which the structure may be subjected in use. It would be possible to set down load conditions that were both safe and economical of structural weight as a result of an analysis of general load-factor measurements. The National Advisory Committee for Aeronautics has been accumulating data over a long period of time with regard to the loads imposed on airplane structures both by the effects of atmospheric turbulence and by all types of flight maneuvers. Analysis of this work alone would give a reasonable basis upon which to formulate design rules, but data obtained by direct measurements on racing airplanes during actual races were considered desirable. At the suggestion of representatives of the above-mentioned association and because the N.A.C.A. is interested in the general subject of airplane loads, steps were taken to get accelerometer records during air races.

The first of these records was made in the Wedell-Williams racer No. 44 during the Miami All-American Air Races in January 1934; at the same races a year later, January 1935, records were made in three more racing airplanes: the Keith Ryder San Franciscan, the Chester Special, and the Wittman Chief. The Wedell racer was of particular interest because it was the fastest landplane in this country. It held the world's landplane maximum speed record for some time and later exceeded that record by 2 miles per hour, making an average speed of 306.2 miles per hour on the 3-kilometer speed course at Cleveland, September 4, 1934. The other three airplanes are representative of the fastest specially built limited displacement racing airplanes now in use in this country.

APPARATUS AND METHOD

The four airplanes in which the records were obtained are listed in the following table with the types and displacements of the engines and the high speeds of the airplanes determined on the 3-kilometer speed course at Cleveland in September 1934. These speeds indicate the maximum performance of the airplanes at the time the Cleveland trials were made. The speeds at the time the acceleration records were made are shown in the last two columns. These latter speeds were necessarily less because of flying on a closed course, but they are reliable

values for the average flying speed while the records were made because timing was started after the airplanes had passed around the scattering pylon and returned to the race course.

The wing loading of the Wedell racer could be estimated from fairly reliable data to be 17 pounds per square foot. Similar data for the other airplanes were not available, but general practice would indicate that the wing loading was nearly 20 pounds per square foot.

Airplane	Engine	Displacement	Maximum speed on 3-km course at Cleveland	Average speeds for races	
				First acceleration record	Second acceleration record
		Cubic inches	M.p.h.	M.p.h.	M.p.h.
Wedell No. 44	Wasp Jr.	985	Not known[1]	236	Not a race
Keith Ryder	Menasco	544	235.3	225.5	205.1
Chester Special	Menasco	363	229.7	221.5	220.3
Wittman Chief	Cirrus Hermes	349	201.1	189.3	184.4

[1]306.2 m.p.h. with Wasp engine.

The accelerometers used in making the records were of the maximum recording type. The usual practice of setting the scales of the instruments to read 1.0g when the airplane was in steady level flight was followed in these tests. The instrument used in the Wedell racer was mounted on the instrument panel and the others were attached to the backs of the pilots' seats. In all cases the instruments were properly oriented for measuring the normal component of acceleration. In the case of the Wedell racer the air speeds were recorded as well as the accelerations.

Damping was obtained by means of friction in these instruments. The adjustment was set as closely as possible to critical damping in each case, but the damping was actually slightly less than critical. No difficulty was experienced with three of the installations, but the instal-

lation in the Chester racer was not entirely satisfactory because for small deflections above and below that for 1.0g the stylus cut through the heavy paper of which the record card was made. The important part of the records for these tests was the maximum reading; and, since the stylus reached the maximum deflections usually only once in the time interval corresponding to the width of the stylus mark, the card was not cut and friction would have been normal when the maximum and minimum deflections were recorded.

The instruments were calibrated both before and after the tests.

PRECISION

The estimated limits of error were as follows: ±0.1g for the instrument used in the Wedell racer, ±0.25g for the instruments used in the Chester and Wittman racers, and ±0.5g for the instrument used in the Keith Ryder racer. The calibrations made before and after the tests checked almost exactly for the first three instruments mentioned and showed a maximum difference of 0.5g in the case of the instrument used in the Keith Ryder racer. The records for this instrument were read on the basis of a calibration curve that was a mean line between the calibration before and the calibration after the tests. There was thus an uncertainty in the calibration of ±0.25g; the remainder of the estimated possible error was allowance for vibration effects on the instrument and errors of reading. The air-speed readings on the Wedell racer were undoubtedly in error by several miles per hour because the air-speed head was only 1 foot directly ahead of the nose of the wing.

When examining the entries in the tabulated data, it will be noticed that frequently an acceleration of less than 1.0g and one of considerably more than 1.0g are entered opposite the same time reading. This grouping occurs only because the time scale was so short that it was difficult to distinguish between events that may have occurred as much as 30 seconds apart.

RESULTS

The following table gives maximum and minimum values of acceleration read over most of the speed range in the Wedell racer.

Accelerometer record of January 13[a]		Accelerometer record of January 14[b]	
Indicated air speed	Acceleration	Indicated air speed	Acceleration
M.p.h.	g	M.p.h.	g
138 to 190	2.0	147	3.2
200	3.0	160	3.6
226	3.6	200	5.3
270	5.1	216	4.3
250 to 260	-.1	237 (max. ind.)	2.0
278 (max. ind.)	1.0 to 3.5	196 to 208	0

[a]Race of 3 laps on 10-mile course; average speed of 236 m.p.h. for race.

[b]Exhibition flight, 3 laps on 5-mile course.

Mr. Wedell reported that, as he was not pressed by the other airplanes in the race of January 13, he did not try to turn closely around the pylons because he wanted to keep out of the way. When he made the second record, he was alone on the course and pulled in close to the pylons.

The records taken in the Keith Ryder, Chester, and Wittman racers were read at the points where the deflections above or below that for 1.0g were greatest. The readings are tabulated in the following table.

Airplane: Keith Ryder Pilot: Roger Don Rae				Airplane: Chester Special Pilot: Arthur C. Chester				Airplane: Wittman Chief Pilot: S. J. Wittman			
Event 18 Jan. 11 Av. speed: 225.5 m.p.h.		Event 19 Jan. 12 Av. speed: 205.1 m.p.h.		Event 18 Jan. 11 Av. speed: 221.4 m.p.h.		Event 19 Jan. 12 Av. speed: 220.3 m.p.h.		Event 18 Jan. 11 Av. speed: 189.3 m.p.h.		Event 19 Jan. 12 Av. speed: 184.4 m.p.h.	
Time	Accel. g	Time	Accel. g	Time	Accel. g	Time	Accel. g	Time	Accel. g	Time	Accel. g
4:24.5	5.2	4:25	3.7	4:21	2.9	4:30	4.5*	4:35	4.0	4:23	4.2
4:25	4.9	4:26	-.6	4:22.5	2.9	4:33	-.5*	4:37	4.7	4:25	4.2
4:25.5	3.5		4.5*	4:23	3.3*		4.3	4:38	-.3	4:26	4.0
4:26.5	5.2	4:27.5	-1.0*	4:24.5	2.7	4:36	-.2		5.0*	4:27	4.0
4:27.5	6.2*		3.5	4:25	-.2		4.5*	4:39	3.8	4:29	-.6
4:28	-.3	4:28	-.6		2.9	4:38	-.5*	4:40	4.5		4.7*
	3.9		3.5	4:26	0		4.1	4:41.5	-.5	4:30	-.6
4:29	-.3	4:29	-.1		2.9				4.5		
	4.1		2.9	4:28	-.4*			4:42	3.3		3.8
4:30	4.3	4:29.5	-.1					4:43	4.5	4:30.5	3.8
4:30.5	3.6		4.0					4:44.5	4.0	4:32	4.6
4:31.5	-.3	4:31	-.1					4:46	3.6	4:35	-1.2*
	4.4		3.5					4:47.5	3.0		3.6
4:33	-.4*	4:31.5	-.1					4:49	-.6*	4:36	3.8
	3.0		3.1						3.3		
		4:32	4.0					4:49.5	-.3		
		4:33	-.4						3.5		
			2.2								
		4:36	2.2								

*Maximum or minimum value for flight.

The deflections at times between those of the readings were not far enough above or below that for 1.0g to be of interest. The number of readings shown is therefore indicative of the number of times that large air loads occurred during the flight.

DISCUSSION

The maximum acceleration obtained in these records was 6.2g recorded in the Keith Ryder racer. Maxima of between 4.5g and 5.0g occurred fairly frequently. The minimum values obtained were -1.2g in the Keith Ryder and -1.0g in the Wittman racers. These values represent the inverted-flight load factors since the accelerometer was set to read 1.0g when the airplane was in steady level flight.

The general appearance of the records showed certain distinguishing characteristics between the different pilots and airplanes. For example, the records made in the Wittman racer showed noticeable regularity of occurrence and uniformity of value of the maximum accelerations, particularly in the first part of the record for event 19. It is quite probable that this uniformity in handling the airplane is due in a measure to the fact that the pilot has used a simple indicating accelerometer mounted on the dash of this airplane for a considerable amount of flying. The value of such acceleration consciousness on the part of the pilot is indicated also by the results from the Chester racer. The pilot in this case had not used an indicating accelerometer, but he had been trying to follow the recommendations of reference 1 in which it was stated the best racing turns should be made with a fairly definite value of maximum acceleration, about 4.75g for a 246 mile per hour airplane. He thus held to fairly uniform accelerations, though of different values on different days. The conditions of competition and his physical condition may have led to the different absolute values on the two days.

These loads may be considered representative of the loads that a racing type airplane experiences during a race. They offer little information, however, on the effect of atmospheric turbulence as the pilots reported the air to be comparatively smooth for all the flights during which these records were made. In view of the large value of the accelerations obtained, it seems that only the most violent of atmospheric disturbances could produce air loads

comparable with those experienced during race maneuvers.

CONCLUSIONS

The maximum acceleration recorded was 6.2g and the minimum -1.2g. These accelerations occurred while the airplanes were flying at near their maximum speeds.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 6, 1935.

REFERENCE

1. Jennings, W. C.: "Cornering" at High Speeds. R. & M. No. 1281, British A.R.C., 1930.