15. A SURVEY OF THE EFFECT OF GROOVED RUNWAY OPERATIONS ON THE WEAR OF COMMERCIAL AIRLINE TIRES

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SUMMARY

Commercial airlines have been exposed to grooved runways for less than 2 years. The investigation of worn commercial aircraft tires indicates that grooved runways have not contributed to any apparent change in tire-wear patterns. The incidence of chevron cutting has increased since grooved runways have become operational, but these superficial cuts have not been considered to be detrimental to aircraft tire wear.

INTRODUCTION

Safer operation of high-speed aircraft can be achieved by a system that improves tire traction. Current aircraft braking systems, as well as tire-tread designs and runway-surface materials are able to cope with most wet or flooded runway conditions. Under extraordinary operating conditions, hydroplaning can occur and can result in loss of braking control and tire traction. Considerable research has been carried out to find useful and effective ways in which to solve this extraordinary operational problem. Techniques explored in the solution of this problem included new tire design, change in tire-tread patterns, various pavement textures, air jets to remove water ahead of the tire tread, and pavement grooving. Each of these techniques display some level of performance in solving the sliding and skidding problems encountered by pilots.

15

Research was carried out in Great Britian at Farnborough (ref. 1) to determine tire wear on an open graded macadam surface and a grooved runway of similar asphalt construction. The open macadam surface contained a considerable amount of coarse aggregate and was therefore very porous in appearance. As a reference for this tire-wear study, a grooved runway was used which was cut transversely with grooves 1/8 inch deep, 1/8 inch wide, and 1-inch pitch. A Meteor Mk. 7 aircraft was used in this study to determine tire wear. The amount of tire wear was determined by measuring groove depth and loss in tire weight. The results indicated that the grooved surface caused approximately 8 percent more wear than the open macadam surface. The increased tire wear was considered to be acceptable when considering the alternative of landing on smooth wet runways with hydroplaning situations being encountered. Similar research at NASA Langley Research Center (ref. 2) has indicated that runway grooving presented the most effective approach in solving the problem of low tire ground friction and traction losses. This research effort was concerned primarily with optimizing the groove configuration with respect to aircraft control. This investigation evaluated groove spacings of 1 inch, $1\frac{1}{2}$ inches, and 2 inches. Groove widths were 1/8 inch, 1/4 inch, and 3/8 inch with groove depths of 1/8 inch and 1/4 inch. These groove configurations displayed various levels of improved braking performance but none of the configurations exhibited any excessive tire wear under the conditions of this research investigation. This preliminary work was not conclusive as to tire-wear—grooved-runway relationships, but these initial studies were very optimistic regarding tire wear under these operating conditions.

The research at Langley Research Center resulted in the recommendation for grooving runways at Washington National Airport, Kansas City Municipal Airport, John F. Kennedy International Airport, and Midway Airport at Chicago. The groove configuration and surface composition for the four grooved commercial runways in the continental United States are summarized in table I. These runways have been grooved in different configurations as part of the overall program of increased tire traction and ground safety. This program of runway grooving by NASA Langley Research Center and NASA Wallops Station is coordinated with Federal Aviation Administration, Air Transport Association of America, and U.S. Air Force to find solutions to this critical problem of aircraft safety.

TABLE I.- GROOVED RUNWAYS IN UNITED STATES

Airport	Date completed	Groove	Construction
Washington National	April 1967	$\frac{1}{8}$ inch wide × $\frac{1}{8}$ inch deep × 1 inch	Asphalt
Kansas City Municipal	May 1967	$\frac{1}{8}$ inch wide × $\frac{1}{4}$ inch deep × 1 inch	Asphalt and concrete
John F. Kennedy International	August 1967	$\frac{3}{8}$ inch wide × $\frac{1}{8}$ inch deep × $1\frac{3}{8}$ inch (sloped to 5/32 inch)	Concrete
Chicago Midway	September 1968	$\frac{1}{4}$ inch wide × $\frac{1}{4}$ inch deep × $1\frac{1}{4}$ inch	Concrete

DISCUSSION

Operations At Grooved Runways

The four domestic grooved runways in the continental United States have been in operation 2 to 18 months. Washington National Airport was the first U.S. commercial terminal to have regularly scheduled airlines operating from grooved runways. Since the grooved runways at Washington National became operational, approximately 600 000 individual main-landing-gear tires covering a large spectrum of tire sizes have been exposed to landing and take-off from this modified surface. The commercial high-speed jet airplanes that are operational from this airport include Boeing 727 models equipped with 49×17 tires as well as smaller aircraft that are fitted with 40×14, 40×12, or 39×13 main-gear tires.

The grooved runway at Kansas City Municipal Airport became operational shortly after the Washington National Airport. The Kansas City Airport traffic has approximately 50 percent of the domestic Washington National operation and has the large high-speed jets operating at their facilities in addition to the smaller jets used by the trunk airlines. The John F. Kennedy International Airport completed the grooving of the main runway in August 1967. Since the completion of this grooving, the runway has been utilized by the scheduled airlines, the tire contact levels established for the John F. Kennedy Airport runway being comparable with those of the Washington National Airport. The domestic operations at the John F. Kennedy Airport have Boeing 707 airplanes with 46×16 tires and DC-8 airplanes equipped with 44×16 tires in addition to similar distributions of aircraft types and tire sizes that were observed at Washington National. The Midway Airport has just completed the grooving of its runways in September 1968 and has not had the grooved runways in operation long enough to establish aircraft types or operational levels. When the overall commercial domestic operation originating from grooved runway surfaces is considered, the data indicate that statistically about 6 percent of all commercial aircraft tires are exposed to grooved runway landings and take-offs. However, if specific airline operations are separated from the overall national averages, the frequency of grooved operations varies considerably. One airline, for instance, has approximately 15 percent of its domestic operations originating from grooved runways. In a similar manner, other airline operations can be separated and demonstrate grooved runway operations above the so-called "6 percent average." The incidence of chevron cuttings has been noticed by these airlines, but they did not express particular concern with this slight cutting.

A leading independent tire retreader solely concerned with aircraft tires has observed approximately 12 000 aircraft tires per month that have been returned for retreading. This company services most of the international airlines as well as domestic airlines. During the processing of commercial tires prior to production, all tires are inspected for structural defects or service damage. As the grooved runways became operational, the incoming worn tires have been monitored for any changes in wear patterns or deep cut propagation as well as for interply separations or bead failures. The investigation of the incoming tires did not show any particular change in ordinary tread wear except for the increased amount of chevron cutting. During this period of tire observations, no tires were removed early for chevron cutting associated with grooved runways.

The field representatives are continually monitoring airline tire maintenance operations at grooved runway airports and have noted little, if any, adverse effects from these runways. Increased chevron cutting has been noted by airline maintenance personnel as the grooved runways became operational, but this type of cutting was not considered to be detrimental to aircraft operation. In the operations an increase in customer response to chevron cutting has been noted, but this condition has not been the cause of premature tire removal. Deep cuts from foreign objects and cut propagation are the principal reasons for tire removal. The chevron cutting associated with grooved runways appears not to contribute to the deep cut problems mentioned previously.

Normal Tire Wear

Normal tire wear for an aircraft tire is a compilation of tread wear, sidewall cracking, bead separations, chafer failure, interply delaminations, cut propagation, groove cracking, as well as rubber reversion due to skid burns. These factors are aggravated by the tire deflection of 30 percent which permits extensive sidewall flexing and resultant heat buildup. All these factors are contributory to tire wear, but the most prevalent cause of premature tire removal is foreign-object cuts. The preventative maintenance for foreign-object cutting is not controllable by tire design but is primarily a housekeeping situation. This type of tire damage has been pointed out in order to demonstrate the distinction between chevron cutting and deep cuts. Chevron cutting has been an integral part of overall tire wear for years. These superficial cuts are generally less than 2/32 inch in depth and can be found well distributed around the circumference of the tread. These cuts can be generated from brake chatter conditions in the aircraft and do not necessarily reflect the condition of the landing surface. These chevron cuts have never been considered to be detrimental to aircraft operation and were never considered as the cause for premature tire removal.

Tire-Wear Pattern Indicative of Grooved Runways

The grooved runways for commercial airlines have been operational for 18 months and represent approximately 1.5 million main-gear tire contacts with these modified surfaces. The exposure to these surfaces, as stated earlier, represents 6 percent of total domestic operation, but will be slightly higher for certain airlines. Since the beginning of 1968, incoming worn tires have been monitored for indication of wear patterns attributable to grooved runway operations. The appearance of chevron cutting on the center rib portions of the tire was the characteristic most noted for grooved runway operation.

Photographs of 49×17 commercial aircraft tires showing examples of chevron cutting are presented as figure 1. This type of cutting is rather superficial and was not the cause of tire removal. Since the tires have been observed for indication of grooved runway effects other than the chevron cuts, no other common wear characteristic has been noted. As can be seen in the photographs, the chevron cuts in some tires appear to have been worn away by normal operations. From the observations the commercial grooved runways are not contributing significantly to increased tire wear. The field representatives maintain a continuing surveillance of customer operations and tire-maintenance related problems. This field contact provides the manufacturer with the current status of his products and informs him of any change in operations that affect tire wear. The incidence of increased chevron cutting was promptly recognized by the tire maintenance personnel, but this condition was not considered to be a factor in aggravated tire wear. This type of cutting has been observed for years and has never been considered a reason for tire removal. The operations personnel felt that grooved runways were contributing significantly to safer aircraft ground operations and that any increase in tire wear was readily compensated by the safer operations.

Grooved Runway Studies at NASA Wallops Station

Since grooved runway operations have less than 2 years experience in this country, the wear characteristics associated with this type of runway operation are not clearly established at this time. The major problem in monitoring such a program with commercial airlines is the fact that the airlines do not have consecutive landings on grooved surfaces. The most intensive study of grooved runways and aircraft operations has been conducted by NASA on the landing research runway at NASA Wallops Station located at Wallops Island, Virginia.

Wallops Station is the site of an intensive program on runway grooving and its effect on aircraft tire traction under dry, wet, and slush-ice conditions. Runway 4/22 at Wallops Station was modified to contain both asphalt and concrete surfaces with grooved and smooth configurations. The surfaces were grooved 1/4 inch wide by 1/4 inch deep on 1-inch pitch configuration which was considered to be optimum for aircraft tire traction. Although the primary interest in this study was aircraft braking and ground control, a supplementary part of this study was the effect of grooving on overall tire wear. A Convair 990 aircraft was used in this study equipped with 41×15.0-18 tires. The study involved the plane being taxied at various speeds and then the brakes being applied on the various surfaces to determine aircraft control and braking. Also included in the study were several touch-and-go landings to evaluate hydroplaning conditions on all surface configurations. During one phase of this investigation, the field representatives participated in the study to ascertain the type and severity of tire-wear characteristics that would be generated on grooved runways. In this phase the conditions of the tires were monitored before and after each operational sequence to detect any change in overall tire appearance.

The Wallops study considered the smooth or worn tire configuration to be the most conducive to hydroplaning and loss of ground control. The use of worn tires in the study was considered to be unsafe; therefore, a smooth tire profile was fabricated to offer pseudoworn tire conditions and the most aggravated situation for hydroplaning.

These special tires were run through the sequence of taxiing and touch-and-go landings and were monitored for wear after each sequence. The usual tire-wear determinations based on groove depth were not applicable to these smooth tires; therefore, overall appearance, cutting, or surface changes were the criteria for evaluation. These test conditions were extraordinary with respect to tire punishment. The aircraft would touch down on wet or iced surface smooth-configuration runways and hydroplane until the grooved section was reached, which would initiate wheel spin-up from the hydroplaning condition and provide braking conditions and ground control. This abrupt change from hydroplaning to rolling conditions leads to extreme stresses being placed on the aircraft tire during the landing. This particular test sequence involved approximately thirty-seven (37) individual operations on the various runway surfaces. Examination of the smooth tires after this severe punishment showed only slight chevron cutting, 2/32 inch deep, which was not considered to be detrimental to continued aircraft operations. These tires did not exhibit deep cuts or other surface changes; therefore, the wear level was not considered to be severe.

The second phase of this study involved the evaluation of conventional tire treads and effect of grooving on tire performance. As in the earlier studies, the aircraft would go through a series of taxis at various speeds and touch-and-go landings. These tires permitted the determination of tire wear by means of tread-groove-depth measurements. Again, the field representative monitored tire conditions during the test sequence. The initial studies were carried out on dry surfaces and were then repeated on damp and flooded runways. After each phase of the test, the tires were checked for wear and cuts. The wear patterns on the tires were considered to be normal. Some chevron cutting was noted, but was not considered to be detrimental to aircraft operation. Operations on damp or flooded smooth surfaces resulted in hydroplaning and when the aircraft reached a grooved area, wheel spin-up occurred and braking control was established. Although these operating conditions were severe, tire wear was considered to be normal and chevron cutting to be nominal. In all these studies where wheel lock-up had occurred, there was no evidence of rubber reversion.

The results of this specific tire study in the overall program of increased tire traction indicated that tire wear was essentially normal for operations on grooved runways under severe operating conditions. These studies involving precisely controlled studies of tire wear and grooved runways clearly indicate that tread wear and cutting are not adversely affected by these modified surfaces. Deep cuts and cut propagation were not detected in these studies; therefore, it appears that grooved runways will be beneficial to safe aircraft operations and will not introduce adverse maintenance problems for commercial airlines.

FUTURE RESEARCH

Research efforts are directed exclusively toward retreading of aircraft tires to improve cut resistance and tread life. These two parameters are considered to be paramount in improved maintenance performance for commercial aircraft operations. Actively under development in the research facilities are new tread profiles designed to reduce hydroplaning characteristics and provide better traction.

CONCLUSIONS

Operations of high-speed aircraft on four commercial grooved runways in current use in addition to tests on the landing research runway at NASA Wallops Station have indicated the following conclusions:

1. Commercial aircraft operations on grooved runways have not demonstrated any significant changes in tire wear.

2. The grooved runways cause superficial chevron cuts on the commercial aircraft tires, but these cuts are not considered to be detrimental to tire service.

3. Observations of worn commercial tires indicate that grooved runways do not tend to propagate deep cut growth or to increase cut migration.

4. There is no evidence to date that suggests grooved runways are contributing to other tire damage problems such as interply delamination, chafer failures, bead separation or groove cracking.

REFERENCES

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2. Horne, Walter B.; and Brooks, George W.: Runway Grooving for Increased Tire Traction – The Current Program and an Assessment of Available Results. NASA paper presented at 20th Annual International Air Safety Seminar (Williamsburg, Va.), 1967.

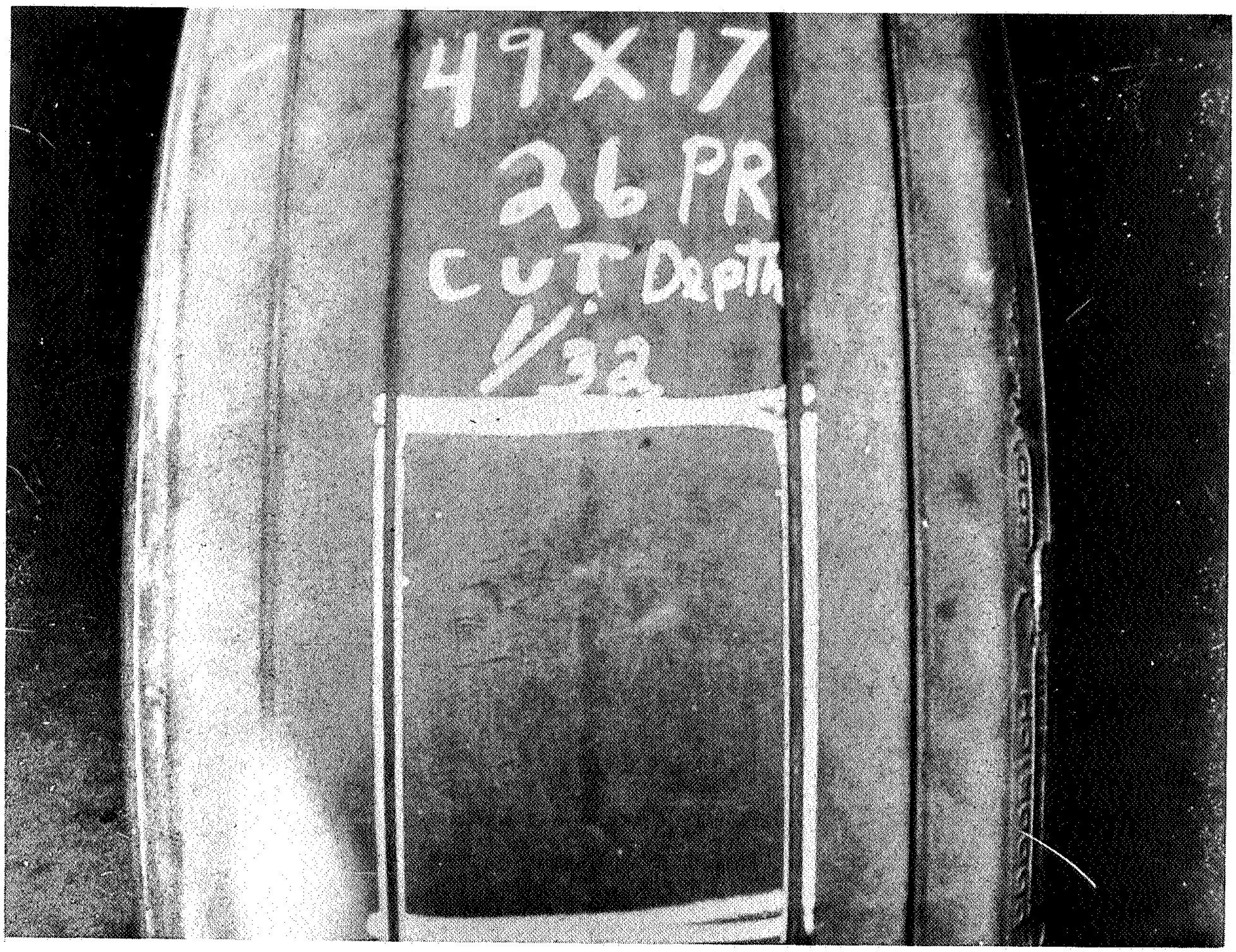

Figure 1.- 49 × 17/26 ply rating tire.

Figure 1.- Continued.

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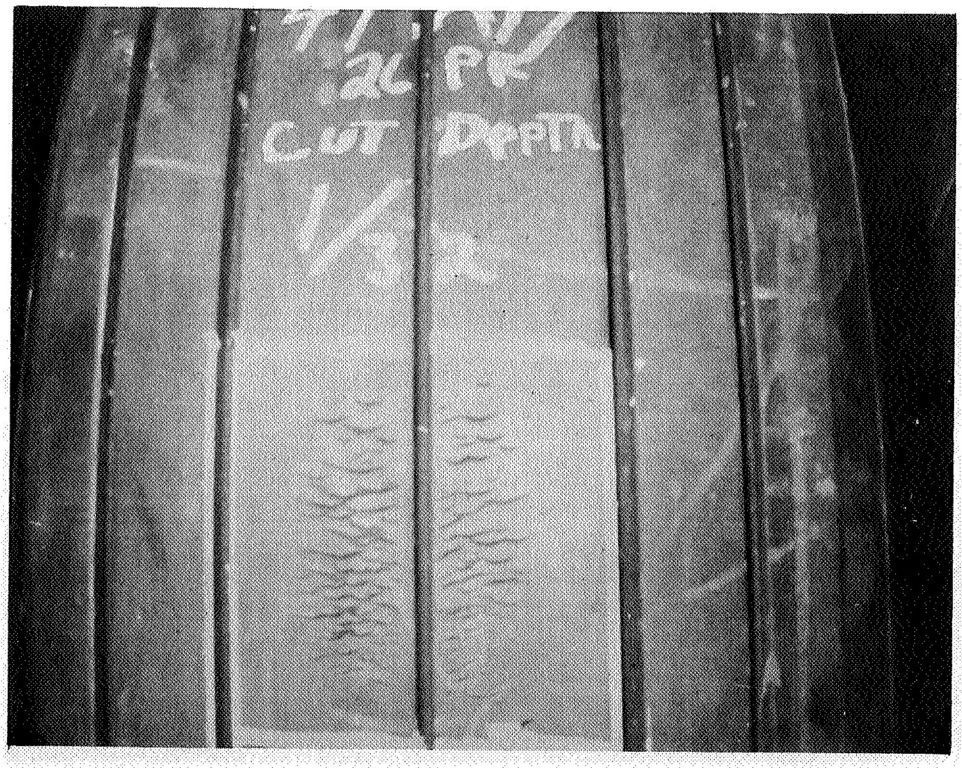

Figure 1.- Concluded.