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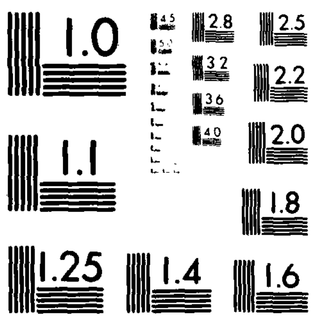


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# TIRE TESTING SYMPOSIA: A SUMMARY


CHARLES P. MERHIB

MATERIALS TESTING TECHNOLOGY DIVISION


December 1981



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ARMY MATERIALS AND MECHANICS RESEARCH CENTER
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## ABSTRACT

Four symposia on nondestructive testing of tires were held from April 1973 to May 1978. Sponsored by AMMRC, these symposia gathered together NDT tire experts from the United States and foreign countries to present the results of their work, exchange ideas, and provide a forum for discussion of problems common to Government and industry. Working panels on various NDT methods were conducted during these symposia. Proceedings of the four symposia, including panel summaries, have been published. This report summarizes and offers comments on the overall findings of the working panels.

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## INTRODUCTION

From April 1973 to May 1978, the Army Materials and Mechanics Research Center, under the chairmanship of P. E. J. Vogel, sponsored four symposia on nondestructive testing of tires.* The purpose of these symposia was to gather together NDT experts in tire testing to present the results of their work, exchange ideas, and provide a forum for discussion of problems common to Government and industry. Working panels on NDT methods pertinent to tire testing were established at each symposia. This report is a summary of the findings of these panels and follow-up recommendations.

It was particularly interesting to note the number of individuals whose main efforts were concerned with nondestructive testing of tires, a narrow, highly specialized field. Moreover, the enthusiasm with which they discussed tire testing clearly indicated deep involvement and strong feelings on the subject. However, the tire manufacturing business is highly competitive and secretive, and information exchange was in the areas of general knowledge. Many companies were extremely cautious about presentations made by their personnel. This caution, to some extent, was caused by adverse legal actions. Such behavior seemed to become more restrictive from the first to the fourth symposium, but seemed to entail specific company plans, and did not stifle the discussions of the technical aspects of tire testing.

## TIRES: BACKGROUND AND DESCRIPTION

Tires vary in size, weight, construction, materials, and usage. Each tire is the sum of the work of many individuals and many processes. The cured tire is a single indivisible product that cannot be reworked to remove or replace a flawed part, though the carcass may be rebuilt with a new tread. To help understand the complexity of a tire, it would be helpful to paraphrase a portion of the keynote address of Mr. R. Meyers, Assistant to the President, Firestone Co., at the first tire testing symposium. He stated that when he started in the tire business, he "had the vague notion that tires were somehow punched out of an enormous sea of materials, cooked in an enormous oven, and rolled out something like doughnuts from a doughnut machine. Nothing could be further from the truth. Tires are hand-crafted on complex machines by an artisan. The materials he handles are mixed and spun and woven and cut to size by other teams of craftsmen and machines. They are built upon cylindrical drums; they come out looking like a barrel with neither head nor foot, and then these barrel-shaped raw tires are moved to presses where they are shaped and curved into the familiar form seen on automobiles. The tire industry as a whole makes more than a half million of these every day."

Mr. Meyers went on to say that each tire is an individual with its own variation from design characteristics. The only proof of its performance is its performance, and only testing to destruction in use can tell how any individual tire will behave in total. Strictly speaking, such a test will tell only how well the tire did behave. Because each tire is the output of an artisan assembling a large number of components, each one of which is subject to variations from standard, each tire is likely to differ slightly from the norm. Sampling, therefore, does not give absolute assurance that each tire in a batch behaves like the sample.

*Proceedings on Nondestructive Testing of Tires; (1) NTIAC 74-1, 1973; (2) NTIAC 75-1, 1974; (3) AMMRC SP 78-2, 1976; and (4) AMMRC SP 80-1, 1978.

The Army uses many different types of tires. They range from commercial passenger tires to rugged tires for off-the-road vehicles to industrial use tires to aircraft tires. In FY77, the Army acquired over 300,000 tires of both military and commercial types. This involved sums of approximately $7.4 million for new tires and $7.2 million for retreads. The Army retreads over 200,000 tires each year at about 50 percent of the cost of a new tire. These figures illustrate and emphasize the importance that the Army must place on the evaluation methods to measure reliability, durability, and safety, both for new tires and retreads.

Army Regulation 750-36, "Rebuild and Retread of Pneumatic Tires," mandates that 75 percent of the Army's tires shall be retreads. Nondestructive determination of the quality of the carcass prior to retread and the quality of the finished product while maintaining a cost-effective mode of operation is a severely perplexing problem.

In cases where a retreading contract is issued to the lowest bidder, the quality of the final product is frequently so poor that motor pool operators are reluctant to use the retreads. It has been reported that the confidence in retreaded tires is so low that the tires are given token service, then replaced by new tires. This wasteful practice permits one to live up to the letter of the law while in reality circumventing the regulation. Obviously, confidence in the retreaded tire must be restored. Information from industry retreaders of civilian market tires indicates that of 1200 to 1300 tire carcasses examined, the retreader buys about 900. Defects showing up during retreading operations reduces the yield to about 700. Of these, approximately 5 to 15 percent are returned by the customer to the retailer for "adjustment" (in the price) because of premature wear or failure.

TACOM has a program underway using an ultrasonic device called the Tire Degradation Monitor (TDM) developed by TACOM and General American Transportation, Inc. (GATX), which is being used to evaluate tires before and after retreading and after field use. Successful completion of the TDM program will answer the following basic questions: (a) Is the carcass worth retreading before it is buffed? (b) Is the buffed carcass good enough so that the rebuilding process should be continued? (c) Is the completely rebuilt tire of a high enough quality to be safely applied to its intended service?

Retreading is not only beneficial from the standpoint of cost, it is also ecologically beneficial. Tire retreading is a method of recycling which means that less basic raw materials are expended, materials presently in use in the form of tires are undergoing a life extension, and the growing problem of disposal of worn tires is lessened.

## FINDINGS OF SYMPOSIA

A constantly occurring question throughout the four symposia was related to anomalies. Among the basic questions at the first symposia were: What does an anomaly mean? What should a test be designed to look for? What is a critical flaw? What is a good reference standard? At the time there were no ready answers and only partial answers have been obtained since. Four basic methods of NDT considered most applicable to tire testing were discussed: ultrasonics, radiography, infrared, and holography. Each method was found to have its pros and cons, and no one method was universally agreed upon as being the best or having the greater potential. The overriding factor in each case was the issue of cost. Industry profit margins on new tires, particularly passenger type tires, is very low. Competition is keen and any test which adds more than a few cents to the cost of a tire is not acceptable. Any nondestructive test must be proven cost-effective and under the present economic restraints, even a fifty-cent test is too expensive.

Beyond visual examination, new tires are not routinely given a nondestructive test of any kind. Even aircraft tires are not tested when new. Retreaded aircraft tires are another matter; they are all examined prior to mounting on an aircraft.

## ULTRASONICS PANEL

Several basic questions were interwoven throughout these panels, and continually surfaced in the other panels, as well as in the various paper sessions. As stated earlier, these questions were: What do we want to detect? What is a good reference standard? What is a critical flaw? No specific answers were received although considerable discussion centered about these questions. The panel pointed out the shortcoming that the ultimate information, correlation of acoustical variations with tire performance, will be generated only by a large sample study. However, when the wide range of acoustical variations are multiplied by the large number of tire styles and building variations within a tire style, the resulting number is astronomical. To run a sampling of each of these variations to destruction for correlative purposes would be prohibitively time-consuming and expensive. Further, the utility of a test method may depend on the area of application; new automotive or rebuilt aircraft tires may not respond equally. Moreover, equipment response to man-made and natural separations are different. The panel nevertheless agreed that acoustical techniques have demonstrated the ability to reveal subtle tire variations or gross delaminations and that a correlation must be made to performance.

On the matter of defects in aircraft tires, the panel recognized that the most common defect in tires is a carcass ply separation. The criticality of the separation is not simple and depends on at least the following variables: where the separation is located (sidewall, shoulder, crown); the size of the separated area and depth into the tire; the carcass quality; if the tread is fabric-reinforced; on which aircraft location the tire is used (main or nose position); and will the aircraft experience land use or (for the Navy) carrier-based operation.

Tire industry needs included greater knowledge of chemical and mechanical degradation and application and quantitative grading. Also needed were increased quality assurance (QA) applications, in particular, gaging, belt edge and ply separation detection, and road test application to reduce testing time. Other needs were a means to accurately predict tire performance and additional correlation of failures to separation and degradation.

The TDM developed during the several years span of the tire symposia was given considerable attention at the final panel session. The TDM is an ultrasonic device developed by GATX for TACOM, which has repeatedly stressed the need to determine cord strength and cord degradation. It has been found to be especially useful for evaluating carcasses prior to retreading. After successful preliminary tests, TACOM began an extensive program on 1800 retreaded tires at the Ober-Ramstadt Army facility in Germany. Initial results are promising and the panel felt that, since the Army is pursuing this program for truck tires, ultrasonics for degradation measurement in aircraft tires should be pursued. The statement was made that ultrasonics is one of the few NDT methods shown to be fast enough for production use.

A final consensus of the ultrasonic panel was that more cooperation should be encouraged between tire manufacturers and NDT equipment manufacturers.

## X-RAY PANEL

The X-ray panel was very active at the first symposium, producing some cogent and substantial observations to which some information was added or improved upon at the following three symposia. It was felt that the state of the art was already developed and that the problems remaining were materials handling, conveying the tire, and conversion from the laboratory atmosphere to the production line. From the beginning, the group recognized the need for automatic imaging techniques including image analysis to speed up inspection and make it cost-effective. This requirement included removing the human operator from the inspection cycle for reasons of fatigue and for cost reduction. However, the group recognized that such equipment is not immediately forthcoming, and past experience with automated decision-making equipment has shown it to be very expensive and unlikely to be cost-effective on a low-profit item. A point adjunctive to the animated discussion, and a major point of concern, was the difference of opinion that seems to exist among tire manufacturers as to what part of the tire or starting point should be used as a reference. Some felt the bead location was good; others did not. This point, which was never resolved, should be; hence, further discussion is needed in this area.

Discussed at the first panel meeting was the inspection of tires in the green stage. Some members felt there could be a substantial cost-saving factor involved if they were able to determine poor building construction on a fair percentage of green tires before curing. It was estimated that something like 40 percent of the total investment in a tire could be saved as a result. However, the term "fair percentage" was not defined. It is possible that production line radiography can prove useful as a temporary cost-effective quality monitor if a large number of poor quality tires are showing up on production runs and a means of controlling and upgrading production is necessary. One of the primary uses of X rays in tire manufacturing is to help in the elimination of the nonconformance tire.

It is interesting to note that X-ray inspection is used very heavily in the development and design stages for new product lines to determine what changes happen to the material placement in the building or curing process. Many of the companies use X-ray inspection as a job-training tool. Personnel building a tire are invited to view some of the X-ray images and learn from these what possible corrections they can incorporate in their fabrication techniques.

Finally, the workshops touched lightly on the matter of accumulating data more meaningful for determining how effective all nondestructive testing is to the rubber industry. Without question, X-ray inspection is one of the more useful methods. It will require the development of automation and automatic feature identification (image interpretation) to be cost-effective.

## HOLOGRAPHY PANEL

Holography is the most recent of the various NDT methods. Because of its newness, there was a limited number of personnel in attendance who had any extensive firsthand experience in holographic testing of tires. Therefore, it can be surmised that many of the attendees were there as observers to learn, rather than as active participants with experiences to share.

The holography panel, like the other panels, commented on the meaning of defects in tires and the need for more details on meaningfulness of various anomalies. An overall

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desire existed for more data from other nondestructive tests for comparison purposes with holographic data. This panel also stressed the need for the tire industry and government agencies to provide a clearer definition of what their needs are.

The holography program conducted by Air Treads, Atlanta, Georgia, was reported as successful. They were testing up to 160 tires a day on many high-speed tires. A variation in tire rejection rate (in 1976) between 0.6 and 13 percent for tires with any separations was reported. Despite certain disadvantages, holography was considered indispensable to operations at Air Treads. However, faster and cheaper holography machines are desired.

Holography, when used in a tire development program, can help produce a better tire initially. It is particularly useful for special purposes such as screening tires for testing on a high-speed test track. One serious shortcoming is in the training area. There are no known schools for teaching practical applications of holographic testing. College courses in holography are available, but practical application is the responsibility of the individual. Companies selling holographic equipment provide initial operating instructions only.

The holography panel, at their last meeting, discussed the basic accept/reject criteria used in the aircraft tire industry. This discussion was triggered by an aircraft accident caused by a tire failure. There was considerable concern as to whether the criteria used at the time was realistic. The panel concluded that experience had shown that a separation diameter of one-half inch ($\pm\frac{1}{4}$") was unrealistic and much too tight. Commercial airline tires were being allowed separations of up to one inch in the central crown region, or rejection for any size separations if the carcass was extremely weak and fatigued. The panel felt an accept/reject criteria of one-half inch ($\pm\frac{1}{2}$") was more realistic, depending on the strength of the carcass.

The panel closed their discussion on a note of disappointment that so few rubber companies had actively participated in the previous sessions. One of the suggestions arising from the panel discussion was that a possible alternative to the procedure used in the four symposia would be to allow individuals to present their views without having them published.

In summary, the panel stated that they would like to see a realistic and objective review of all the NDT methods and a comparison of their cost-effectiveness and their basic technical effectiveness. They would like to see more emphasis on the overall aspects of materials evaluation, such as cord strength and cord degradation. In addition, a summary is desired of the basic quality assurance tests and procedures presently used by the rubber industry. On the subject of standards, the panel encouraged more work in this area, and though such work would be premature, a start should be made.

## INFRARED PANEL

The infrared panel agreed with the other panels that not enough was known about the failure mechanisms in the tire and exactly what should be looked for using a nondestructive inspection method. Nevertheless, infrared nondestructive tire testing has unique detection capabilities.

Infrared has an advantage that none of the other NDT methods have, namely, that it can inspect tires under dynamic load conditions which closely simulate actual use conditions of a tire. In addition, it can detect some variations in material processing, compounding, or cure, variations which can cause a tire to run hotter and decrease its durability. Further, infrared is useful in detecting the initiation of a flaw and monitoring its growth, even if that flaw was not originally in the tire or was not detectable by other means. As an aid to tire design, infrared has been used to determine the effects of material, construction, and operating parameters on the running temperatures. Because of its dynamic test ability, infrared provides information that allows a test to be stopped before a tire has completely come apart, which provides a better chance to determine the failure mechanism of a tire. It was suggested that infrared instruments can serve as on-board detectors for underinflated and overheated tires.

The disadvantages of infrared are the lack of sensitivity and the relatively long length of time it takes the heat signal to develop. The signal takes one to two minutes to come to the surface, too long for production line use.

In summary, infrared does not have the potential nor the sensitivity for a fast production nondestructive test to detect small defects in tires in the sense that X ray and ultrasonics can be used. Nevertheless, infrared may have the potential for rapid detection of factors affecting tire operating temperatures that other NDT methods do not have. The greatest utility of infrared techniques in tire work at present is as a research and development tool to explore the effects of material, construction, and operating properties on the running temperatures, durability and power loss of tires, and to detect the generation and growth of flaws in tires being tested.

## STANDARDS PANEL

The standards panel met only at the final symposium. The nine participants, representing a good cross section of the rubber companies and government, generally concluded that the field of standards is very complex and no immediate breakthroughs were expected. A proposal was made to provide sample standard blocks to evaluate X ray, ultrasonics, and holography. The standard block could be a step block with built-in separations which could be used within the industry and government to coordinate a standard type of testing and to give suppliers a suitable standard by which they could evaluate their products.

The panel felt that a standard block would be easier to utilize than a standard tire. A block would be easier and cheaper to make and have closer manufacturing controls than a tire. Several blocks could be made with different types of construction to simulate the many varieties of tires and include various types of defects at various depths as desired. In addition, shipping of blocks for round-robin purposes would be simpler and less costly.

## QUALIFICATION PANEL

The qualification panel met only once, at the fourth symposium, and was not composed of a representative cross section of the tire or rubber industry. Representation was mainly from aircraft-related organizations. The group discussed existing standards for training, qualifying, examining, and certifying nondestructive inspection personnel. The most prominent of those discussed were the American Society of Nondestructive Testing recommended practice SNT-TC-1A and MIL-STD-410.

One of the needs cited was equipment qualification; another was uniformity among the many facilities performing nondestructive tire inspection. Moreover, the inspection is often restricted because the speciality is just too new and not properly understood by supervision and management. Many organizations have no formal inspector training programs. Direct supervision frequently has no real appreciation for nondestructive test methods since they have not had the training or exposure, and management, which is further removed from the actual work level, is even less appreciative. Navy retreading contractors have a document for standard qualification, but the panel was not aware of any from commercial tire companies.

The main difficulty in the final analysis boils down to the fact that the quality assurance people often have no real control of nondestructive processes. The panel noted many cases that demonstrated improved product reliability because of nondestructive inspection, but they also recognized that facilities do not always have the desired uniformity of capability among themselves. For example, one organization may have a half dozen or a dozen facilities, and serious inspection capability differences can exist between them. Some organizations even have selected preferences for the quality of work that comes from certain of their facilities.

The overall conclusions and recommendations are that qualification and certification standards are necessary, and that standards should be common for all commercial or aircraft tires. Separate qualification certification should be required for each inspection method, and MIL-STD-410 should be updated to include holography.

A final request by the panel was that the report, "Nondestructive Testing of Tires," by P. E. J. Vogel, and published as a two-part article in *Rubber Age,* November and December 1974 issues, be updated. The report was considered to be of great value to the entire rubber community. Such a state-of-the-art survey should include equipment and techniques and as much statistical information as possible to assist in understanding the capabilities of the various inspection methods.

## CONCLUSIONS

Throughout the various symposia, including the panel sessions, the most significant shortcomings voiced were the lack of basic knowledge that exists regarding anomalies in tires and their meaning to ultimate tire performance; a lack of understanding of the failure mechanisms that occur; and the cost-effectiveness of NDT methods.

A tire is a very complex structure and, as stated earlier, is a hand-crafted product composed of many different components made of different types of material that are not always compatible with one another. Such a conglomeration is a ready-made breeding ground for the germination of problem areas. The situation is further complicated by the fact that so little is known about the effects of certain design deviations in manufacture on ultimate tire performance. This lack of basic knowledge limits predictions relating to tire performance to conjecture or to extrapolations. Experience with tires has shown that, frequently, flaws are not revealed until the tire has received substantial use. Therefore, short of controlled long-term field tests, much of the knowledge regarding tire performance as affected by design or manufacturing variations remains conjectural.

Another significant problem that arose was the cost-effectiveness of NDT methods. It was stated, and rightly so, that a company producing a tire with a $.67 profit margin cannot afford a $10 nondestructive test for that tire. However, a relatively expensive holographic test is conducted for retreaded aircraft tires, and is justified because of the criticality of the usage of the tire. A $10 or $15 test is a small investment in a $500 tire that will be used on a multimillion dollar aircraft carrying over 250 people.

For new tires, including new aircraft tires, no NDT is performed; there is only visual inspection. It is obvious that for new tires a very low cost per tire inspection device would be required after a determination is made as to what one is to inspect for and where.

The greatest potential for NDT seems to be in the area of retreads. Because of the wear and tear which a tire has undergone, the question of suitability for rebuild arises. The basic questions of carcass condition, before and after buffing, and final quality of the rebuilt tire, need economical and reliable answers.

The rebuilt tire accounts for a high percentage of the Army's inventory as stated in AR 750-36. Obviously, it is important that only suitable carcasses be used for rebuild, and some means to determine suitability is necessary. Attempts to comply with AR 750-36 have been frustrated by low-quality products which have undermined the confidence expected from rebuilt tires.

The present Army program being conducted by TACOM is attempting to restore that confidence by utilization of an ultrasonic testing device which gives a good indication of carcass acceptability. The TDM has undergone initial evaluation at both the Red River Army Depot and the Yuma Proving Ground with optimistic results. It is presently being used on a full-fledged field test involving 1800 rebuilt tires at the Ober-Ramstadt Army Depot in Germany. The tires are being inspected before and after rebuild, and field results will be correlated with TDM readings. If successful, the TDM is expected to be placed at various Army depots as a cost-saving measure for determination of unsuitable carcasses prior to shipment to a tire rebuild depot. The reduction in shipping costs alone should make the TDM cost-effective. The resulting upgrade in quality of retreads will be a significant factor in restoring confidence in retreads for the Army.

## RECOMMENDATION SUMMARY/NEEDS

1. Conduct programs to correlate the various tire artifacts with performance and failure mechanisms.

2. Evaluate the results of the Army's Tire Degradation Monitor Program.

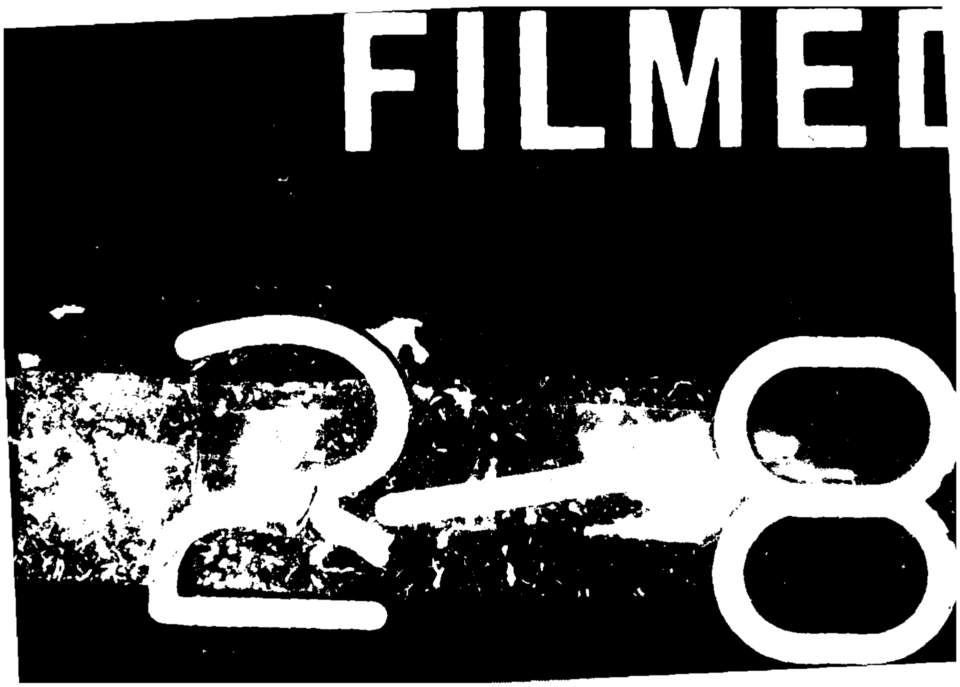
3. Encourage an increase in coordination between tire manufacturers and NDE equipment manufacturers.

4. Improve the speed and especially the cost of NDT (including tire handling and test automation).

5. Conduct a review of NDT methods applicable to tire testing to compare their technical and cost-effectiveness.

6. Encourage the development of physical test standards (blocks) for technique comparison and calibration purposes.

Numerous basic NDE techniques are available which could be applied in a much more meaningful manner if the above six items were pursued.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