SAFER WINTER TIRES USING OIL-EXTENDED NATURAL RUBBER

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The grip of oil-extended natural rubber winter tires made of both cross-ply and radial-ply construction has been assessed during three separate trials in Scandinavia. The tests have been carried out on ice and hard-packed snow at temperatures as low as -15 C. The variability of ice makes it difficult to obtain reliable data unless a large number of measurements are made on several different occasions. It has not been possible to correlate the variability of the results with the more obvious climatological factors such as temperature or amount of sunshine. The results presented here show that oil-extended natural rubber has better grip than conventional high hysteresis synthetic tire treads and may even perform better than studded conventional tires on some occasions. The use of oil-extended natural rubber winter tire treads would make a significant contribution to road safety under winter conditions.

•TIRES have to perform satisfactorily under a wide variety of conditions; therefore it is not usually possible to improve one feature without changing other characteristics. Winter tires are no exception. Their primary purpose is to give better grip than ordinary tires under winter conditions. However, performance on roads not covered with snow and ice must also be satisfactory, and this restricts the choice of compounds. The formulations given here have better wear properties under low ambient temperature conditions and have equal grip in the wet when compared with conventional synthetic tires.

Tire manufacturers have concentrated their efforts to improve winter tires on changes in tread design to give better grip on soft snow and have paid relatively little attention to the type of tread compound. In practice, the majority of tire manufacturers use the same compound for the treads of winter tires and ordinary tires. The object of this paper is to show that natural rubber and, in particular, oil-extended natural rubber treads will make better and safer winter tires.

Two methods are available for producing an oil-extended natural rubber (OENR) compound. Either the oil and rubber are mixed in an internal mixer during the normal factory processing, or an oil-extended masterbatch can be used. The final product is the same whichever method is chosen. Mixing schedules where up to one-third of the rubber is replaced by oil have been published (1) for factory-sized mixers.

One of the most important properties of a winter tire is its grip on ice and hard-packed snow. A convenient way of measuring the skid resistance in the laboratory is by means of the Road Research Laboratory portable skid tester (2). Results for typical compounds are shown in Figure 1. Above 0 C on wet concrete, the conventional tread rubber, which is a blend of oil-extended styrene butadiene rubber and butadiene rubber (OESBR-BR), has higher friction than natural rubber; however, below 0 C on ice, the position is reversed and natural rubber is better. The OENR compound is a useful compromise having good skid resistance on both surfaces.

FULL-SCALE TIRE TRIALS ON SNOW AND ICE

Results such as those shown in Figure 1 have led to three full-scale trials during the past few years using winter tires with natural rubber treads. The first trial was carried out in Sweden on a road surface covered with hard-packed snow (3). The tread compounds are given in Table 1 (compounds 1 through 6) and were used to retread tires of cross-ply construction (size 6.40 × 13). The tests were carried out using a two-wheeled trailer originally designed for wear tests (4).

The trailer and car were first accelerated to a constant speed, the car was allowed to free wheel, and then the trailer brakes were applied rapidly using compressed air. The distance the car and trailer traveled before stopping was recorded automatically. The deceleration of the car and the force at the towing point on the car were also recorded. The friction coefficient was calculated from these measurements, and the results in Table 2 are given in the form of ratings relative to a conventional tire tread compound (OESBR-BR) that has been arbitrarily given a rating of 100.

In all cases, the natural rubber-based compounds are better than the SBR-based compounds. The addition of BR tends to reduce the friction coefficient, whereas studs improve the friction. However, the advantage of OENR over OESBR is still apparent with the studded tires.

A second trial was also carried out in Sweden (5) with retreaded cross-ply tires. The compounds used are given in Table 1 (compounds 7 through 11), and the tests were carried out on smooth ice, which was a frozen lake surface, or on a hard-packed snow-covered road surface. As before, skid tests were carried out using the test trailer, and the results obtained on lake ice are given in Table 3. The unstudded tires show the advantages of the natural rubber-based compounds over SBR-based compounds. The differences between the studded tires are not significant at the 10 percent level, whereas the differences between the unstudded tires are significant at the same level. The results on hard-packed snow are given in Table 4. On this surface, there is no significant difference between the unstudded compounds, but there are differences in favor of OENR that are statistically significant for the studded tires.

As well as the tests just described, circle tests using the car alone were also carried out. A circle 33 meters in diameter was marked out on the lake ice, and the car was driven around it as fast as possible using each set of tires in turn. The results are given in Table 5. Under these conditions, the superiority of OENR in both the studded and unstudded tires is apparent.

These two trials illustrate the difficulty of characterizing the frictional behavior of tires on ice and hard-packed snow. The results show that, under some conditions, there are no differences between compounds, whereas under other conditions the OENR compounds are significantly better than conventional OESBR-BR compounds.

The current trend in tire design is toward radial-ply tires, and a third trial was carried out during the early part of 1971 in Norway on radial-ply winter tires (size 185 × 15) (6). It was apparent from the previous trials that a more comprehensive trial was required with a large number of repetitions so that the significance of the results could be improved.

The compounds tested are given in Table 1 (compounds 12 through 14), and the tests were again carried out using the car and test trailer as before. In addition to the instruments described previously, a side-force measuring device had been added to the trailer, and the compressed air system had been modified to allow the brakes to be applied progressively as well as instantaneously. The side force is a measure of the friction coefficient under cornering conditions. The magnitude of the side force depends on the slip angle, the tire construction, and the friction coefficient. Because all the tires are of the same construction and the angle of the wheels is constant, the side force is a measure of the friction coefficient measured while the wheel is rotating. It is a more reliable method than circle tests with the car because the skill of the driver is not brought into play during the measurements.

The first part of the trial was concerned with evaluating different test methods, and for this purpose only two compounds, OENR and OESBR-BR, were used. There was no evidence that one test method was more discriminating than any other, and the results in individual comparisons varied from no effect on some occasions to a rating of 144 for OENR and an OESBR-BR rating of 100 on other occasions. The averages of all the results obtained are given in Table 6 where it can be seen that OENR is 15 percent better than OESBR-BR. This superiority is reflected in the results on studded tires as well.

Table 1. Compounds used in full-scale tire trials.

Characteristic	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Natural rubber[a]	67	—	53.6	—	40.2	—	100	80	70	56	—	75	60	—
SBR 1712	—	92	—	73.8	—	55.2	—	—	—	—	77	—	—	72.5
BR[b]	—	—	13.4	13.4	26.8	26.8	—	—	—	14	14	—	15	22.5
HAF black	55	55	55	55	55	55	50	55	55	55	55	—	—	—
ISAF black	—	—	—	—	—	—	—	—	—	—	—	55	55	55
Aromatic oil[c]	36	11	36	15.9	36	21	5	21.6	32.6	32.6	11.6	25	25	5
Zinc oxide	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Stearic acid	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Antioxidant[d]	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sulfur	2	1.4	2	1.4	2	1.4	2.5	2	2	2	1.4	1.5	1.5	1.4
CBS	0.4	0.8	0.8	0.8	0.8	0.8	0.5	0.8	0.8	0.8	0.8	1.75	1.75	0.8
TMTD	—	—	—	—	—	—	0.025	—	—	—	—	—	—	0.05
Percentage of BR[e]	0	0	20	20	40	40	0	0	0	25	25	0	25	30
Percentage of oil[e]	33	33	33	33	33	33	0	20	30	30	30	25	25	25

[a]Compounds 1 through 6 are RSS1; compounds 7 through 11 are HC and SMR20; and compounds 12 through 14 are SMR5.
[b]Compounds 1 through 11 are Intene 55NF; and compounds 12 through 14 are Europrene Cis.
[c]Sundex 8125.
[d]Isopropyl paraphenylene diamine.
[e]Relative to total rubber content.

Figure 1. Skid resistance of winter tires using OENR compounds.

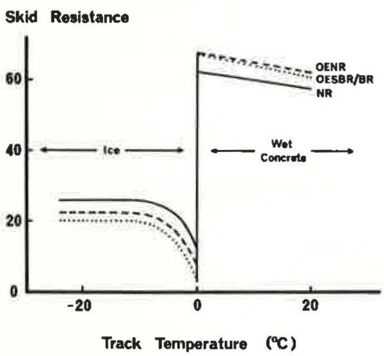

Table 2. Skid ratings on road ice at a surface temperature of -6 C to -2 C.

Percentage of BR	Unstudded		Studded	
	OENR	OESBR	OENR	OESBR
0	131	100	135	121
20	127	92	138	120
40	104	91	118	102

Note: Ratings are expressed relative to the unstudded OESBR tire containing no BR, which is arbitrarily given a rating of 100.

Table 3. Skid ratings on lake ice at a surface temperature of -2 C.

Mix	Unstudded	Studded
Natural rubber	119	119
OENR	118	119
OESBR-BR	101	137
Commercial tire (60 SBR and 40 BR)	100	123[a]
Level of statistical significance	10 percent	None at 10 percent

Note: Friction coefficient of unstudded commercial tire is 0.106, and this is arbitrarily given a rating of 100.

[a]This tire contained 133 studs compared with 100 studs in each other tire.

Table 4. Skid ratings on hard-packed snow at a surface temperature of -6 C.

Mix	Unstudded	Studded
Natural rubber	99	157
OENR	109	173
OESBR-BR	103	123
Commercial tire (60 SBR and 40 BR)	100	155[a]
Level of statistical significance	None at 20 percent	1 percent

Note: Friction coefficient of unstudded commercial tire is 0.141, and this is arbitrarily given a rating of 100.

[a]This tire contained 133 studs compared with 100 studs in each other tire.

In another series of experiments on another lake surface, the differences between the compounds were much smaller (about 4 percent). Measurements on hard-packed snow, which had been compacted so that the tires left no impression on the surface, under similar conditions showed larger differences between the compounds. The average results (significant at the 5 percent level) are as follows:

Mix	Unstudded	Studded
OESBR-BR	100 ± 3	112 ± 4
OENR	114 ± 7	–

It can be seen that the unstudded OENR tires perform better than both studded and unstudded OESBR-BR tires.

The results of the two earlier trials and particularly of the last trial illustrate the difficulty of making reliable measurements on ice. Such is the variability of ice that many repeat measurements are required to establish an effect. The situation is further complicated because it appears that both compound and stud effects may disappear under some conditions. An example of the variability of the results is shown in Figure 2 where the results obtained in the third trial using different test methods and on different occasions are shown in the order in which they were obtained. A particular set of tests may show relatively small scatter with a mean standard deviation of less than 4 percent compared with a mean standard deviation for all tests of 16 percent. This indicates that a small number of results, obtained under one set of conditions only, may be misleading with regard both to the mean friction coefficient and to the scatter in the results. Other factors come into play over a longer period of time, which affect the relative performance of the compounds. It is obvious, therefore, that many tests under a variety of conditions are necessary to ensure a reliable estimate of the behavior of the compounds under investigation. It has not been possible to correlate the effects with the more obvious climatological factors such as ice temperature, air temperature, or amount of sunshine during tests.

In spite of the complications and difficulties experienced in obtaining reliable data, an important conclusion can be drawn. During all the measurements that have been made in three separate trials under a wide variety of conditions and test methods, conventional OESBR-BR treads have never consistently outperformed OENR. The most recent and comprehensive set of data obtained using a variety of test methods shows an average improvement of 15 percent for OENR over OESBR-BR. This was the result of more than 200 tests on each compound. Each test consisted of several measurements of the friction coefficient.

CONCLUSIONS

It can be concluded that the grip of OENR tires whether of cross-ply or of radial construction on ice and hard-packed snow is superior to that of conventional OESBR-BR treads under many conditions and has never been found to be significantly worse than OESBR-BR compounds. In some circumstances, the OENR tire without studs may be better than an OESBR-BR tire with studs although studs can be beneficial to all compounds. The variability of ice makes it necessary to carry out a large number of measurements to establish the improvements to be gained from compounding or from studs.

The wet skid resistance of OENR compounds is comparable to conventional high hysteresis (OESBR-BR) compounds. The wear resistance of OENR treads is better than that of OESBR-BR treads at low tire surface temperatures such as are encountered under winter conditions.

All the results described in this paper substantiate the claim that the grip of winter tires on ice and snow could be significantly improved, and consequently winter driving could be made safer if the tread compound of winter tires was made from oil-extended natural rubber.

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Table 5. Velocity ratings in closed-circle breakaway tests at a temperature of -1.5 C to -1 C.

Mix	Unstudded	Studded
Natural rubber	124	131
OENR	111	120
OESBR-BR	92	111
Commercial tire (60 SBR and 40 BR)	100	127[a]

Note: Ratings are expressed relative to the commercial tire, which is arbitrarily given a rating of 100.

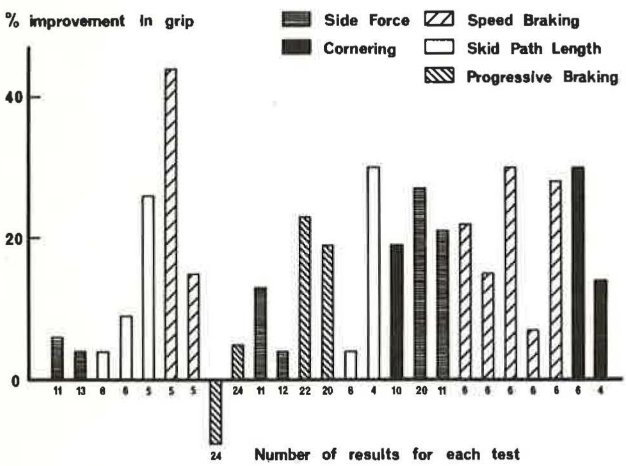
[a]This tire contained 133 studs compared with 100 studs in each other tire.

Table 6. Friction ratings using various test methods on ice at a surface temperature of -8.5 C to -0.3 C.

	Unstudded		Studded	
Test Method	OESBR-BR	OENR	OESBR-BR	OENR
Side force	100	114	107	131
Cornering	100	121	114	133
Speed braking	100	123	142	151
Skid	100	112	—	—
Progressive braking	100	109	—	—
Mean	100 ± 2	115 ± 2	120 ± 4	138 ± 5

Note: The unstudded OESBR-BR tire is the control and is arbitrarily given a rating of 100. Limits of means are quoted at the 5 percent level of statistical significance.

Figure 2. Safety characteristics of winter tires using OENR compounds.



REFERENCES

1. Moore, C. G, Simpson, K. E., Swift, P. M., and Wheelans, M. A. In Rubber Age, Vol. 97, 1965, p. 61.
2. Giles, C. G., Sabey, B. E., and Carden, K. H. F. In Rubber Chemistry and Technology, Vol. 38, 1965, p. 840.
3. Grosch, K. A. In Rubber Age, Vol. 99, 1967, p. 63.
4. Grosch, K. A., and Schallamach, A. In Wear, Vol. 4, 1961, p. 356.
5. Grosch, K. A., Schallamach, A., Southern, E., and Swift, P. M. In Rubber Developments, NR Technology Supplement 9, 1970.
6. Southern, E., and Walker, R. W. Jour. Institute Rubber Industries, Vol. 6, 1972, p. 249.