Sborník vědeckých prací Vysoké školy báňské – Technické univerzity Ostrava
číslo 1, rok 2008, ročník LI, řada hutnická
článek č. 1399

QUANTIFICATION OF ADHESION BETWEEN RUBBER AND STEEL CORD BY ULTRASONIC DEFORMATION

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ABSTRACT: This work deals with problematic of fatigue lifetime of adhesion bond between rubber and steel cord material. Like an experimental material was taken the part of radial tire which is the most stressed part under deformation during lifetime of tire. The main aim of work was determination of adhesion bond level between steel cords of construction 3x0,20+6x0,35 HT, bead wire with diameter 1,6 mm and two different rubber compounds used in belt and bead area of truck tyre. A special attention is paid to development and possibility to apply in practise of new test method, which makes possible to strain test sample by high-frequency ultrasonic oscillation. This non standard method provides many advantages in comparison with other adhesion test method. The results are discussed and compared with the results were obtained by static tensile adhesion T - test and dynamic cycling Henley - test.

KEY WORDS: steel cord-rubber adhesion, ultrasonic frequency, tire test method

1. INTRODUCTION

The performance of all steel-belted radial tires is, to a large extent, dependent on the strength and durability of the bond formed during the vulcanization between the rubber of the tire cord coating stock and the steel reinforcement which is assorted in wire constructions[1].The mechanism of rubber-brass bond formation and particularly of adhesion degradation is extremely complex and dependent on a large number of variables, which include both cord and compound parameters[2].The mechanical fatigue in the elastomeric materials like rubber is demonstrates progressive drop of their physical properties due to repeated deformation much lower than the braking strain, resulting in unserviceability of an article during use [3]. It is generally attributed to the growth of the repeated tearing from flaws under application of dynamical strain or deformation in the test piece. This may be accentuated by the rise in temperature due to repeated deformation and chemical changes. The considerable change is the low-pitched change of stiffness. Prolongation of the static strain can cause the stress relaxation as well as time-dependent cracks propagation of many synthetic rubbers. Beneficial effect on the fatigue life of crystallizing rubber occurs, because the crystalline barrier to tearing at the tips of the flaws will not disappear.

According to long-time performance of tires and different service conditions the tire producers making intensive use of a large numbers of tire aging simulation tests [4,5,6] possible degradation phenomena that may occur in the different tire areas, e.g. bead, carcass, shoulder and breaker, a correct simulation of the composite sample is necessary.

The requirements for adequate adhesion testing include repeatability and reproducibility, sensitivity to interfacial cohesion force measurement, and the possibility of aging. The commonly used test to evaluate steel cord-rubber adhesion is the ASTM D-2229 test, a pull-out test where the force needed to pull a cord out of rubber is described. Simultaneously the coverage of rubber on cord is rated. A large number of investigations also aimed at evaluating the adhesion retention after cyclic loading. For research purposes the Henley test is more suitable and often use [7].

2. FORMATION

Experimental composites were prepared in the form to simulate the most stressed part under deformation during lifetime of truck tire, the shoulder and the bead area. All experiments were realised with two kinds of reinforcement materials: steel cord with construction 3x0,20+6x0,35 HT, bead wire with diameter 1,6 mm. Two of used rubber compounds have different chemical composition and properties. Rubber compound A contains from natural rubber matrix. Compound B has polymer matrix from polybutadien-styren.

To investigate the influence of static and dynamic loading combination on adhesive bond of experimental specimens there was a new test method developed, which provide the cyclic deformation of composite with using ultrasonic working frequencies ($f \approx 20$ kHz), means 20 100 cycles/sec. a simultaneously the sample was statically loaded with selected weight [221]. Fig. 2 shows schematically of ultrasonic fatigue test machine. The machine is centered around an acoustic amplifying horns, and the tested specimen. The acoustic energy is supplied by a high frequency power supply. An amplitude-measuring device and a means of dissipating the heat generated by the deformation process are also necessary. A frequency display, cycle counter and temperature-measuring equipment are used to monitor the test. Ultrasonic (high-frequency) fatigue testing is based on a resonant test approach. The wave is generated by a relatively small periodic stimulus at the same frequency as the natural frequency of the test specimen [8].

To simulate cyclic deformation in the shoulder bead area of the tyre the varying level of dynamic strain amplitude of ultrasonic was applied. The samples with steel cord material shaped In cylinder were deformed with strain amplitude σ in range 2 - 6 MPa a the samples with bead wire shaped in block were deformed with strain amplitude σ in range 6 - 9 MPa. The fatigue limit of high operation frequency for testing of samples was a very long fatigue lives (> 10^9 cycles). The loud static strain limit of experimental composites was 10.9 MPa during the whole test time. In comparison with threshold tensile deformation applied during the laboratory pull - out T-test (40 MPa) was the load approximately 4-times less.

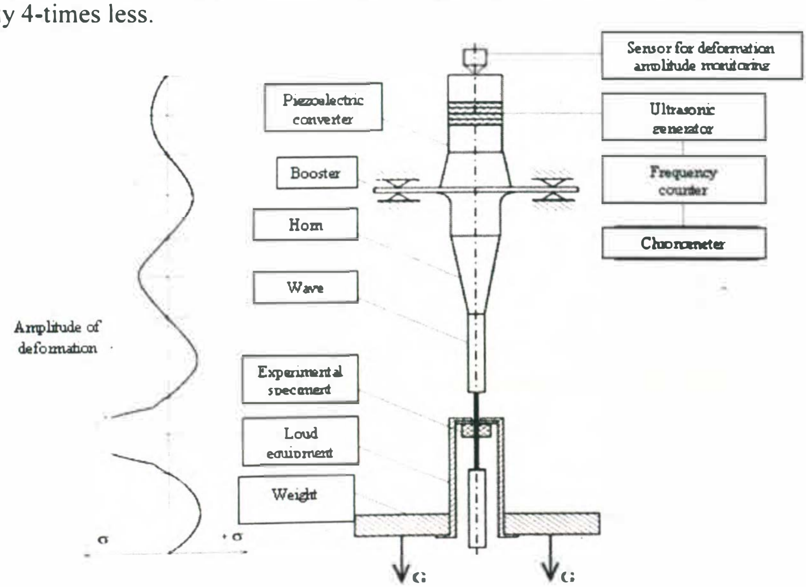

Fig. 2: Resonance system with load equipment and development of deformation amplitude

The surface of steel cord wire after fatigue ultrasonic test shows fig. 3. Photograph in fig. 4 detect the surface of bead wire.

Fig. 3: Steel cord after ultrasonic fatigue test sample 3/ 4,97*10^7 cycles

Fig. 4: Bead wire after ultrasonic fatigue test sample 1/ 5,58*10^7 cycles

The achieved results of the test are in graphic form in fig. 5 and 6.

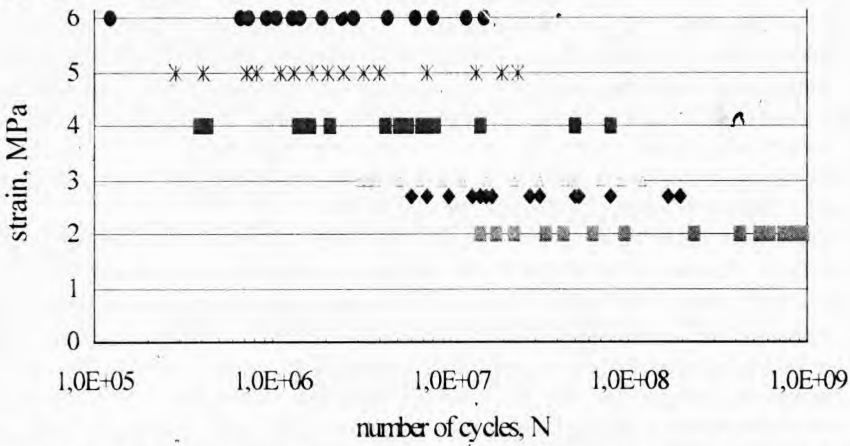

Fig. 5: Result of experimental samples with steel cord wire after ultrasonic fatigue test with pre - loaded deformation Henley 3

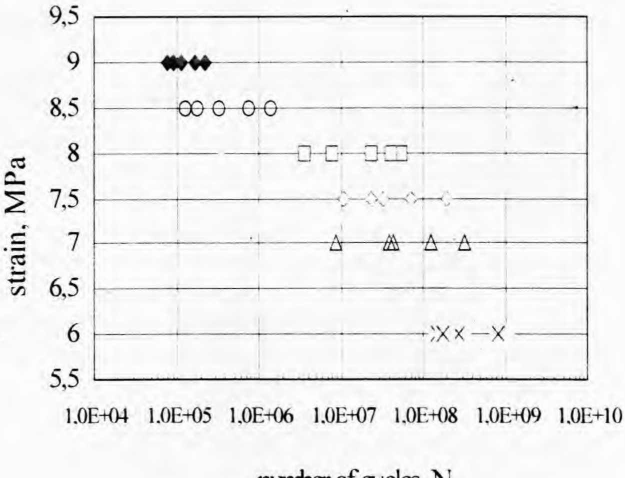

Fig. 6: Result of experimental samples with bead wire after ultrasonic fatigue test

During the test performance were monitored by the installed thermocouples the temperature inside of composites. In fig. 7 is possible followed and identified time course of different level of used strain deformation and to investigate the heat built-up inside the composites under the cyclic deformation influence.

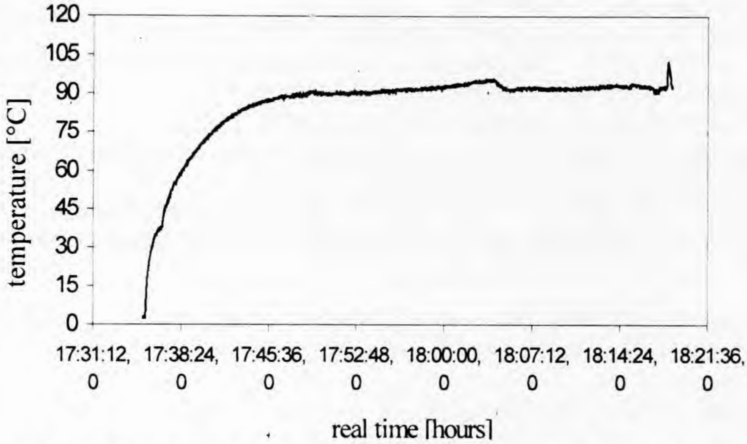

Fig. 7: Built up of temperature during the ultrasonic fatigue test

CONCLUSION

The use of ultrasonic test method is suitable and sufficiently sensitive to investigate the changes during the degradation process of composite adhesion between steel cord and rubber compound. This method makes possible flexibility in adjusting of test condition in different ways. In the first case the cyclic deformation, like the strain deformation is constant and the static load of samples is changed during the test and the fatigue time of samples are measured. The another possibility to set up the test condition is to use constant static load of samples and together application varying amplitude of dynamical loading for each sample and the fatigue time of samples are measured.

The ultrasonic test machine allowed to apply individually only dynamical strain in the frame of defined strain amplitude and later on use the tensile test to evaluate the rest of force which is needed to pull -out the cord from the composites.

With using ultrasonic working frequencies ($f \approx 20$ kHz) can be significantly shorten testing in comparison with conventional fatigue machines ($f \approx 20 - 200$ Hz).

The cyclic deformation amplitude above 7 MPa damage the rubber part of samples by heat generation, which represents the deformed dissipated energy (loss) in rubber

The heat built up in the sample is dependent on the dynamic loading as well as on the static loading. The large of static loading is higher the temperature of composite is higher even in a case that the large of dynamical factor is not changed. It is the same applied regarding to changes of dynamical loading and stable static loading. Character of temperature increase is dependent on experimental test conditions.

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