Marian JÓSKO
Instytut Maszyn Roboczych i Pojazdów Samochodowych Politechniki Poznańskiej
ul. Piotrowo 3, 60-965 Poznań, Poland
e-mail: marian.josko@put.poznan.pl

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NON-DESTRUCTIVE TESTING OF VEHICLE ELEMENTS RESPONSIBLE FOR SAFETY OF THEIR OPERATING TIME

Summary

The main purpose of the paper is presentation of the possibilities of non-destructive methods for determination of structural discontinuity of the selected parts of motor vehicle chassis systems, responsible for safety of their operating. In the paper are shown non-destructive methods in aspect of their application to condition assessment of parts of machines and vehicles, and examples of application of selected non-destructive methods to the parts responsible for operating safety. As conclusion, is stated the possibility of application of non-destructive methods to evaluation of material discontinuity of vehicle and machine parts that impacts the technical condition subassemblies of vehicles and safety during their operating time.
***Key words**: Non-destructive testing methods, testing of vehicle elements, safety of operating time*

BADANIA NIENISZCZĄCE ELEMENTÓW POJAZDÓW ODPOWIEDZIALNYCH ZA BEZPIECZEŃSTWO ICH UŻYTKOWANIA

Streszczenie

Głównym celem artykułu jest przedstawienie możliwości metod nieniszczących dla określenia nieciągłości struktury wybranych części układów podwozi pojazdów mechanicznych, odpowiedzialnych za bezpieczeństwo ich eksploatacji. W artykule przedstawiono nieniszczące metody badań w aspekcie ich zastosowania do oceny stanu części maszyn i pojazdów oraz przykłady zastosowania wybranych metod nieniszczących do części, odpowiedzialnych za bezpieczeństwo użytkowania. W konkluzji stwierdzono możliwość zastosowania metod nieniszczących do oceny nieciągłości materiału części, odpowiedzialnych za stan techniczny podzespołów pojazdów i maszyn oraz bezpieczeństwo podczas ich użytkowania.
***Słowa kluczowe**: nieniszczące metody badań, badania elementów pojazdów, bezpieczeństwo użytkowania*

1. Introduction

The safety of vehicles as well as agricultural machines during their operating time is determined – among other – by condition of some their parts directly responsible for safety. Use of such technical objects as vehicles and machinery is safe (for those technical objects and environment), if their essential parts are in good condition. There are some systems of vehicle responsible for traffic safety. First of all, there are such systems as braking, steering and suspension system [1].

The condition of whole chassis assemblies of motor vehicles and tractors are periodically controlled by designated control stations using of diagnostic lines. Often, some of separated mechanical parts of mentioned systems decide to a certain degree about the safety of all the chassis systems. Those parts get worn during their operating period and can be damaged, sometimes in an invisible way. Increasing safety during operating time can be accomplished by monitoring the status of parts and replacing them in case of deterioration of their functionality, e.g. by structural discontinuities.

Non-Destructive Testing (NDT) methods are usually used in non-destructive control during production's process [2, 3, 4] of machines, motor vehicles and their elements. But most of the NDT methods can be also used for an assessment of condition of many vehicle parts during exploitation period. Also bodies of automotive vehicles (especially integral bodies) can be destroyed during road accidents or during abnormal, strenuous operating time. This factor influences road safety as well. NDT methods are also useful for condition evaluation of elements of motor vehicle that took part in road accidents for detection of possible discontinuities in material structure.

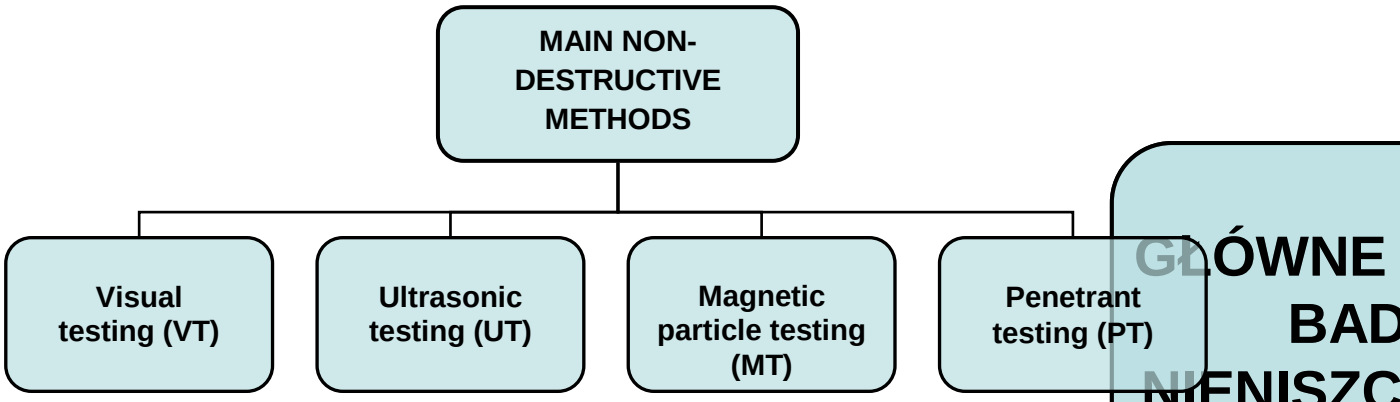
Another case of NDT application concerns a repairing process of assemblies of working machines and road vehicles – renovation or replacing of spare parts as well as when remanufacturing of them [3, 5]. In such situations the control of physical conditions of simple parts of vehicles is very important from the operational reliability and safety point of view . In such case, NDT methods can be applied directly not only to whole diagnosed system of vehicles or machines, but predominantly after full or partial disassembling of the tested components of machines and vehicles chassis.

Several methods of non-destructive testing are well known and can detect discontinuities in material structure during operating time. These methods are accessible to the user and can be a convenient tool to assist the process of use. However, using these methods is not widespread because of insufficient knowledge of the possibilities of detection methods and their variations in exploitation period of working machines and vehicles. Tested pieces influence on the safety, therefore non-destructive methods can make easier to decide on their replacement in the proper time of use, which affects the safety of the machine and on the environment, e.g. during work or road traffic.

Consequently, the purpose of this article is to present the selected examples of the successful use of non-destructive testing methods for the discontinuity assessment of the parts responsible for safety of operating time of machines and vehicles.

2. Methods of non-destructive testing

There are several main non-destructive methods which can be applied for assessment of physical condition of automotive vehicle and machine parts – Fig. 1.



Source: own work /Źródło; opracowanie własne

Fig. 1. Division of main, particularly useful for testing of machine parts non-destructive methods and generally accepted their designations

Rys. 1. Podział głównych, szczególnie przydatnych do oceny części maszyn, metod badań nieniszczących i ogólnie przyjęte ich oznaczenia

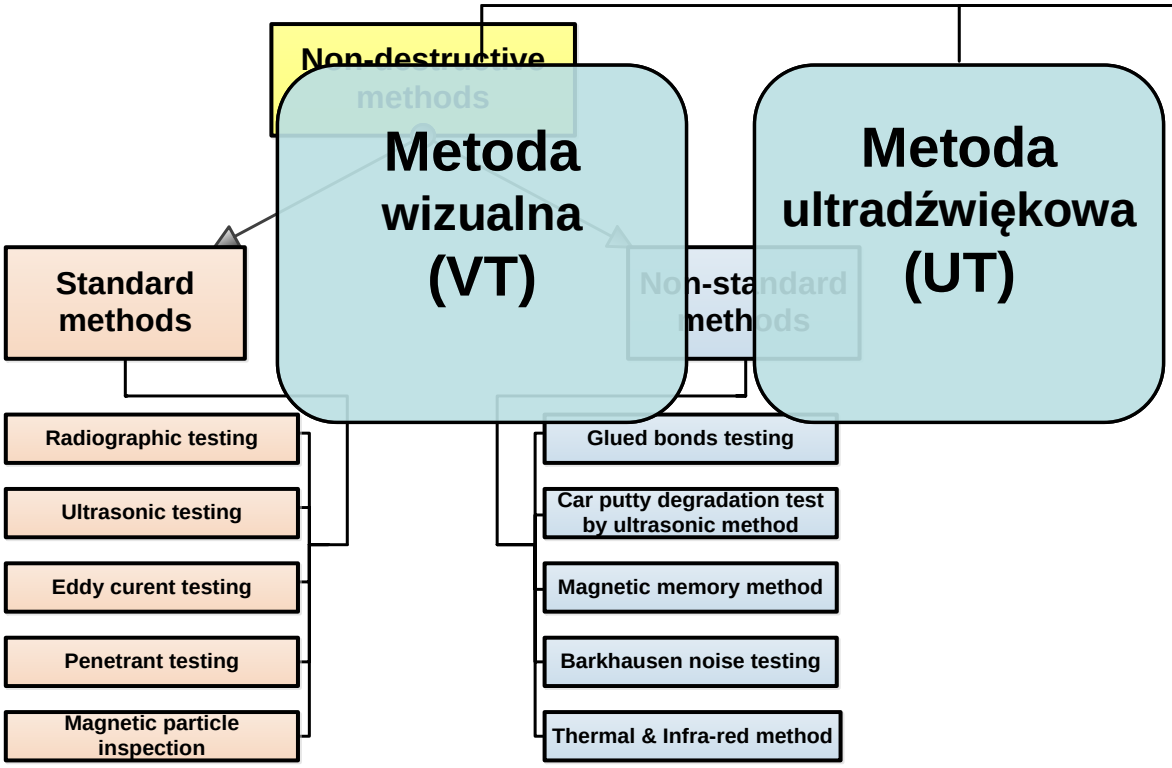


Fig. 2. The overall division of non-destructive testing methods [6]

Rys. 2. Ogólny podział nieniszczących metod badań [6]

Among several traditional (i.e. standard) methods there are some non-standard methods also useful for solution specific problems (Fig. 2). To that group of methods belong also entirely new methods based on modern achievements of physics, chemistry and other fields. These methods mentioned here represent a significant instrumental base to facilitate non-destructive evaluation of material of individual parts to ensure their structural integrity and safety during use.

Analysing of standard methods in aspect of their suitability in condition of repair or service workshop we can state that radiographic method is rather not very useful, because is troublesome and needs to keep special safety requirements. In contrary, penetrant method is simple, cheap, has universal application (for almost all materials), and can be applied in different conditions, even directly on the object, i.e. machines and automotive vehicle.

Ultrasonic method is limited by dimension and shape of tested part and needs the especially trained, qualified operator. Additionally, ultrasonic apparatus and probes are rather expensive. Magnetic or magnetic particle method can be widely applied but is limited by kind of material (only ferromagnetic), and tested elements needs to be demagnetised after examination [4].

Other defined as non-standard (Barkhausen noise, magnetic residual memory, ultrasonic monitoring by selected waves) NDT methods cannot be broadly applied but can be useful for particular problems related to evaluation of level of stresses or bonding between glued elements of vehicle

body and other adhesive bonds, for example between regenerative or preventive coating and substrate [5].

As the summary of this analysis we can state, that such tool of diagnosis as NDT methods enable us to assess the condition in the range of structural discontinuity of many part of machines and automotive vehicles during their operating period, in diagnosis or in repairing process and can influence on the safety of their operating time.

3. Examples of worn parts influencing on safety during operation time

Some examples of parts can be selected as important for traffic safety or operating safety in specific conditions of use. These parts must be assessed in non-destructive way from point of view of their influence on traffic safety. In this paper, only chosen parts examined in the research [6, 7] will be considered and their continuity of material structure will be evaluated by NDT methods.

Braking system of automotive or agricultural vehicle is mainly responsible for road safety and also for the safe use during the realization of agro-technical tasks. The effectiveness of braking process depends not only on kind of construction of the brake (drum or disk), but among others on the physical condition of working surfaces their frictional components (Figs 3 and 4). Brake drum or brake disk, together with brake lining or block (shoe), creates friction couples of automotive brake. These important elements get hot during intensive braking and can crack, therefore both the safety of use and road safety will be worsen in such situation. In many cases, we can directly use the NDT methods without any specially preparation, except washing or cleaning the examined elements. However, some elements of motor vehicle need a partially or the full dismantling before an application of NDT method.

Fig. 3. View of the abrasive worn surface of an exploited automotive brake drum [7]
Rys. 3. Widok zużytej ciernie powierzchni samochodowego bębna hamulcowego [7]

Another part of an automotive vehicle that, as an element of suspension sub-assembly, there is particularly responsible for traffic or operating safety, is suspension arm (Fig. 5) or axle of semi-trailer (Fig. 6). Both elements were overloaded or after a road accident as they were deformed with suspected cracks.

Fig. 4. A heavily worn brake disk in motor vehicle with suspicion of cracks [7]
Rys. 4. Silnie zużyta tarcza hamulcowa samochodu z podejrzeniem pęknięcia [7]

Fig. 5. Deformed arm of independent suspension of automotive vehicle as a result of intensive use or accident [7]
Rys. 5. Odkształcone ramię niezależnego zawieszenia pojazdu samochodowego, jako wynik intensywnego użytkowania lub wypadku [7]

a)

b)

Fig. 6. View of BPW axle of semi-trailer with suspicion of cracks (a) and detected crack by penetrant method (b) [7]
Rys. 6. Widok osi naczepy BPW z podejrzeniem pęknięć (a) i wykryte pękniecie metodą penetracyjną (b) [7]

4. Selected examples of discontinuities of tested vehicle parts

Although, the condition of such element as brake drum or brake disk has a great meaning for the safety, it is difficult visually to assess the disk condition with point of view of the presence any discontinuities (Fig. 3, 4). Using the penetrant method we can detect very small cracks and microcracks in the brake disk, oriented in the characteristic way, i.e. in radial direction on perimeter of friction surface of the disk (Figs 7 and 8).

In Figures 7 and 8 are shown for comparison the two non-destructive techniques of disk brake examination, namely by fluorescent penetrant technique (Fig. 7) and common coloured penetrant technique (Fig. 8). Both techniques are acceptable for reliable assessment of structural continuity of tested parts, but the first technique (Fig. 7) needs a special fluorescent powder and an UV lamp and there is rather more sensitive than the second technique (Fig. 8).

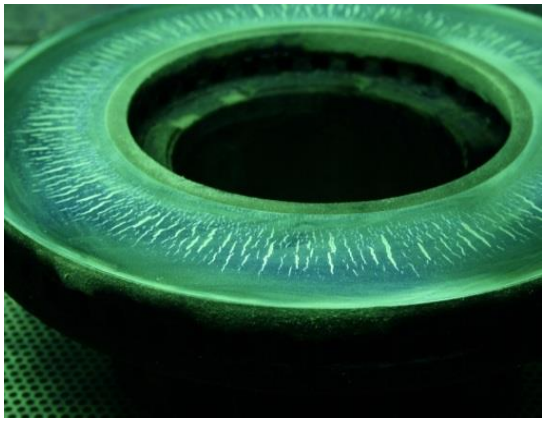


Fig. 7. View of the brake disk tested using fluorescent penetrant [7]
Rys. 7. Widok tarczy hamulcowej zbadanej penetrantem fluorescencyjnym [7]

Fig. 8. A fragment of the brake disk tested by coloured penetrant technique [7]
Rys. 8. Fragment tarczy hamulcowej testowany koloryzującym penetrantem [7]

It is rather easy to verify the material condition of loaded elements of motor vehicle e.g. the bent (as in Fig. 5) arm of suspension system in vehicle. In this case can be possible a quick detection of discontinuities, using magnetic particle or penetrant method (Figs 9 and 10). Specific discontinuities in the form of strips or clusters have been identified here.

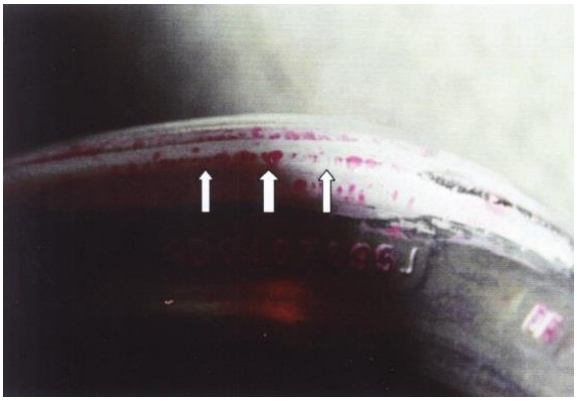


Fig. 9. So called striped cracks in deformed suspension arm detected by penetrant method [7]
Rys. 9. Tak zwane pęknięcia pasemkowe ramienia zawieszenia wykryte metodą penetracyjną [7]

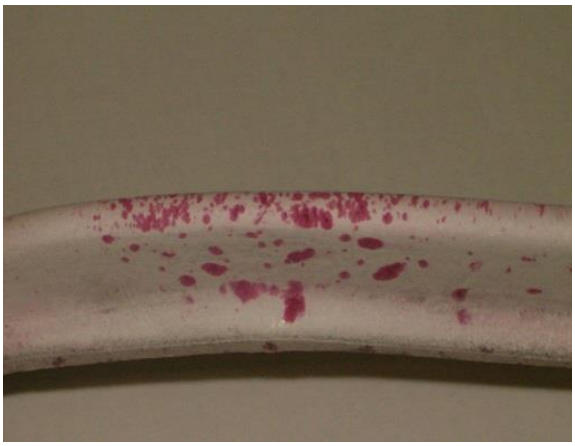


Fig. 10. Another part of the deformed arm suspension with a cluster of discontinuities [7]
Rys. 10. Inna część odkształconego ramienia zawieszenia z klastrem nieciągłości [7]

In the Fig. 11 is shown the eye of a lever as an element of suspension system of vehicle examined by using the special arms of magnetic device. Any crack, that can occur during operation (for example as in Fig. 12) is particular essential for road safety and for the use, because during loading it may propagate.

Fig. 11. View of the lever eye of truck suspension tested by the magnetic device using special arms [7]
Rys. 11. Widok ucha dźwigni zawieszenia ciężarówki testowanego defektoskopem magnetycznym ze specjalnymi końcówkami [7]

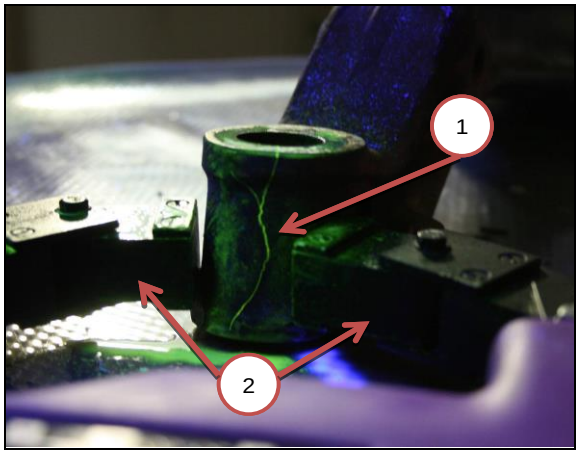


Fig. 12. UV magnetic particle method for car suspension part (balance lever): 1 – crack, 2 – arms of the magnetic device [7]
Rys. 12. Metoda magnetyczno-proszkowa UV w badaniu części zawieszenia (ucha dźwigni): 1 – pęknięcie, 2 – końcówki defektoskopu magnetycznego [7]

Many surface cracks can be detected by usage of penetrant or magnetic particle method. In Figs 13 and 14 are shown chosen results of the tests carried out with aid of these NDT methods. These results help to take a decision about replacing worn or damaged details of automotive vehicle on new spare parts.

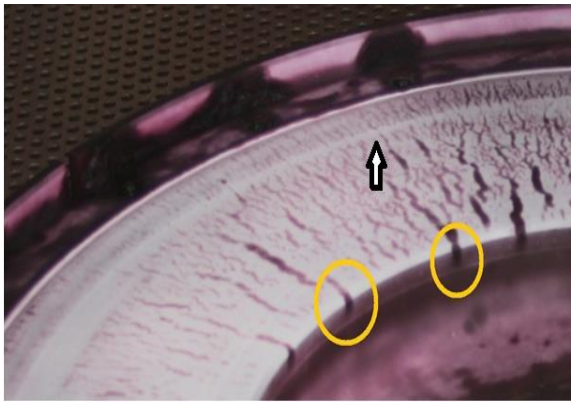


Fig. 13. The area of cracks and microcracks detected in surface of flywheel by common coloured penetrant method [7]
Rys. 13. Obszar pęknięć i mikropęknięć wykrytych w powierzchni koła zamachowego przez zwykłą koloryzująca metodę penetracyjną [7]

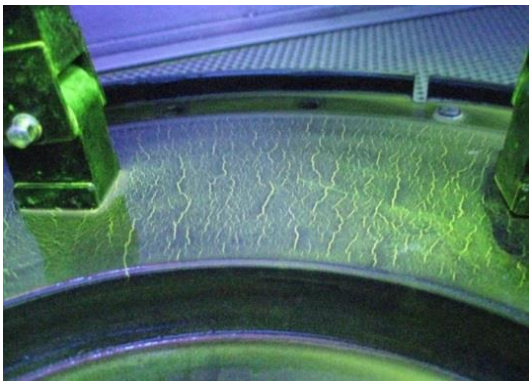


Fig. 14. The area of cracks detected in surface of flywheel by florescent magnetic inspection with UV light [7]
Rys. 14. Obszar pęknięć wykryty w powierzchni koła zamachowego przez fluorescencyjną inspekcję magnetyczną w świetle UV [7]

In this case, the sensitivity of the fluorescent magnetic particle method is also higher as compared to the coloured penetration method, although in the case of the penetration method it is easier to detect the edged cracks that disqualify the further use of this part.

Some chosen examples of testing of automotive parts and their results show that an assessment of physical condition many vehicle parts, especially responsible for safety of their operating time, is possible. This condition is determined – among other – by discontinuity of structure of the parts, in particular their surface. It is also significant, that such non-destructive tests as the examples presented here can be carried out in terms of automotive shops, machine repair shops and even farms, and they are relatively cheap, simple and safe.

5. Conclusions

As a results of investigations, observations, numerous data and the analysis carried out, can be formulated following conclusions:

– Beside problems connected with organization, managing and road traffic regulations also technical condition of subassemblies and physical condition of automotive and machine parts has an influence on the safety during their operating time.
– Often some parts from such chassis systems of motor vehicles as braking, steering and suspension systems are particularly responsible for operating safety, for example brake disks, drums and pads, tie rods, shafts of steering system as well as levers, arms and springs of car suspension system, etc.
– There are some non-destructive methods of evaluation of vehicles and machines parts that can be useful for structure monitoring and their material discontinuity assessment during exploitation period, for example penetrant and magnetic particle methods. These methods can be applied even in the terms of service shops of vehicles or workshops of machines, because of their simplicity and low costs.
– Many results of own experiments on real parts of exploited motor vehicles and machines confirm the possibility of application of NDT methods for material discontinuity evaluation of elements of vehicles and machines that can positively influence on their operating period in general, and on traffic safety in road transportation – in particular.

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