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Study on Carbon Nanostructures Influence on Changes in Static Friction Forces

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***Abstract*—**The Chair of Thermal Engineering at Poznan University of Technology has been conducted research works on the possibilities of using carbon nanostructures in energy and mechanics applications for a couple of years.

Those studies have provided results in a form of co-operation with foreign research centres, numerous publications and patent applications.

Authors of this paper have studied the influence of multi-walled carbon nanostructures on changes in static friction arising when steel surfaces were moved. Tests were made using the original test stand consisting of automatically controlled inclined plane driven by precise stepper motors. Computer program created in the LabView environment was responsible for monitoring of the stand operation, accuracy of measurements and archiving the obtained results. Such a solution enabled to obtain high accuracy and repeatability of all conducted experiments.

Tests and analysis of the obtained results allowed us to determine how additional layers of carbon nanostructures influenced on changes of static friction coefficients. At the same time, we analyzed the potential possibilities of applying nanostructures under consideration in mechanics.

***Keywords*—**Carbon nanotubes, static friction, dynamic friction.

I. Introduction

SUSTAINED technologic development is the best impetus for conducting innovative research, aimed at determining potential areas of application for many new materials. Among most interesting materials of 21st century, for which not all mass applications are still developed, there are carbon nanotubes. They are cylindrical structures based on flat structure of graphene one- or multidimensional rolled into a close shape. Carbon nanotubes may be built of one or some cylinders arranged concentrically. Those built of one cylinder are called single walled carbon nanotubes (SWCNT), those built of two cylinders are called double walled carbon nanotubes (DWCNT), and those built of three or more cylinders are generally called – multi walled carbon nanotubes (MWCNT). Each of such cylinders is a rolled graphene sheet. Usually, the ends of nanotubes are open, however, studies on the usage of nanotubes for energy or substances accumulation enabled to develop a technology of closing the ends of nanotubes with fullerene caps.

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In the Chair of Thermal Engineering of Poznan University of Technology studies on mechanical and thermal properties of carbon nanotubes have been conducted for several years.

Due to a close cooperation with scientific centres in Berlin and Boston a certain area of research concerning the impact of carbon nanotubes on the reduction of static and dynamic friction occurring on the contact area of two metal surfaces has been identified.

It is worth to note that nanotubes belong to most resistant and rigid materials ever-known. Tensile strength of multi walled carbon nanotubes reaches the value of 63 GPa. For comparison, strength of hardened steel reaches the value of about 1.2 GPa. When combined with low density of 1.3-1.4 g/cm2, it brings the best result among materials ever-known to humankind [1], [2]. Those parameters in combination with reduction of friction forces would create many new possible applications of multi walled carbon nanotubes.

II. Research Scope and Methodology

Presented tests continue previous research works on the above-mentioned subject matter. Their objective was to measure and analyze changes in static frictional resistance, generated by interaction between two solid bodies, resulting from application structures of multi walled carbon nanotubes. Due to intended use of such solution previous tests were carried out using elements made of steel. One of surfaces was a planished sheet of dimensions of 50x1000 mm and the gauge of 10 mm, having a low-valued roughness coefficient Ra=0.08; the second one was a galvanized steel plate of dimensions 100x100 mm and the gauge of 1mm.

Previous tests indicated clearly that carbon nanotubes influenced on reducing static friction. Fig. 1 presents results of previous tests conducted using manually operated inclined plane.

Presented results indicate a wide range of heights of lifting the inclined plane for all four measuring series. Such result was probably influenced by the low stability of velocity of lifting the inclined plane, resulting from the usage of manual pulley block mechanism. Despite attention to retaining the same velocity in each test, some changes in it were observed and they influenced on the tests results. A decrease in static friction forces is noticeable for the plate coated with the layer of carbon nanotubes. The difference is approx. 18 % of the height of lifting the inclined plane. Next important information is that of the increase in static friction forces with the number of conducted tests. This phenomenon occurred because of lack of cleaning the steel plate after each of tests. It was done for purpose as it was intended to determine the intensity of abrasion of the carbon nanotubes layer and to recognize its influence on the occurrence of the static friction forces. [3]

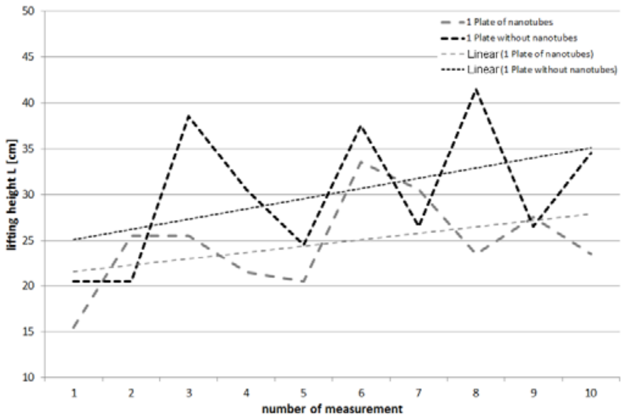

Fig. 1 Graphical interpretation of test results for the plate No. 1 [3]

Taking into consideration the above-mentioned problems relating with conducted tests, both, the test stand and the measuring methodology, were modified.

To eliminate errors in measurements caused by such factors as:

– non-uniform velocity of increasing the angle of the inclined plane being a result of its manual lifting,
– inability to determine precisely the moment of overcoming the force of static friction,
– inaccuracy in reading being a result of measuring rule usage and manual reading of the value measured,
– pressure force unevenly distributed on the whole surface of the steel element, a new measuring stand was designed and built.Previous tests indicated.

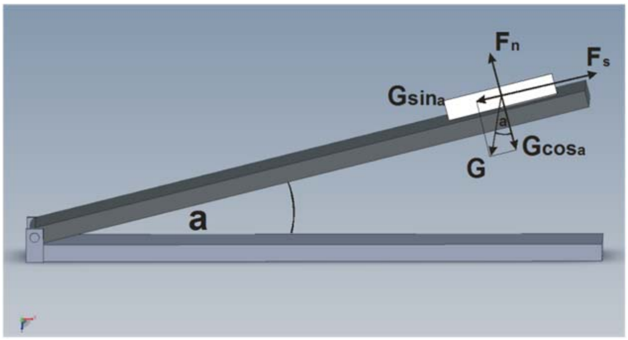

Fig. 2 The view of new automatic measuring stand

Fig. 2 presents automatic measuring stand. The inclined plane is driven by a precise stepping motor with exact circulating ball feeding screw. System of two micro-contact sensors was responsible for detection the movement of the element; it captured even the slightest movement of the measuring element. The whole measuring stand was controlled using original program created in the LabView development environment.

Fig. 3 presents a piece of program created in the LabView development environment which was responsible for determining the initial position of the measurement system.

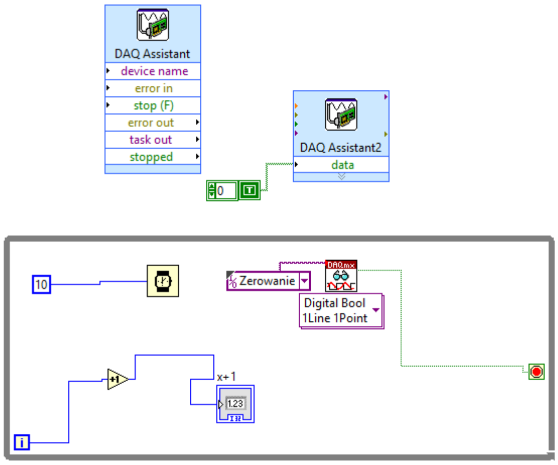

Fig 3 Piece of program for operating the measurement stand in the LabView environment

In Fig. 4 the front panel is presented; it shows such parameters as time-meter for sliding-down plate, calculated angle at which the movement is initiated and the number of currently conducted test.

Both, the surface of the inclined plane and the surface of the element under test were made of steel. To reduce forces of static friction both elements were subject of abrasive machining on the magnetic grinder.

Parameters of the element under test were as follows:
– dimensions: 80 x 80 x 10 mm
– weight: 489.4 g
– surface roughness Ra: 0.11

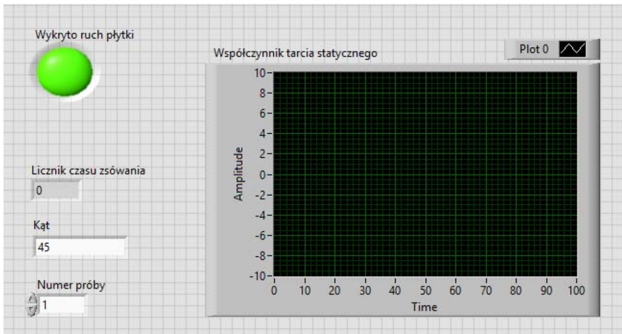

Fig. 4 View of control panel of the measurement stand in the LabView environment

The steel element was coated with the layer of carbon nanotubes. For this purpose, the solution of carbon nanotubes diluted with tetrahydrofuran in the ratio suggested by the producer of the nanotubes was used. Since the layer of nanotubes should be spread evenly on the whole surface of the plates, it was done using the spray method with the precise airbrush. Fig. 5 presents the operations of spreading carbon nanotubes with the airbrush. Next, the test plates underwent heat treatment to harden the layer of multi walled carbon nanotubes.

As a result of those operations, the evenly spread structure of multi walled carbon nanotubes was obtained, as shown in Fig. 6. It is a typical structure consisting of tangled, conglutinated by amorphous carbon randomly oriented nanotubes, reminding spaghetti on a plate [4].

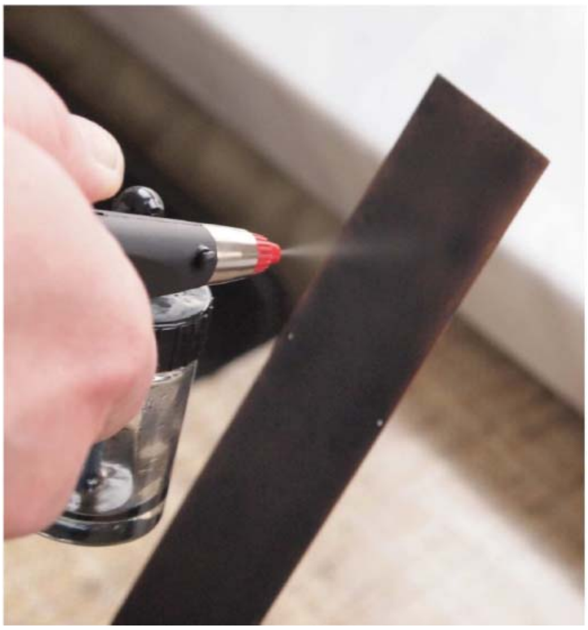

Fig. 5 Spreading carbon nanotubes with the airbrush [5]

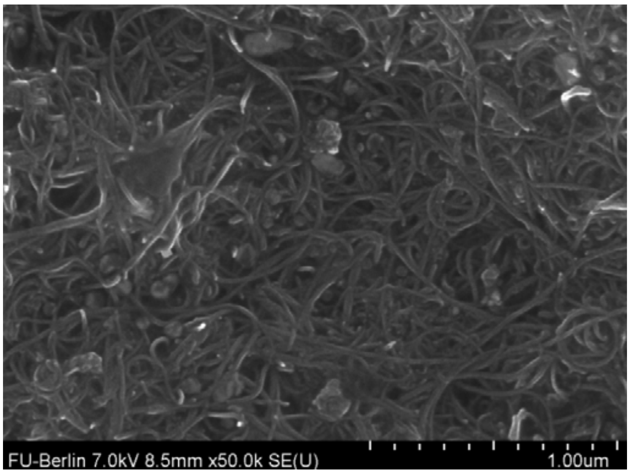

Fig. 6 View of the structure of the applied multi-walled carbon nanotubes

To obtain a reliable measurement series and to eliminate random errors in measurements, 30 tests for each of plates, that coated with the layer of carbon nanotubes and that without such a layer (where only the static friction being the result of friction between two steel surfaces was tested), were carried out. For all tests the angular velocity of the inclined plane was 0.448 o/s.

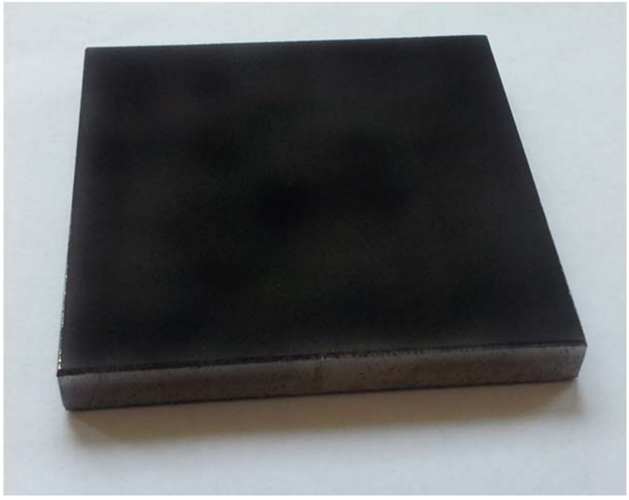

Fig. 7 View of the tested plate with nanotubes

III. Analysis of Results

Tests results clearly show that coating one of frictional surfaces with a layer of multi walled carbon nanotubes reduced the coefficient of static friction by approx. 40 % when compared with tests where there were no surfaces with nanotubes. Due to eliminating errors related to methodology of conducting tests, identified during first tests on influence of carbon nanotubes on the coefficient of static friction, we obtained reliable and repeatable tests results.

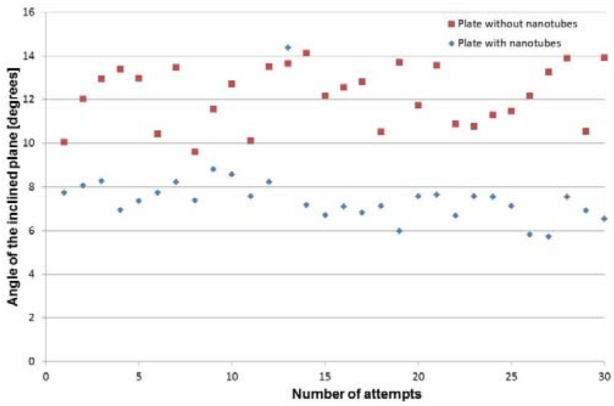

Fig. 8 Overall summary of test results for both plates

Fig. 8 presents overall summary of test results for both plates (that without and that with the surface of carbon nanotubes) for all 60 tests. Obtained results allow supposing that it is possible to apply carbon nanotubes to eliminate friction forces in engineering appliances where two metal surfaces come into direct contact.

IV. SUMMARY

Presented research tests constitute another scientific iteration related with an attempt to find the impact of surfaces of multi walled carbon nanotubes on the coefficient of static friction. Obtained results show that during tests there were significant differences between plates with and without carbon nanotubes. Application of nanotubes enables to reduce the friction coefficient by approx. 40 %, what makes the essential difference, taking into consideration the fact that both surfaces were characterized by low surface roughness coefficient, Ra. It means that further research work on practical application of nanotubes in mechanical processes should be conducted.

Unfortunately, today there are many barriers which make it impossible to apply carbon nanotubes for a large scale. One of the most important barrier is still high purchase cost of carbon nanotubes; another – often observed problems with obtaining mechanically resistant layer which would not wear off when being in contact with another metal surface.

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