

# Nanocomposite coatings in polymeric matrices and their effect on friction coefficient

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**Abstract.** This paper deals with possibilities of production of new nanocomposite coatings in polymer matrix on aluminium alloys, namely the formation of a composite coating in a polymer matrix on an aluminium alloy. It is a PMMA coating (polymethylmethacrylate) with the addition of TiO<sub>2</sub> particles. Working with these particles requires not only safety but also a suitable preparation process to obtain particles of suitable size, their subsequent homogeneous distribution in the coating (particles of this size are influenced by electro statically attractive forces and have a strong tendency to aggragate). The aim is to determine if the coatings will affect the surface's condition and its properties. The focus of the work is on selecting of the appropriate preparation of sample technology, examining the particle distribution in the coating and the effect of the coating on the coefficient of shear friction. Consequently, what can be achieved is the coefficient of shear friction of the surface of the coated part compared to the uncoated surface (at different particle concentrations in the spin) and the distribution of TiO<sub>2</sub> particles on the surface of the sample.

**Keywords:** Nanocomposite coating, polymer, coefficient of friction, surface analysis.

## 1 Introduction

The usage of polymeric materials as a matrix for nanocomposite materials has become a frequent case. This is mainly due to their features and availability. It is important to keep in mind the size of the nanoparticles used and their amount in the matrix. The aim of the research is to investigate the possibility of forming PMMA matrix nanocomposite coatings. An influencing factor is particle selection and coating technology. For evaluation, it is important to measure and analyse the resulting coatings. Therefore, shear friction coefficient by tribometric assays and particle size distribution in electron microscopy will be tested.

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## 2 Used materials

### 2.1 Characteristics of the underlying material

The base material, which is the material on whose surface we form the coating, is the Al-Si alloy. The base material was obtained from previous research of metal forms designed especially for the production of tires. These metal molds are made of Al-Si alloys.

### 2.2 Matrix material

Polymethyl methacrylate (PMMA) was selected as the matrix material. It is an amorphous thermoplastic with perfect light transmission. Due to the chemical composition, it is a polar plastic that has excellent mechanical properties. It has a wide range of applications, especially in the automotive and construction industries. The modulus of elasticity reaches up to 3200 MPa. [1-4]

### 2.3 Reinforcement material

Titanium dioxide (TiO<sub>2</sub>) was chosen as the reinforcement material of the nanocomposite coating. It is very suitable for coating for its properties in nanoparticle scale. Its material of high hardness is antistatic and is resistant to mechanical wear. [5-7] It has a high refractive index and is just like PMMA UV resistant. TiO<sub>2</sub> nanopowder from the previous research was used. TiO<sub>2</sub> was milled as a nanopowder by a planetary ball mill. [8-11]

## 3 Nanocomposite coating preparation

As a matrix for the nanocomposite coating, polymethylmethacrylate (PMMA) was used, which is available to buy in the form of plates. Titanium dioxide (TiO<sub>2</sub>) in the form of a milled nanopowder was used as reinforcement.

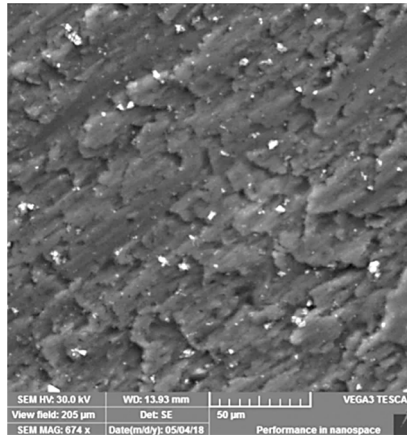
A solution method was chosen for the preparation. As the PMMA solvent, chloroform (CHCl<sub>3</sub>) was chosen.

**Table 1.** Labeling of created samples

Solution dilution - 1:10		Solution dilution - 1:10	
Application Method - dipping		Application Method - by brush	
Sample	Concentration of TiO <sub>2</sub> [%]	Sample	Concentration of TiO <sub>2</sub> [%]
1A	0	1C	0
2A	0.01	2C	0.01
3A	0.1	3C	0.1
4A	1	4C	1
Solution dilution - 1:3		Solution dilution - 1:3	
Application Method - dipping		Application Method - by brush	
Sample	Concentration of TiO <sub>2</sub> [%]	Sample	Concentration of TiO <sub>2</sub> [%]
1B	0	1D	0
2B	0.01	2D	0.01
3B	0.1	3D	0.1
4B	1	4D	1

The final coating solution was already applied to samples of the backing material. Two coating methods were chosen: first being the dipping method, which consists in submerging the prepared backing material into the coating solution. The second method was the brush

application method. Brush dipped in the coating solution and such is apply it to the substrate. The resulting coating is allowed to dry at room temperature.



**Fig. 1.** Sample 4A coated by dipping method in a solution diluted 1:10

Figure of the sample 4A (Figure 1) shows that the higher titanium dioxide concentrations in the coating (1%) by the chosen coating method - by dipping in a solution diluted 1:10, i.e. the same coating and dilution method as in all samples marked as A, it results in a better distribution of the particles in the coating. However, there are still areas with accumulated dust particles in the coating. Care must be taken to ensure that the environment is clean.

## 4 Research tools - Tribometric assays

It was necessary to analyse the examined coatings for the evaluation. The coefficient of shear friction of the coated surfaces was tested by tribometric assays.

Measurement of the friction coefficient was performed by the universal tribometer Bruker UMT Tribolab. We used a two-axis power sensor with a maximum load of 1000N and 50N.

Input values:

- Tribometer Body - ball  $\varnothing$  10 mm
- Track length  $x = 20$  mm
- Velocity  $v = 10$  mm·s<sup>-1</sup>
- Measuring time  $t = 60$  s
- Load force  $F_z = 5$  N

## 5 Results of the Measurement

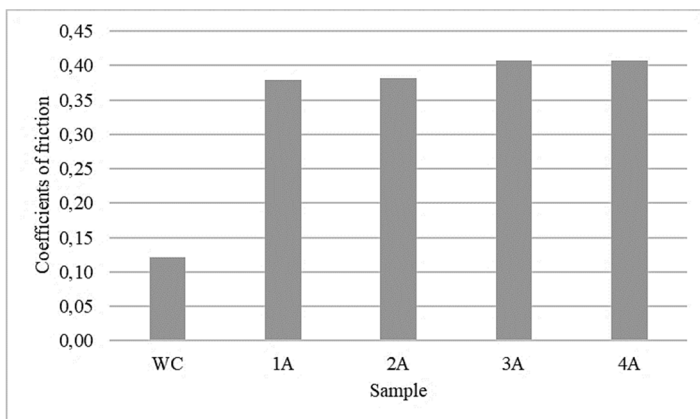
The usage of polymeric materials as a matrix for nanocomposite materials has become a frequent case. This is mainly due to their features and availability. It is important to keep in mind the size of the nanoparticles used and their amount in the matrix. The aim of the research is to investigate the possibility of forming PMMA matrix nanocomposite coatings. An influencing factor is particle selection and coating technology. For evaluation, it is important to measure and analyse the resulting coatings. Therefore, shear friction coefficient by tribometric assays and particle size distribution in electron microscopy will be tested.

**Table 2.** Measured coefficients of friction

Sample	Coefficients of friction	Standard deviation
Sample without coating (SO)	0.1216	0.00898

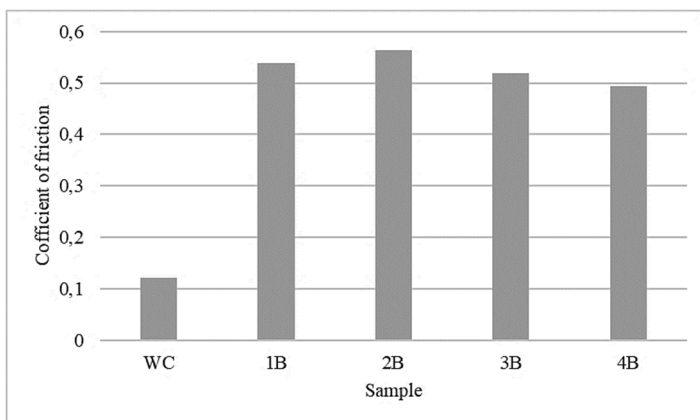
**Table 3.** Measured coefficients of friction 1A – 4A

Sample	Concentration of TiO <sub>2</sub> [%]	Coefficients of friction	Standard deviation
1A	0	0.3788	0.03119
2A	0.01	0.3812	0.03796
3A	0.1	0.4075	0.03773
4A	1	0.4076	0.04143



**Fig. 2.** Comparison of measured coefficients of friction (A)

The friction coefficient values measured in samples 1A to 4A are compared in Figure 2. There is well visible a jump increase in the coefficient of friction coefficient value of coated samples over a non-coated sample. Furthermore, a slight increase in the friction coefficient value can be observed with the increasing concentration of titanium dioxide in the coating.

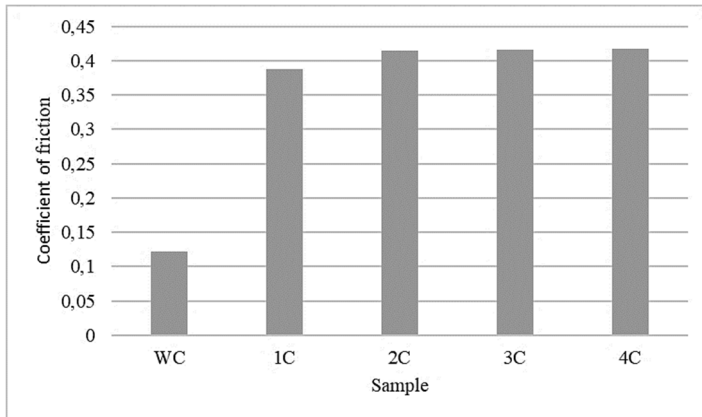


**Fig. 3.** Comparison of measured coefficients of friction (B)

The friction coefficient values measured in samples 1B to 4B have the highest increase. Its value is almost fivefold compared to the uncoated sample. It can be seen from Figure 3 that the increase is remarkable for all coated samples. However, the rule does not be applied to the increasing coefficient of friction with the increasing percentage of titanium dioxide.

**Table 4.** Measured coefficients of friction 1C – 4C

Sample	Concentration of TiO <sub>2</sub> [%]	Coefficients of friction	Standard deviation
1C	0	0.3876	0.03998
2C	0.01	0.4147	0.03768
3C	0.1	0.4155	0.04208
4C	1	0.4166	0.05153

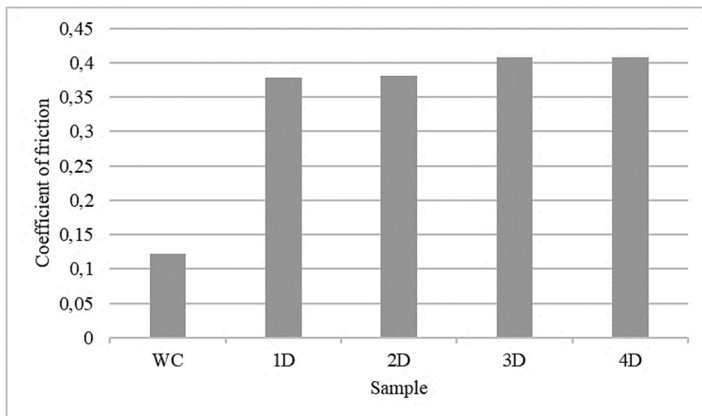


**Fig. 4.** Comparison of measured coefficients of friction (C)

For samples marked 1C to 4C also applies the jump increase of the coefficient of friction value. Here we can observe a slight increase in the coefficient of friction and the increasing percentage of titanium dioxide in the coating. The highest coefficient of friction is thus on the sample 4C, which is also observable in Figure 4.

**Table 5.** Measured coefficients of friction 1D – 4D

Sample	Concentration of TiO <sub>2</sub> [%]	Coefficients of friction	Standard deviation
1D	0	0.4733	0.04683
2D	0.01	0.4909	0.04756
3D	0.1	0.4935	0.05142
4D	1	0.4941	0.06319



**Fig. 5.** Comparison of measured coefficients of friction (D)

The friction coefficient values measured in the 1D to 4D samples show again a stepwise increase in the friction coefficient of the coated samples compared to the uncoated sample. It can be seen in Figure 5 that the greatest friction coefficient is for sample 4D is. The increase is approximately four times the coefficient of friction of the uncoated material. It is also a valid phenomenon that increasing the percentage value of titanium dioxide increases the coefficient of shear friction.

## 6 Conclusions

The aim of the experiment was to evaluate the measured friction coefficients of the coated samples and their comparison with the uncoated sample. It was important to choose the kind of added reinforcement particles in the matrix. Several variants of the concentrations of the added particles were also tested in the coatings, namely titanium dioxide particles. There were prepared two variants of dilution of the coating solution and the technology of its application to the underlying material.

Measurement of the friction coefficient produced an expected and targeted finding that the coated samples exhibited a jump increase in the coefficient of friction versus uncoated samples. On the frame of the three variants of the coated samples, there is a link between the increasing TiO<sub>2</sub> concentration and the friction coefficient value. For all samples A, B, C, D, more than three times the coefficient of friction was measured compared to uncoated samples. A new beneficial finding in general is that the highest coefficient of friction in coated samples was found in samples with the highest TiO<sub>2</sub> concentration, it means with concentration 1% of TiO<sub>2</sub> in polymer matrix.

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