HERMES

Development of smart and flexible freight wagons and facilities for improved transport of granular multimaterials

Deliverable D2.1
Characterisation of surface tension and friction coefficient of already existing paint products in the market

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Abstract	The D2.1 deliverable presents surface tension and friction coefficient values obtained with 4 Hempel commercial paints.

Versioning and Contribution History

Version	Date	Modified by	Modification reason
v.01	29/10/2015	VICTOR GARCIA	Initial draft
v.02	30/10/2015	Ingrid Picas	Final Revision

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Executive Summary

The present deliverable document D2.1 presents a test method and list of the results of surface tension and friction coefficient values obtained with Hempel commercial paints. This is a first step in order to start the following tasks, related to the development of a new coating fit for the project. Four Hempel paint coatings were tested of which Hempadur Ultra-Strength 47500 presented the lowest surface tension, and Hempadur PW 355ES showed the lowest coefficient of friction. The Hempadur Ultra-Strength 47500 paint presented the highest friction coefficient values.

All 2.1 task deliverable objectives have been reached and no deviations or open issues remain.

1 Introduction

The present deliverable document forms part of work package WP2: Study and implement coating solutions for wagon interior surfaces (research activity) of the Hermes project, a topic of MG-2.2-2014 Smart Rail Services in the H2020-MG-2014_TwoStages call. The main objective of WP2 is to develop a novel coating for the interior surface of cargo wagons. The paint coating should have a friction coefficient that leads to an increase of bulk discharge speed at terminals, but at the same time the coating must show high resistance to abrasion and corrosion due to the transport of potash and vacuum salt. The paint must be able to be applied using a brush and a roller on new buildings and during maintenance. Also the paint coating must have the flexibility intended in the project with regard to the diversification of freights, and fulfilment of the requirements for contact with food or goods for human consumption. The results of this deliverable document serve as a benchmark for further testing on coatings in WP2, which will feed the surface tension, and friction coefficient values, needed for computer loading and discharge simulations of WP4.

In many applications the ability of liquids to wet solid surfaces is a fundamental factor in determining the performance of a product. Wetting is defined as a process in which one liquid spreads totally over a substrate. The wetting process in turn is guided by the surface tension or surface energy of the liquid and solid coming in contact with each other. Surface tension is a property of liquids that arises due to the fact that the molecules at the surface of a liquid have a different potential energy than those in the bulk. Molecules that are at the surface are "missing" neighbours with whom they have attractive interactions (**Fig. 1.1**). As a result, they have a higher energy than molecules in the bulk that are surrounded by other molecules. Liquids will therefore minimize their surface area in order to minimize the number of higher energy molecules at a surface. For a coating to wet a substrate completely and subsequently bond to it, it must have a lower surface tension than that of the substrate.

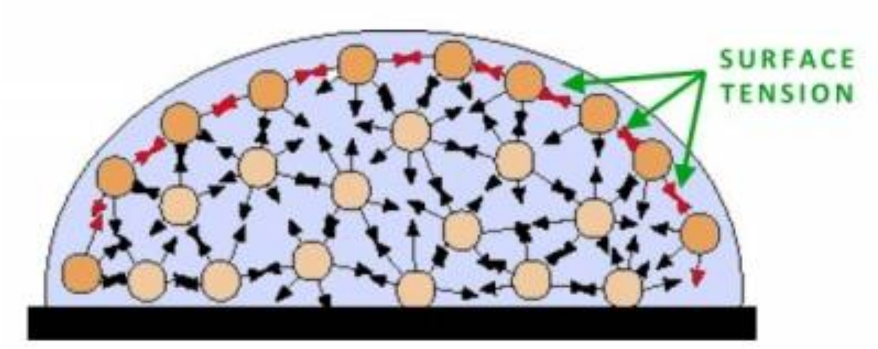


Fig. 1.1 Enhancement of the intermolecular attractive forces at the surface is called surface tension.

Most of the solvent-borne surface coatings based on organic binders and solvents have a surface tension in the range of 25-40 dyn/cm (where 1 dyn = 1 g·cm/s^2). This is why such coatings cannot adhere satisfactorily on oil-contaminated steel (surface tension of 20 dyn/cm) or on a very low surface energy material like well-cleaned Teflon (surface tension of 17 dyn/cm), see example in **Fig. 1.2**.

Fig. 1.2 Detachment of a coating from oil-contaminated substrate.

Apart from adhesion failure, almost all surface defects are related to surface tension and by fine-tuning or correcting the surface tension or surface tension gradient of the systems many surface defects can be solved. In order to correct the surface tension and the surface tension gradient of the system, surfactants need to be added as additive in small amounts and these surfactants are mainly based on modified poly-dimethylsiloxane or a modified or unmodified acrylic polymer. These surfactants will reduce the surface tension of the system and the magnitude of the reduction is highly depending on the original surface tension of the surfactant and how they are orientated themselves on the surface.

Below are some of the surface defects that can be rectified by correcting the system surface tension or surface tension gradient.

1) Levelling & Orange peel (see **Fig. 1.3**), vertical and horizontal levelling.
2) Craters or fish eyes.
3) Substrate wetting.
4) Edge crawling / framing effect.
5) Telegraphing and ghosting.
6) Bernard cells.
7) Air draft sensitive.
8) Over spray.

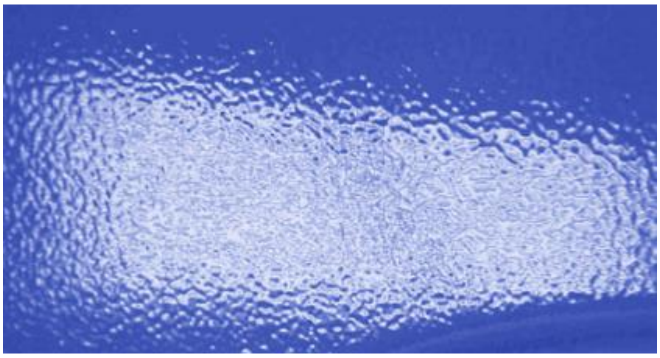


Fig. 1.3 Orange peel defect.

2 Experimental methodology

2.1 Materials

With the aim of measuring the surface tension of four different HEMPEL products (Hempadur Quattro 17634, Hempadur Impact 47800 and Hempadur Ultra-Strength 47500 and Hempadur PW 355ES) the following method was carried out:

1) Three steel panels were coated with each product.
2) The paint was allowed to dry during seven days.

The four selected HEMPEL products are certified for food contact or potable water regulations:

- 17634, 47500 and 47800 comply with Section 175.300 of the Code of Federal Regulations Title 21 – Dry Foodstuff. They are also tested for non-contamination of grain cargo at the Newcastle Occupational Health & Hygiene, Great Britain.
- 355ES was certified for contact with potable water by OTEC following the "Real Decreto 118/2003 de 31 de Enero de 2003" and "Real Decreto 866/2008 de 23 de Mayo de 2008".

2.2 Test Procedures

2.2.1 Measurement of surface tension

– Twelve different mixtures water/ethanol were prepared (see

Table 2.1) in order to evaluate the surface tension of the different coatings. One drop of each mixture was applied on all the substrate. When a drop is totally spread on the surface (Fig. 2.1), the surface tension of this coating is found between the surface tension of this mixture and the closest upper value.

Table 2.1 Surface energy of different ethanol/water mixtures at 25ºC.

Surface energy at 25ºC (dyn/cm)	EtOH (g)	H_20 (g)
22	100	0
24	87,6	12,4
26	72,44	27,56
28	55,63	44,37
30	43,49	56,52
33	38,02	67,98
35	27,43	72,57
37	23,39	76,61
40	18,78	81,22
50	8,64	91,36
60	2,96	97,04
70	0	100

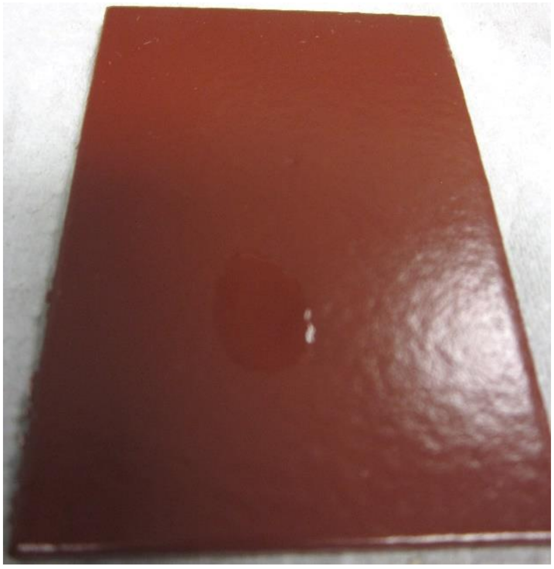


Fig. 2.1 Drop totally spread. Surface tension of the coating is higher than the liquid.

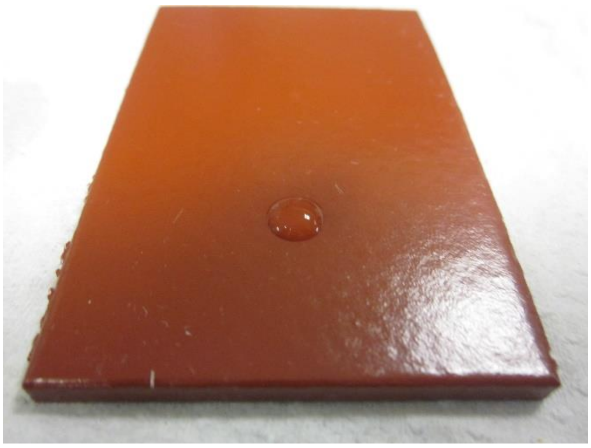


Fig. 2.2 Drop-like shape. Surface tension of the coating is lower than the liquid.

2.2.2 Friction tests

Friction coefficients were determined using a Bruker/CETR UMT-2 multifunction tribometer. Tests were performed at room temperature, using a 9.5mm polycrystalline alumina ball as friction counterpart. Samples were slid at 1 mm/s, under constant load of 2 N for approximately 25 seconds. In order to ensure repeatability, two replicas were performed of each test. The main test parameters are summarized in Table 2.2.

Table 2.2: Main parameters in friction tests.

Test Parameters	
Configuration	Ball-on-disk
	Unidirectional sliding
Counterpart	9.5 mm Al_2O_3 Ball
Normal force	Constant, 2 N
Sliding velocity	1 mm/s

During the test, instant forces (normal and tangential) are measured online. Using these values, the instant Coefficient of Friction is calculated using the Coulomb approach:

$$COF = \frac{F_X}{F_N}$$

Where:

COF: Coefficient de Friction

Fx: Tangential force measured during sliding

Fn: Normal force applied

As an inert alumina has been used as a friction counterpart, the obtained coefficient of friction is a good evaluation parameter for a painting system that needs to be used for different purposes.

Use of a large diameter ball under low load ensures that mechanical interaction of surface asperities is kept to a minimum. However, it needs to be taken into account that the different mechanical response of the tested paints (particularly hardness) results in differences in mechanical interaction.

3 Results and discussion

3.1 Surface tension

The surface tension of the products was:

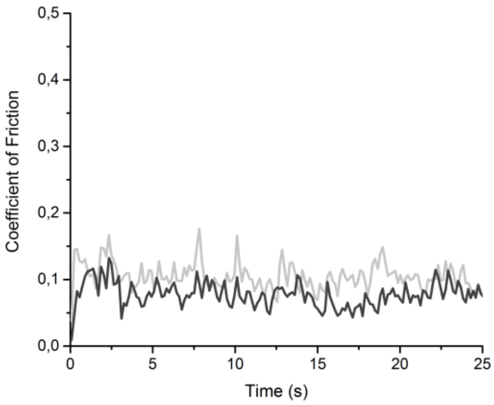
Table 3.1 Surface energy values at 25ºC of the selected paints.

Product	Surface energy at 25 ºC (dyn/cm)
Hempadur Quattro 17634	33 - 35
Hempadur Impact 47800	35 - 37
Hempadur Ultra-Strength 47500	30 - 33
Hempadur PW 355ES	35 - 37

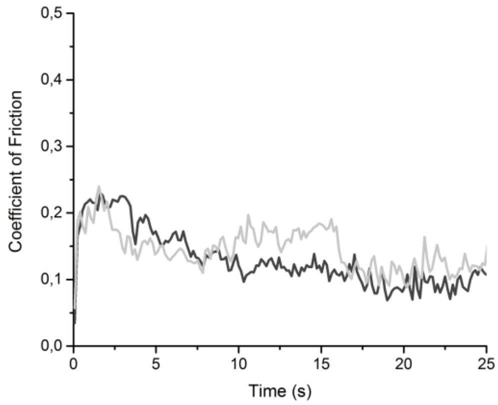
The tests indicate that Hempadur Ultra-Strength 47500 paint has the lowest range values of surface energy (30 to 33 dyn/cm), followed by Hempadur Quattro 17634, and by the two other paints, which have the same range values (35 to 37 dyn/cm), namely Hempadur Impact 47800, and Hempadur PW 355ES.

3.2 Coefficient of Friction

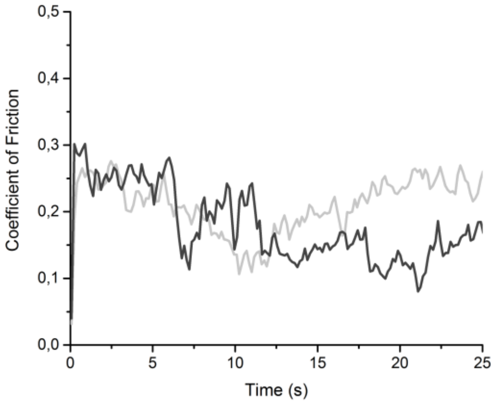
Frictional behavior of the four painted systems were investigated using the test methodology described in section 2.2.2. Fig. 3.1 shows the coefficient of friction measured during the test. For each of the paints, two test repetitions are shown. Friction coefficient values are summarized in Table 3.2.



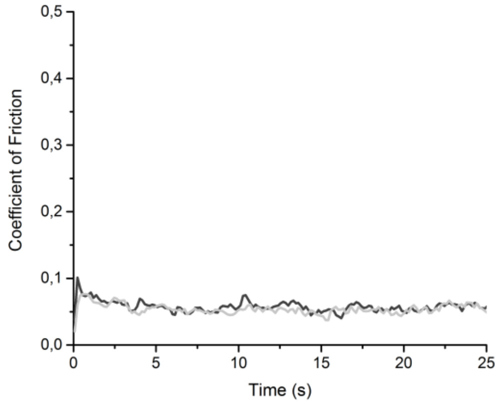
a) Hempadur Quattro 17634



b) Hempadur Impact 47800



c)Hempadur Ultra-Strength 47500



d) Hempadur PW 355ES

Fig. 3.1 Friction coefficient values obtained for the different paint systems. Two test repetitions are shown for each product.

Table 3.2: Summary of the measured coefficients of friction

Material	Test	COF		
Hempadur Quattro 17634	1	0.105	±	0.020
	2	0.078	±	0.018
Hempadur Impact 47800	1	0.145	±	0.031
	2	0.130	±	0.042
Hempadur Ultra-Strength 47500	1	0.179	±	0.055
	2	0.209	±	0.042
Hempadur PW 355ES	1	0.058	±	0.008
	2	0.054	±	0.007

Hempadur Quattro 17634 (**Fig. 3.1a**) showed low COF (0.10 in the first test replica and 0.078 in the second).

Paints Hempadur Impact 47800 (**Fig. 3.1b**) and Hempadur Ultra-Strength 47500 (**Fig. 3.1c**) showed the second-highest (approximately 0.14) and highest (approximately 0.18) coefficient of friction of the tested samples. Both systems showed high variability among the two test repetitions. Moreover, coefficient of friction varied during the test, and the test itself was less stable than for paints Quattro 17634 and PW 355ES. This can be related to surface finish of the samples.

Finally, Hempadur PW 355ES showed remarkably low COF (under 0.06), and the lowest of the studied samples. Measurement variability was also remarkably low: tests showed good repeatability, and coefficient of friction was stable within each test.

4 Conclusions

The Hempadur Ultra-Strength 47500 paint presented the lowest range value of surface energy (30 to 33 dyn/cm), out of the four paints tested, and will probably remain cleaner and be easier to clean. Both Hempadur Impact 47800, and Hempadur PW 355ES paints presented the highest surface energy value (35 to 37 dyn/cm).

In terms of friction, the paint system Hempadur PW 355ES showed the lowest coefficient of friction, as well as the most stable. This paint system should result in better overall frictional behavior.

Higher COF was measured on Hempadur Quattro 17634 and Hempadur Impact 47800. Hempadur Ultra-Strength 47500 showed the highest coefficient of friction, as well as the most variable behavior.