TESTING OF NANOPARTICLE CONTAINING POLYMERS FOR AVIATION APPLICATIONS

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2. Organisations involved

Exova is an international consulting company with a testing laboratory in Linköping, Sweden. The main work of the testing laboratory is material testing for the aviation industry.

3. Description of the case

3.1. Introduction

Exova manufactures nanomodified (containing nanoparticles of various kinds) samples and tests their properties mainly for the aviation industry. The samples are parts of the customers' material research and will hopefully be part of improving the aircrafts of tomorrow. Different kinds of physical properties of the nanomodified materials are tested. For example the mechanical properties are tested to learn more about how the nanoparticles improve the material strength and in what applications the modified material can be useful, e.g. for reducing weight or enhancing wear resistance. In this testing laboratory, it is mainly the same person who works with the nanomaterials and the quantities of nanoparticles in use are not very large, less than 50 g per year. In most cases, the nanoparticles being used are dispersed in a polymeric resin. After the dispersion process, a hardener is added and samples are made by moulding the mixture, or coating a surface with the product.

This testing laboratory uses many hazardous materials, and has devised guidelines and basic principles for working with these materials in a safe way.

3.2. Aims

Various kinds of nanoparticles are used in the laboratory to test different properties of materials for the aviation industry. The testing procedures include different mechanical procedures like coating, grinding, cutting and polishing the samples.

The aim in the laboratory is that the nanoparticles in use will not spread into the laboratory air and the workers do not become exposed to the nanoparticles during their workday.

3.3. What was done, and how?

Risk assessment and management

The risk assessment was conducted using in-house expertise in work place environment and safety issues (Exova is a consulting company).

The first risk assessment was done at the start of the first nanomodification project 2003. In conjunction with this project, a profound evaluation of the risks associated with working with nanomaterials was undertaken. The linked risks with the fibre shape of the particles were studied and protection measures assessed. It was also decided that since it was not yet clear how harmful these particles were, that workers should adhere to a high safety level in the laboratory and handle all nanoparticles with the same precautions as used for asbestos.

In-house expertise was used to create a nanosafe working method, which is still being developed, covering the needed expertise for working with new nanomaterials and new processes. The company intends to devise guidelines for how to make a nanosafe area for the customers.

The risk assessment states, in short, that inhalation and skin contact with the nanoparticles should be avoided. In practise, this means that the nanoparticles not dispersed have to be kept within the fume hood and gloves must always be used. All weighing, mixing etc has to be conducted inside the fume hood. If the particles have to be handled outside of the hood, e.g. due to an accident, protective clothing, gloves and respiratory protective device class P3[1] need to be used. It is recommended to use the powered air respirator with the P3 filters. A full facemask or a hood can be used as a face piece. During the spraying procedure, personal protection equipment (PPE) is used even though the spraying is being done in the specially ventilated room.

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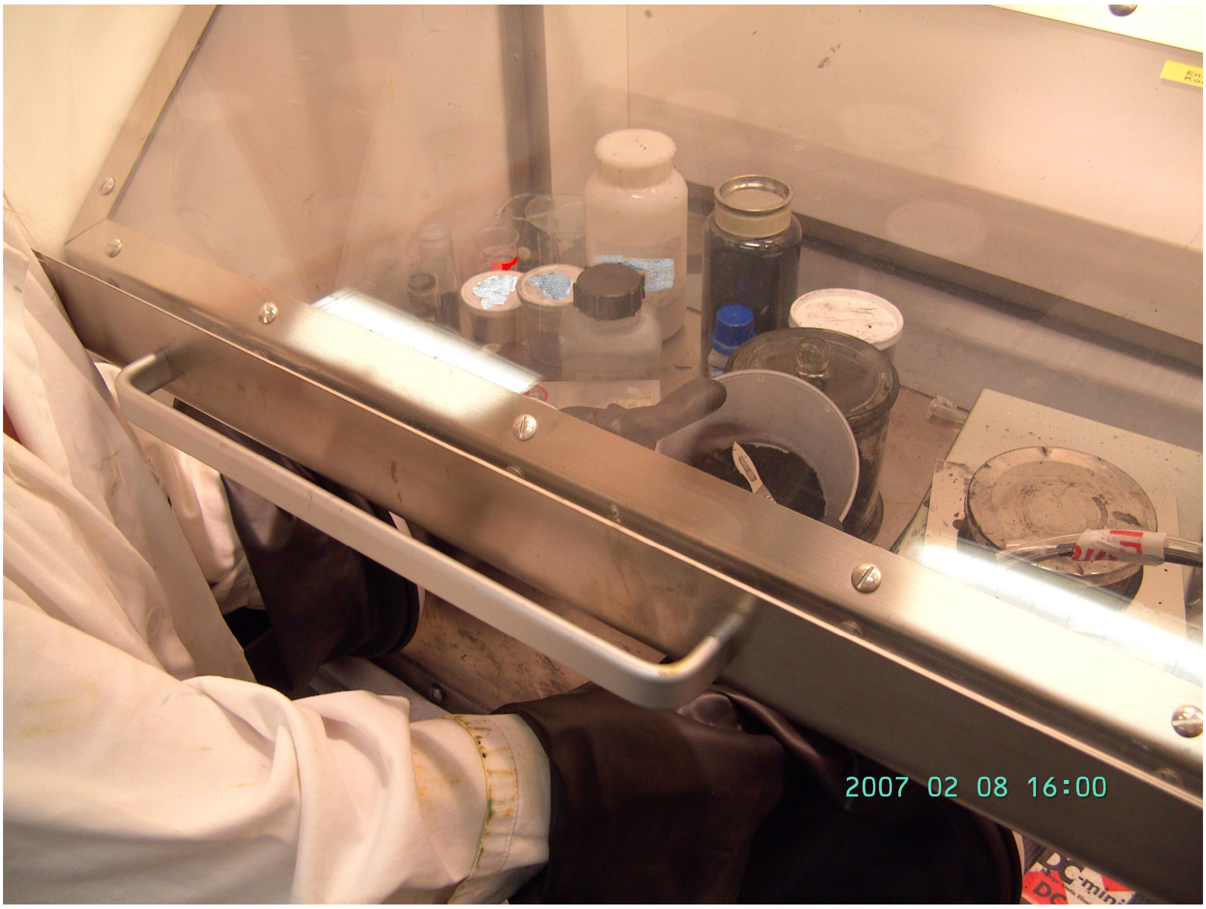
[1] This protective equipment has been used before nanomaterials were handled in the laboratory to protect from hazardous fumes etc. Device class P3 is the most effective filter used in respirators.

Figure 1: **Working with the nanoparticles in a glove box.**



Source: Courtesy of IVL, Sweden.

Work practice in laboratory

The nanoparticles not dispersed are always handled in a fume hood, preferably in a glove box. The particles can be stored outside the fume hood in a closed container. The dispersion process, which is done through ultrasound and mixing, is kept within the fume hood. The particles are thoroughly wetted before any mixing is started. The used equipment is cleaned afterwards within the fume hood.

After dispersion, the sample will be made through either moulding or coating. Moulding is done within the fume hood, which reduce the operator's exposure. Coating is done through spraying the nanomodified polymer on a panel. The coating is done in a specially ventilated room. The coating operator wears protective clothing and a protective mask, i.e. overalls, gloves and a half-faced mask. The respirator has a filter of class P3. This is the same protection level, which is used for normal spray painting of aircrafts etc. The half-faced mask will be changed to the powered air respirator with a full facemask.

Figure 2: **Coating operator with protective clothing. (Measuring device within black circle).**

Source: Courtesy of IVL, Sweden.

After curing[2], the nanomodified material often needs be cut or machined into the testing samples. It is important to add water continuously during the processing to keep the dust from dispersing into the air and to cool the specimens. At temperatures that are too high, the plastic could combust and might release nanoparticles into air. The maximum machining temperature depends on the polymer. The polymers, which are normally used, e.g. ---will not combust at temperatures below 250°C.

Disposal of samples and handling of waste

When discarding nanoparticles that are not dispersed, they are put into double layers of closed bags when still in the hood and then before being disposed, is marked as higher risk garbage. Uncured resin containing dispersed nanoparticles is also sorted as higher risk garbage. A finished sample containing nanoparticles can be treated as industrial waste.

[2] Curing is the hardening of the polymeric resin by crosslinking of polymer chains. It normally takes a few hours at elevated temperature. After curing the nanoparticles are caught within the matrix materials and will be harmless until released through fire, machining o.d.

Figure 3: **The amount of airborne (nano)particles is monitored during the dispersion of the nanoparticles. A small sampler with a filter collects the particles in the operator's breathing zone (inside the circle) and the measuring devices are used to monitor the amounts of airborne nanoparticles and nanofibres inside and outside the fume hood.**

Source: Courtesy of IVL, Sweden.

Exposure measurements in the workplace

The amounts of nanoparticles have been measured in the air outside and inside the fume hood during the dispersion process, coating, grinding, cutting and polishing the samples by the Swedish Environmental Research Institute (IVL). Safety procedures were followed when the measurements were being conducted.

Airborne particles were monitored with several measuring devices e.g. EPS 3090 (this is a SMPS scanning mobility particle sizer), GRIMM 1.108 (GRIMM is a brand, this is a OPC: optical particle counter) and FAM-1 (fibrous aerosol monitor) on three places, in the operator's breathing zone, inside and outside the fume hood. EPS 3090 and GRIMM monitor the amounts of particles with sizes in the range 6 nm – 1000 nm. FAM-1 measures the amount of fibres with diameter 100 nm – 4500 nm. No increased levels of nanoparticles or fibres compared to the background levels were found in the air, which led to the conclusion that the levels are very low. Increased levels of nanoparticles were detected within the fume hood during some activities but the number of nanoparticles found in the filter placed in the breathing zone of the operator was very low.

There are no standardised measuring methods or reference levels for nanoparticles today, nor is it certain that all nanoparticles can even be measured with the devices that are available today. This makes it difficult to state that the method is safe, but the measurement devices outside the fume hood responded more strongly to activities in the next room than to the activities in the fume hood.

An accident (or a 'worst case scenario') was simulated with nanofibres and the amounts of fibres in the air were measured both during the 'accident' and the subsequent sanitation process. These measurements showed much higher levels of nanofibres than encountered during normal work practice. Sanitation was done in three ways; wiping with a dry cloth, dampening the nanofibres with water and drying with a cloth, dampening the nanofibres with a dust binder and wiping with a cloth. The reason for using a dust binder was to bind dust of nanoparticles into larger, less harmful agglomerates. It was noticed that the dust binder caused a significant reduction of the amount of dust in the air. For that reason, different kinds of dust binders will be evaluated in the laboratory in the near future.

3.4. What was achieved?

- The health risks can be controlled as long as there is adherence to the safety procedures, which have been developed based on the results of the risk assessment. The risk assessment focused on nanotubes and nanofibres but can be used for other nanoparticles as well if they are judged less harmful than nanotubes. This is the case with all other nanoparticles that are used in the laboratory nowadays. New risk assessments and environmental measurements have been made with respect to changes in the process or materials but the safety procedures have not needed to be changed.
- Nanomaterials are mostly used in a resin where nanoparticles are not able to be dispersed into the air.
- Inhalation and skin contact with the nanoparticles can be avoided by keeping those nanoparticles not dispersed within the fume hood and always using gloves. In the spraying procedure, the PPE should be used even though the spraying is conducted in the specially ventilated room.
- Exposure measurements have shown that the airborne (nano)particle levels occurring during the handling of nanoparticles are not increased in the laboratory.

3.5. Success factors

The key success factor has been the knowledge gained in conjunction with the exposure and risk assessment conducted in the workplace. The procedure to develop a way of handling nanoparticles and nanomodified materials was very much facilitated by accessing knowledge of environmental and work environmental issues from other consultants at Exova who are working in this area. They contributed useful extra information. In addition, attending conferences has been an important way to gain more knowledge regarding this subject, i.e. Euro NanOSH.

3.6. Further information

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3.7. Transferability

These working procedures regarding working environment and effects on the environment for nanomaterials and nanomodified materials are considered safe if used when nanoparticles are dispersed in a resin or some similar material. The working procedures for achieving safe working environment are easy to transfer to any other test laboratory. Also the expenses are not high if the laboratory has already an effective fume hood or a special ventilated room for spraying. Knowledge of risk assessment procedure and risk management measures (e.g. PPE) is needed.

4. References, resources:

- The Swedish work environment authority (Arbetsmiljöverket) (2011). *Kolnanorör - Exponering, toxikologi och skyddsåtgärder i arbetsmiljön.* Kunskapsöversikt. Rapport 2011:1. Available at: http://www.av.se/dokument/publikationer/rapporter/RAP2011_01.pdf
- KEMI (Swedish chemicals agency) (2010). *Säker användning av nanomaterial, behov av regleringar och andra åtgärder –rapport från ett regeringsuppdrag.* En rapport från Kemikalieinspektionen. Rapport Nr 1/10. Available at: http://www.kemi.se/upload/Trycksaker/Pdf/Rapporter/Rapport1_10_nanomaterial.pdf