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Rheology of white paints: How Van Gogh achieved his famous impasto

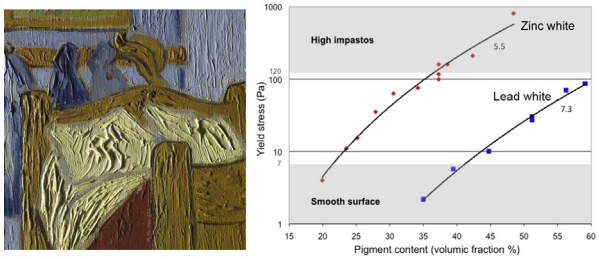
J. Salvant Plisson[a], L. de Viguerie[b,c,*], L. Tahroucht[d], M. Menu[a,g], G. Ducouret[d,e,f]

[a] Centre de Recherche et de Restauration des Musées de France, C2RMF, Palais du Louvre, 14 Quai François Mitterrand, Paris F-75001, France
[b] UPMC Univ Paris 06, UMR 8220, Laboratoire d'archéologie moléculaire et structurale, LAMS, Paris F-75005, France
[c] CNRS, UMR 8220, LAMS, F-75005 Paris, France
[d] UPMC Univ Paris 06, UMR 7615, Laboratoire de Sciences et Ingénierie de la Matière Molle (SIMM), Paris F-75005, France
[e] CNRS, UMR 7615, SIMM, Paris F-75005 France
[f] ESPCI, UMR 7615, SIMM, Paris F-75005 France
[g] Institut de Recherche de Chimie Paris, IRCP, 11 rue Pierre et Marie Curie, Paris F-75006, France

HIGHLIGHTS

- The rheological properties of 19th century white paint formulations have been compared.
- Lead and zinc white paints both exhibit viscoelastic properties, characteristic of paste suspensions.
- Yield stress and elastic moduli are strongly dependant on the nature, treatment and proportion of oil.
- At all studied concentrations, yield stress and elastic modulus at 1 Hz are higher for zinc white paints.
- This zinc white property can explain its specific use by V. Van Gogh, to create impasto.

GRAPHICAL ABSTRACT



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ABSTRACT

Paints based on white pigments are the basic materials found in ground layers of ready-made canvases as well as in painting layers mixed with other colours. It is surprising that Vincent Van Gogh, whose unique style is world famous, resorted to not one but two types of white paints. Indeed, Van Gogh often used both lead white and zinc white in the very same painting, contrasting then with the majority of his contemporaries who have only used the traditional lead white. To trace the evolution of his painting technique and to respond to the issues of authentication, dating and preservation raised by his artwork, it is essential to have a good knowledge of the painting materials he used and how he used them.

This paper describes the reconstructions of 19th century white paint formulations and their rheological characterization in order to compare their flow properties: by adjusting them, different paint finishes from smooth surfaces to high impastos can be produced. We define a general procedure for paint rheology characterization, useful for old recipes reconstructions in the field of conservation science. Both lead white and zinc white based paints exhibit a similar rheological behaviour, with a fluid to solid transition, and variations of their properties such as yield stress and elastic moduli, depending on their formulation (oil nature, content, and treatment). An explanation on the specific use of zinc white can be proposed as it allows higher impastos than a lead white paint containing the same oil content.

* Corresponding author at: CNRS, UPMC, UMR 8220, LAMS, F-75005 Paris, France. Tel.: +33 1 44 27 82 26.
E-mail address: laurence.de_viguerie@upmc.fr (L. de Viguerie).

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1. Introduction

Paint based on white pigments is one of the most commonly used by artists: indeed, white paints, often mixed with small amount of coloured paints, constitute the basis of many painting layers. For example, if one has a look to the orders of oil paint tubes by Vincent Van Gogh (1853–1890), precisely described in his letters, it appears clearly that he used a very large amount of white oil paint tubes to produce his artworks known for their bright colours [1]. This was also confirmed by different studies performed in the past: analyses have shown that coloured painting layers are commonly made of white pigments with a small amount of coloured pigment [2]. At the end of the 19th century, two types of pigments were available to produce white paints: lead white (generally mixture of lead carbonates, $PbCO_3/2PbCO_3{\cdot}Pb(OH)_2$) and zinc white (zinc oxide, ZnO). Since Antiquity, lead white has been one of the only white pigment used in oil painting as it possesses excellent properties. It was produced industrially during the 19th century by using the *Dutch Stack* process, consisting in exposing metallic lead strips to vinegar fumes (acetic acid) and manure in a close space for several months. Lead white remained the only white pigment used in oil painting until lead white toxicity became an important concern [3]. This is why, from the end of the 18th century, there was a crucial need to develop an alternative white pigment for oil paint. Zinc white appeared to be the best alternative. After improving the manufacturing, zinc white became available on an industrial scale around the middle of the 19th century [4].

Zinc white remained of very little use to artists from the second half of the 19th century, such as the Impressionists, who usually chose to use the traditional lead white, probably because zinc white was said to be slower to dry and had poor covering power,(i.e. the ability of a paint to obscure the surface upon which it is applied) [5]. Unlike his contemporaries, Van Gogh used both zinc white and lead white paints to produce artworks: indeed, orders of large amount of oil paint tubes of *blanc d'argent* (referring to lead white) and *blanc de zinc* (referring to zinc white) are regularly mentioned in his letters [1]. Additionally, Van Gogh often used both zinc white and lead white paints simultaneously in the very same painting according to previous research [6–10]. Despite complaining in many letters about the slow drying of zinc white [11], Van Gogh indicated that it had other advantages [12] that he did not specify. One can wonder which specific advantages Van Gogh found in each type of white paint and how he was using them in his artworks.

As can be found in ancient catalogues from paint suppliers (*Le Père Tanguy* catalogue dating from ca. 1888 to 1890 or 1876 *Lefranc* catalogue) [5,9], lead and zinc white oil paint tubes were the same price. Some major differences between lead white and zinc white paint properties have already been described in literature. Lead white paint has a shorter drying time and a better covering power, whereas zinc white give better colours in mixture with pigments [4–6,13,14]. Among appearance and drying properties, the paint texture and consistency are also crucial, particularly in the case of Van Gogh, well-known for his high impastos, resulting from the application of paint in thick layers to produce a textured surface (Fig. 1). Indeed, artists by adjusting paint consistencies and textures can produce very different effects, ranging from very smooth surface to very high impastos.

Based on reconstructions of 19th century oil paints, we investigated the use of white paints by Vincent Van Gogh in relation to their consistency and texture. To get a better understanding on the different use of lead and zinc white paints in Van Gogh's artworks, their rheological properties have been characterized. A discussion is then proposed on the levelling properties of paint materials applied to Van Gogh's paint layers.

2. Materials and methods

2.1. Paint samples reconstructions

Reconstructions of 19th century oil paint were prepared according to previous investigations and to the specific oil absorption value of each pigment investigated [2–4,15,16]. Three different pigments were used to prepare the formulations: zinc white, lead white and cobalt blue (suppliers indicated in Table 1). They were first imaged by SEM (see Supporting Information, S1). Paint made of 37%vol of zinc white were prepared, ground with different oils (nature, treatment and supplier in Table 1) in order to compare their rheological properties and choose an appropriate oil for further measurements. We used linseed and poppy oils similar to oils that were commonly employed during the 19th century. The two linseed oils from Laverdure are both cold pressed but their treatments are different: oil "cat. B", which has been chosen for further experiments, has been refined whereas the oil "cat. A" has been purified.

Paints with linseed oil ("cat. B") and different proportions of one or two white pigment(s) were prepared and tested according to the proportions listed in Table 2. The paints based on respectively zinc white/lead white/cobalt blue are noted ZW/LW/CB together with numbers indicating the pigment volumic content (%vol). As an example, the paint named ZW30-CB10 contains 30%vol of zinc white, 10%vol of cobalt blue and thus 60%vol of oil. For the mixtures of two pigments, the oil content is fixed at 60%vol, which has been estimated as the usual concentration in Van Gogh white paints estimated by a combination of PIXE and RBS techniques [17].

10–20 g of paint was prepared from raw pigments and oil at the different compositions. First the appropriate amount of oil was added to the pigment and mixed with the palette knife. The mixture was then roughly divided into three parts and each third was ground under the muller on a glass plate during 120 s (Fig. 1). The three parts were then mixed together to homogenize the whole and divided again by third and ground for 40 s.

Some formulations were unstable over few days and released oil. Moreover, it was observed that some lead white based formulations, when allowed to rest, get spontaneously more fluent within a short time. Such a behaviour was not detected for zinc white and cobalt blue paints. This change of consistency could be explained by the improvement of the oil-wetting of lead white pigments and/or by the oil diffusion with time in the aggregates that remain poorly dispersed, leading progressively to a better lubrication of pigment

Table 1
Different oils and pigments tested. The oils viscosity was measured and estimated at c.a. 5×10^{-2} Pa. s.

	Nature	Supplier	Density	Preparation and treatment
Oil	Linseed	Laverdure		Cat. A: cold-pressed, purified
	Linseed	Laverdure		Cat. B: cold-pressed, refined
	Poppy	Kremer		Refined
Pigment	Zinc White	Kremer (No. 46,300)	5.6	
	Lead white (mainly hydrocerussite)	Natural Pigments	6.5	Dutch stack process
	Cobalt Blue	Kremer (No. 45,710)	4.3	

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