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Wetting and Coalescence Prevention of Drops in a Liquid Matrix. Ground and Parabolic Flight Results

An experimental and numerical analysis of the behavior of drops in a liquid matrix, in presence of temperature differences, is carried out in preparation for a MAXUS sounding rocket flight to study wetting and coalescence prevention induced by thermal Marangoni effect.On-ground experimentation has been carried out using micro zone apparatus. Different pairs of liquids (drop and matrix) have been analyzed; wetting prevention has been observed with drops of different diameter and critical temperature differences have been measured for each pair. To avoid buoyancy effects similar experiments have been carried out during the 30th ESA parabolic flight campaign. The main objective of the experiments is facility tests in a parabolic flight for the MAXUS flight. During the parabolic flight a hanging drop of Silicone oil 10 mm diameter has been injected in a matrix of Fluorinert and in air; wetting prevention has been observed in presence of a temperature difference between the drop and the lower surface.The theoretical-numerical study of the problem has been carried out with a thermofluidynamic model based on the assumption of the existence of a fluid film between the drop and the lower surface.

After the campaign, the video images of the experiment have been analyzed and velocity measurements have been obtained analyzing the motion of tracers. Measured and computed velocities are in sufficient agreement, in particular for the Silicone oil/Fluorinert configuration.

Introduction

Recent works with transparent liquids have shown some intriguing phenomena related to wetting and coalescence prevention due to Marangoni effects. The first articles on the subject [1-2] presented evidence of the unexpected phenomenon of coalescence suppression, observed during the microgravity Spacelab D2 mission in April 1993. The authors report extensive ground experimental results with small drops of different liquids. Different explanations were initially proposed for the non-coalescence phenomenon: 1) a thin film of air between the two liquids due to the Marangoni effect; 2) a liquid-liquid interface with an interface tension, depending on the velocities of the liquids; 3) an electric repulsive charge; 4) explanations in terms of thermal radiation forces. Two thesis works [3-4] developed under the tutorship of the senior author proved the air film assumption. In this case, contrary to other proposed physical mechanisms, the air film, responsible for coalescence or wetting prevention, is due to surface tension unbalance (Marangoni effect). More specifically, the ambient air is entrained between the two interfaces (liquid-liquid or liquid-solid) by the drop surface velocities and reaches pressures sufficiently large to prevent coalescence and to balance the overpressure necessary to deform the drops.

A fluid-dynamic model of non coalescing liquid drops was formulated [5] to explain the intriguing phenomenon of the film formation and its stability in presence of two counteracting driving actions along the surfaces of two drops (sessile and hanging) brought into contact in presence of a temperature difference, and to numerically correlate experimental results on temperature differences, surface deformations, applied pressure and film thickness. The model was then extended and applied to the problem of wetting prevention of a hanging drop held by a circular disk and squeezed on a flat plate maintained at a lower temperature [6] and to the non coalescence of a hanging drop immersed in a pool of the same liquid [7].

Dell'Aversana, Banavar and Koplik [8] presented further experimental results, molecular dynamics simulations (for the case of isothermal drops and applied shear stress) and a simplified lubrication model, to explain presence of the air film responsible for the experimental phenomena described in the previous works. The air gap between the drop interface and the liquid bath is approximated assuming a stationary plate inclined at some angle over an infinite moving plate. For the non-isothermal case, the velocity of this plate is taken to be the characteristic Marangoni speed. Further experimental results on the subject have been presented in [6, 9, 10] which the phenomenon of wetting and coalescence prevention was studied independ-

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ently using laser interferometry, measuring the film thickness and its time evolution at different experimental conditions. In this work preliminary ground experiments and parabolic flight tests in low gravity conditions have been carried out in preparation of a sounding rocket flight to extend previous results to drops in an immiscible external liquid matrix. The problem is particularly important for applications in the processes of soldering or brazing [11, 12] or in the field of Material Science, due to its implications on the behavior of drop-solidification front interactions [13]. Ground experiments, numerical simulations of the thermofluidynamic field inside the cell and results of the parabolic flight experiment will make it possible to define and optimize the facility and the experimental sequence for the sounding rocket experiment.

2. On-ground experimentation

On-ground experimentation has been carried out using a micro zone apparatus, including an experimental cell, a stepper motor for micro positioning, an injection device, a thermal control system and computerized temperature and video acquisition; different illumination systems were available (light-sheet illu-

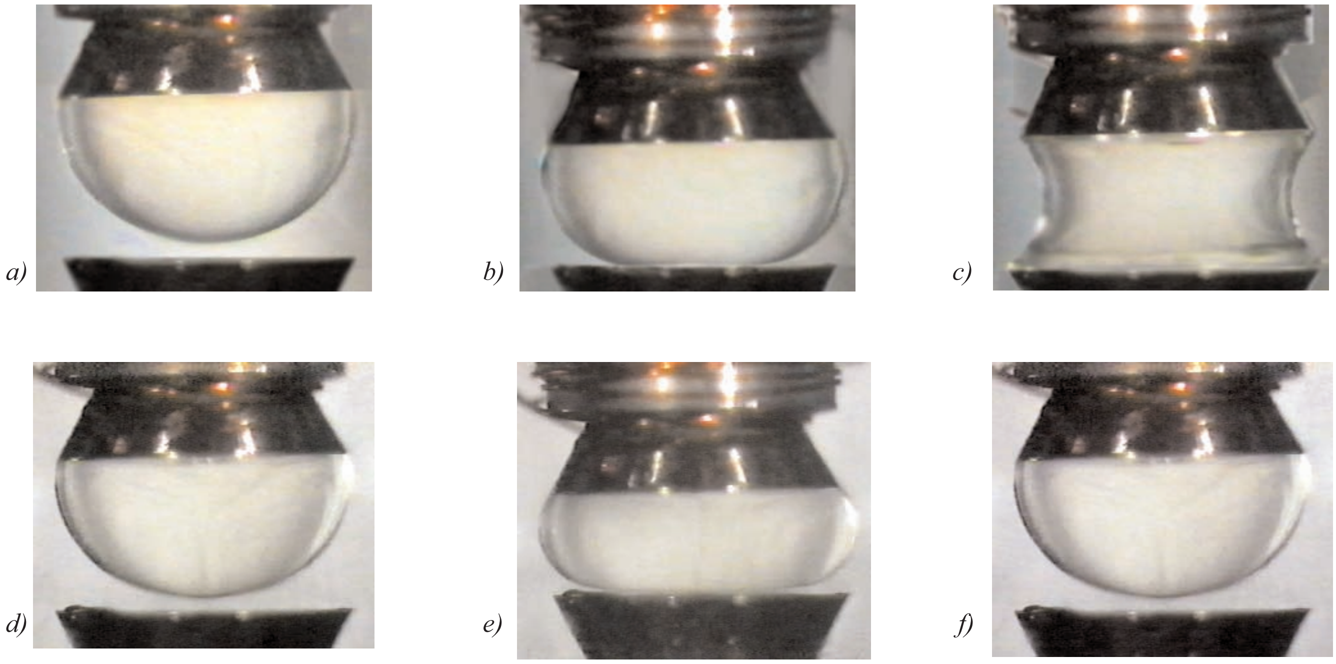


Fig. 1.: Soya oil drop formation (d = 10mm) in a Silicone oil 3cSt matrix, contacting a nickeled surface with small deformation (16%) and wetting in isothermal condition (a, b, c); wetting prevention with large deformation (34%) Δ T = 30° C (d, e, f); background illumination.

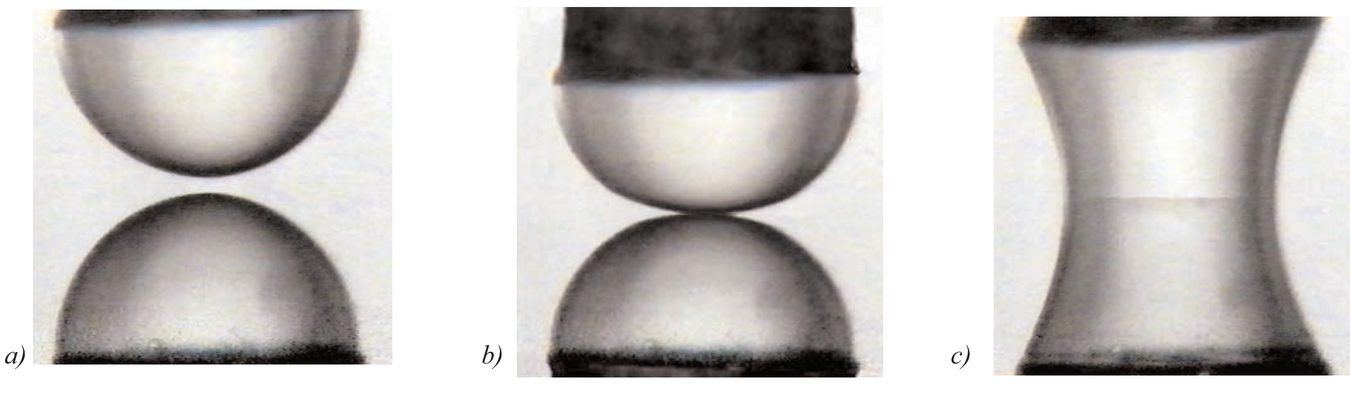
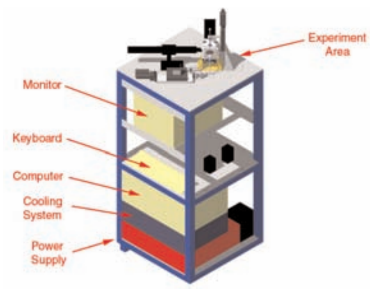


Fig. 2.: Soya oil drops formation (d = 2mm) in a silicon oil 3cs matrix (a); coalescence prevention in non isothermal conditions (b); coalescence due to temperature difference reduction (c); background illumination.

mination and background illumination). The system consists of a cylindrical support whose temperature can be controlled by a Peltier element and a power generator driven by a computer. A hanging droplet is formed by a microliter syringe and suspended to the support. A lower support can be used to study sessile drops. The size of the drop is also monitored by a CCD camera (lateral view). Tracer motion inside the droplet can be detected with laser sheet illumination. Once the drop is formed, a vertical temperature gradient is established since the temperature of the support disk is higher than that of the lower surface; a temperature gradient is therefore established along the drop surface. Generally, Marangoni effects arise at liquid-air or liquid-liquid interfaces due to surface tension gradients induced by surface temperature or concentration gradients. In particular, solutal Marangoni effects can be important in systems with a miscibility gap during the drop dissolution phase. In the present work the attention is focused on thermal Marangoni effects only, since the liquids investigated are practically insoluble in the temperature ranges investigated.

It must be pointed out that during ground experiments buoyancy plays an important role, especially at large temperature differences. Free convection may arise in presence of the gravity acceleration vector if non negligible density differences are induced by temperature differences. Since the characteristic Marangoni velocities are proportional to the drop radius R, whereas the buoyancy velocities are proportional to R^2, the relative importance between buoyancy and Marangoni effects can be reduced using very small droplets (i.e. with a micro zone facility). However, buoyancy effects in the external liquid matrix cannot be prevented and can be, in general, concurrent or counteracting with Marangoni effects. However, to avoid Rayleigh instabilities, the hanging drop was systematically heated from above. Different pairs of liquids have been analyzed, but only three show any interesting behavior from the experimental point of view: Soya oil drops (high kinematic viscosity, ν = 100cSt) in a Silicone oil matrix (low kinematic viscosity ν = 3cSt); Silicone oil drops (low kinematic viscosity, ν = 3cSt) in a Fluorinert FC-43 matrix (low kinematic viscosity, ν = 2.6cSt);



a)

b)

Fig. 3.: Rendering of the rack (a), rack in flight configuration (b).

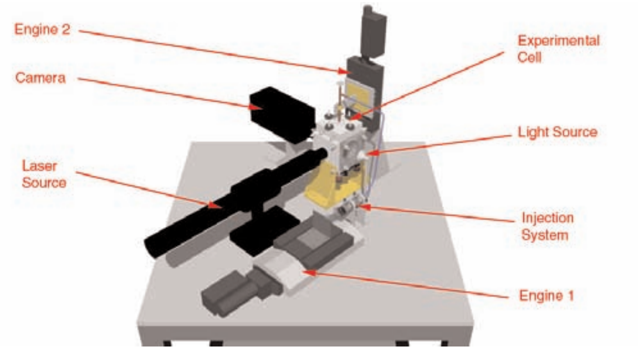


Fig. 4.: Rendering of the upper deck with its subsystems

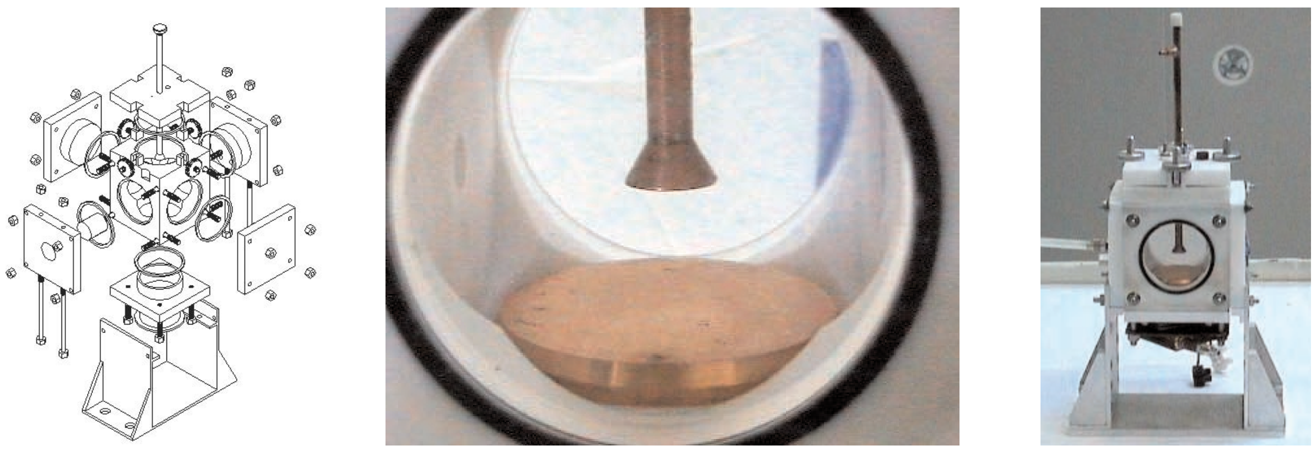


Fig. 5.: Experimental Cell

95% Ethanol drops in a Silicone oil matrix (low kinematic viscosity, $\nu = 3$cSt). For each pair of liquids, wetting prevention is observed in presence of sufficiently large temperature gradients, with drops of different diameter. When the temperature difference between the upper and the lower support is reduced (with a very small temperature ramp, to avoid unsteady effects) wetting is generally observed at sufficiently small values of ΔT. The corresponding value of ΔT is called critical temperature difference and is denoted by ΔT_c. In the following paragraphs the experimental results for each configuration are described.

2.1 Drops of vegetable oil in a Silicone oil external matrix

The small density difference ($\Delta\rho \cong 0$ at ambient temperature) between the liquid of the drop and of the matrix made the formation of large drops (diameter up to 10 mm) possible, similar in shape and volume to those formed during the experiment in microgravity. These experiments made it possible to define requirements for the injection and translation systems of the flight facility. Figure 1 shows the behavior of a 10 mm Soya oil drop in a Silicone oil 3cSt matrix. If the disk and the solid surface are at the same temperature (ambient temperature) no motion arises in the liquid drop. At these conditions, if the drop is put in contact to the wall, by moving the disk down, the liquid spreads over the solid surface forming a liquid bridge in terms of milliseconds (fig. 1a-c). If this experimental sequence is repeated after establishing a temperature difference between the disk and the horizontal surface (by heating the pendant drop and/or by cooling the solid wall compared to ambient temperature), then Marangoni flows will appear inside the liquid drop, due to the surface tension unbalance induced by surface temperature differences. In particular, since the surface tension is a decreasing function of the temperature, the velocity along the drop surface is downward (opposite to the imposed temperature gradient), i.e. is directed from the upper disk to the region of contact between the drop and the solid surface. By continuity, the flow inside the drop close to the symmetry axis is directed from the contact region towards the upper disk. When the drop is now slowly brought in contact with the surface, if the temperature difference is sufficiently large (a few degrees centigrade), no wetting occurs (fig. 1e). If the drop is pressed against the solid surface, it is deformed in a completely reversible way, similarly to an elastic balloon (1d-f). If the temperature gradient is reversed (by cooling the disk and/or by heating the solid surface), then the Marangoni flow is reversed and is directed from the contact region to the solid support (along the liquid drop surface) and when the drop contacts the solid surface the liquid spreads over the solid surface (as in the isothermal situation). Figure 2 shows the behavior of two drops of the same liquid (Soya Oil) in the same liquid matrix (Silicone Oil 3cSt). When a temperature difference is established the drops do not coalesce but are slightly deformed (fig. 2b). At this point the temperature difference is slowly reduced until the drops form a liquid bridge (fig. 2c).

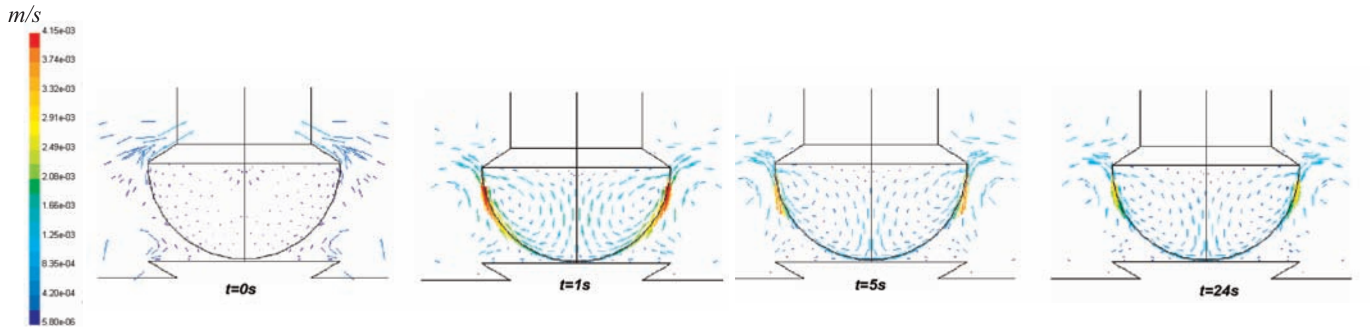


Fig. 6.: Velocity vectors during the microgravity period - matrix: Fluorinert

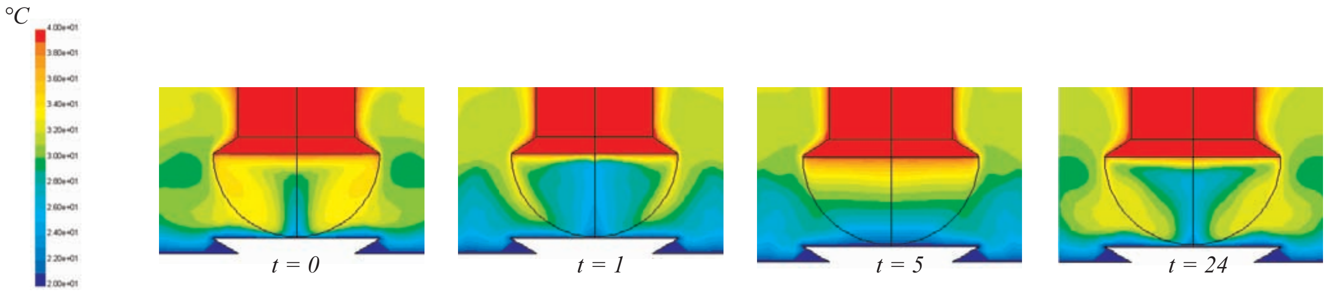


Fig. 7.: Temperature field during the microgravity period - matrix: Fluorinert

2.2 Silicone oil drops in a Fluorinert external matrix

In this case the large density difference between the liquid of the drop and of the matrix ($\Delta\rho \cong 0.98$ g/cm^3) allows only small diameter drops (φ<4mm) to be formed. The experimental sequence is similar that of the previous configuration: first the behavior in isothermal conditions is analyzed, then a temperature difference is established and wetting and coalescence prevention is observed. For some configurations the critical temperature difference was measured.

2.3 Ethanol drops in a Silicone oil external matrix

Due to the small density difference ($\Delta\rho = 0.086$ g/cm^3) relatively large drops can be formed, but only drops up to R=1.5 mm have been investigated. In actual fact, larger drops tend to make thermalization times too long, and this is not convenient because increasing the temperature the Ethanol drop exhibits a partial dissolution in the matrix of Silicone oil. The experimental sequence is the same as above. Wetting and coalescence prevention were observed for drops of different diameters and critical temperature difference was measured.

2.4 Critical temperature differences

Table 1 shows the measured critical temperature differences for different drop diameters for the configuration described above. For all configurations ΔT_c is an increasing function of the drop diameter. To explain this behavior two different effects should be taken into account. Increasing the radius (R) the pressure difference between the drop and the matrix ($\Delta P = 2\sigma / R$) decreases; i.e. overpressure in the liquid film (between the drop and the lower surface) is smaller. Furthermore, for a fixed value of the temperature difference (ΔT), by increasing the drop radius (R) the thermal gradient ($\Delta T/R$) decreases. The measured increase of ΔT_c seems to show that the second effect, leading to reduced Marangoni motion due to the small temperature gradient, prevails on the other. Furthermore, increasing the drop size the drop exhibits large deviations from the spherical shape and the importance of buoyant convective motions increases. These two effects play an important role on ground when the drop diameter increases. On the basis of the above considerations microgravity experiments were prepared and carried out to study only Marangoni effect in spherical drops.

3. Microgravity experiments

As discussed earlier, a sounding rocket experiment on "Wetting and Coalescence Prevention" is in preparation. The experiment will be performed to study the Marangoni effects and wetting and coalescence prevention of drops in an immiscible external matrix. As a precursor experiment of the sounding rocket investigation the WECOP (WEtting and COalescence Prevention by Marangoni Effect) experiment has flown during the 30th parabolic flight campaign which took place in May 2001 at the air-

Drop diameter (mm)	ΔT_{crit} (Soya Oil drop in Silicon Oil)	ΔT_{crit} (Silicon Oil drop in Fluorinert)	ΔT_{crit} (Ethanol drop in Silicon Oil)
2	16.2 ± 0.6 K	5.0 ± 0.3 K	13.0 ± 0.7 K
3		7.8 ± 0.8 K	16.0 ± 0.9 K
4		9.6 ± 0.4 K	
5	19.7 ± 0.5 K		

Tab 1.: Critical temperature difference ΔT_c measured varying the drop diameter and the experimental liquids

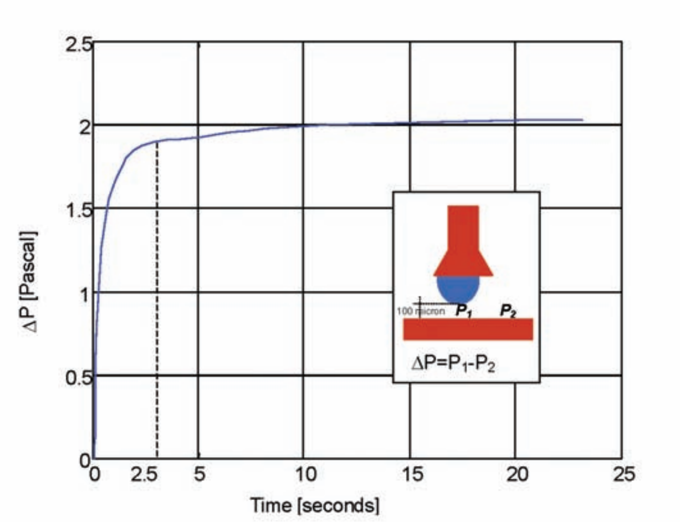


Fig. 8.: Pressure increase in the liquid film

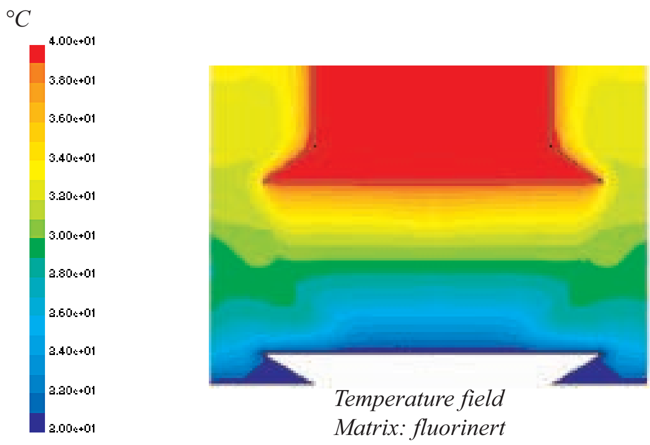


Fig. 9.: Tempereature field between the disks at the end of the parabola

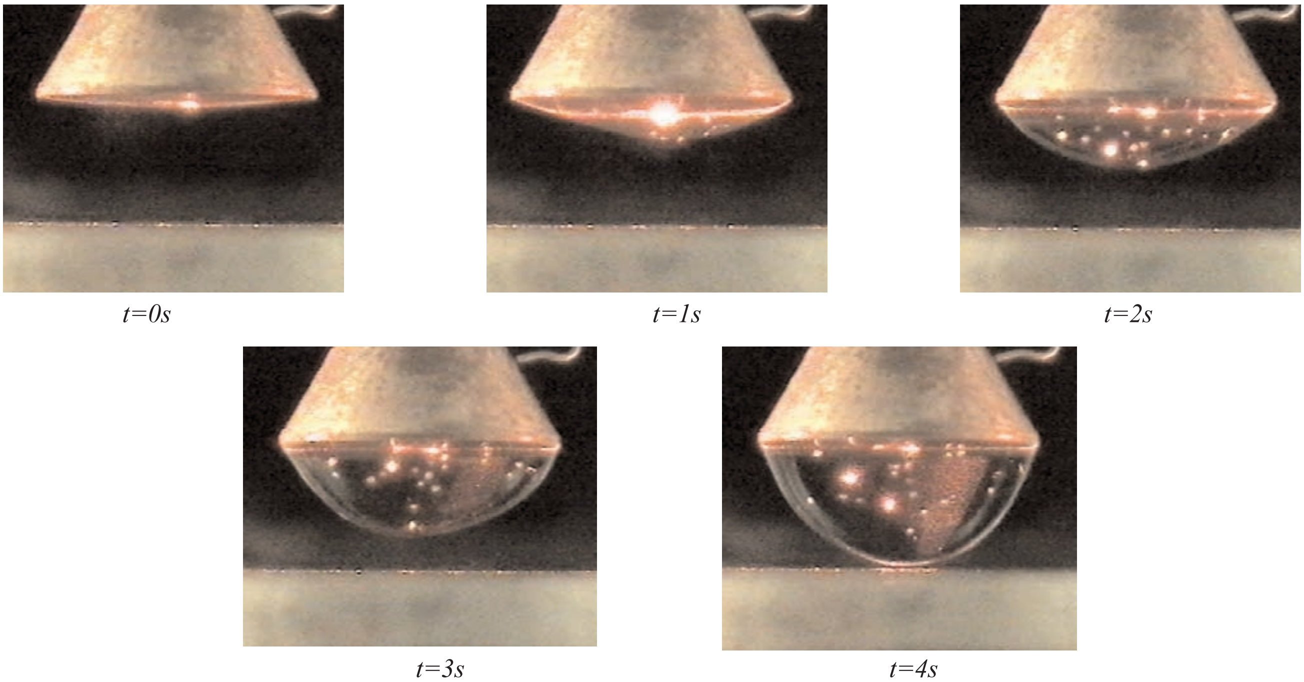


Fig. 10: Injection sequence of a Silicon Oil 3cSt drop in a Fluorinert matrix

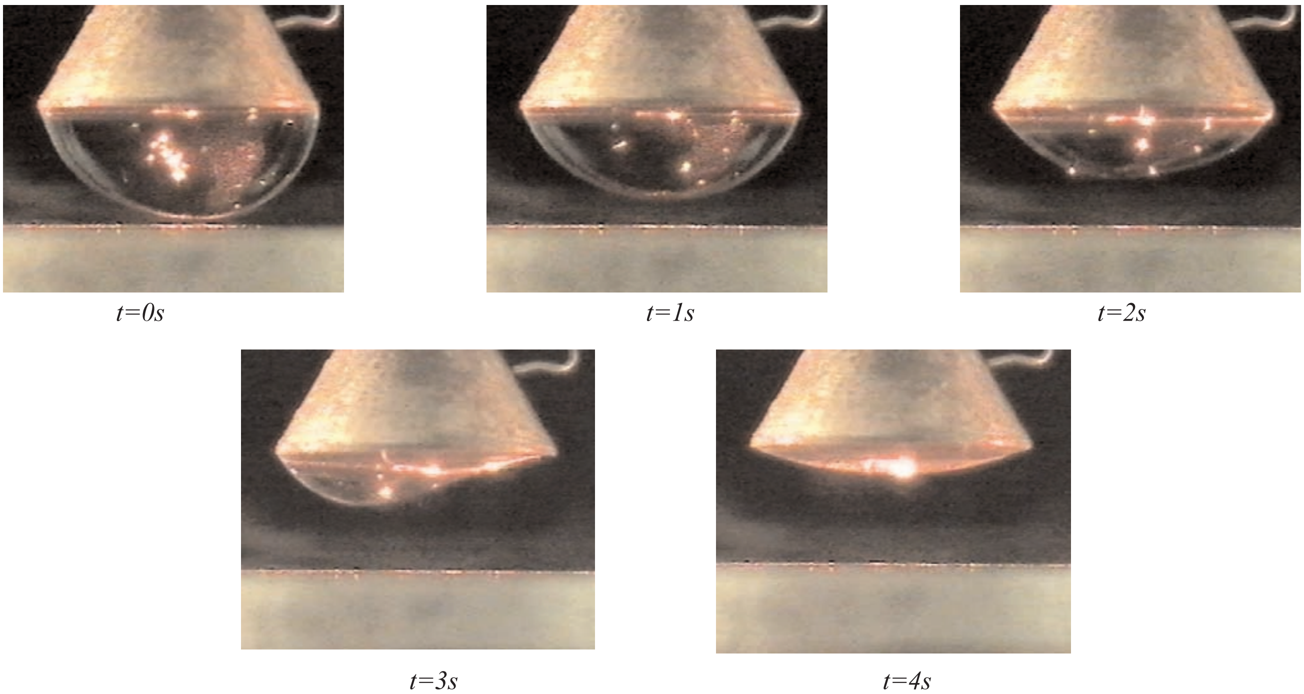


Fig. 11: Suction sequence of a Silicon Oil 3cSt drop in a Fluorinert matrix

port of Bordeaux-Merignac. The main objective of the experiment was the study of the wetting behavior of a Silicone oil drop on a solid surface, in presence of a surface tension gradient due to an imposed temperature difference between the drop and the surface. During the microgravity period a pendant drop of Silicone oil 3cSt was formed in a cell filled with Fluorinert FC-43 (or in air). The experimental liquids are the same selected for the Maxus 5 experiment. However, due to the short microgravity time available during each parabola and to the low quality of the microgravity environment, only qualitative results could be achieved (only unsteady conditions could be investigated and no reproducible conditions could be achieved from parabola to parabola). The main objectives of the experiment included: Marangoni motion observation; evaluation of the maximum injection rate needed to avoid drop detachment from the upper disk and the study of wetting prevention in presence of Marangoni motions. The experimental sequence consists of two phases: the first is aimed at evaluating the best injection rate; in the second Marangoni motions and wetting prevention are investigated. Both sequences were repeated either in Fluorinert or in air.

3.1 The facility for the parabolic flight experiment

The facility (fig. 3) for the parabolic flight experiment has been designed and manufactured to withstand certain requirements provided by NOVESPACE and regarding the structural resistance, the electrical absorption and the sealing of subsystems that contain liquids. The core of the experiment is the upper deck (fig. 4) on which the main systems are positioned. The test cell ($5 \times 5 \times 7\,cm^3$) is made of Teflon and filled with Fluorinert or air, the liquid drop of Silicone oil is injected inside it (fig.5). Some faces of the cell are made of Plexiglas to allow the observation of the drop by light-sheet technique. The upper side of the cell is removable to allow cleaning of the needle between two different injection sequences. The removable cap has a hole in the center for the movable injection needle. It can be moved upward and downward by a translation stage set upon the cell. The lower side consists of a central copper cylindrical body on which the drop is pushed when wetting prevention is observed. The injection needle is made of a copper cylinder (h=150mm, φ = 5mm) with a coaxial hole (φ =1mm) to allow the injection of the experimental fluid. The lower side of the needle houses a frustum of cone to whose lower surface the drop is attached. Drop injection is ensured by an independent expandable syringe, driven by a translation motor (Physik Instrumente-M155.11). The syringe is automatically controllable: both flow rate and the volume of the liquid to be injected can be set independently. The injection subsystem is connected to the needle by a flexible pipe, which allows the movement of the needle inside the cell leaving the syringe pump fixed. The drop is moved inside the cell by a translation stage (Physik Instrumente- M400), connected to the needle. This allows a vertical translation of the drop, independent from the injection, in order to squeeze the drop against the lower side of the cell (which should be cooled by the Peltier). The translation is motorized, with an accuracy of a micron. An elastic balloon, connected to the cell with a pipe, allows volume variations of the matrix due to thermal expansion, to the injection of the drop and to the translation of the needle inside the matrix. All the phenomena occurring during the experiment were observed and recorded by a CCD video-camera (Sony digital handy cam - DCR PC 100E) located as shown in fig. 4. In order to observe the Marangoni effects, tracers were used. Their motion was observed through a light sheet made by a diode laser (Oriel 15mW) located in a plane perpendicular to the camera. The thermal control system acquires the temperatures inside the cell through two thermocouples: one positioned on the upper disk, the other under the lower surface. The thermal gradient inside the fluid cell is generated by a heating element around the upper disk and by a Peltier cooling the copper cylinder on the lower side of the cell. The heat sink (for the Peltier) is made of a copper element inside which cool water circulates. The cooling subsystem is made of a radiator and an electrical pump for water circulation and is positioned in the lower part of the rack. A programmable power supply provides the current for the heating element and the Peltier. The Central Processor Unit provides the control of all the systems of the rack. The digital acquisition board and the motor control board are installed inside the computer together with the software necessary to perform the experiment. The computer is assembled in a drawer manufactured to be positioned in the rack. A rack monitor (Sony - Trinitron fine pitch) was used to observe either the drop or the computer desktop.

3.2 Parabolic flight campaign

The WECOP experiment was performed during the 30th ESA parabolic flight campaign that took place in Bordeaux-Merignac on 15, 16, 17 May 2001. During this campaign 14 experiments were carried out; 8 in physical science, 3 in life science and 3 experiments proposed by students. During the campaign Airbus A300 "Zero G" performed 93 parabolas, obtaining more than 30 minutes of microgravity.

Day 1 - During the first flight day preliminary tests of the experimental apparatus were performed; the cell was filled with Fluorinert. During the flight the sealing of the cell and the injection system were checked, squeezing tests of the drop were also carried out. Hemispherical drops (volume 250 μ l) were formed with an injection rate ranging from 50 μ l/s a 100 μ l/s (injection time ranging from 5 to 2.5 seconds). During the experimental tests the number of tracers injected in the drop was not sufficient: in actual fact some tracers remained attached to the injection pipe and the syringe. This caused a low density of tracers in the drop with consequent difficulty for the observation of Marangoni motions (fig. 10).

Day 2 - During the second flight day, experiments were carried out to observe Marangoni motions inside the Silicone oil drop and inside the Fluorinert matrix. The density of tracers in the syringe was increased and some good quality tests, with temperature difference ranging from 15°C to 20°C, were carried out (fig. 12 a, b). During the last five parabolas the temperature difference was reduced to observe wetting of the drop and to measure, quantitatively, critical temperature difference (about 0.3 °C) as shown in fig. 12 c, d.

Day 3 - During the third flight day similar experiments on Silicone oil drops in air were carried out. In this configuration Marangoni velocity inside the drop turned out to be greater; this is due to the fact that air viscosity is smaller than that of Fluorinert and the surface tension derivative with the temperature of the oil/air interface is greater than for the oil/Fluorinert interface. During some parabolas the drop was squeezed against the lower surface and wetting prevention was observed.During the last parabolas the temperature difference was reduced to measure critical temperature difference (about 0.1 °C). As the

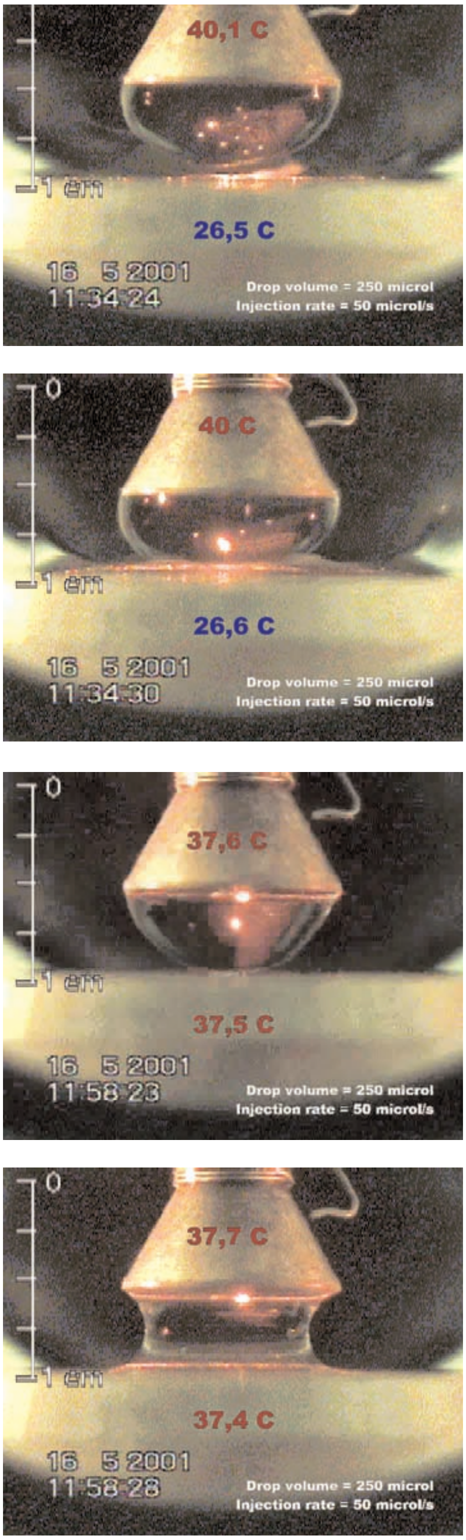
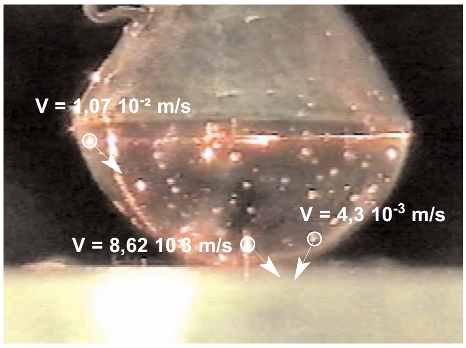


Fig 12.: Day 2: 5/16/2001 - Silicon oil 3cSt drop in a Fluorinert matrix Injection and wetting prevention during the 23th parabola (a,b) Injection and wetting for the measurement of critical temperature difference during the 30th parabola (c,d)

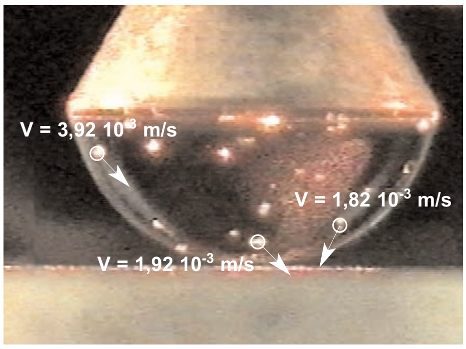
images show (fig. 15), the density of the tracers inside the drop was increased by inserting them directly under the upper disk when the cell was opened to be cleaned.

3.3 Numerical simulations

The theoretical-numerical study of the problem was performed by introducing a thermofluidynamic model based on the assumption of the existence of a fluid film between the drop and the lower surface. This film is sustained by the entrapment action of surface motions on the fluid around the drop, directed towards the "potential" contact zone. The pressure difference at the drop interface is balanced by capillary pressure due to the drop curvature; in particular at the contact zone, assumed to be flat, pressure inside the drop and inside the film should balance themselves (zero curvature of the interface drop-film). The drop and the lower surface are bounded by a finite volume similar to the experimental cell; this system is isolated from the external environment by the external walls that are supposed to be adiabatic. The Navier-Stokes equations were solved imposing, for the boundary conditions, the continuity of the thermal flux inside and outside the drop (coupled solution between drop and matrix); the initial velocity is zero everywhere except at the interface drop/matrix where the Marangoni condition has to be satisfied:



Silicon Oil 3cSt in air matrix



Silicon Oil 3cSt in fluorinert matrix
Fig 13.: experimental velocities

$$\tau_1 - \tau_2 = \sigma_T \frac{\partial T}{\partial s}$$

τ_1 and τ_2 are the viscous shear stress at the interface, s the curvilinear coordinate

$$\tau_1 = \mu_1 \left(\frac{\partial v}{\partial n}\right)_1 ; \tau_2 = \mu_2 \left(\frac{\partial v}{\partial n}\right)_2$$

and *n* is the direction normal to the interface. The computations were carried out with the finite volume technique, solving the time-dependent Navier-Stokes equations in the primitive variable formulation, using a uniform grid (sometimes with a co-located arrangement). Grid convergence is achieved in almost all the computations since further grid refinement does not produce significant differences (less than 1%) on the results. For further details on the numerical model see [14-16]). To obtain thermofluidynamic conditions as similar as possible to experimental conditions, the parabola was divided into its main parts and numerical simulations were carried out for each. For each simulation, the initial conditions and results may be defined in terms of thermofluidynamic field, which represents the initial conditions for the next simulation.

The aim of the numerical simulation is to prove that the few seconds of microgravity are sufficient to generate Marangoni motions and to prevent wetting; for this reason only the configuration Silicone oil/Fluorinert was analyzed, since in this case thermalization times are longer and convective velocities are smaller, compared to the Silicone oil/air configuration.

DROP: SILICON OIL 3CST - MATRIX: FLUORINERT FC-43

Position where the velocity has been measured	Experimental value [m/s]	Numerical value [m/s]	Percentage variation (Vs-Vn)/Vs
V1	3,92 10^{-3}	3,72 10^{-3}	+ 5,1 10^{-2}
V2	1,92 10^{-3}	1,79 10^{-3}	+ 6,7 10^{-2}
V3	1,82 10^{-3}	1,72 10^{-3}	+ 5,5 10^{-2}

DROP: SILICON OIL 3CST - MATRIX: AIR

Position where the velocity has been measured	Experimental value [m/s]	Numerical value [m/s]	Percentage variation (Vs-Vn)/Vs
V1	1,07 10^{-2}	9,8 10^{-3}	+ 8,4 10^{-2}
V2	8,62 10^{-3}	7,2 10^{-3}	+ 16,0 10^{-2}
V3	4,3 10^{-3}	4,0 10^{-3}	+ 7,0 10^{-2}

Tab 2.: Comparison between experimental and numerical velocity

$1g_0$ Simulation - There is no drop inside the matrix; initial temperature is equal to ambient temperature. The thermofluidynamic field generated by warming the upper disk and cooling the lower disk is computed. A steady numerical simulation was performed to compute the regime thermofluidynamic field: this is a sound hypothesis as the thermal gradient is established at the beginning of the flight (about 30 minutes before the parabola 0). It may be observed that the temperature field between the two disks is purely diffusive. However, there are strong convective motions around the injection needle but the velocity in the region where the drop is injected (between the two disks) is about zero.

$1.8g_0$ Simulation - Again, there is no drop inside the matrix; initial temperature and velocity field is that computed in the previous simulation. The simulation is unsteady because interest lies in what happens during 20 seconds in hypergravity conditions.The temperature field does not exhibit appreciable changes when compared to the previous one, convective motions are stronger but velocities are negligible between the upper rod and the lower disk.

Simulation of the microgravity period - The Silicone oil drop was injected into the matrix: the boundary conditions properly simulate Marangoni motions. The initial conditions for the temperature and the velocity fields are those computed in the previous simulation. Residual acceleration along the Z axis is $10^{-2}g_0$; no residual accelerations were considered along the X and Y axes. The aim of simulation is to prove that 24 seconds would be enough to activate Marangoni motions and to establish a quasi steady velocity field. Just after 1 second of simulation the motions are completely developed (fig. 6). At the end of the microgravity period a decrease of the velocities along the drop/matrix interface may be observed; this is caused by a decrease of surface temperature gradient due to Marangoni motions (fig. 7). The pressure-time variation in the liquid film was computed (fig. 8). The pressure increase (Δ P) is the main agent responsible for wetting prevention; Δ P reaches the highest value (about 2Pa) after 2-3 seconds of simulation, confirming the results in terms of velocity. The theoretical pressure difference between drop and matrix was computed with the Young-Laplace formula:

$$\frac{2\sigma}{R} \cong 2Pa$$

The similarity between the theoretical and numerical value underlines the suitability of the numerical model adopted.

Simulation after the microgravity period ($1g_0$ and $1.8g_0$) - There is no drop in the matrix and the initial conditions were obtained from the previous simulation. A steady simulation was performed with a gravity level first of $1.8g_0$ and later of $1g_0$. The temperature field was computed (fig. 9) to verify that the experimental conditions to start a new sequence will be reached (stratified temperature field between the two disks).

3.4 Post-flight Analysis

After the campaign the best images were selected and the velocity of some tracers was measured (fig.13). These experimental velocities were compared with numerical velocities. Good agreement was obtained, in particular in the oil/Fluorinert configuration the percentage error never exceeds 6.7 %; in the oil/air one it is never greater than 16%. In both configurations the greater errors are computed for the tracers in the center (6.7% oil/Fluorinert and 16% oil/air), for the boundary tracers the error is always lower (5.1% oil/Fluorinert and 8.4 % oil/air). Table 2 summarizes the comparison between experimental and numerical velocity.

4. Conclusions

The WECOP experiment has been successfully carried out showing the feasibility of the experiment on sounding rocket MAXUS 5. The main experimental results can be summarized as follows:

a) pendant Silicone oil drops (10mm diameter) have been formed either in a Fluorinert or in an air matrix;

b) Marangoni flows due to thermal gradients have been observed;

c) During some parabolas wetting has been prevented by the temperature difference established between the upper and the lower disk; some numerical experimental correlations have been found.

d) Mainly qualitative results have been obtained; this is due to the short microgravity period (about 20 seconds) and to the acceleration disturbances of the aircraft.

List of symbols

φ	disk diameter [m]
ΔP	pressure difference across the drop interface [N/m^2]
ρ	density [Kg/m^3]
h	cylinder length [m]
ν	kinematic viscosity [m^2/s]
n	normal coordinate [m]
P	pressure [Pa]
R	drop radius [m]
s	tangential coordinate [m]
T	temperature [K]
V	velocity [m/s]
ΔT_c	critical temperature difference [K]
ΔT	temperature difference [K]
$\Delta \rho$	density difference [Kg/m^3]
μ	dynamic viscosity [Kg/m/s]
σ	interface tension [N/m]
τ	viscous shear stress [N/m^2]

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