PSP/TSP ACTIVITY IN TsAGI

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KEYWORDS:

Main subjects: Pressure and heat transfer distribution measurements on the model surface
Fluid: air flows, hypersonic flows
Visualization method(s): Pressure sensitive paint (PSP), Temperature sensitive paint (TSP)
Other keywords: paint formulation, luminescent coatings

ABSTRACT: TsAGI was a pioneer of PSP technology in the world. A large amount of efforts were devoted on a paint development. Now pressure sensitive paints based on pyren derivative and silicon rubber are the most relevant in our aerodynamic researches. The advantages of this formulation are: large quantum yield, optimal sensitivity for 1 bar pressure, small response time, absence of hysteresis and internal temperature compensation. Temperature sensitivity does not exceed 0.3%/^{0}C. The main disadvantage of the paint is a short wavelength excitation (<340 nm) that requires quartz wind tunnel windows for paint illumination.

In TsAGI PSP technology is called for three types of aerodynamic tasks:

1. Investigations of large scale models of civil and military aircrafts at transonic speeds. Binary (two-color) PSP is used. The binary paint contains additional reference luminophor that is insensitive to pressure and emits light with an intensity directly proportional to the excitation light intensity. Powder of europium doped crystal phosphor is used as a reference luminophor in combination with pyren derivative. Both luminophors (pressure sensitive and reference) are excited by the light of the same wavelength but radiate in different spectral ranges, thus determining the separate recording of two images, e.g. using two cameras with appropriate light filters. Luminescence of reference luminophore is used for pixel-by-pixel correction of excitation light intensity variations during the test.

2. Pressure field measurement on the propeller blade surface is extremely complicated problems of experimental aerodynamics. Application of PSP technology to propellers has some specific features. The main problem is an image acquisition of moving blade. Linear speed of blade tip can reach up to 200÷300 m/sec. To eliminate blade displacement during image acquisition the measurement time must not exceed 1÷2 μsec that corresponds to blade tip displacement of 0.2÷0.5 mm. The problem is solved by using of pulsed nitrogen laser operating in stroboscopic mode (light pulse duration is 6-8 nsec). The other parameter affecting on the spatial resolution of pressure measurement on blades is luminescence decay time of PSP after excitation light pulse. Its effect on image blur is the same as an effect of illumination time. PSP formulations based on pyren derivative are optimal for the models moving with high speed since the lifetime of pyren derivative molecules is less than 400 nsec (lifetime in vacuum).

3. PSP application for hypersonic flows is problematic because of significant PSP temperature sensitivity. Temperature problem is overcome by: a) tests conduction in short duration wind tunnel; b) model manufacturing from heat-conducting material (aluminum alloy) and c) application of PSP with fast response time.

Response time of PSP is determined by oxygen diffusion in the polymer layer and is directly proportional to the square of polymer layer thickness. Usage of permeable polymer applied as very thin layer (about 2-5 micrometers) allows to get response time less than 5 msec

Temperature Sensitive Paint is used for heat transfer measurements in short duration wind tunnels: Ludwieg wind tunnel UT-1 (TsAGI) and pressure multiplier wind tunnel AT 303 (ITAM SB RAS). Both wind tunnels have time duration about 40 msec. For these applications TSP has advantages over other methods.

Two-color TSP based on a complex of europium (temperature-sensitive luminophore), Coumarin (reference luminophore) and epoxy resin is used for the tests in short duration wind tunnels. Paint thickness is very small (3-5 μm) and usually can be leave out of account. Europium complex has red luminescence, and Coumarin emits in the blue spectral range. Both probes are excited by UV light (<350 nm). The optimal temperature for this TSP is 20-60°C. In this range the average sensitivity is 3% /°C.