Flight measurement of elevator bending moment of small sport aircraft

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Abstrakt

Příspěvek se zabývá letovými měřeními, která proběhla ve spolupráci s firmou Fantasy Air na letounu Allegro 2007. Cílem měření bylo posoudit vliv na rozloženi ohybového mementu na vodorovné ocasní ploše v závislosti na úhlu nastavení vztlakových klapek. Pro vyhodnocení ohybového momentu bylo na hlavní nosník stabilizátoru instalováno šest dvojic tenzometrů zapojených do půlmostu. Po sestavení VOP a její instalaci na letoun proběhla série měřeni pro různé letové režimy. Pro záznam naměřených hodnot byla použita tenzometrická ústředna Spider 8 od firmy HBM, instalovaná na palubě letounu. Měřená data zaznamenával palubní počítač se vzorkovací frekvencí 50Hz a současně byla zobrazována na LCD display instalovaný v kabině posádky. Naměřená data byla konzultována se zástupci firmy a měla sloužit pro ověření zatíženi letounu stanoveného dle předpisu UL-2.

Keywords

In-Flight, Measurement, Bending moment, Strain gauges

1. Introduction

The goal of the measurement was to set curves of bending moment and the main beam flange stress of Allegro 2007 aircraft elevator. Firstly was installed a set of strain gauges and after this their calibration procedure was done. Measured values such as speed, angle of attack, flight load factor and strain gauges response were recorded by data acquisition system HBM Spider 8.

1.1 Airplane Allegro 2007

The Allegro is a modern strutted shoulder-wing monoplane, whose all metal wing, centre-section truss, horizontal tail and rudder are combined with a composite fuselage and with an integral vertical fin. Allegro is powered by a four-stroke Rotax 912 engine. The fuselage is made of the well proven glassfibre/aramid (Kevlar) hybrid composite, providing enhanced safety (compared to pure glass or carbon structure), due to Kevlar's superior toughness**.** The main undercarriage legs are also made of the same hybrid composite.

Table 1. *– Allegro 2007 basic characteristics*

Engine	Rotax 912 UL 80hp
Wingspan	10,8 m
Length	6,1 m
Height	2,1 m
Wing Area	11,4 m^2
Maximal take off weight	450 kg
Fuel capacity	63 l
Never exceed speed	220 km / h
Stall speed	65 km / h

Fig. 1. *Allegro 2007*

2. Measured values

Values measured during in flight testing

- response from installed strain gauges (elevator)
- dynamic pressure
- indicated air speed
- angle of attack
- flight load factor at center of gravity

2.1 Indicated air speed and angle of attack

Special designed Pitot - static tube with electronics differential pressure sensor CRESTO TMG H4N was used for indicate air speed measurement.

Pitot - static tube was made from aluminum alloy. It had 8 mm diameter and 200 mm length. The tube was inserted in aluminum alloy socket at the end of composites adapter. All this system was attached to the left wings strut. The position of the tube was selected for minimal interference due propeller flow.

Fig. 2. *Pitot-static system and pressure sensor*

The Indicated air speed IAS was calculated by this equation:

$$IAS = \sqrt{\frac{2.p_D}{\rho}} \tag{1}$$

where p_D is a measured dynamic pressure and ρ is a air density.
To obtain exact relation between output voltage and dynamic pressure the experimental calibration of pressure sensor was done.
Resulting relation is on Fig.3.

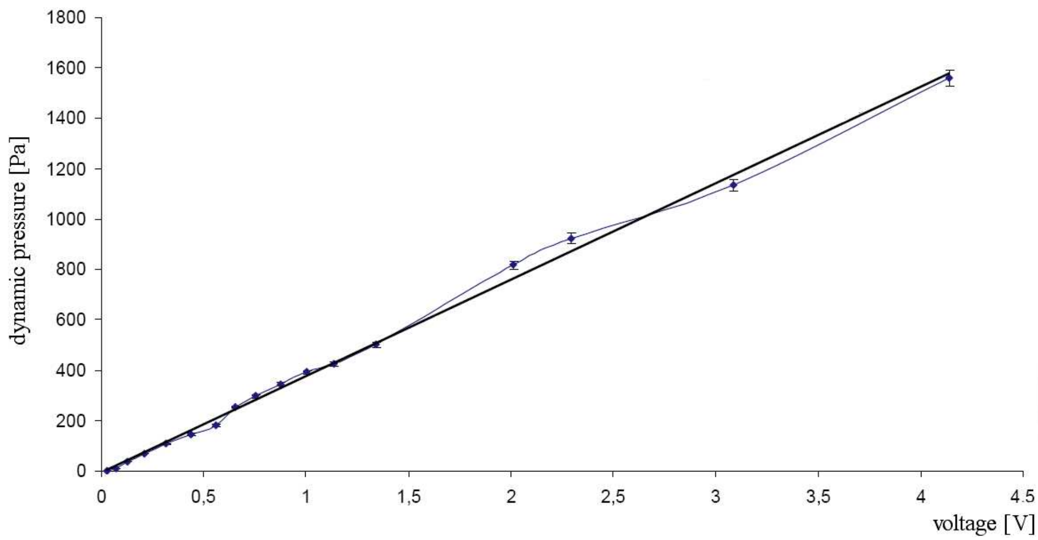

Fig. 3. *Relationship between dynamic pressure a output voltage*

The angle of attack (angle between vector of velocity and longitudinal axis of the airplane) was measured by a pivoted vane (Fig.2.). Its position was measured by a rotating resistance potentiometer.

2.2 Load factor

Flight load factor was recorded in three axis of aircraft axis system during flight. Three Analog Devices accelerometers ADXL 190 EM were used for the measurement. Accelerometers were mounted at the center of gravity.

2.3 Elevator loads

Totally there were installed 12 strain gauges of the type HBM LY-11-6/120 in 6 cuts along the wingspan. Five-wire bending half bridge circuit was used for all strain gauges. These circuits enable to eliminate other loads such as normal loading, torsion and thermal strain and cancel thermal effect on leadwires. Strain gauges placing are on Fig.4.

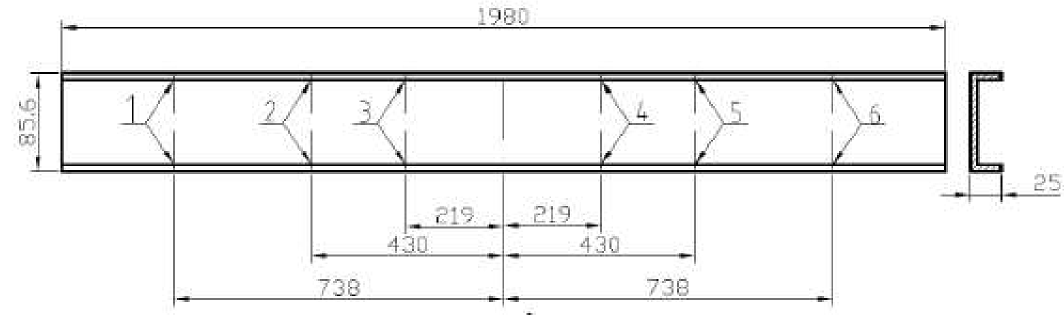

Fig. 4. *Beam - strain gauges placing*

2.3.1 Calibration of strain gauges

Definition of relations between moments (forces) effecting the elevator and responses from strain gauges was needed for our purposes. It was done by loading of elevator. The loading 29,43 N was applied on end rib of the elevator. In this way, the relation between the signal obtained from the strain gauges and bending moment was defined in the form of the equation

$$Mo_i = C_i . m_i \tag{2}$$

where Mo_i is a bending moment in place i, C_i is a calibration coefficient in place i and m_i is a response from strain gauges in place i.

Table 2. *– Calibration coefficient, F=30N*

Position - i	Mo_i [Nm]	m_i[μm/m]	C_i [-]
1	7,416	7,25	1,0227
2	16,481	13,22	1,2468
3	22,691	23,37	0,9710
4	22,691	23,08	0,9831
5	16,481	13,72	1,2150
6	7,416	7,36	1,0067

2.3 Data acquisition system

Data acquisition system HBM Spider 8 with PC was used for recording of all values. Four Spider 8 units were placed in the trunk behind pilot seats. There was LCD display on the dashboard, where pilots could watch measured values (Fig.5.).

Fig. 5. *Dashboard with display unit*

3. In-flight measurement

Totally there were done 12 in-flight measurements with different conditions (different load factor, speed, turn, flaps position) with continuous data recording. Data were recorded with sampling frequency 50 samples per second.

4. Measured and calculated value

Evaluation of measured values was done in the form of tables and graphs for each flight. Bending moment of flight with steady turns and extended flaps is presented as an example. The flaps were set to take-off and landing positions. Turns should be flown at rolling of fifteen and thirty degrees at IAS 90, 100, 110 km/h. All flights mode could not be flown, because aircraft had not enough performance for it. Results of measured value are on Fig. 6,7 and 8 and in tables 3, 4 and 5.
Asymmetrical curves of bending moment are caused by influence of propeller flow.

Table 3. *– Bending moment, take-off flaps, turn 15°*

IAS [km/h]	g [-]	Mo[Nm]					
		position					
		1	2	3	4	5	6
85	1,08	-0,37	-4,23	-10,48	-22,64	-5,42	1,34
94	1,06	-1,62	-7,56	-19,19	-23,71	-6,48	3,17
104	1,08	-1,98	-8,77	-21,42	-27,64	-11,49	1,37

__Table 4.__ – Bending moment, take-off flaps, turn 30°

IAS [km/h]	g [-]	Mo[Nm]					
		position					
		1	2	3	4	5	6
96	1,29	-3,10	-10,57	-17,42	-27,88	-9,28	1,10
105	1,25	-2,61	-10,27	-16,83	-26,93	-9,87	0,33

__Table 5.__ – Bending moment, landing flaps, turn 15°

IAS [km/h]	g [-]	Mo[Nm]					
		position					
		1	2	3	4	5	6
83	1,08	-2,11	-11,63	-21,90	-27,29	-11,89	0,48
92	1,10	-3,85	-15,87	-34,96	-35,75	-16,65	-0,36
104	1,12	-4,46	-19,50	-42,49	-48,86	-22,54	-2,56

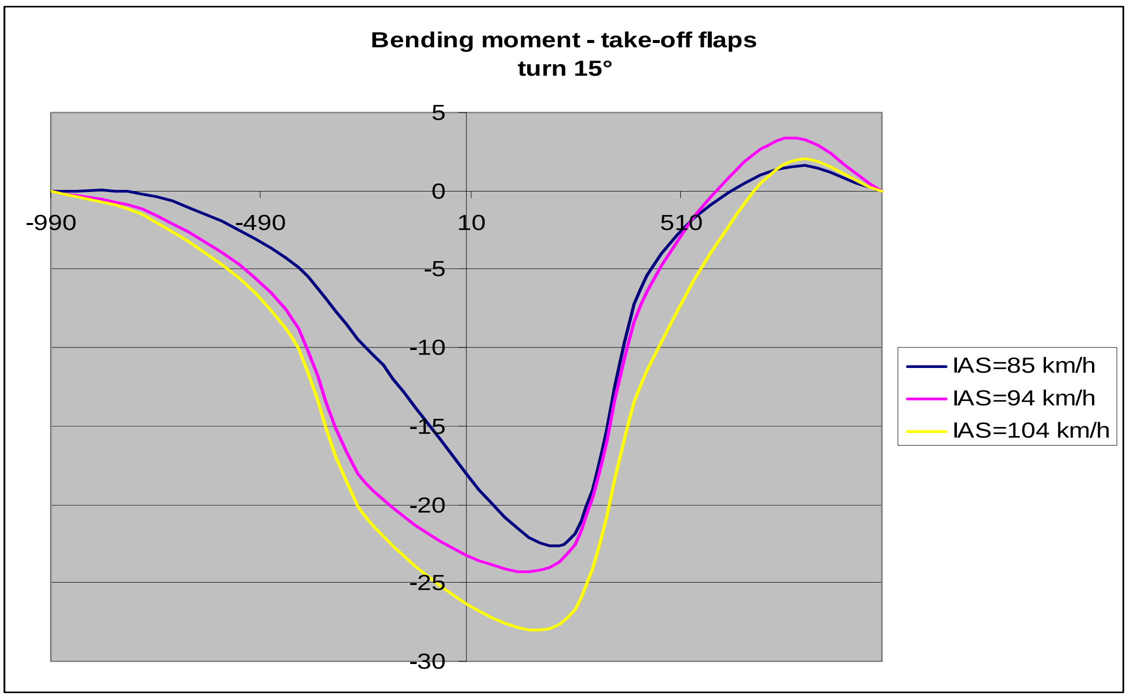

__Fig. 6.__ Distribution of bending moment along wingspan

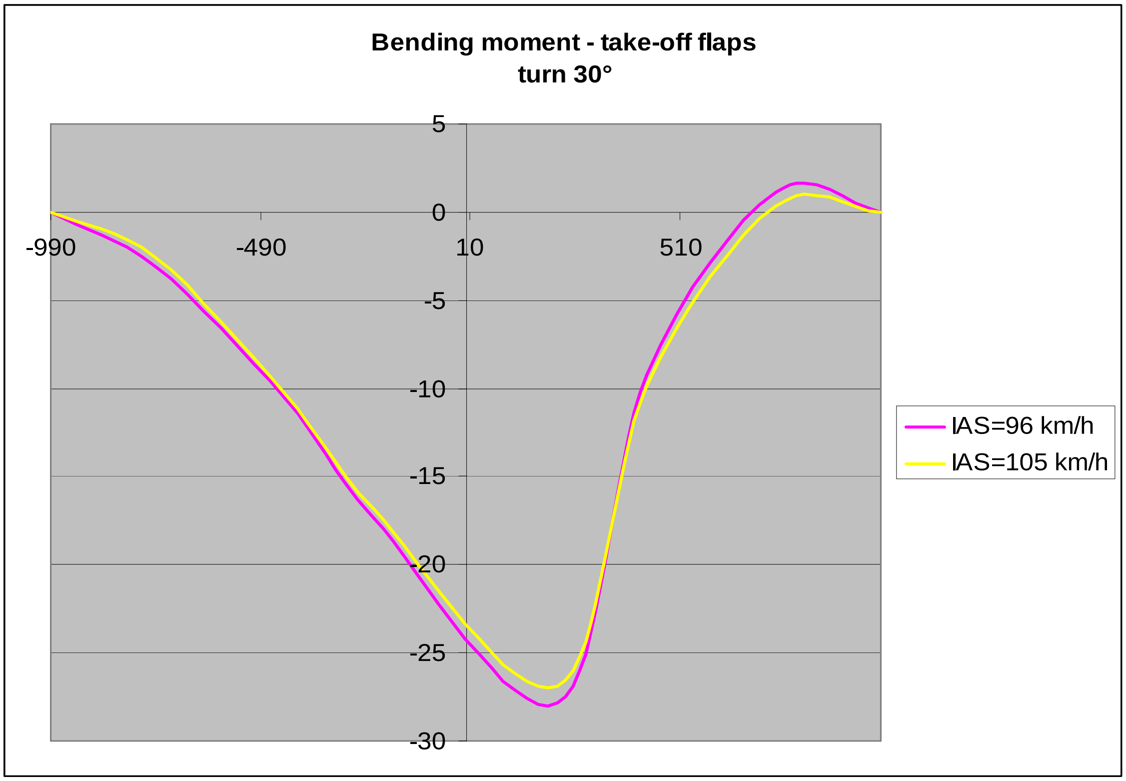

Fig. 7. *Distribution of bending moment along wingspan*

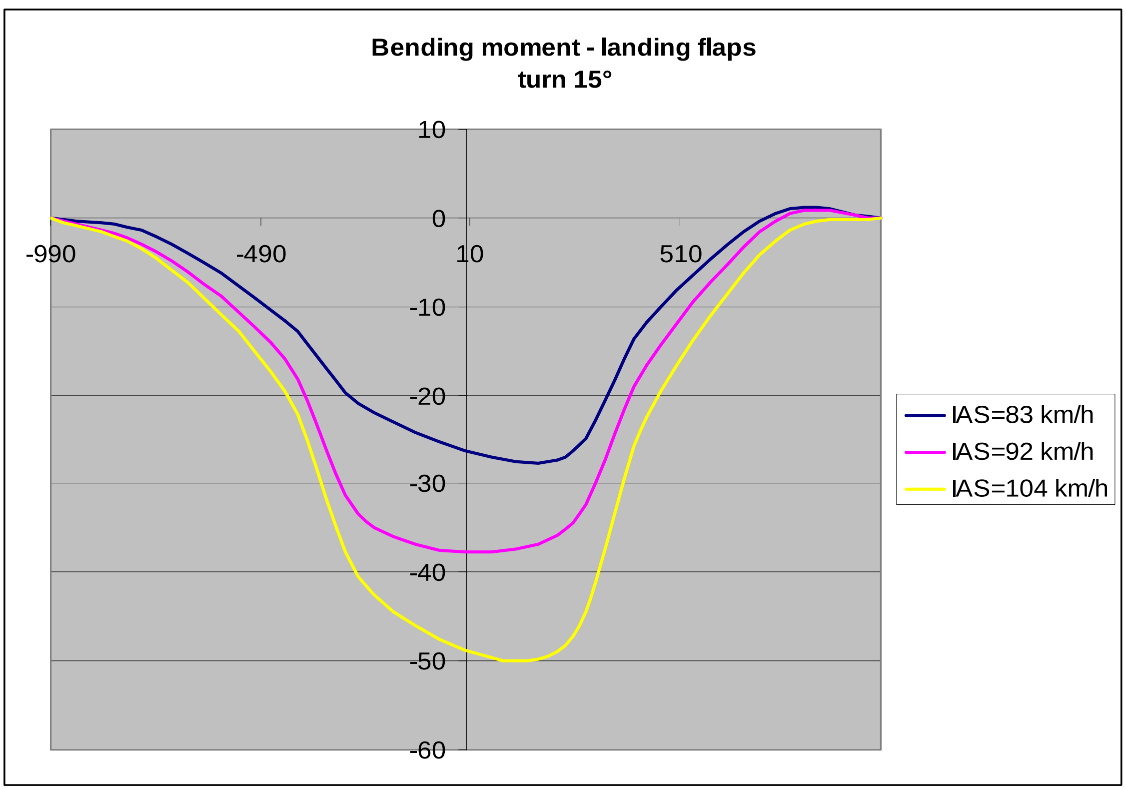

Fig. 8. *Distribution of bending moment along wingspan*

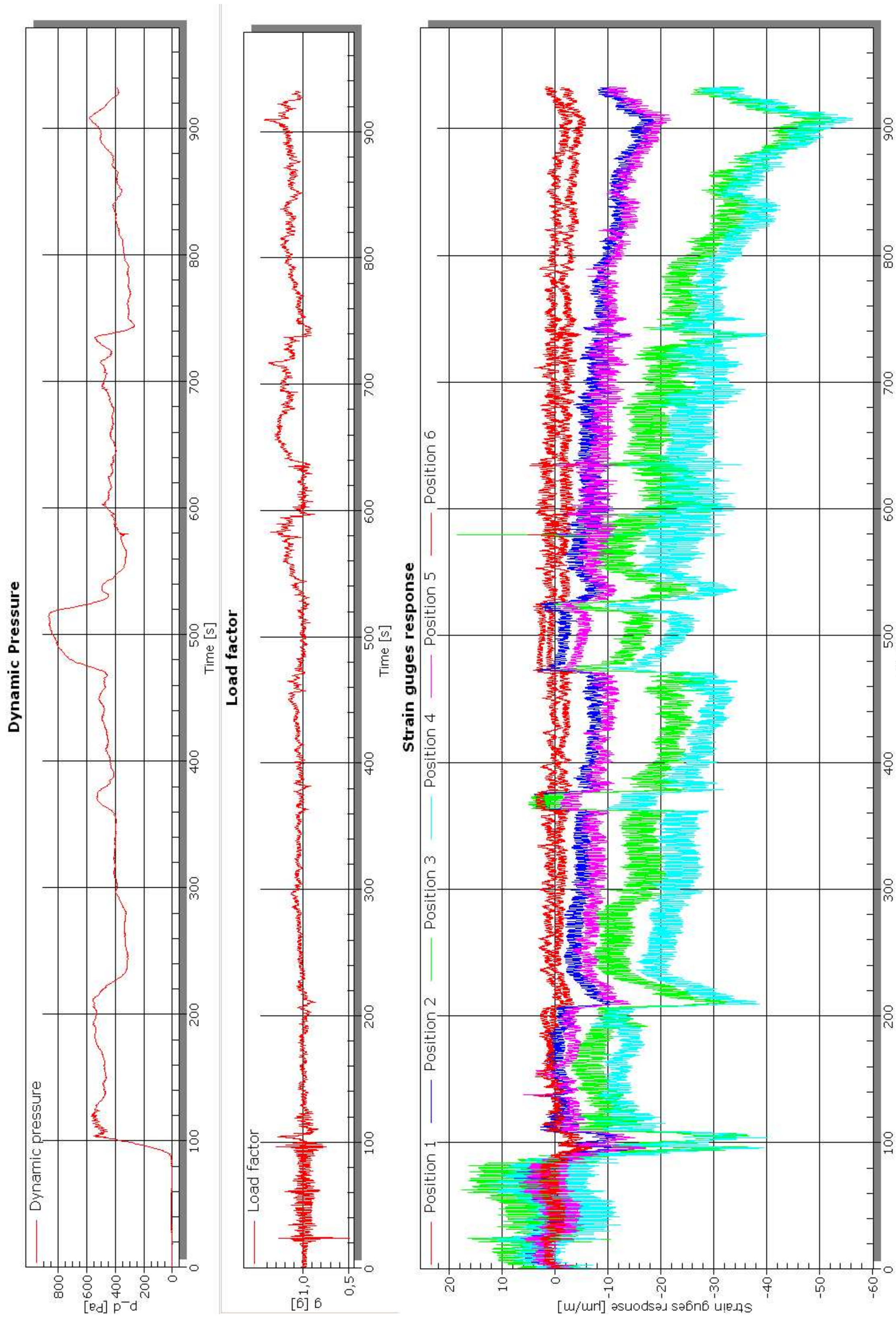

Fig. 9. *Measurement value*

5. Conclusion

It was performed in flight measurement of Allegro 2007 elevator for investigation of bending moment. IAS, angle of attack, dynamic pressure and flight load factor was simultaneously recorded. Strain gauges system was calibrated. Measured data was brought on LCD display in the cockpit. Bending moment distribution along the elevator span was used by manufacture for strength analysis.

Nomenclature

IAS	indicated air speed	[m/s]
Mo	bending moment	[Nm]
p_D	dynamic pressure	[Pa]
g	load factor	[-]
C	calibrating coefficient	[$Nm^2/\mu m$]
m	strain gauges response	[μm]
ρ	density	[$kg \cdot m^{-3}$]

Literature

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