Determination of Adiabatic Index for Hydrogen Injector Design

In hydrogen fuel cells, the hydrogen injector is responsible for supplying hydrogen and recovering hydrogen from the exhaust gas. Hydrogen injectors have established their superiority with their excellent performance, such as no power consumption, recovery of hydrogen, no failure, etc.

There are many physical parameters involved in the design of a hydrogen pilot. The adiabatic index is one of them.

The process of high-pressure hydrogen injection can be regarded as an adiabatic process, and the calculation of many of its state parameters must depend on the determination of the adiabatic index. For mixtures of gases, such as recycled tail gas, it is also necessary to calculate the adiabatic index according to the actual components.

According to the definition of adiabatic index, the ratio of the constant pressure specific heat capacity to the constant volume specific heat capacity of an ideal gas is its adiabatic index, also called specific heat capacity ratio.

$$k=Cp/Cv$$

In contrast, the adiabatic equation of state for an ideal gas is:

$$\frac{P}{\rho^k}=\mathrm{Constant}$$

The generalized equation of state for ideal gases allows the determination of parameters such as density, specific volume, temperature, and pressure at subcritical, critical, and supercritical flow rates.

To determine the adiabatic index, we also need to know an important equation ---- Meyer's equation.

Meyer's equation states that at the same temperature, the specific heat of pressure of any ideal gas must be greater than its specific heat of capacity, and the difference between the two is always equal to a constant. Meyer's equation is one of the most important formulas for studying the thermophysical properties of ideal gases, and its expression is as follows:

$$k=Cp-Cv$$

The difference between the constant pressure specific heat capacity and the constant volume specific heat capacity of an ideal gas at a given temperature is the gas constant.

Thus, if the constant pressure specific heat capacity of a gas at a certain temperature is known, the adiabatic index at the corresponding temperature can be calculated

For mixed gases, the molar constant pressure specific heat capacity of the mixed gases can be calculated according to the molar fraction of each component, and then the adiabatic index can be obtained.

The adiabatic index of the hydrogen fuel cell recycle gas, which is a mixture of hydrogen, nitrogen and water vapor, can be calculated according to the above method.

For the common temperature range of the adiabatic index does not change much, can also be used in accordance with the table value.

For the adiabatic indices of real gases, different equations need to be followed, which will be described in a separate paper.

表 2-86　某些有机、无机物气体在 1.01325×10^5 Pa（1atm）下质量热容比 c_p/c_v[2]

化学式	中文名	英文名	t/℃	热容比 $k=c_p/c_v$	化学式	中文名	英文名	t/℃	热容比 $k=c_p/c_v$
C_2H_4O	乙醛	acetaldehyde	30	1.14	HCN	氰化氢	hydrogen cyanide	65	1.31
$C_2H_4O_2$	乙酸	acetic acid	136	1.15				140	1.28
C_2H_2	乙炔	acetylene	15	1.26				210	1.24
			−71	1.31	HI	碘化氢	-iodide	20～100	1.40
	空气	air	925	1.36					
			17	1.403	H_2S	硫化氢	-sulfide	15	1.32
			−78	1.408				−45	1.30
			−118	1.415				−57	1.29
NH_3	氨	ammonia	15	1.310	I_2	碘	Iodine	185	1.30
Ar	氩	argon	15	1.668	C_4H_{10}	异丁烷	Isobutane	15	1.11
			−180	1.76	Kr	氪	krypton	19	1.68
			0～100	1.67	Hg	汞	mercury	360	1.67
C_6H_6	苯	benzene	90	1.10	CH_4	甲烷	methane	600	1.113
Br_2	溴	bromine	20～350	1.32				300	1.16
CO_2	二氧化碳	carbon dioxide	15	1.304				15	1.31
			−75	1.37				−80	1.34
CS_2	二硫化碳	disulfide	100	1.21				−115	1.41
CO	一氧化碳	monoxide	15	1.404	$C_3H_6O_2$	乙酸甲酯	methyl acetate	15	1.14
			−180	1.41	CH_4O	甲醇	alcohol	77	1.203
Cl_2	氯	chlorine	15	1.355	C_2H_6O	甲醚	ether	6～30	1.11
$CHCl_3$	氯仿	chloroform	100	1.15	$C_3H_8O_2$	二甲氧基甲烷（俗称甲缩醛）	methylal	13	1.06
$(CN)_2$	氰	cyanogen	15	1.256					
C_6H_{12}	环己烷	cyclohexane	80	1.08				40	1.09
CCl_2F_2	二氯二氟甲烷	dichlorodifluormethane	25	1.139	Ne	氖	neon	19	1.64
					NO	氧化氮	nitric oxide	15	1.400
C_2H_6	乙烷	Ethane	100	1.19				−45	1.39
			15	1.22				−80	1.35
			−82	1.28	N_2	氮	nitrogen	15	1.404
C_2H_6O	乙醇	ethyl alcohol	90	1.13				−181	1.47
$C_4H_{10}O$	乙醚	ether	35	1.08	N_2O	氧化亚氮	nitrous oxide	100	1.28
			80	1.086				15	1.303
C_2H_4	乙烯	ethylene	100	1.18				−30	1.31
			15	1.255				−70	1.34
			−91	1.35	O_2	氧	oxygen	15	1.401
He	氦	helium	−180	1.660				−76	1.415
C_6H_{14}	正己烷	hexane（n-）	80	1.08				−181	1.45
H_2	氢	hydrogen	15	1.410	C_5H_{12}	戊烷	pentane（n-）	86	1.086
			−76	1.453	P	磷	phosphorus	300	1.17
			−181	1.597	K	钾	potassium	850	1.77
HBr	溴化氢	hydrogen bromide	20	1.42	Na	钠	sodium	750～920	1.68
HCl	氯化氢	hydrogen chloride	15	1.41	SO_2	二氧化硫	sulfur dioxide	15	1.29
			100	1.40	Xe	氙	xenon	19	1.66