EXPERIMENTAL STUDIES OF METHANE STEAM CONVERSION IN THEROCHEMICAL REACTOR

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IX International Workshop
“Thermochemical processes in plasma aerodynamics”
St.Petersburg, 2 -6 July 2012

INTRODUCTION

The use of hydrocarbon fuel conversion for cooling heat-stressed areas of high speed vehicles and organization of their burning in supersonic air flow have been considered by the experts from the sixties of the last century.

Hydrocarbon steam conversion is highly endothermic process requiring large amounts of heat supply. For example, the steam conversion of methane is described by two reactions:

$CH_4 + H_2O = CO + 3\ H_2$ — 206 kJ/mol

$CO + H_2O = CO_2 + H_2$ + 41 kJ/mol

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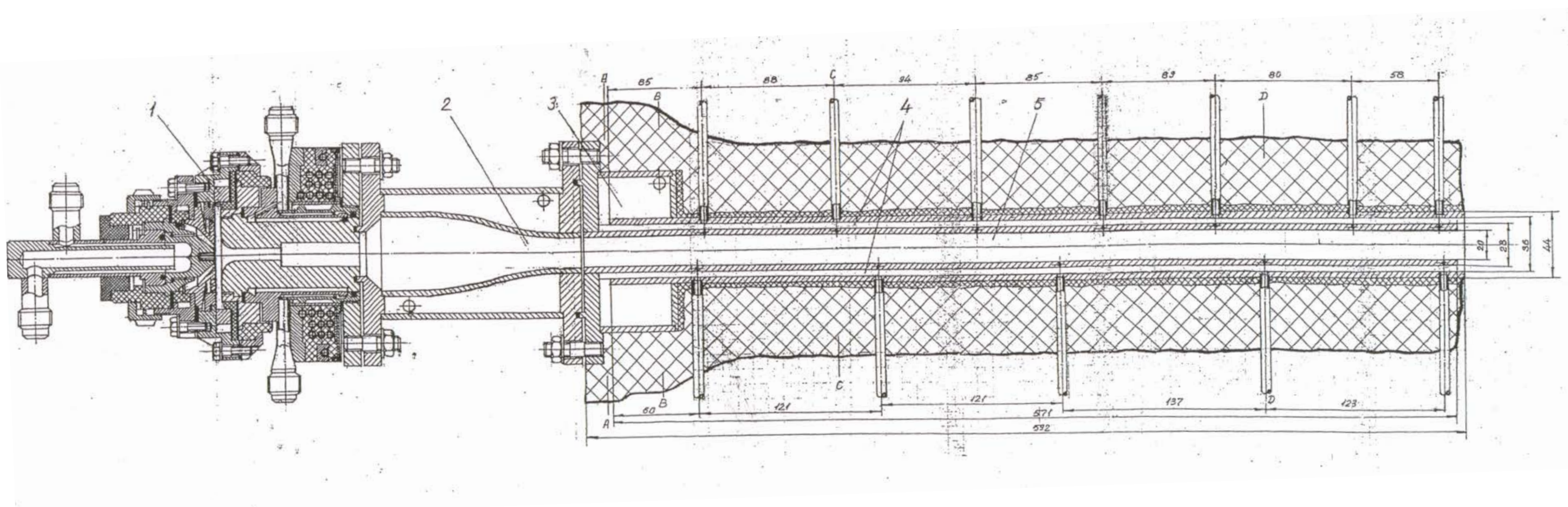
Model thermo-chemical reactor

The model thermo-chemical reactor on the base of plasmotron ЭДП-109/200М



A high-temperature jet of nitrogen, heating heat-transfer walls of the two slot channels (4) was fed into the central rectangular channel of the reactor (5) from plasmotron (1) via adapter (2). Preheated mixture of hydrocarbons and water vapor was fed to the channels (4) which actually were the reactive zone with 571 mm length, 60 mm width, and 4 mm height.

Experimental studies I

Parameters	Parameter Values				
Distance of sampling site from entrance to reactor	501	421	247	153	65
Consumption of natural gas, g/s	0,212	0,217	0,217	0,217	0,220
Flow of water vapor, g/s	0,480	0,482	0,482	0,482	0,470
The ratio of water vapor flow to natural gas consumption	2,26	2,22	2,22	2,22	2,14
Nitrogen consumption through plasmotron, g/s	9,0	9,0	9,0	9,0	9,0
Plasmotron power, kW	30,97	30,97	30,97	30,97	30,97
Vapor-gas temperature at the outlet of the heater, ^{o} C	443	446	446	446	4465
Velocity of the gas in the reactor at a distance of from the entrance, m/s	7,28	7,28	7,27	7,27	7,18
The degree of methane conversion in %	5.85	5,6	2,7	1,3	1.5
Composition of “dry” gas samples without water in % of volume					
CH_4	91,7	93,1	97,2	93,3	98,7
CO	5,1	4,8	2,5	0,8	0,8
CO_2	0,6	0,7	0,2	0,5	0,5
H_2	2,6	1,4	0,1	0,4	0

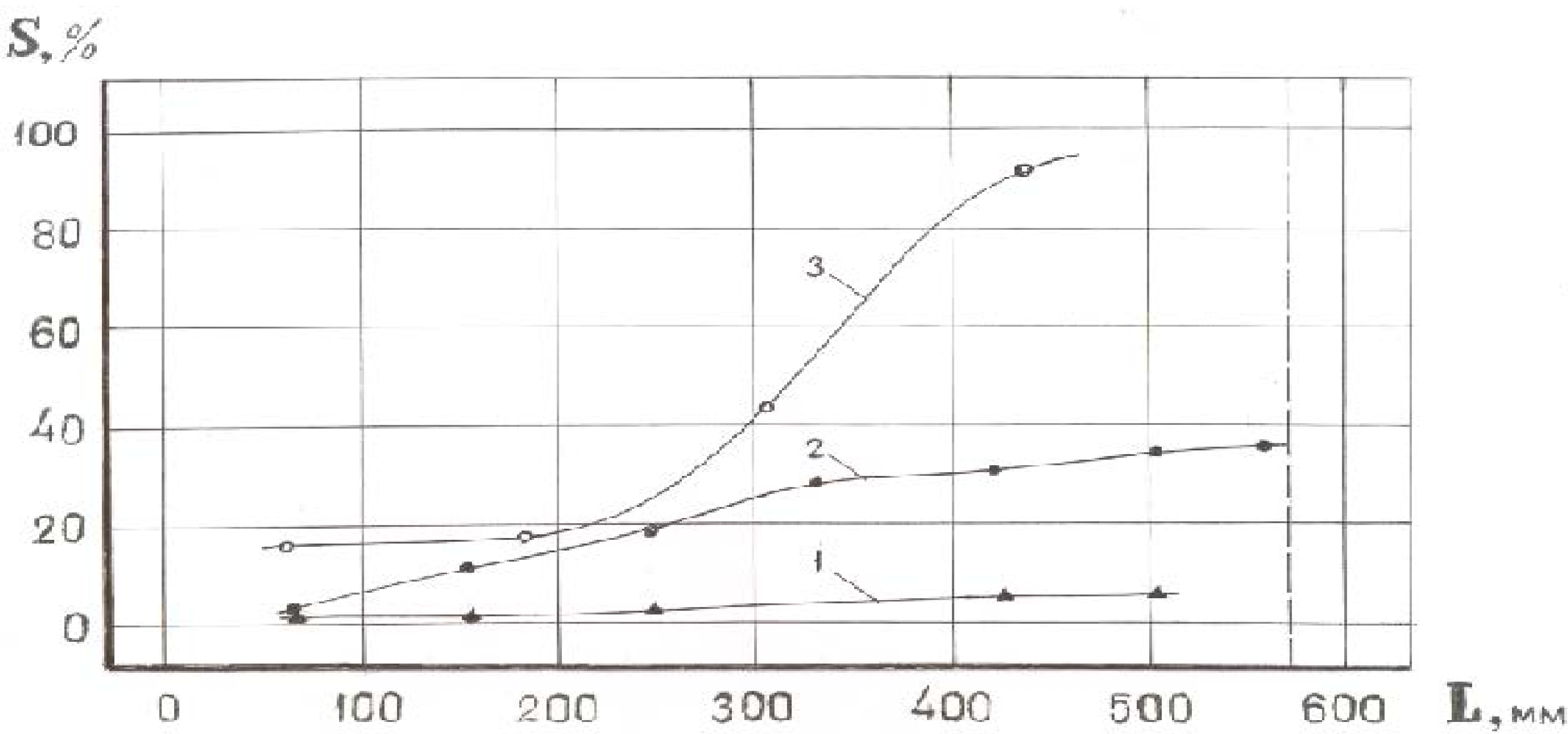
Experimental studies II

Parameters	Parameter Values						
Distance of gas sampling site from entrance to the reactor, mm	559	501	421	332	247	153	65
Plasmotron power, kW	26,78	26,78	26,78	25,34	24,48	25,06	25,06
Nitrogen consumption through plasmotron, g/s	9	9	9	9	9	9	9
Consumption of natural gas, g/s	0,047	0,047	0,046	0,046	0,046	0,046	0,0465
Flow of water vapor, g/s	0,106	0,103	0,099	0,100	0,106	0,013	0,100
The ratio of water vapor flow to the consumption of natural gas	2,23	2,29	2,13	2,15	2,28	2,215	2,215
Vapor-gas temperature at the outlet of the heater, ^{o} C	410	405	410	412	410	412	408
Gas velocity at the 1st sampling site, m/s	1,265	1,282	1,298	1,324	1,414	1,389	1,379
Conversion degree of natural gas, %	35,4	34,0	30,6	28,2	19,2	11,5	3,1
Composition of “dry” gas sampling without water in % of volume							
CO_2	4,5	4,2	3,8	3,3	3,4	2,5	2,3
CO	29,0	26,8	24,8	23,2	14,2	8,8	0,7
CH_4	61,1	59,5	64,6	67,5	76,8	86,7	94,6
H_2	5,4	9,4	6,8	6,0	5,6	2,1	2,4

Experimental studies III

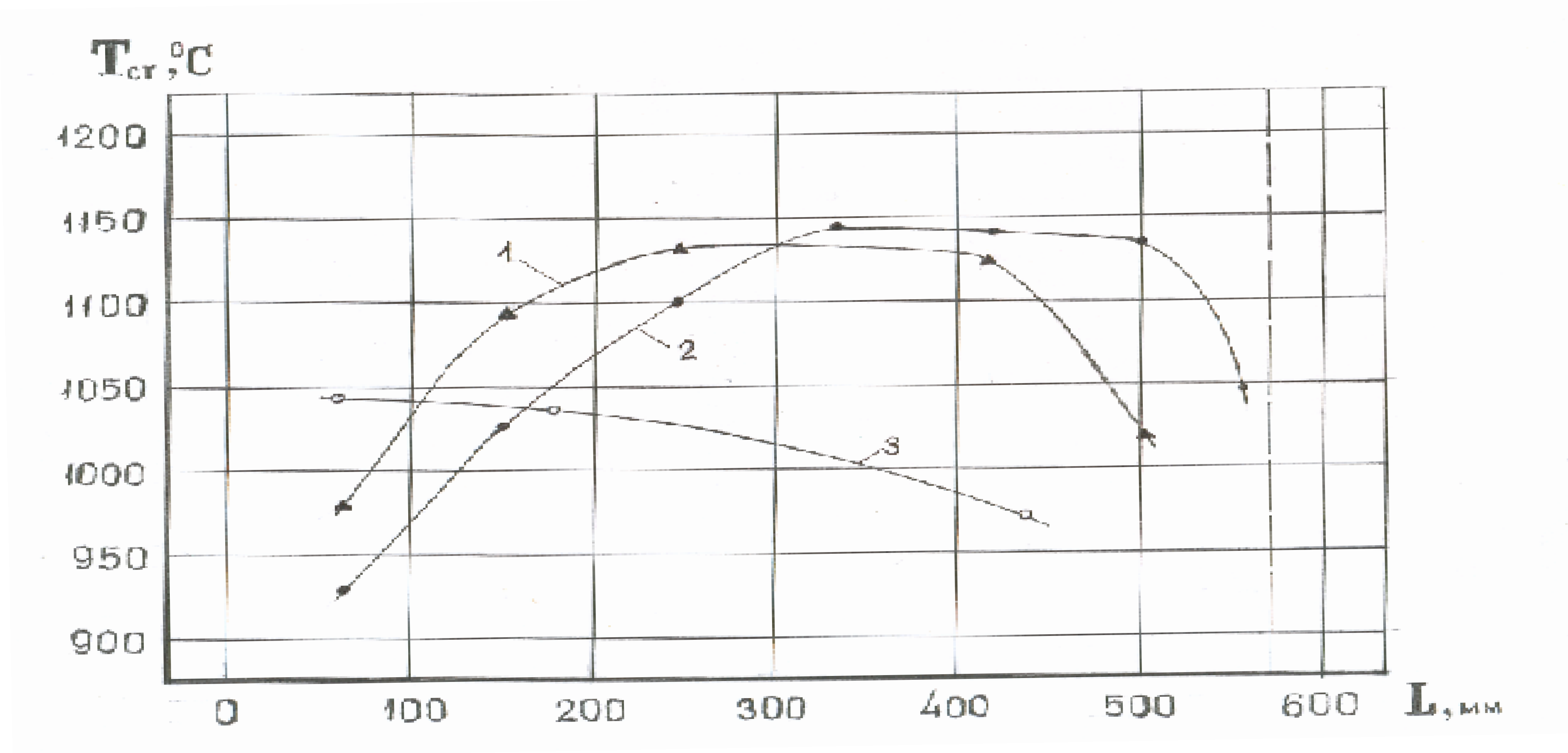
Consumption of natural gas, g/s	0,215	0,225	0,260	0,265
Flow of water vapor, g/s	0,431	0,452	0,522	0,531
Nitrogen consumption through plasmotron, g/s	9,02	9,02	9,02	9,02
Power of plasmotron, kW	30,1	30,1	30,1	30,1
Temperature of natural gas at the reactor inlet, º C	355	360	360	358
Temperature of water vapor at the reactor inlet, º C	400	410	410	412
Temperature of the heat-transfer wall of the reactor, º C	1044	1035	-	970
The degree of methane conversion, %	16,74	17,7	43,96	91,08
Composition of the “dry” gas samplings without water in % of volume				
H_2	9,02	22,15	36,64	20,18
CH_4	74,90	63,77	35,18	5,08
CO	13,51	11,35	25,75	48,78
CO_2	1,55	2,36	1,85	3,04
O_2	1,02	0,37	0,58	2,92

Experimental studies



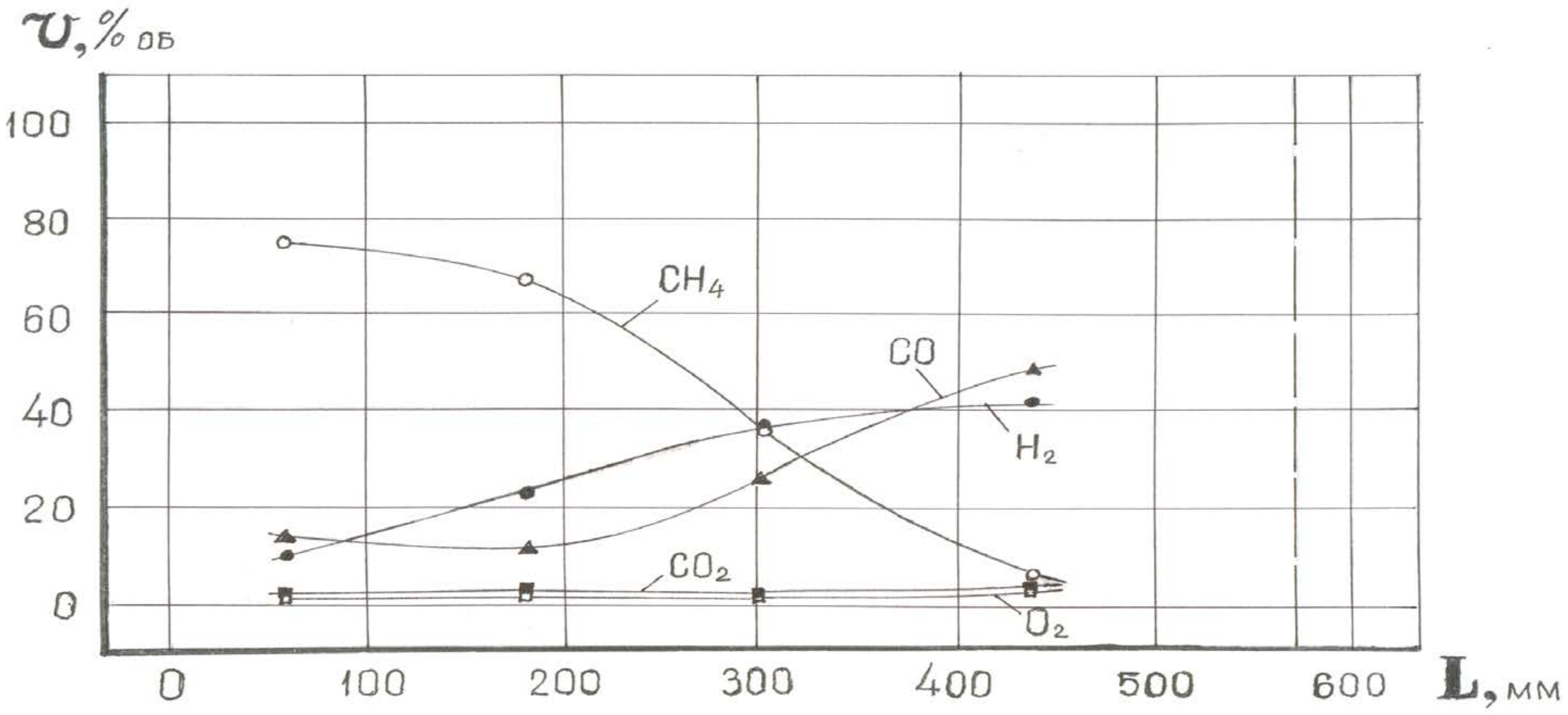
Alteration of conversion degree of methane *S* along the length of the reactor *L*;
1, 2, 3 – numbers of testing stages

Experimental studies

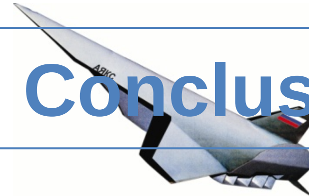


Temperature alteration for heat transfer walls T_w along the length of the reactor L; 1, 2, 3 – numbers of testing stages

Experimental studies



Alteration of the volume concentration of conversion products *V* along the length of the reactor *L* during the 3rd stage of testing



Conclusion

Analyzing experimental results obtained during realization of three stages of the reactor testing the following basic conclusions can be drawn:

1. The selected compositional material for the reactor allows to heat its heat transfer walls and exploit them for a long time at the temperatures (1000 – 1100 º C) which are characteristic of the working conditions for combustion liners (flame tubes) of combustion chambers of the modern air-breathing propulsion systems.

2. Confirmed is the need for a catalyst for obtaining hydrocarbon conversion rate close to 100 %, with the implementation of the conversion process in the reactor under the above-mentioned thermal conditions.

3. When using the mesh catalyst in the double-split model reactor under adopted conditions of its testing, the degree of methane conversion was achieved close to 100 %, while hydrogen content in the products of conversion was exceeding 40 %.