

## PRELIMINARY RESEARCH OF MICROGASTURBINE INJECTION RING

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### Abstract

*Fuel supply systems used in microgasturbines are designed in experimental way. In literature they exist as geometrically prescribed that is proper in general. In commercial aeroengines injection system is the most vulnerable part which failure generates high thermal loads and causes overheating of whole "hot section" or part of it. Microgasturbines are subjected to overheating due to relative short combustion section and uneven fuel distribution in injection points. Presented article contains preliminary research of fuel injector ring designed for microgasturbine turbojet. Tested fuel collector is supplied from the single source and feeds five vaporizers. Investigations are focused on mass flow measurement from each supply point. Research methodology is similar to supervisory tests carried out on commercial aeroengines. Injector was tested with two types of microfuelpumps: JetCAT A601405 and FlightWorks 200C. As a working liquid the JET A1 kerosene was used. For each probe constant volume of liquid was pumped through the system. Pumps were tested in full operational range of voltage. Electric power characteristics were obtained for fuel pump and whole fuel system. The strong influence of throttling on stability of microfuelpumps was affirmed. As a conclusion there is a modernization proposal that aims on quality and quantity of fuel distribution.*

**Keywords:** *gasturbine, rc gasturbine, propulsion, fuel supply*

### 1. Introduction

Most common mistake made by designer of hot section in microgasturbine design is to treat combustor and fuel supply as one part. The main requirement for combustor is to release maximum quantity of energy in combustion process. Combustion process should also proceed as low as possible to prevent flames roaring out of the turbine nozzle. Majority of microgasturbine engines has reverse flow combustion system with longer burning patch. Key to archive stability and reliability of combustion is to obtain proper recirculation level in primary combustor flow. Recirculation process could be intensified by flame stabilizer, disadvantage of flame stabilization is possibility of cranks propagation on combustor outer ring due the point overheating [1]. Injector ring should provide possibly even fuel distribution in supply points. With the use of liquid fuels there are two possible methods of forming the mixture: atomization and vaporization. Majority commercial aircraft engines employ fuel atomization, whereby complex injection pumps force the fuel into injectors under high pressure. The quality of combustion is very largely determined by the droplet size of the atomized liquid: the smaller the individual droplets equal faster combustion. In practice atomization only works effectively if the injection pressure is high, as the throughput of an atomizer jet rises with the square root of the injector pressure. Atomization process also provide correction and regulation possibility for: fuel mass flow separately and summary, angle of injection. The technique of prevaporization is primarily used in small and micro size gasturbines. It was developed by Armstrong-Siddeley (Rolls-Royce) and used successfully in the Viper series of engines [2]. The advantage of this technique is that vaporization process takes place under combustion chamber pressure and injection pressure is only about 0.5 bar higher than the pressure in combustor. Vaporization itself has no effect on the injection process, so oscillations in the column of kerosene in the system do not occur as in atomization process. At idle the injector pressure is

very low that even the hydrostatic pressure difference in the injector ring manifests itself and results slightly stronger combustion in the lower part of the combustion chamber. Injector ring is mounted inside the engine (Fig. 1) and it's preheated by secondary airflow from combustor. Temperature of secondary airflow is related to temperature at the end of compression process. Heat exchange between secondary fuel flow and injector ring works similar to "fuel heater" in commercial gasturbines, different is only liquid but idea and mechanism stays the same. Title of paper consists "preliminary" word because the investigations aim on patency of the fuel stream and flow estimation in individual points. Presented researches are connected with project involved in design, manufacture and test of microgasturbine mSO-1. Short time constrains forced team to concentrate only on indication problems that will be prepared for far detailed investigations in the future in terms of hierarchy of validity.

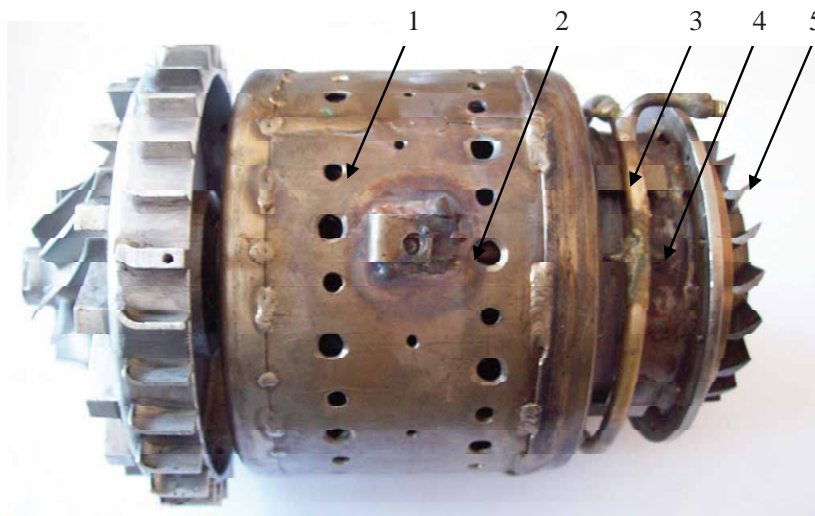


Fig. 1. mSO-1 micro gasturbine prepared for inspection (1 – combustor, 2 – vapouriser, 3 – injection ring, 4 – nozzle guided vane NGV, 5 – turbine rotor)

## 2. Test stand

An experimental part of the work was focused on achieving two essential aims. One of them was to test the multi-point fuel injection ring. The other one was to determine choking points and the influence on fuel micropumps functioning. Collector investigation requires another design a test stand that is similar to full scale injector ring in used in commercial gasturbines diagnostic.

A schematic diagram of the diagnostic-research test stand with the multi-point fuel injection ring is presented in Fig. 2. The same configuration with reducing jets instead of the ring (not shown on the diagram) was also used during tests.

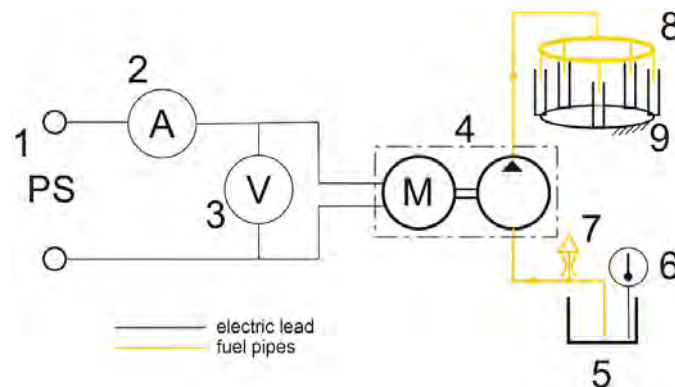


Fig. 2. Schematic diagram of diagnostic-experimental test rig

The entire stand consists of few fundamental components. The electric energy is provided by the source (1) which is a stabilized laboratory-type power supply unit (PS). It keeps direct current and voltage (which level may be adjusted) to feed the fuel-pump electric motor. The current drawn by the pump is measured by the ammeter (2). The voltmeter (3) helps to maintain the demanded value of the voltage. The motor-pump unit (4) pump in fuel from the fuel tank (5). The fuel temperature is measured by the thermometer (6) and the fuel itself is deaerated by the vent (7). The fuel is pumped through flexible pipes either to the injection ring (8) or to the reducing jets. Each injection point of the ring mates, with a distinct corresponding graduated cylinder (9) what enables a measurement of the fuel flow rate through the individual injection jets. During the tests, additional equipment was used. These were a laboratory balance and a stopwatch. The balance served to determine mass of the fuel pumped through a system and the stopwatch was used to measure the time of fixed fuel quantity pumping to evaluate the fuel flow rate. The motor and fuel pump assembly (4) depicted in Fig. 2 as two distinct symbols is, in fact, a uniform device integrated in a common casing and there is no possibility to disengage its components without breaking them down.

As a electric motor feeding device, the Manson SPS-9602 power supply was taken. It provides an output direct current up to 30 amperes and a range of voltage between 1 and 30 volts, adjustable with 0.1 volt step. The power supply keeps constant voltage independently apart from load current. The voltage was measured by the voltmeter (3) with accuracy of 0.1 volt and the current drawn from power supply – by the ammeter (2) with accuracy of 0.01 ampere.

The measurements were conducted within the operational ranges of fuel pumps voltage, from 1 to 6 or 7 volts (correspondingly for JetCat and FlightWorks pumps) with a step of 0.5 volt.

### **3. Research procedure**

Research was based on procedure that measure fuel flow distribution from injector ring after 100 flighthours.

Research procedure contains:

1. Preliminary actions
  - 1.1. Leakproofnes check
  - 1.2. Fuel installation deaerating (as required)
  - 1.3. Fuel injector ring and measuring space installation
  - 1.4. Leakproofnes and deaerating test
  - 1.3. Pumping 0.5 [dm<sup>3</sup>] JET A1 kerosene through the system
2. Measurements
  - 2.1. Fuel temperature measurement.
  - 2.2. Voltage setup.
  - 2.3. Pumping 0.5 [dm<sup>3</sup>] JET A1 kerosene through the system
  - 2.4. Final actions and notation.
3. Final action
  - 3.1. Fuel removal
  - 3.2. Disassembly and clearing of measuring space
  - 3.3. Test stand assembly
  - 3.4. Fuel refilling (as required)

### **4. Test results**

Figure 3 presents fuel injector ring numbered individual supply points and its distribution through injector ring. After assembly of the microgasturbine point number 3 is the furthest from test stand basis.

Research starts with FlightWorks 200C microscale fuel pumps which characterized by summary free fuel flow on 0.66 [dm<sup>3</sup>/min]. This micropumps has the lowest fuel flow from pumps that we had.



Fig. 3. Injection ring supply points

Relatively low fuel flow permits to estimate patency of the fuel stream and patency for individual points also. The significant fuel flow fall was observed in second point the admission. This point is in direct closeness of main fuel admission point. There was suspicion of partial obstruction in fuel line feeding (Fig. 4a). Test tails was interrupted at current of 5.5V causing leakage between electric motor and geared pump. Lowering current to 5V obstruct the leakage. Fuel injector ring was treated by boring at all pipes that supply fuel to the nominal diameter. Comparing fuel flow rate at supply points presented on Fig. 4a and 4b qualitative growth in all points was affirmed. Boring procedure was successful, injector ring and microfueelpump was leakproof. System passed test at all requirement currents. Troubleshooting width leakage comes from manufacturing in hard soldering process. Small quantities of welding material were sucked into micro pipes causing partial obstruction that was clearly shown at second supply point. Suction in hard soldering comes directly form heat transfer and propagation from hot to cold part causing lasted defect which could be partial removed by boring.

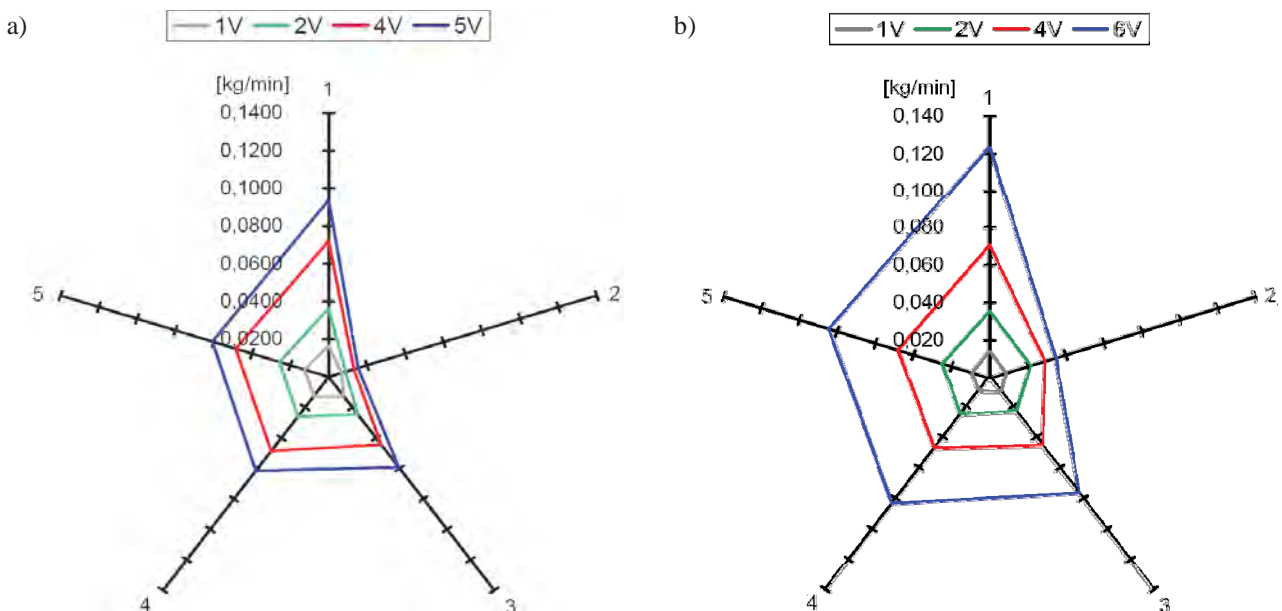


Fig. 4. Fuel flow from injector ring before modification, fuel pumps FlightWorks 200C: a) before modification, b) after modification

In comparison to the free stream, summary flow form injector ring was average lower by 13% before modification, boring procedure lowered summary flow loses in injector ring to the level of 5.6% (Fig. 5). Fig. 6 presents growth of fuel flow by individual points of fuel supply ring.

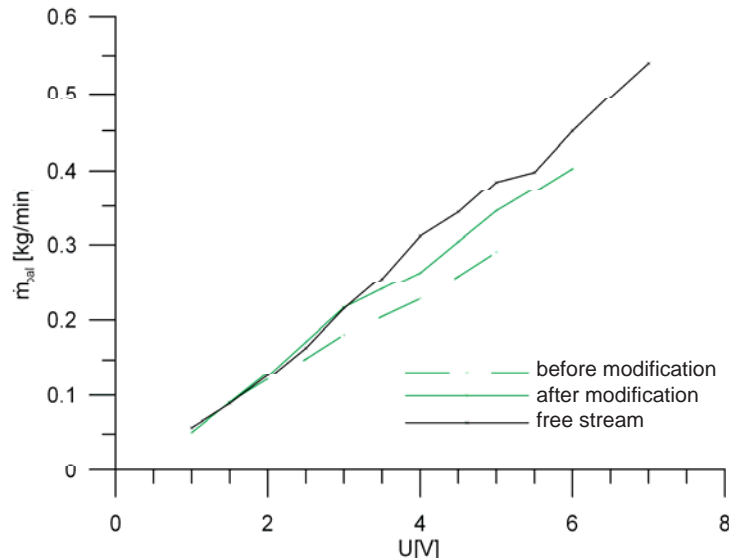


Fig. 5. Summary fuel flow from injector ring modification result. Fuel pump FlightWorks 200C

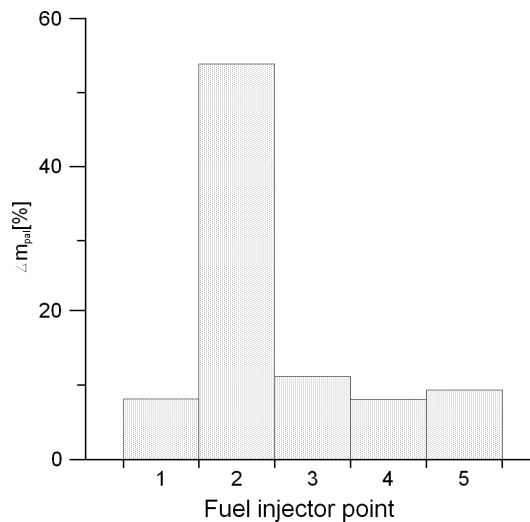


Fig. 6. Modification result for individual supply points. Fuel pump FlightWorks 200C

Injector ring was also tested with micropump JetCat type A601405 (Fig. 7), which has higher free stream fuel flow throughput by 50% in comparison to the FlightWorks 200C.

In comparison to the free stream, summary flow form injector ring width JetCat A601405 micropump was average lower by 9.1% (Fig. 8).

## 5. Summary

Fuel injector ring is most vulnerable part of microgasturbine. Trails for leakproofnes and fuel flow from supply points are obligatory. Test reduces fire hazard and hot spot overheating during initial trails on assembled engine. In terms of technology, miniaturization causes lot of difficulties with quantity and quality of fuel distribution making flow uneven. In reference to commercial gasturbines there's no possibility to smooth correction of fuel flow in individual supply points. It exists only one possibility of regulation by creasing injector micro pipe, this modification has irreversible character so authors do not recommend this in practice. Hard soldering also makes problems width common used micropipes (diameter  $\leq 1$  [mm]). To avoid obstruction or choking in working area covering plate on joint part is recommended. Covering plate should be made form native material of injector ring. High skill and qualification of welder is strongly recommended.

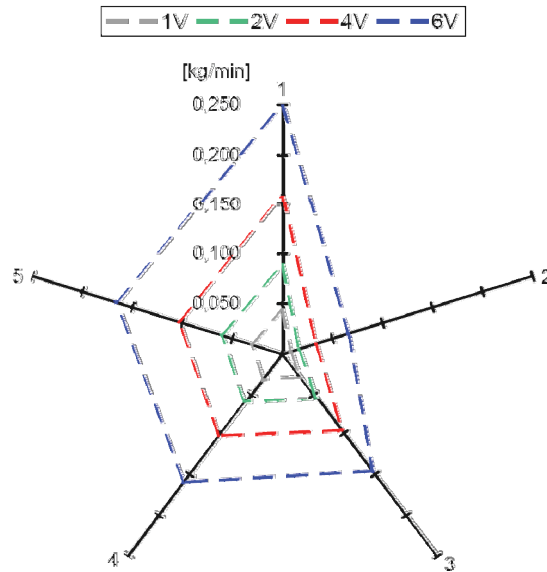


Fig. 7. Fuel flow from injector ring. Fuel pump JetCat A601405

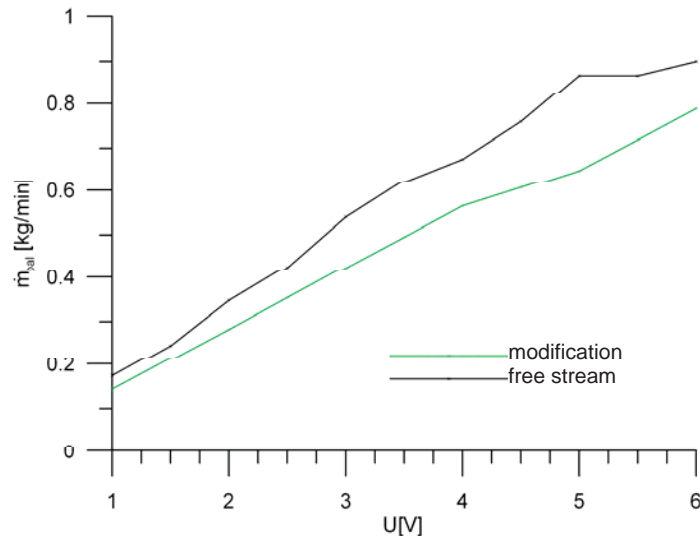


Fig. 8. Summary fuel flow from injector ring: fuel pump JetCat A601405

Presented method is useful and effective, for manufacturing prototype collectors. This approach makes possibility to the identification of the defects on very early stage of production. Testing and measure fuel flow from injector ring conclude that in first assumption fuel flow loss in injector ring is equal about 10% in reference to free stream fuel flow.

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