Institute of Thermomechanics
Prague, Czech Republic

DEPARTMENT OF ELECTROPHYSICS

SPATIAL DISTRIBUTION OF OSCILLATIONS IN A MODULATED DC PLASMA JET

J. Gruber, J. Šonský

Institute of Thermomechanics AS CR, v. v. i., Dolejškova 5, 18200 Praha 8, Czech Republic

gruber@it.cas.cz, soda@it.cas.cz

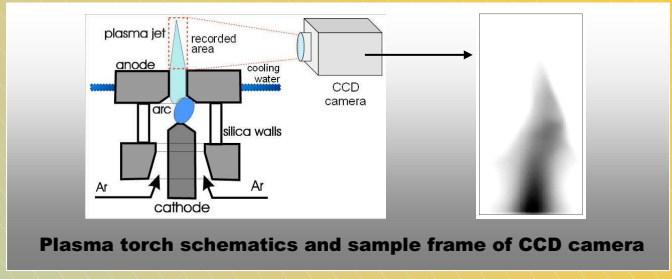
INTRODUCTION

Thermal plasma jets are used for variety of industrial applications (including plasma chemistry, plasma spraying, cutting, welding, etc.). Better understanding and controlling the dynamics of plasma jets is crucial for reproducibility and improved control of such applications.
Here we present results of modulating the **input current** of our experimental plasma torch. The **modulation** was done **by sine waves** of various frequencies (**15 Hz - 7500 Hz**). Among methods suitable for investigating the underlying dynamics is the **recording** and **analysis** of modulated **optical radiation** with high spatial resolution. We show comparison of oscillations present in optical records from different parts of the jet depending of the frequency of arc current modulation.

ESTIMATION OF SPATIAL DISTRIBUTION

To assess effect of this current modulation on plasma oscillations we made **Fourier analysis** of jet optical radiation in different parts of the jet, calculated **power spectral density** (**PSD**) and compared cases with and without modulation respectively.
Spatial resolution of our CCD camera was 256 x 64 pixels. One pixel equals approximately 0.12 mm in our experiment. CCD camera sampling rate was 100 kHz.

EXPERIMENTAL ARRANGEMENT

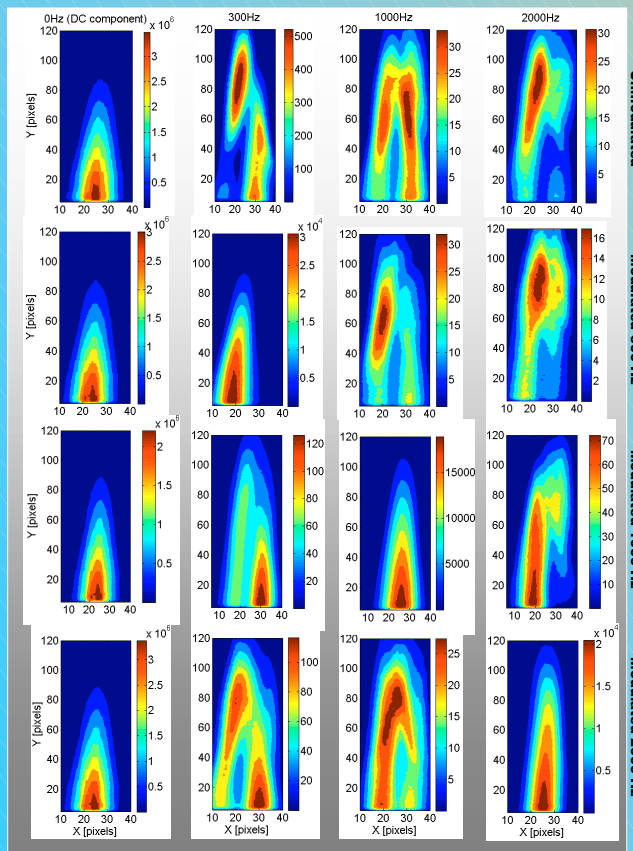


Plasma torch schematics and sample frame of CCD camera

Plasma jet is generated by the experimental vertically oriented plasma torch device at atmospheric pressure. We use argon as the working gas and switching power supply as the current source.
Arc length is **5 mm** and the nozzle diameter is **6 mm**. Mean d.c. arc current was set, depending on the experiment, **130 A or 150 A** and argon flow rate **0.7 g/s**. Argon is fed in both tangentially and axially.
Arc current was generated by a switching power supply with feed trough topology driven by function generator *HP33120A*, and recorded by oscilloscope *LeCroy 9354AM*.
Amplitude of the current modulation was between **15-25 A**.

OSCILLATIONS SPATIAL DISTRIBUTION

Frequency-defined structures differ both in position and in their contribution to overall jet optical radiation. In the unmodulated case, maximal amplitude of electric frequency **300 Hz** is about 15x higher than amplitude of frequencies **1 kHz** and **2 kHz**.
Situation changes when the input current is deliberately modulated by 300 Hz, 1 kHz and 2 kHz respectively. As expected, the modulation increases energy of the respective oscillations. The **position** of these oscillations **changes to the jet core**. At the same time, **oscillations** at different frequencies can be **moved and attenuated**.



Planar distribution of PSD (= |FFT|^2) [a.u.]

OVERALL OSCILLATIONS INTENSITY

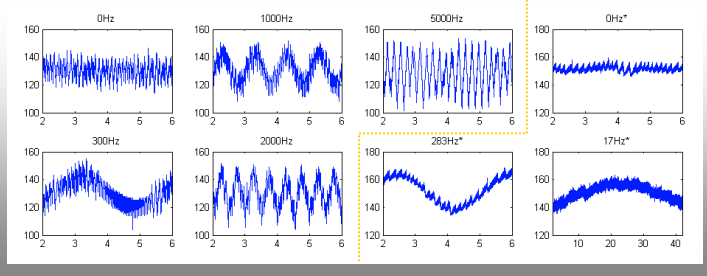
Contribution of different oscillation to overall jet radiation was also compared for each modulation case. Because each record has slightly different overall intensity, **amplitude of PSD** was **normalized** to **DC** component. We present results from two sets of experiments differing by mean current.
Modulation of input current with frequency **7.5 kHz had little effect**, because choking coil, present in circuit for suppressing control loop oscillation, suppresses also high frequencies.
Modulating of input current always **increases** amplitude of the oscillations at the **corresponding** frequency in the jet. Other oscillations are attenuated more or less significantly.

Amplitudes [normalised, x 1E4]	No Modulation*	Modulation* freq. 17 Hz	Modulation* freq. 283 Hz	Modulation freq. 300 Hz	Modulation freq. 1 kHz	Modulation freq. 2 kHz	Modulation freq. 5 kHz	No Modulation
PSD at 283 Hz	0.341	0.330	68.546	0.053	0.078	0.058	0.073	0.058
PSD at 300 Hz	0.378	0.277	0.403	51.789	0.336	0.164	0.063	1.295
PSD at 1 kHz	0.180	0.110	0.123	0.022	60.828	0.041	0.058	0.046
PSD at 2 kHz	0.019	0.026	0.019	0.014	0.054	88.008	0.009	0.029
PSD at 5 kHz	0.033	0.014	0.020	0.019	0.017	0.024	110.835	0.018

Amplitude of the normalised power spectral density at selected frequencies for different deliberate modulation of input current.
*** - mean current = 150 A, otherwise mean current = 130 A**

EFFECT ON ARC CURRENT

Except modulation with high frequency (7.5 kHz), all modulation is clearly visible in arc current records.



Samples of arc current records for different modulation [A; ms]

CONCLUSION

We have **deliberately modulated** input **current** of vertical oriented DC plasma torch by sine waves of various frequencies. Modulation amplitude was between 10-20% of mean arc current and the impact to the oscillations in the generated thermal plasma flow is very significant.
Modulation **stimulates oscillations at the same frequency** (as frequency of the modulation) and increases their amplitudes of **2 or 3 orders** of magnitude compared to unmodulated case. These stimulated oscillations are **present mostly in the jet core**, close to the nozzle exit. At the same time, oscillations at **different frequencies** are influenced both by **amplitude attenuation** and by **spatial position push**. Those oscillations at different frequencies can be attenuated several times of magnitude.
We have demonstrated that by relatively small modulation, it is possible to influence coherent structures present in the plasma jet and distribution of energy among them.

18th Symposium on Physics of Switching Arc, Nove Mesto na Morave, Czech Republic, September 7 - 11, 2009