Chapman-Jouguet detonation of methane-oxygen mixture

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1 Introduction

The purpose of the project was to conduct a study of Chapman-Jouguet detonation of methane-oxygen mixture for different initial conditions using Cantera and SDToolbox software.

2 Model description

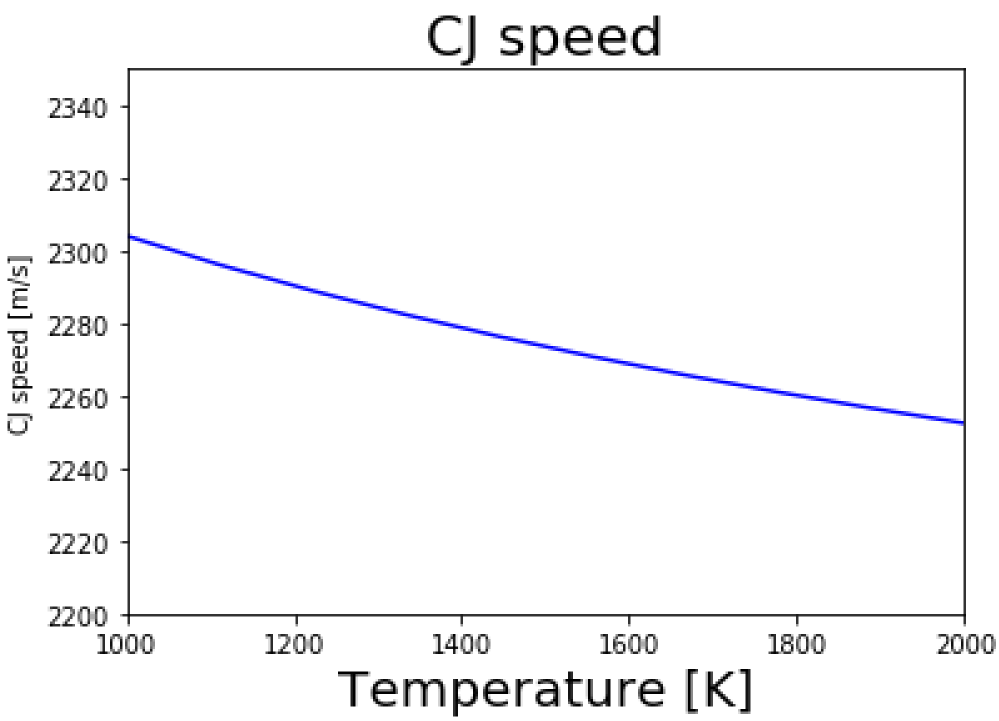
The Chapman–Jouguet condition holds approximately in detonation waves in high explosives. It states that the detonation propagates at a velocity at which the reacting gases just reach sonic velocity (in the frame of the leading shock wave) as the reaction ceases. For this case, we used gri30 mechanism. The stoichiometric reaction of complete combustion of methane in oxygen:

$$CH_4 + 2O_2 -> CO_2 + 2H_2O$$

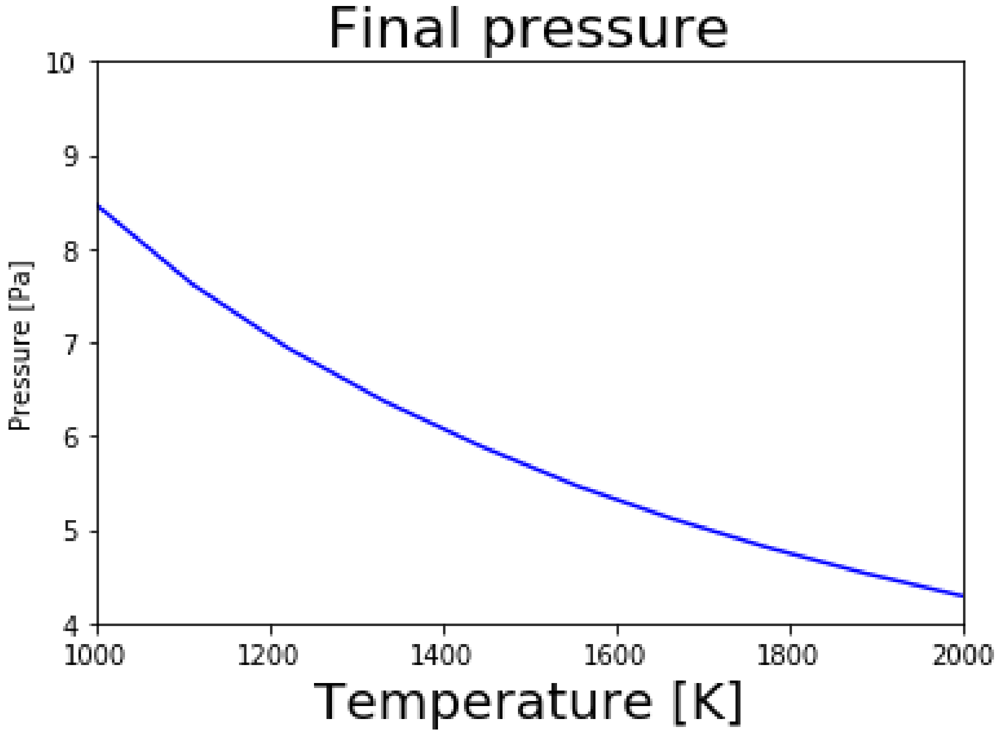
ae - equilibrium sound speed
af - frozen sound speed

3 Results

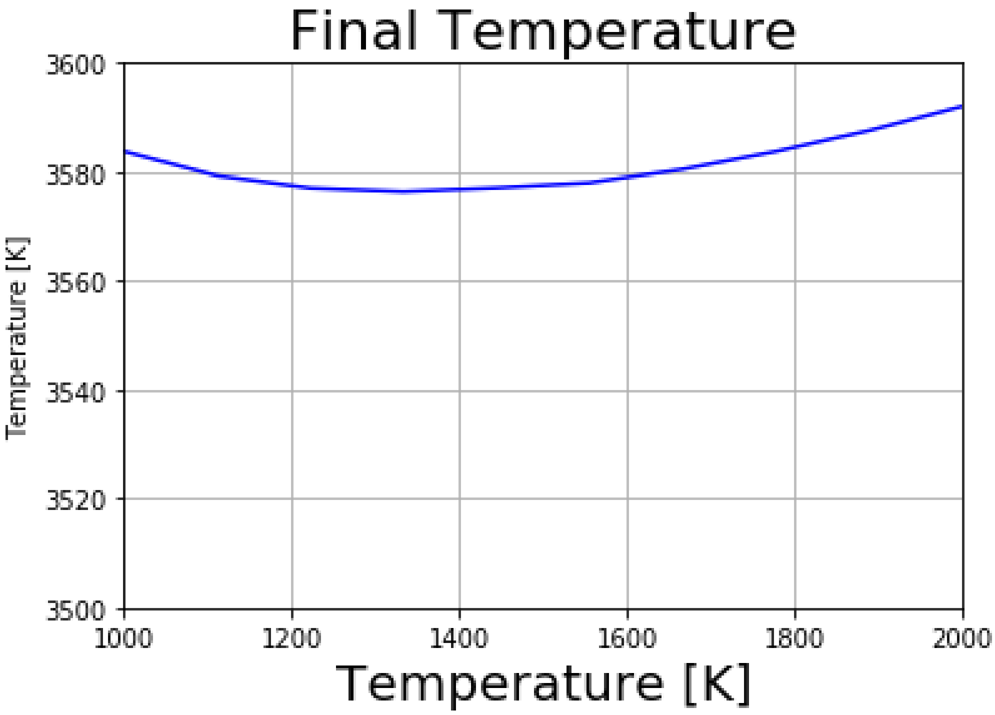
3.1 Results for ϕ =1, P=1013,25hPa and different initial Temperatures 10 iterations in range <1000-2000>K



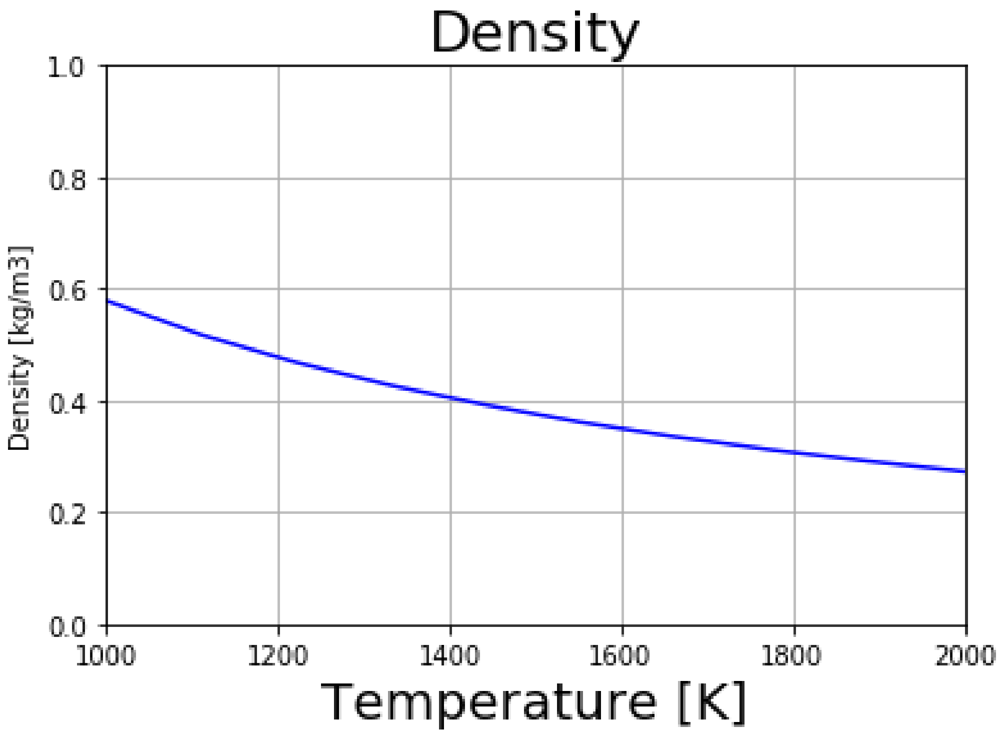
Plot 1: influence of initial temperature on C-J detonation speed



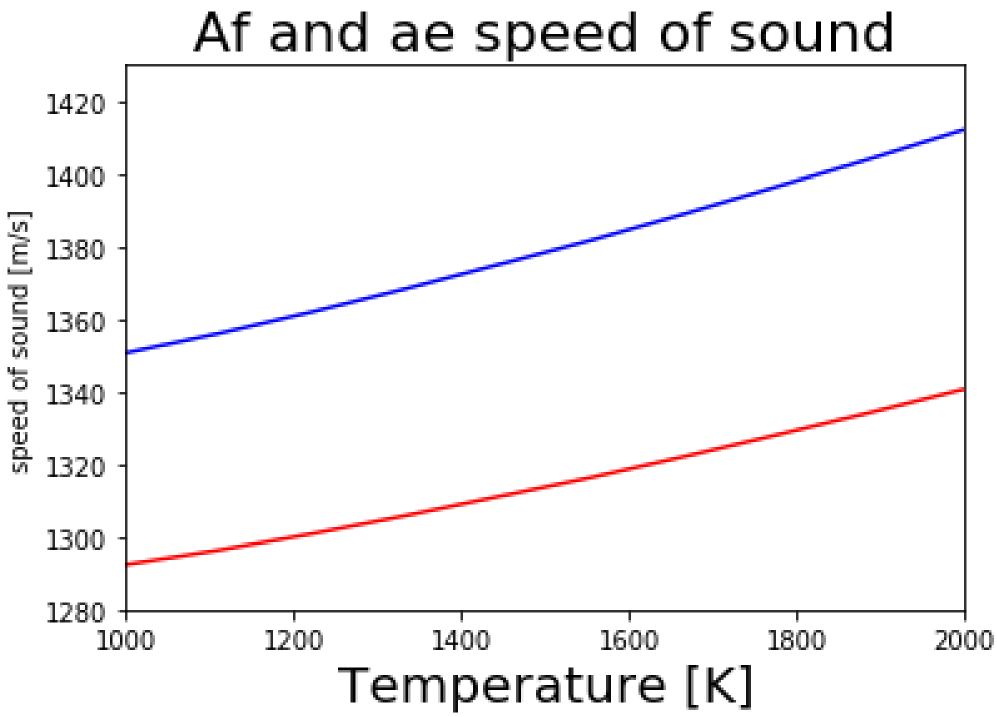
Plot 2: influence of initial temperature on detonation pressure



Plot 3: influence of initial temperature on detonation temperature

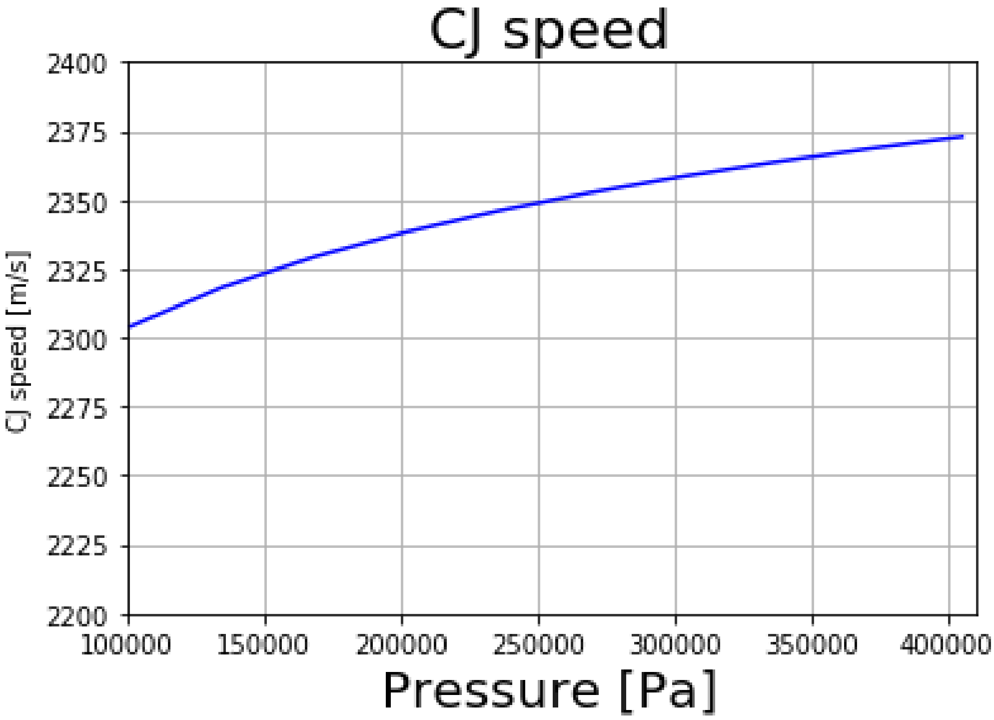


Plot 4: influence of initial temperature on detonation density

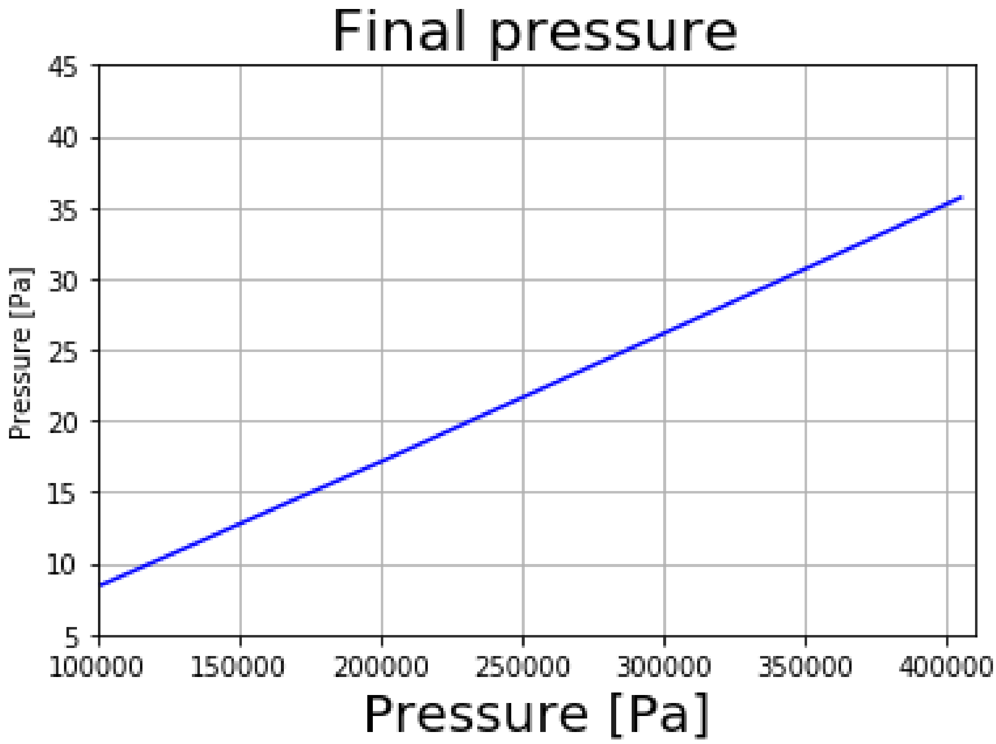


Plot 5: influence of initial temperature on detonation sound speed

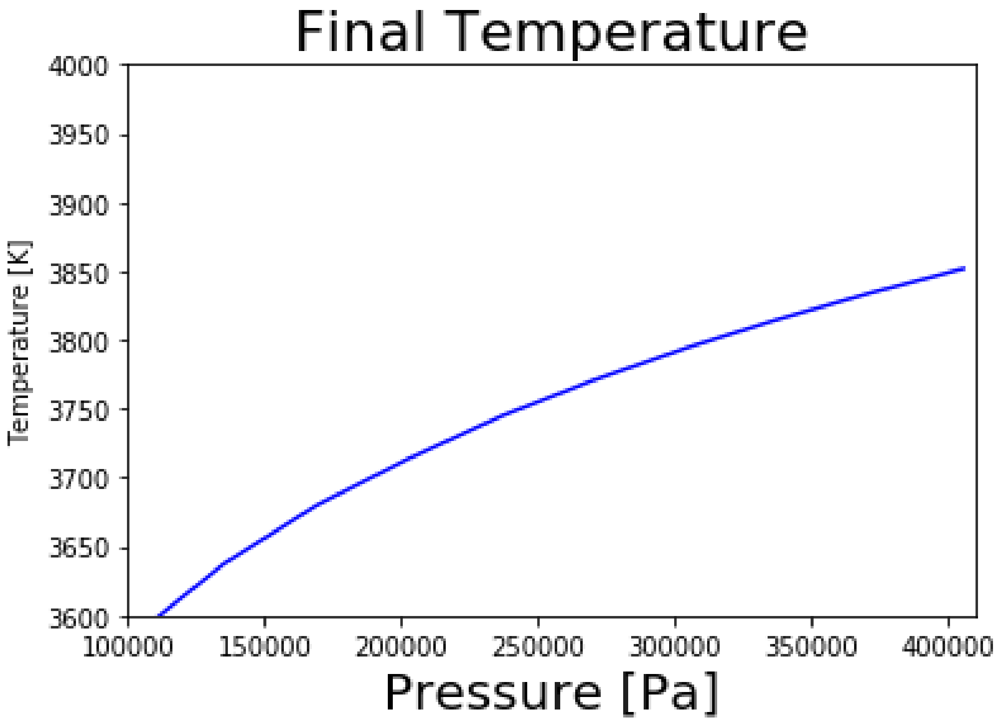
3.2 Results for ϕ =1, T=1000K and different initial pressures 10 iterations in range <1-4>atm



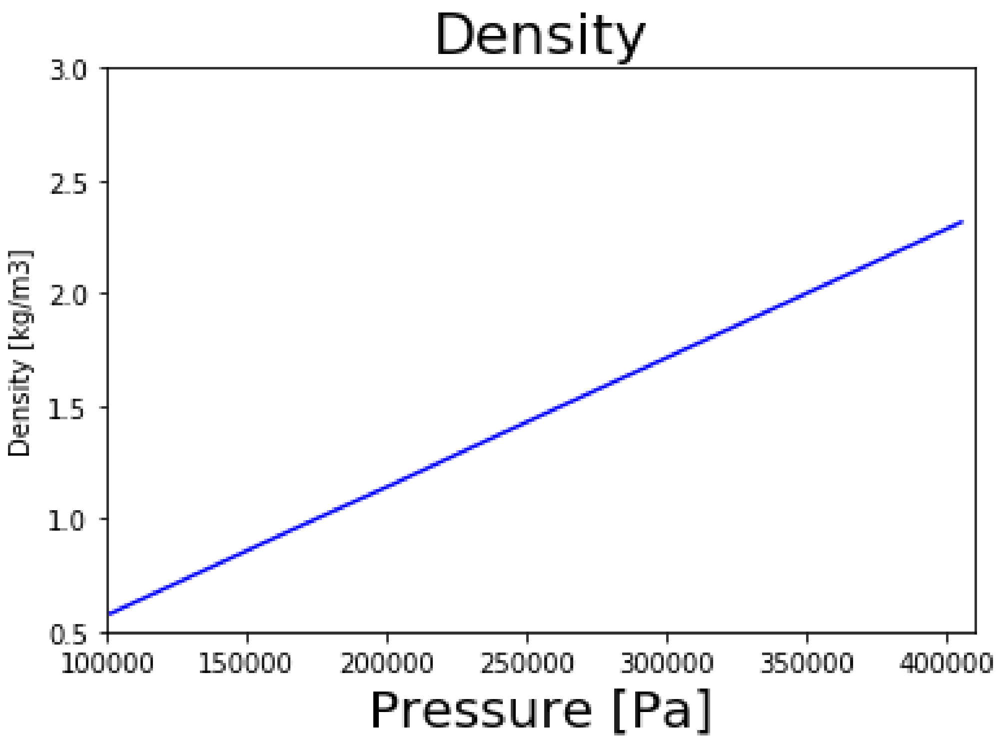
Plot 6: influence of initial pressure on C-J detonation speed



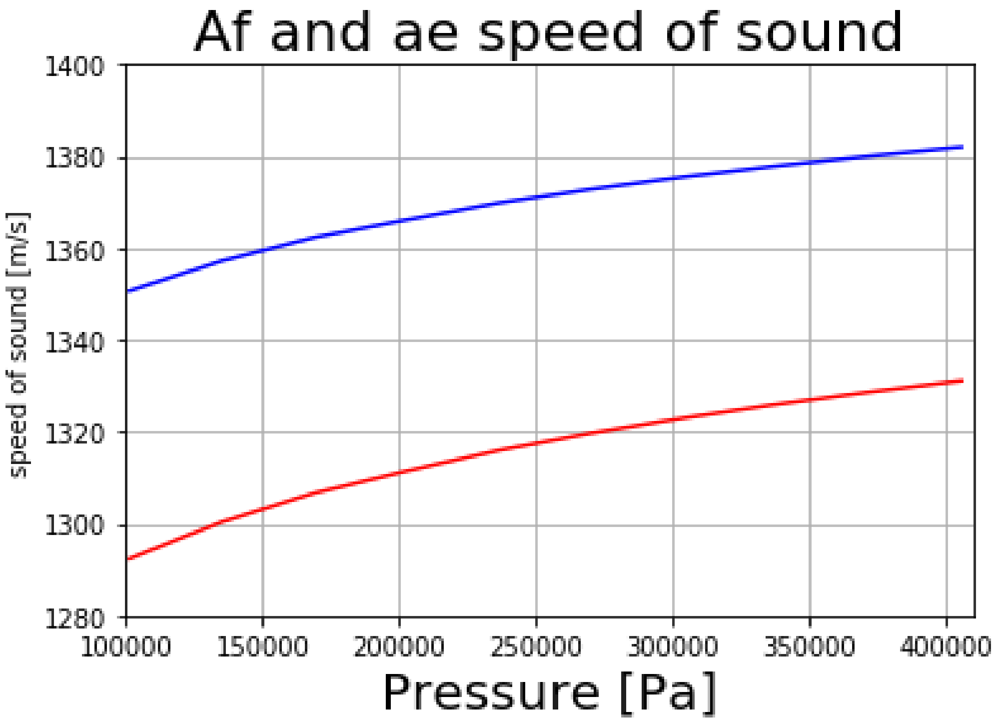
Plot 7: influence of initial pressure on detonation pressure



Plot 8: influence of initial pressure on detonation temperature

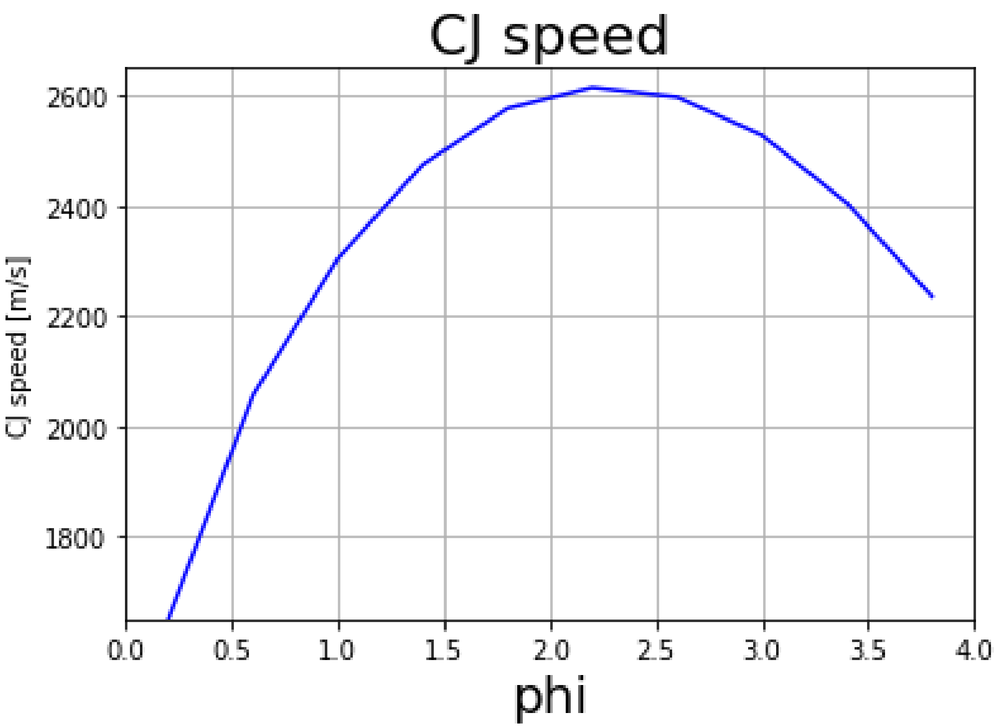


Plot 9: influence of initial pressure on detonation density

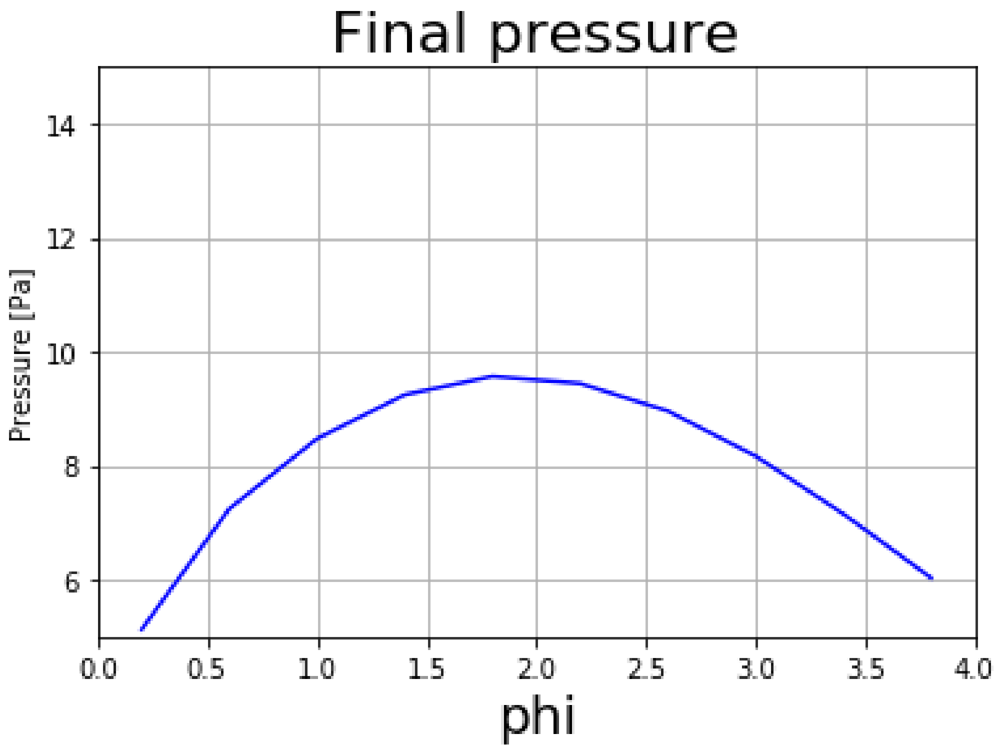


Plot 10: influence of initial pressure on detonation sound speed

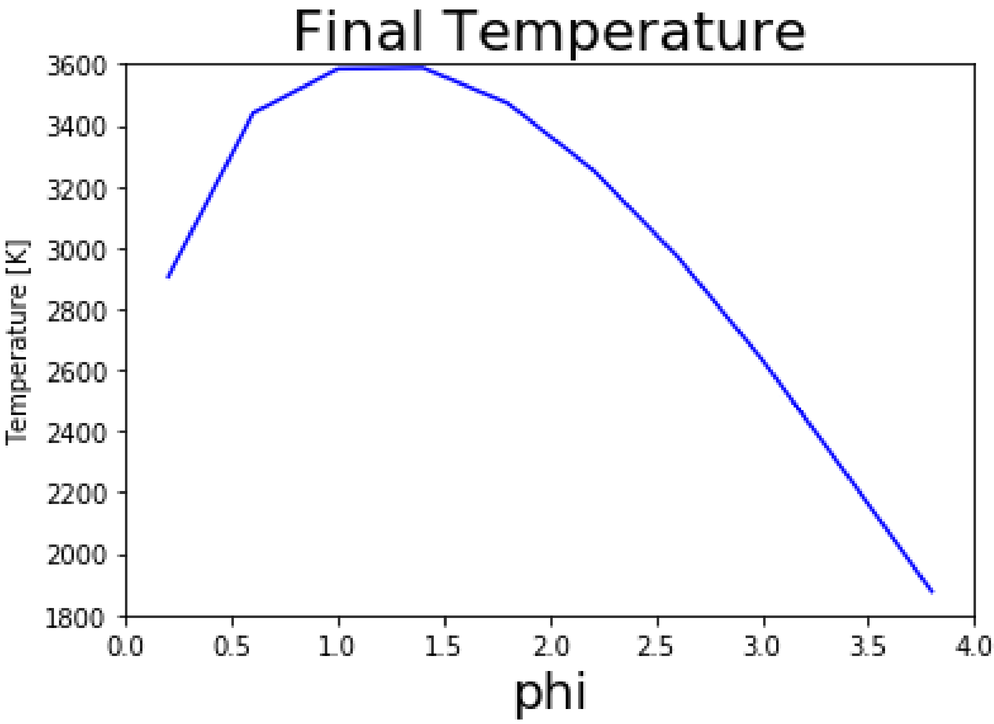
3.3 Results for T =1000K, P=1013,25hPa and different initial equivalence ratio values (ϕ) 10 iterations in range <0.2-3.8>



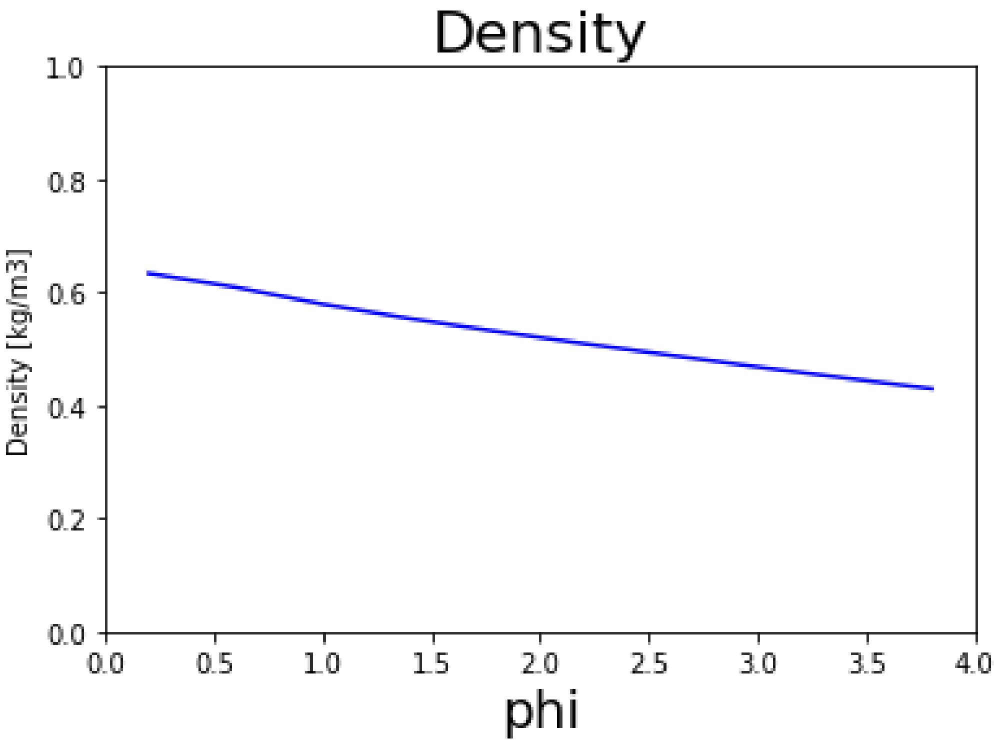
Plot 11: influence of initial ϕ on C-J detonation speed



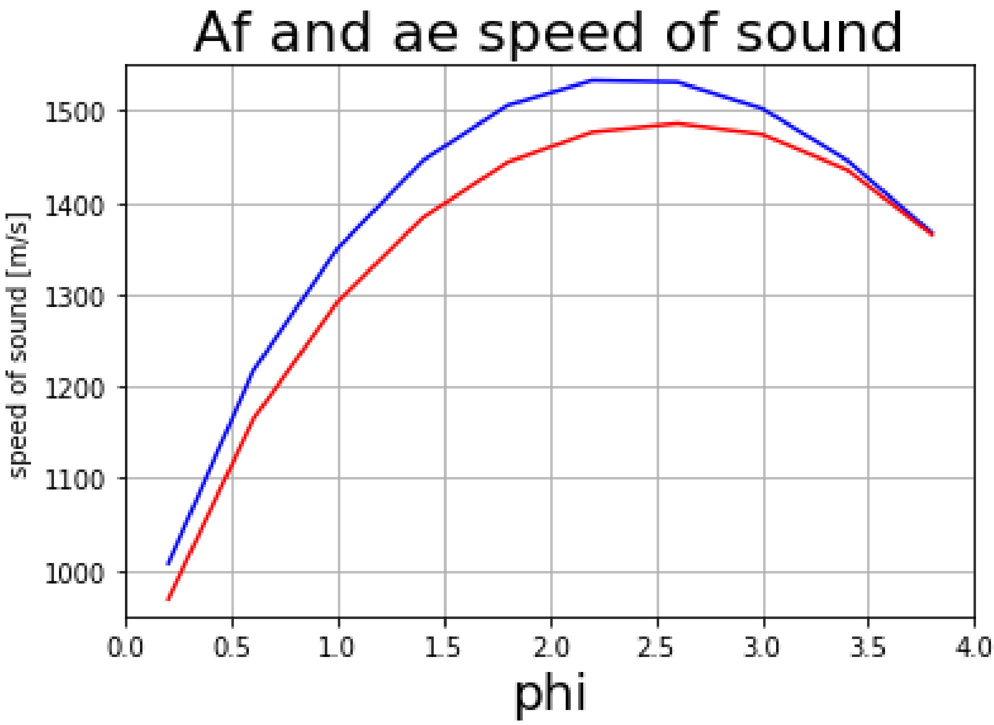
Plot 12: influence of initial ϕ on detonation pressure



Plot 13: influence of initial ϕ on detonation temperature



Plot 14: influence of initial ϕ on detonation density



Plot 15: influence of initial ϕ on detonation sound speed

4 Conclusion

C-J detonation speed is dependent of initial parameters such as temperature, pressure, and equivalence ratio value. When initial temperature is increased C-J speed decreases, when initial pressure increases C-j speed also increases. Dependency of equivalence ratio and C-J speed is parabolic, and its maximum is reached with $\phi = 2.2$, and C-J speed 2610 m/s.

5 References

https://en.wikipedia.org/wiki/Chapman\T1\textendashJouguet_condition
https:
//www.mech.kth.se/courses/5C1219/Hand_out_PDF/SG2219_NT_Lecture%205%20HT10.pdf
http://shepherd.caltech.edu/EDL/public/cantera/html/SD_Toolbox/