FLOW FIELD COMPUTATION BY UNPWIND MESHFREE METHOD FOR SIMPLIFIED HIGH VOLTAGE GAS CIRCUIT BREAKER MODEL

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ABSTRACT

We consider the computational problems related to high voltage (HV) circuit breakers. To effectively design HV circuit breakers, a meshfree method which was proposed by the authors is tested. The meshfree method is implemented to a simplified model for the HV circuit breaker and showed a robust behavior even in a severe boundary condition. A good shock capturing is shown in the computations and a delicate gas diffusion through a slit is also computed, which is usually difficult to catch. Vector splitting method is employed to exploit the merit of meshfree methods in the hyperbolic problems.

INTRODUCTION

Much progress has been made in the design of high voltage (HV) circuit breakers since 1960's although we could not cover all the detailed history and researches here. Briefly speaking, the first SF6 puffer circuit breaker appeared in 1964 and since then there have been various models to describe the physical phenomena like Swanson-Roidt[1], Hermann-Ragaller[2], Lowke-Lee[3], and Chan-Cowley-Fang[4]. However, designing a HV circuit breaker is still a complicated work in view of experiments and theories. It is a formidable task to compromise flow analysis, mathematical models to complicated phenomena, complex geometry and fast moving boundary. It is our view that now a reasonable mathematical model can be established and we can analyze the suggested model in a certain depth.

On the contrary computer simulation has become a necessary design tool to predict HV circuit breakers. It would be impossible to get optimized process without computer simulations since there are infinitely many variations. Therefore computer simulations in HV circuit breaker technology could reduce the research and development (R&D) cost significantly and improve mathematical models theoretically. Now that numerical techniques to compute partial differential equations are well established, it is more and more important to optimize by using computer simulations.

One of the most time consuming process in implementing a numerical technique is to design a proper mesh for the computational geometry. The HV circuit breaker has a complicated shape

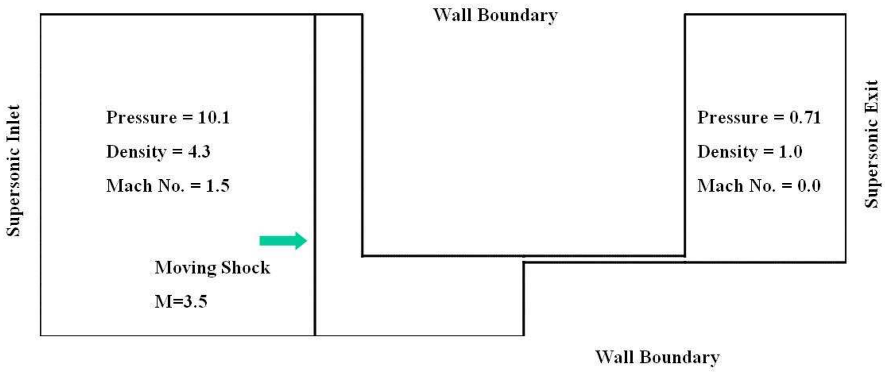

Figure 1. Simplified model of HV circuit breaker.

and it is not a simple matter to find a mesh for finite element method or finite difference method. In this note we introduce a meshfree method. Meshfree method can handle large deformation of moving body and have resolution capability as well as it is robust to complex geometry.

Computer simulation of a HV circuit breaker switching involves fluid phenomena, electric field and heat diffusion process. Finding a simple model and discrete algorithm to simulate entire physics is our long term goal. As a first step, we analyze the shock phenomena and gas diffusion in a stationary HV circuit breaker using a simplified model to fully understand gas physics inside of a HV circuit breaker. The electric field has a much large period and thus we need to consider the fluid part and heat part in a much smaller scale. So, for our simplified model, we disregard the electric field and arc model and it is assumed that there is no energy source term due to electric field. In the forthcoming paper, we will consider the full gas dynamic model including heat source as well as moving boundary.

NUMERICAL RESULTS AND CONCLUSIONS

We have a plan to investigate and to make a mathematical model to simulate all the physical phenomena existing in HV circuit breakers. As a starting point, we apply the meshfree scheme to a simplified model of HV circuit breakers to check robustness of the scheme under the severe conditions which HV circuit breakers experience. We consider a simplified model as shown in Fig. 1. The moving shock from the left inlet represents the gas shock generated by the piston in HV circuit breaker and the step wall boundary represents the moving electrode. Here we assume our HV circuit breaker has two dimensional shape.

Figure 2 shows time evolution of pressure contour. The upper part of the incident shock reflects on the first step while the lower part marches to the downstream. The first reflect shock becomes bent around the corner. At $t = 0.2$, the lower part of the incident shock reflects on the second step and the rest of the incident shock moves through the slit. The first reflect shock strikes the lower surface and starts to merge into the second reflect shock. At $t = 0.3$, we see transition of the first reflect shock from regular reflection to single Mach reflection. Due to strong interactions between the shocks, the upper part of the second reflect shock is curved to the upwind direction. The incident shock comes out of the slit. At $t = 0.4$, the Mach stem grows up and we clearly see the triple point. Interestingly, the maximum pressure region is detached from the second step and positioned behind the second reflect shock. This is because flow from the inlet collides against flow reflected from the second step at the region. The incident shock becomes accelerated rapidly and exhausted to the exit. At $t = 0.5$, the triple point further moves to the upstream. The maximum pressure ratio almost reaches up to 100 behind the second reflect shock. This result is much worse than actual cases. It has to be kept in mind that the result comes from the fact that the recoiling thrust part, which has smooth curvature and moves fast to backward when SF6 gas blows, is modelled as step and stationary as well as more sever initial condition is given.

We apply the upwind meshfree scheme to the simplified model of high voltage circuit breakers under the assumption of 2D inviscid flow. While we have simulated the simple and fixed model, meshfree methods have innate advantage for complex geometry and moving body problems. Since we show robustness of the present scheme, computation over actual geometry of high voltage circuit breakers including moving boundary will be done in near future.

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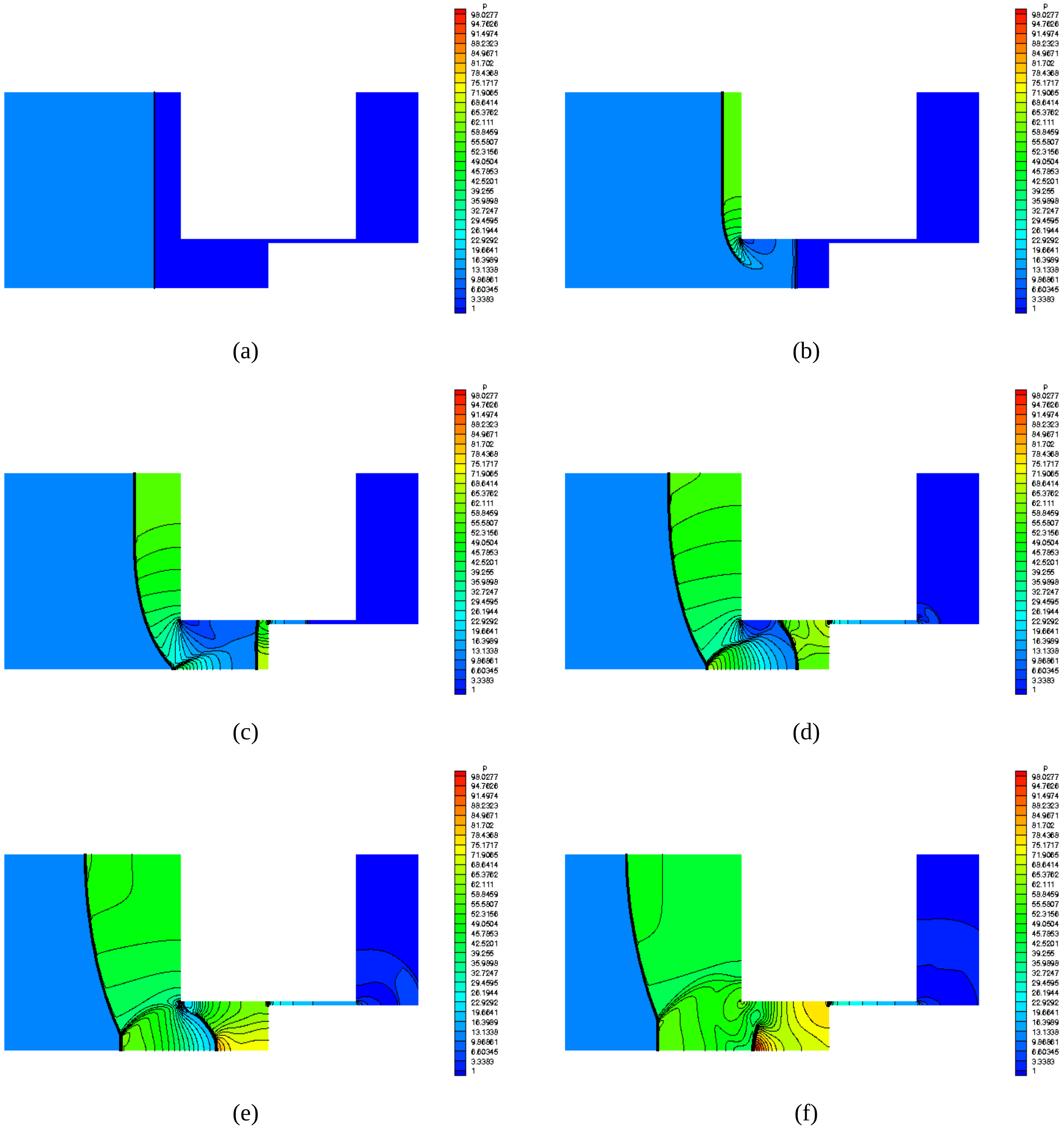

Figure 2. Pressure contour: (a) $t = 0.0$, (b) $t = 0.1$, (c) $t = 0.2$, (d) $t = 0.3$, (e) $t = 0.4$, and (f) $t = 0.5$.