PARALLEL SIMULATION AND MULTI-MODE EVOLUTION GENETIC ALGORITHM OPTIMIZATION FOR CRASHWORTHINESS OF THIN-WALLED TUBE WITH FOLDING PATTERNS

Hailong Sun,Yunkang Sui[a)]& Hongling Ye
Numerical Simulation Center for Engineering, Beijing University of Technology,Beijing, 100124, China

Summary The optimization model of thin-walled tube established by response surface method (RSM), necessary data for fitting response surface is to be obtained by parallel simulation computation, otherwise it would take most of total optimization time. The improved multi-mode evolution genetic algorithm to solve the above model, not only avoids the problem without solution of the traditional sequential quadratic programming method due to non-positive of Hesse matrix, but also improves the global search ability and convergence rate.

INTRODUCTION

Structural optimization design on the thin-walled tube of ductile metal has been a focus in academic fields in recent years[1]. In this paper, crashworthiness of a new thin-walled tube which is smooth cylindrical shells added by pyramid corrugated is optimized. Highly nonlinear collision procession leads to very complex relationship between objective function(energy absorption value) and design varables(wave heigh and angle) without explicit function expression. In order to improve optimization efficiency for the problem, an Approximate explicit function is fitted by response surface method from Literature [2]. calculated time reduce due to MPI parallel method adopt. The evoluted process simulated by Genetic Algorithm assuming good diversity in artificial genetic process is too simplified[3], and thus it exist the defect of early maturity and local convergence. For single-species evolution, multi-mode evolution is an effective strategy to improve the global search ability and convergence speed. Both function test and optimized application on thin-walled tube crashworthiness show that the algorithm is efficient.

.

ANALYSIS MODEL AND PARALLEL COMPUTING

Section shape and geometric parameters of pyramidal folding patterns tube, shown in Fig.1, whose finite element model is created with APDL applying SHEEL 163 bilinear isotropic material in Fig.2. Shear factor is 5/6, thickness of tube wall is 2mm, elastic modulus is 210GPa, poisson's ratio is 0.3, yield stress is 230MPa, shear modulus is 10GPa. Contact type is defined as SURFACE TO SURFACE. Both dynamic and static friction coefficient of contact surface are 0.1. translational freedom of Z direction on the left boundary node is constraint, right boundary nodes in contrary. It is impact along the axial by quality of 500kg and the initial velocity of 50km/m. Parallel computing cluster of master-slave distributed memory built base on the IBM cloud platform, shown in Fig.3. It is a dynamic task allocation scheme to use a master node dispatching five slave nodes in Fig.4. Parallel computing performance is evaluated by speedup and parallel efficiency, shown in Table 1.

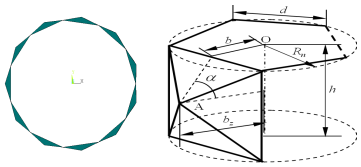

Fig.1 Section shape and geometry of pattern model

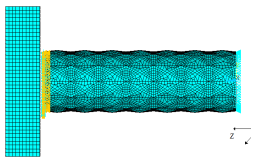

Fig.2 Pyramid corrugated thin-walled tube

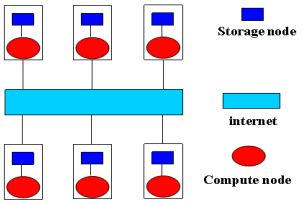

Fig.3 distributed parallel system

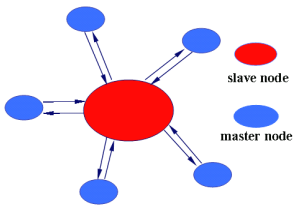

Fig.4 master-slave parallel program

Table1 Serial versus parallel

Algorithm	node number/p	total computing time/s	parallel Part time /s
serial	1	1463	1325
parallel	6	301	267
Algorithm	**speedup**	**parallel efficiency**	**acceleration multiple**
serial			
parallel	4.860	0.810	4.980

MEGA BASIC OPERATION AND PERFORMANCE TEST

Concrete methods: **Coding method**: binary Gray code[4] and real-coded are selected by the program depending on the conditions, the default priority to real-coded; **Selection modes**: non-linear ranking selection used in evolution prophase and tournament selection used in the late abandon the simple roulette selection existing many defects[5-6]; **Cross methods**: binary coding adopts multi-point crossover and uniform crossover which increases gradually the probability. Real-coded used the discrete crossover in the early evolution, arithmetic crossover in the

Table 2 Expression of test functions

Shaffer's F6	$\max f_1(x,y)=0.5-\frac{\sin^2\sqrt{x^2+y^2}-0.5}{(1+0.001(x^2+y^2))^2}$ $-4\le x,y\le 4$
Rosenbrock	$\max f_2(x,y)=100(x^2-y)^2+(1-x)^2$ $-2.048\le x,y\le 2.048$

a) Corresponding author. Email: ysui@bjut.edu.cn.

medium, AEA reorganization in the post; **Mutation methods**: binary coding used random mutation and real-coded used adaptive mutation. **Inversion**: Appropriate inversion may improve the population diversity. Two typical test functions Shaffer's F6 and Rosenbrock with considerable complexity are selected to carry out the experiments, function expressions shown in Table 2. Results show that efficiency of multi-mode evolution genetic algorithm are larger than that of a simple genetic algorithm by comparing evolutionary generations of global optimum solution required, and then convergence speed improves six to eight times. Evolution is shown in Fig.5 and Fig.6.

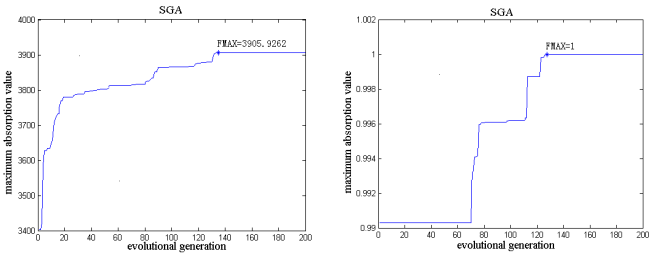

Fig.5 optimizing Rosenbrock and Shaffer's F6 function with SGA

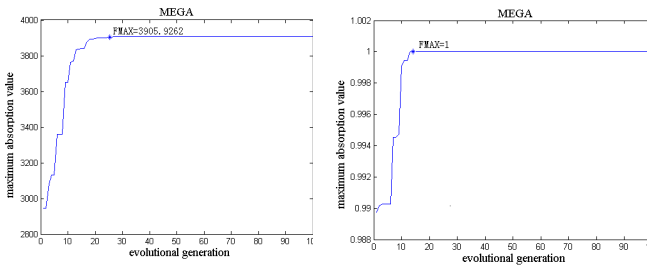

Fig.6 optimizing Rosenbrock and Shaffer's F6 function with MEGA

OPTIMIZATION MODEL AND RESULTS

Taken maximum absorption value as objective function, height h and angle α as the design variables, an optimization model of pyramidal folding patterns thin-walled tube with regular polygon cross-section under axial impact load is establish, shown in Fig.7. Optimization model solved by MEGA, the algorithm will converge after 14 generations evolution, shown in Fig.8. The optimized regular polygon cross-section folding pattern-tube deformation under impact load is shown in Fig.9. 10ms after collision occurred, the absorption energy of optimized structure is 26378J, 44.3% more than 18314J that of non-optimized, which obviously surpass traditional structure and non-optimized structure.

$$\begin{cases} Find \quad h, \alpha \\ Make \quad f(h,\alpha) \rightarrow \max \\ \text{s.t.} \quad \dfrac{\pi}{3} \le \alpha \le \dfrac{\pi}{2} \\ \qquad 20 \le h \le 100 \end{cases}$$

Fig.7 Optimization model

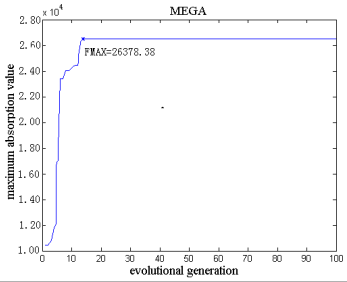

Fig.8 optimizing maximum value with MEGA

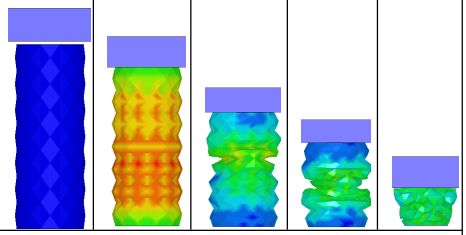

Fig.9 The optimized folding pattern-tube with regular polygon section under impact load

CONCLUSION

Approximate explicit objective function obtained by response surface method make the optimization mathematic model established; Distributed Parallel Computing Strategies deal with the most time-consuming part in finite element simulation, which speed up to 5 times; Multi-mode evolution improves the global searching ability of single species simple genetic algorithm, so that it has a faster convergence rate; Optimized maximum energy absorption value of thin-walled tube increased 40 percent, which significantly improved the original design. In summary, explicit approximate optimization model established and then solved by modern swarm intelligence algorithms are indeed combined the advantages of both, which not only improve solution efficiency, but also ensure that nonconvex problem can find the global optimal solution.

ACKNOWLEDGEMENT

The authors do thank the financial support of National Natural Science Foundation of China (Grant No.11172013,and No. 11072009) and Beijing Natural Science Foundation of China (Grant No.3122004)

References

[1] Forsberg J, Nilsson L.: On Polynomial Response Surfaces and Kriging for Use in Structural Optimization of Crashworthiness. *Struct Multidisc Optim* **29**: 232-243, 2005.
[2] Sui YK Bai HB.: Plate-shell structural optimization based on central point's accurate response surface method. *J. Mach Des* **22**: 10-11, 2005.
[3] HU Gui-wu.: Scotch cousin intercross genetic algorithm and its application in supply chain optimization. *Compu and Modern* **12**:1-4, 2008.
[4] Yang XH, Yang ZF.: A gray code hybrid accelerating genetic algorithm and its property analysis. *J. Beij Normal Univ* **06**:831-836,2004
[5] Zhang C, Zhan ZH.: Comparisons of selection strategy in genetic algorithm. *Compu Engi and Des* **23**:5471-5478,2009.
[6] Goldberg D E, Korb B, Deb K.: Messy Genetic Algorithms: Motivation, Analysis and First Results. *Complex Systems* **3** :493-530, 1989.