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Evaluation and Comparison of Seismic Performance of Structural Trusses under Cyclic Loading with Finite Element Method

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***Abstract*—**The structure is made using different members and combining them with each other. These members are basically based on technical and engineering principles and are combined in different ways and have their own unique effects on the building. Trusses are one of the most common and important members of the structure, accounting for a large percentage of the power transmission structure in the building. Different types of trusses are based on structural needs and evaluating and making complete comparisons between them is one of the most important engineering analyses. In the present study, four types of trusses have been studied; 1) Hawe truss, 2) Pratt truss, 3) k truss, and 4) warren truss, under cyclic loading for 80 seconds. The trusses are modeled in 3d using st_{37} steel. The results showed that Hawe trusses had higher values than all other trusses (k, Pratt and Warren) in all the studied indicators. Indicators examined in the study include; 1) von Mises stresses, 2) displacement, 3) support force, 4) velocity, 5) acceleration, 6) capacity (hysteresis curve) and 7) energy diagram. Pratt truss in indicators; Mises stress, displacement, energy have the least amount compared to other trusses. K truss in indicators; support force, speed and acceleration are the lowest compared to other trusses.

***Keywords*—**Hawe truss, Pratt truss, K truss, Warren truss, cyclic loading, finite element method.

I. Introduction

DURING earthquakes and severe storms, the structure is subjected to large loads, which are essential for the proper structural system to transfer the incoming forces. Steel structures have a variety of power transmission systems, the most important of which are trusses, which play an important role in the design and construction of structures. The truss is a rigid structure of triangular units made of thin, long components. Truss members have the ability to withstand tensile and compressive forces. Trusses are among the simplest load-bearing structures that generally act as bending structures and are used in roofs, stairs, and aerospace structures. In such structures, due to the lack of shear force and flexural anchor in each of the truss components, the connections must be modeled in detail. In general, it is important to evaluate and compare the performance of truss because it recognizes the advantages and disadvantages of each of them in the structure compared to other types, which should be fully evaluated [1]-[3]. Lianto et al. evaluated 4 types of truss systems and their specifications [4]. Jiharaman et al. designed the trusses on the roofs of factories (Fabank trusses) based on economic returns. The results showed that the design method is effective on truss efficiency [5]. Fig. 1 shows some examples of trusses.

(a)

(b)

(c)

Fig. 1 Three examples of trusses used in industry

II. Methodology

A. Software

Modeling was performed using Abaqus/Cae 6.12.3 software.

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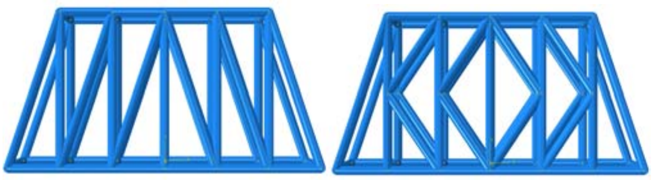
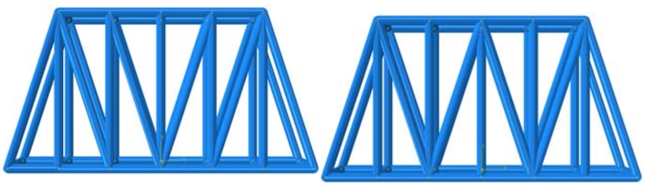
B. Design Geometry

In the present study, 4 types of engineering trusses, 1) Hawe, 2) K, 3) Pratt and 4) Warren, have been modeled and analyzed (Fig. 2). The length of loading openings is the same in all models and is equal to 1 meter.

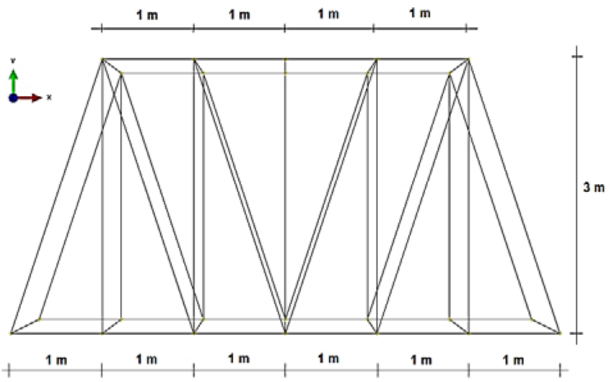


(a) Hawe (b) K



(c) Pratt (d) Warren

Fig. 2 Geometry of models designed from trusses with Abaqus software



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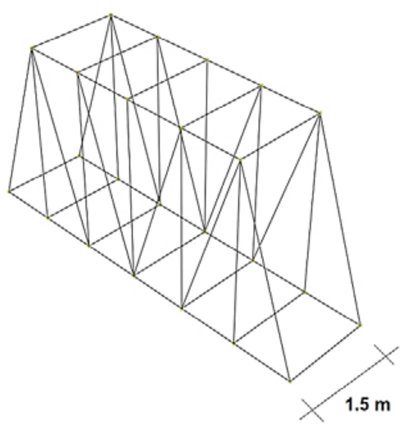


(b)

Fig. 3 Dimensions of the designed truss

C. Materials

All models are made of st37 steel. The specifications of the steel used are given in Table I.

TABLE I
SPECIFICATIONS OF STEEL USED IN TRUSS MODELING

Density	Young's' Modulus	Poisson's Ratio
7800	210×10^9	0.3

D. Loading and Backing

Loading of trusses is done using a cyclic load. The support is available on all designed models. The location and direction of the applied loads and supports are specified in Fig. 4.

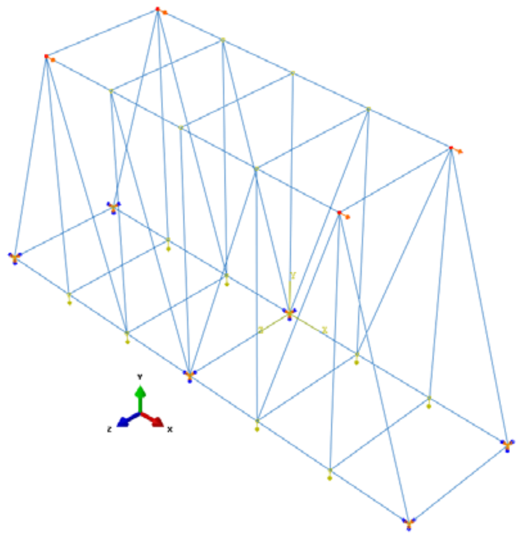
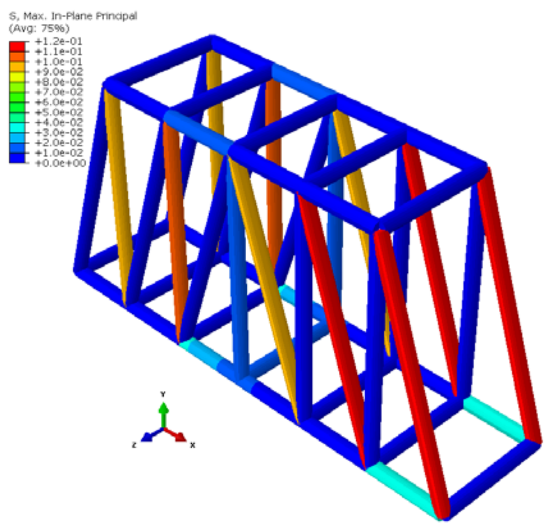


Fig. 4 Location and direction of loads applied in trusses

III. PRESENTING AND ANALYZING THE RESULTS

A. Von Mises Stress



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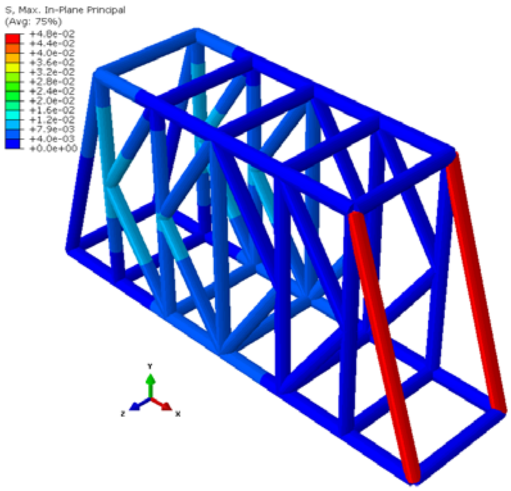

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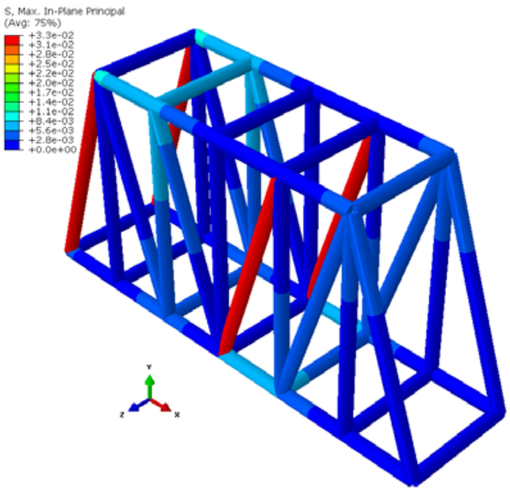

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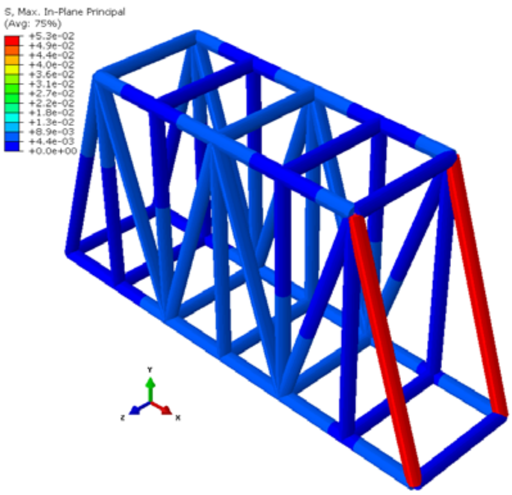


(d)

Fig. 5 Von mises stress in trusses: (a) Hawe, (b) K, (c) Pratt and (d) Warren under cyclic load

The results in Fig. 5 show that the stress of von Mises in Hawe, K, Pratt and Warren trusses under cyclic loads is 0.12, 0.048, 0.033 and 0.053 megapascals, respectively (Fig. 6). The highest and lowest stress levels of von Mises are created in Hawe and Pratt trusses, respectively. The difference in stress between the von Mises in the Hawe and Pratt truss is 126%, which is a lot.

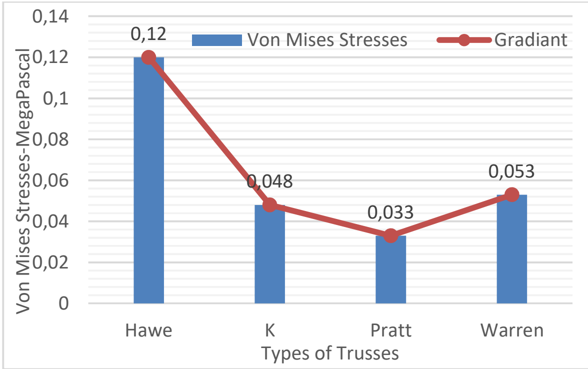
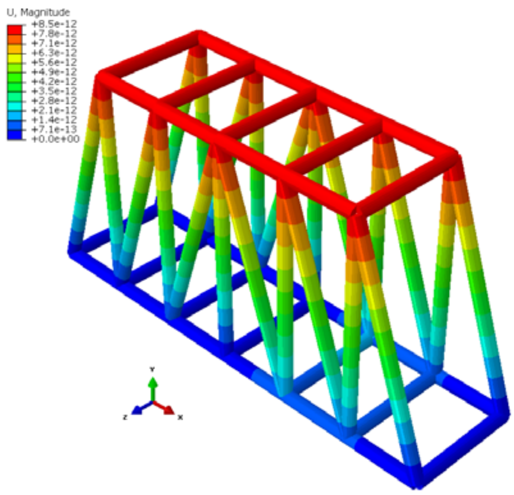


Fig. 6 Curve of the maximum amount of stress of the Mens von in the trusses under a cyclic load

B. Displacement

The results in Fig. 7 showed that the displacement in Hawe, K, Pratt and Warren trusses under the cyclic load was 8.5 $\times 10^{-12}$, 1.6 $\times 10^{-12}$, 1.3 $\times 10^{-12}$ and 2 $\times 10^{-12}$ meter (Fig. 8). The highest and lowest displacement values were created in Hawe and Pratt trusses, respectively. The difference between the possible shifts in the two trusses of Hawe and Pratt is 654%, which is a very large amount.



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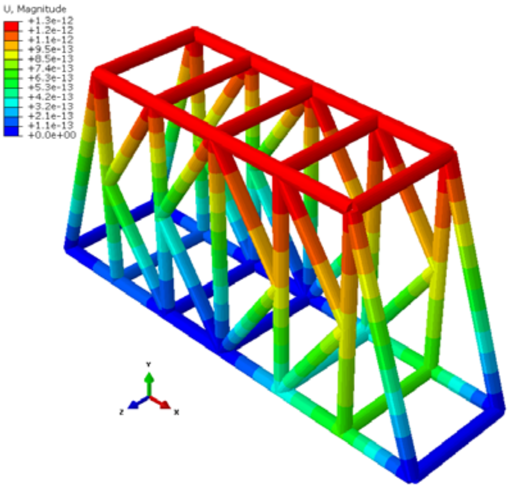

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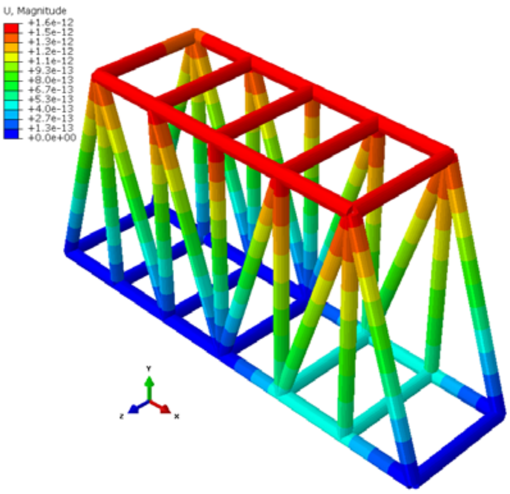

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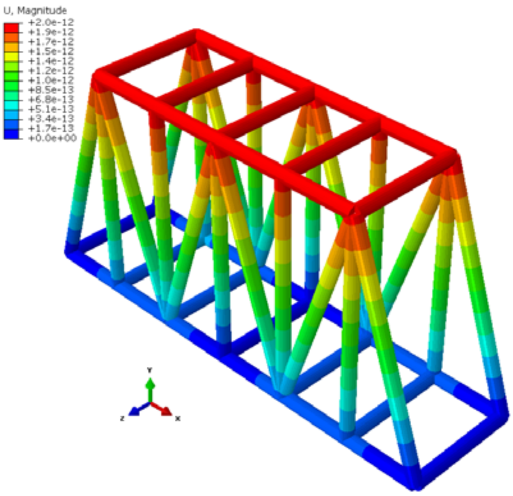


(d)

Fig. 7 Displacement in trusses a) Hawe, b) K, c) Pratt and d) Warren under cyclic load

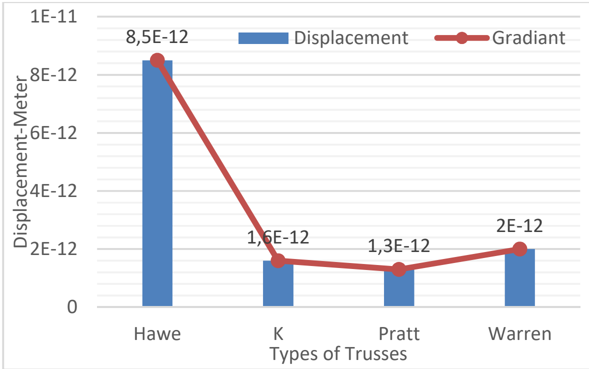
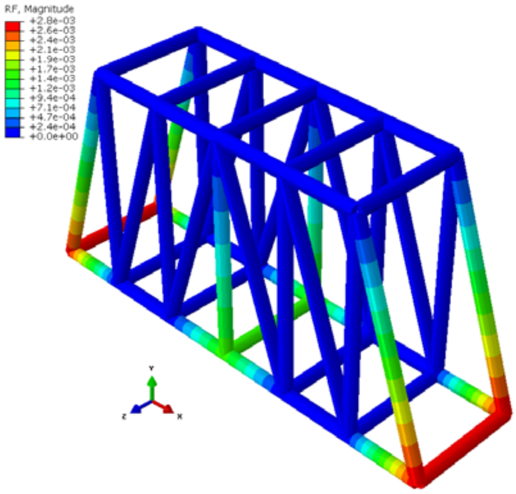


Fig. 8 Curve of the maximum displacement values in trusses under cyclic load

C. Support Reaction Force



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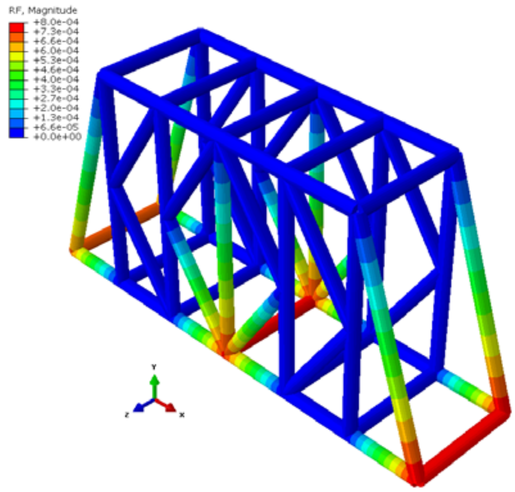

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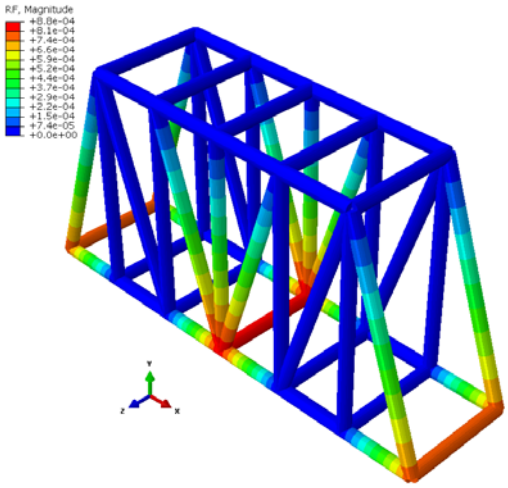

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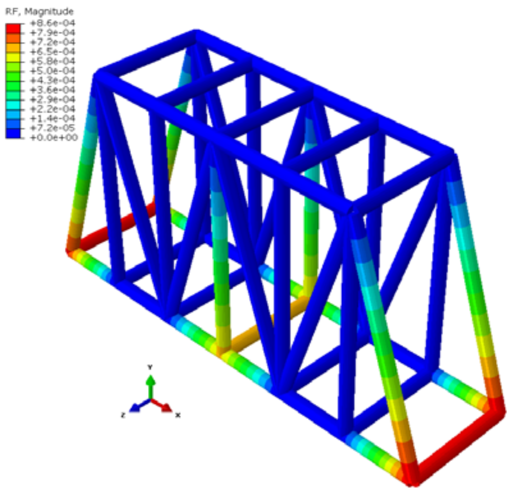


(d)

Fig. 9 Support reaction force in trusses a) Hawe, b) K, c) Pratt and d) Warren under cyclic load

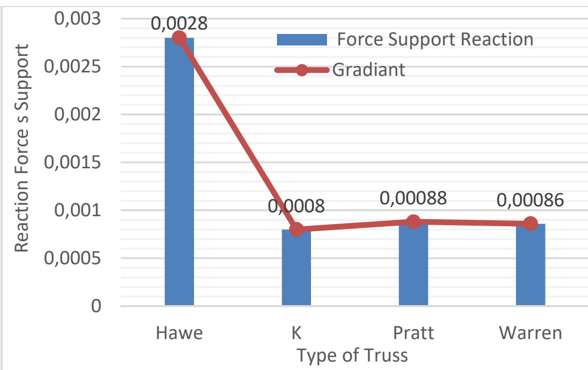
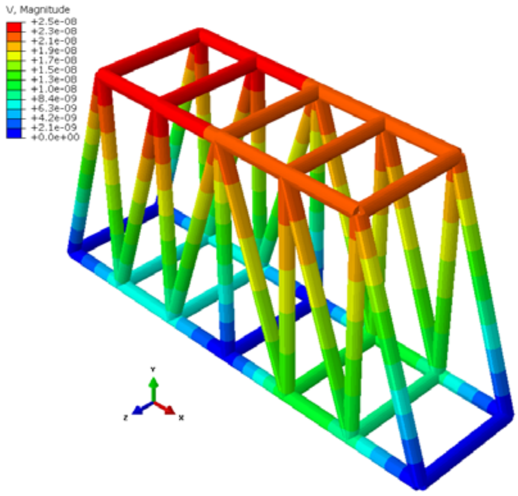


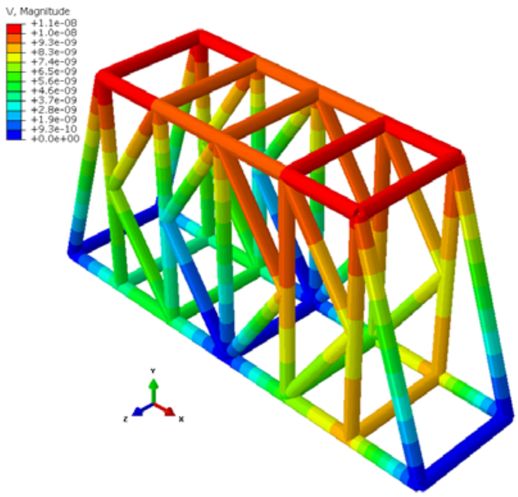
Fig. 10 Curve of the maximum amount of support reaction force in trusses under cyclic load

The results in Fig. 9 show that the support reaction force in Hawe, K, Pratt and Warren trusses under cyclic loads is 0.0028, 0.0008, 0.00088 and 0.00086 Newton, respectively (Fig. 10). The highest and lowest reliability responses were generated in Hawe and K trusses, respectively. The difference between the support reaction in the two trusses of Hawe and K is 71%.

D. Velocity



(a)



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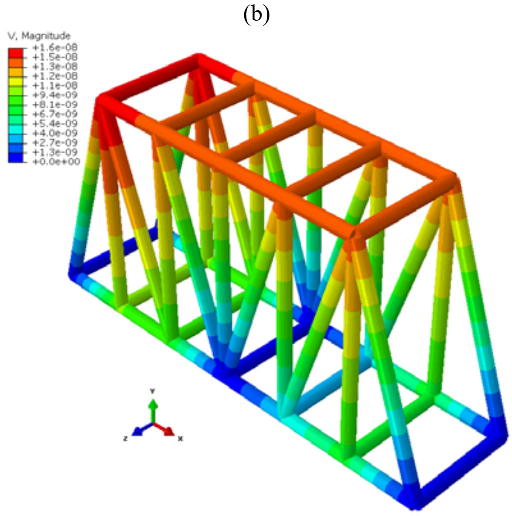

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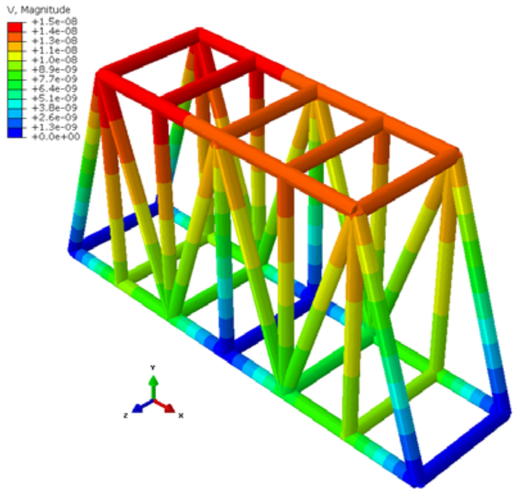


(d)

Fig. 11 Speed in trusses a) Hawe, b) K, c) Pratt and d) Warren under cyclic load

The results in Fig. 11 showed that the velocities in Hawe, K, Pratt and Warren trusses under cyclic loads were 2.5 $\times 10^{-8}$, 1.1 $\times 10^{-12}$, 1.6 $\times 10^{-12}$ and 1.5 $\times 10^{-12}$ respectively (Fig. 12 -The numerical value of the speed in the three trusses is very small and they are very small compared to the speed of the hawe truss). Hawe and K trusses have the highest and lowest speeds, respectively. The difference in speed between the Hawe and K trusses is 56%.

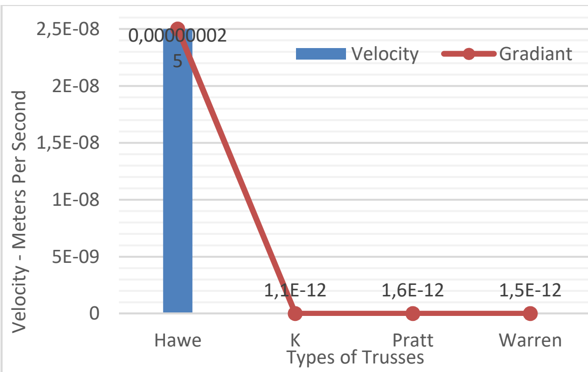
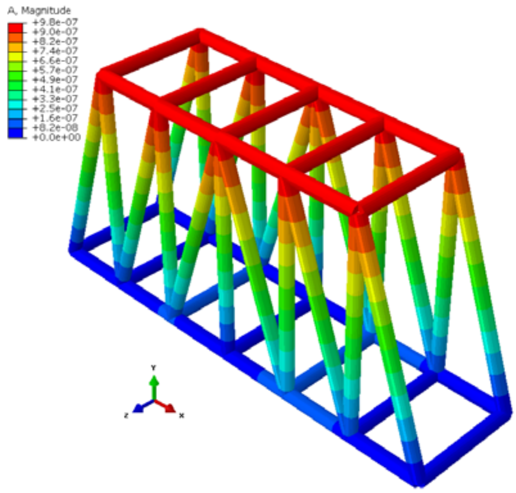


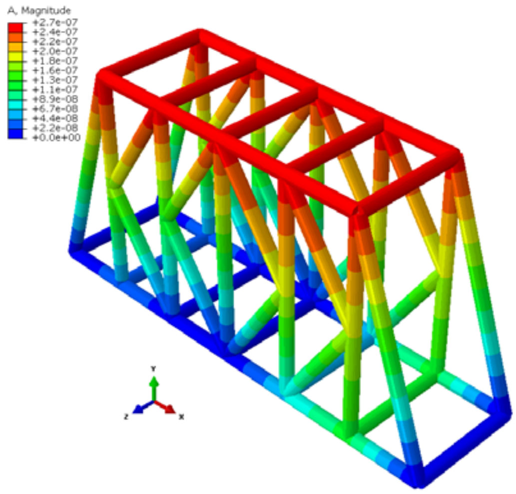
Fig. 12 Curve of maximum velocity in trusses under cyclic load

E. Acceleration

The results in Fig. 13 showed that the acceleration in Hawe, K, Pratt and Warren trusses under cyclic loads was 9.8 $\times 10^{-7}$, 2.7$\times 10^{-7}$, 3.5$\times 10^{-7}$and 3.2$\times 10^{-7}$meters per second, respectively (Fig. 14). Hawe and K trusses have the highest and lowest speeds, respectively. The difference in speed between the Hawe and K trusses is 262%.



(a)



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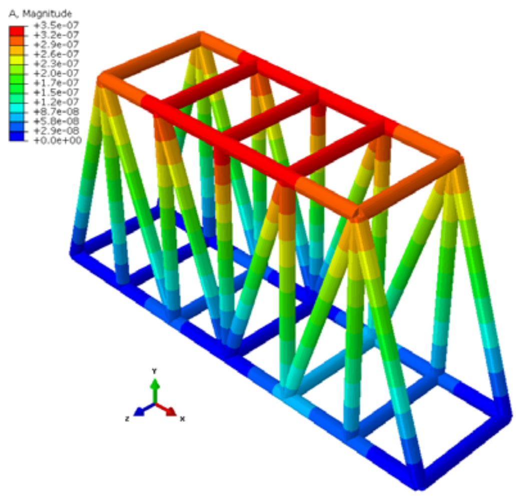

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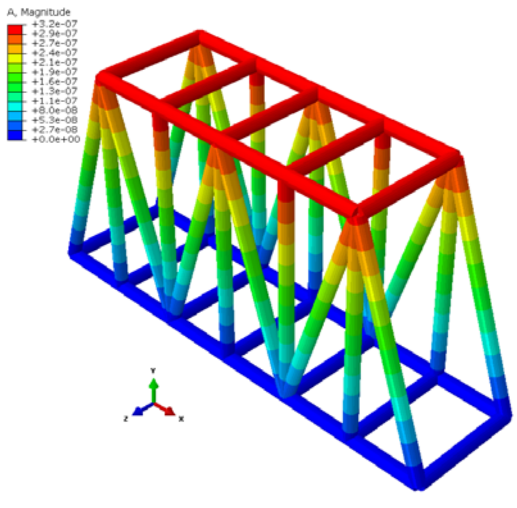

(d)

Fig. 13 Acceleration in trusses a) Hawe, b) K, c) Pratt and d) Warren under cyclic load

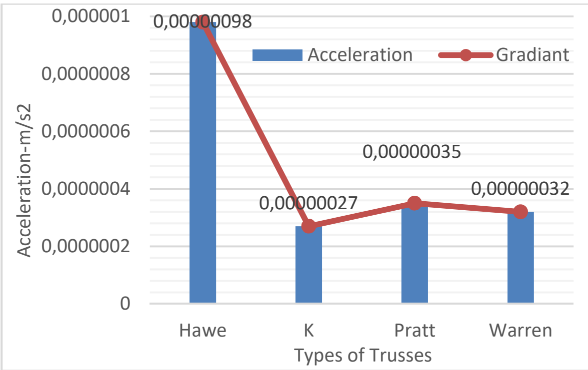

Fig. 14 Curve maximum acceleration in trusses under cyclic load

F. Hysteresis Curve

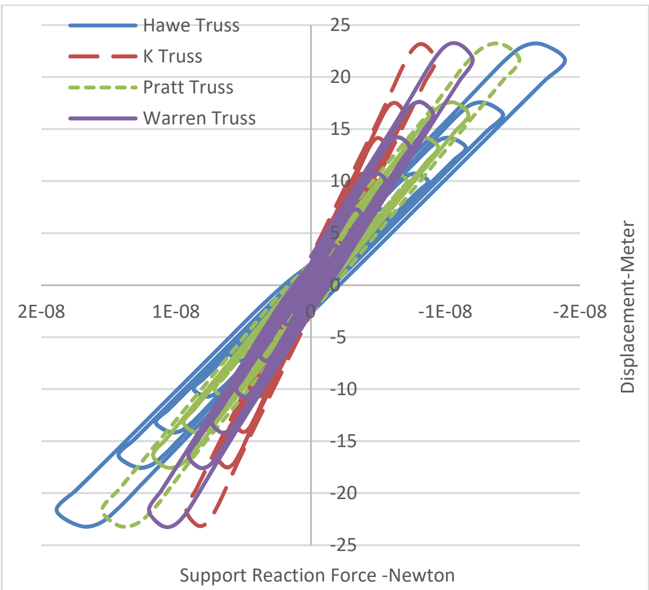

Fig. 15 Hysteresis curve in trusses under cyclic load

The results in Fig. 15 showed that the hysteresis curve has the highest capacity in Hawe, K, Pratt and Warren trusses, respectively, under cyclic load. The results showed that the highest and lowest structural capacities were created in Hawe and K trusses, respectively.

G. Total Energy Curve

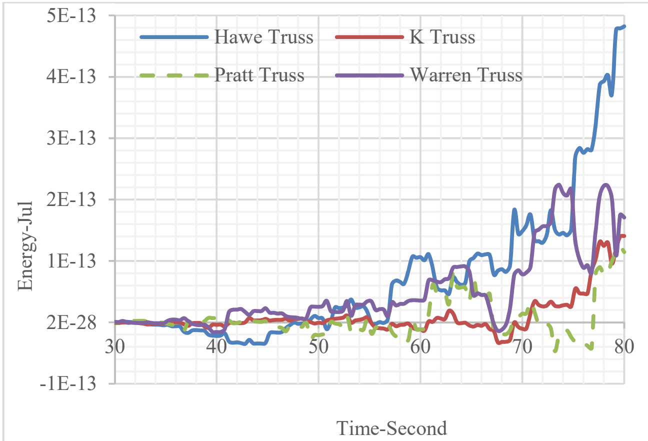

Fig. 16 Total energy curve in trusses under cyclic load

The results in Fig. 16 showed that the total energy of Hawe truss has the highest rate among the trusses evaluated in the present study. This truss has much more energy than the other three trusses, which shows its high power. The Pratt truss has the lowest total energy, which is very different from the K truss.

IV. Conclusion

In the stress section of the von Mises stress, the Hawe truss has the highest and the Pratt truss has the lowest value of the index. In the change section, the Hawe truss has the highest and the Pratt truss has the lowest value of the index. In the support reaction force section, the Hawe truss has the highest and the K truss has the lowest value of the index. In terms of speed, the Hawe truss has the highest and the K truss has the lowest value of the index. In the acceleration section, the Hawe truss has the highest and the K truss has the lowest value of the index. In the hysterical curve, the Hawe truss has the highest and the K truss has the lowest structural capacity. In the total energy diagram section, the Hawe truss has the highest and the K truss has the value in the mentioned index.

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