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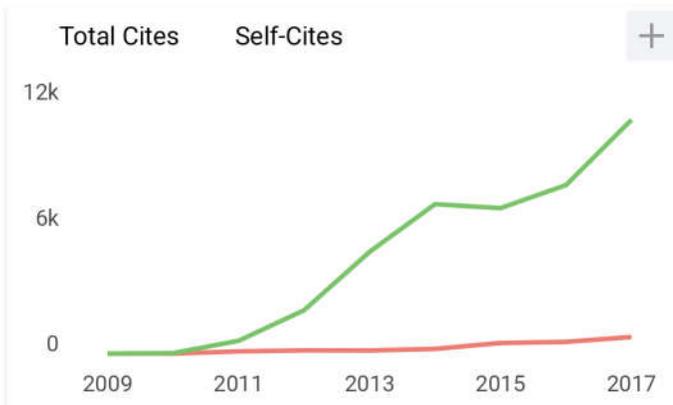
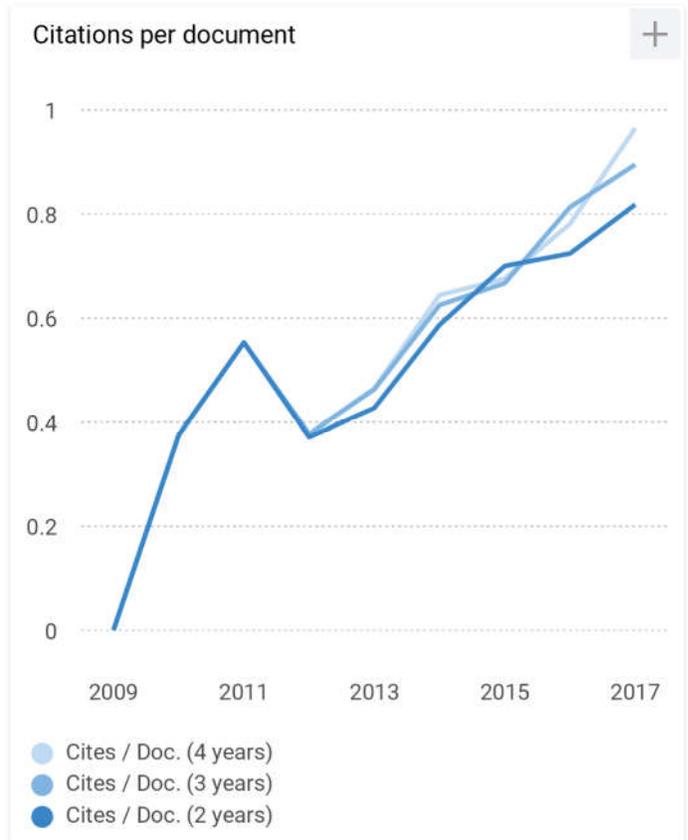
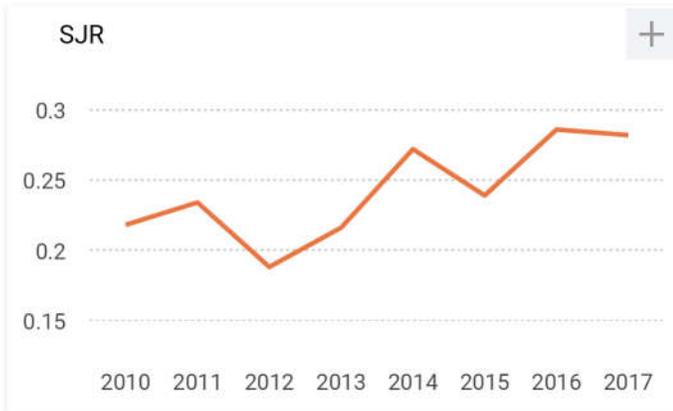
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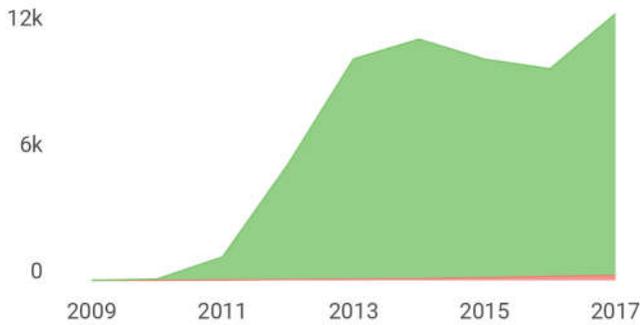
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- HAKI, Indonesian Society of Civil and Structural Engineers *)
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- HAHI, Indonesian Association of Hydraulic Engineers *)
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- MTI, Indonesian Transport Society *)
- ACECC, The Asian Civil Engineering Coordinating Council *)

TECHNICAL/SOCIAL TOUR

The organizing committee is working together with a local tour and travel service to organize social tour (optional), i.e.:

- Sunrise Bromo Mountain Overnight Tour (2D/1N)
- Exotic Bali Tour (3D/2N)
- Wonderful Bromo Bali Tour (4D/3N)
- Spouse Program
- Surabaya City Tour

More detail information on the social program can be obtained from the conference website <http://eacef5.petra.ac.id>

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First Announcement and Call for Papers
“Civil Engineering Innovation
for a Sustainable Future”

VENUE AND ACCOMODATION

Petra Christian University
Jalan Siwalankerto 121-131
Surabaya, Indonesia, 60236
<http://www.petra.ac.id>

The list of accommodation will be made available soon on the conference website.

TENTATIVE PROGRAM

Tuesday, 15 September 2015

Registration and welcome reception

Wednesday, 16 September 2015

Registration, opening speeches, keynote lectures, technical sessions, conference dinner

Thursday, 17 September 2015

Keynote lectures, technical sessions, closing speeches

Friday, 18 September 2015

Technical/social program

CORRESPONDENCE AND INQUIRIES

EACEF-5 Secretariat

Email : eacef5@petra.ac.id
Tel : +62 31 2983398
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EACEF-5

The 5th International Conference of
Euro Asia Civil Engineering Forum

Surabaya, Indonesia
15-18 September 2015



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2015



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The International Conference of Euro Asia Civil Engineering Forum (EACEF) is a forum to promote the cooperation and understanding between civil engineers and researchers from European and Asian countries in other parts of the world, focusing on Civil Engineering expertise. The preceding EACEF conferences have been held successfully in Jakarta (2007), Langkawi (2009), Yogyakarta (2011) and Singapore (2013). The 5th EACEF conference will be organized at Petra Christian University, Surabaya, Indonesia, in 2015. The theme for this conference is 'Civil Engineering Innovation for a Sustainable Future', expecting delegates not only from European and Asian countries, but also from other regions, to exchange ideas, findings and expertise, as well as to build up network.

CALL FOR PAPER

The organizing committee invites papers describing original work on innovations and new developments in the following civil engineering sub-disciplines (but not limited to):

- Structural and Construction Engineering
- Geotechnical Engineering
- Green Civil Engineering Materials
- Environmental Engineering (incl. Water & Climate Changes)
- Infrastructure Engineering (incl. Transportation System & Public Facilities)
- Construction Project and Safety Management

Participant(s) who are interested in presenting a paper(s) are invited to submit a maximum 500-word in English (with or without figures). Abstract should be submitted on-line in MS-WORD format to <http://eacef5.petra.ac.id>. Detailed guidelines for preparing and submitting abstracts and full length papers may be found on the conference website <http://eacef5.petra.ac.id>. Abstract and full paper will be reviewed by the Scientific Committee. Authors of accepted papers are expected to attend the conference and present the paper(s).

IMPORTANT DATES

Abstract submission	January 17, 2015
Notification of abstract acceptance	February 14, 2015
Full paper submission	May 16, 2015
Full paper notification of acceptance	July 18, 2015
Final paper submission and registration	August 15, 2015
Early bird registration	August 15, 2015
Conference	September 15-18, 2015

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PUBLICATION

After a careful refereeing process, all accepted papers will be published in the following international journal:

Procedia Engineering

(ISSN: 1877-7058)

<http://www.journals.elsevier.com/procedia-engineering/>

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REGISTRATION

	On/before 15 August 2015	After 15 August 2015
Overseas participant	USD 300	USD 350
Indonesian participant	IDR 1.500.000	IDR 2.000.000
For each additional paper*)	USD 100	USD 100

*) With the same presenter, maximum 1 additional paper.

The registration fee includes seminar kit (hardcopy of abstract, CD proceedings and publication fee in Procedia Engineering), lunches and coffee breaks for two days, welcome reception and conference dinner.

OFFICIAL LANGUAGE

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Estimating the ultimate energy dissipation capacity of steel pipe dampers

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Abstract

Steel pipe damper specimen tests are very important but expensive and time consuming. Therefore efficient tools are needed to minimize the expense and the time by avoiding unnecessary or unneeded tests. This paper elaborates a practical component integrity assessment using finite element ductile fracture simulation based on local approach, and estimates the ultimate energy dissipation capacity of steel pipe dampers using energy based damage model. Ductile fracture in steel components that happens in fewer than twenty constant amplitude loading cycles is known as Ultra Low Cycle Fatigue (ULCF). Under ULCFs load steel pipe dampers experienced large scale cyclic yielding. Accurate preliminary prediction of ductile fracture is critical to estimate the performance of steel pipe dampers. The hysteretic behavior and ultimate energy dissipation capacity are investigated via finite element simulation after the component integrity assessment has been done. A micromechanics-based model which provide accurate criteria for predicting ductile fracture and an energy-based damage model to quantify the ultimate energy dissipation capacity of steel pipe dampers are applied. Using these approaches, ultimate energy dissipation capacity of steel pipe dampers can be estimated under various patterns of loadings. The approaches described here can also be applied to other steel dampers subjected to randomly flexural/shear stress reversals.

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Keywords: ductile fracture; energy dissipation capacity; hysteretic behavior; micromechanics-based model; steel pipe damper

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1. Introduction

Passive energy dissipation systems are now recognized as an effective and inexpensive way to mitigate earthquake risks to structures. In passive control systems, the energy input from earthquakes is delivered to special devices called seismic dampers. Circular steel pipes can be utilized as dampers because they have geometrical elasticity, easy to be installed and maintained. Circular steel pipe dampers are displacement activated devices. When dampers are placed at locations which are known to have large displacements they dissipate seismic input energy effectively through hysteresis of the metal. Circular steel pipe dampers can be installed in buildings or bridges as part of passive energy dissipation systems to enhance the seismic protection of those structures. The ultimate estimation of energy dissipation capacity of vertical steel pipe dampers, using micromechanics-based model and energy-based damage model, will be discussed in this paper.

2. Numerical simulation and ductile fracture prediction

A try-out research to investigate the potential of circular steel pipes as dampers had been done. The vertical steel pipe damper and its components are shown in Fig. 1. The vertical steel pipe is strengthened by two trapezoidal plates attached at the outside of the pipe and three inner rings. Under cyclic loadings the role of the rings was to stabilize the pipe cross section and was not designed to yield while the pipe and trapezoidal plates were designed to yield to dissipate, in parallel, the induced earthquake input energy.

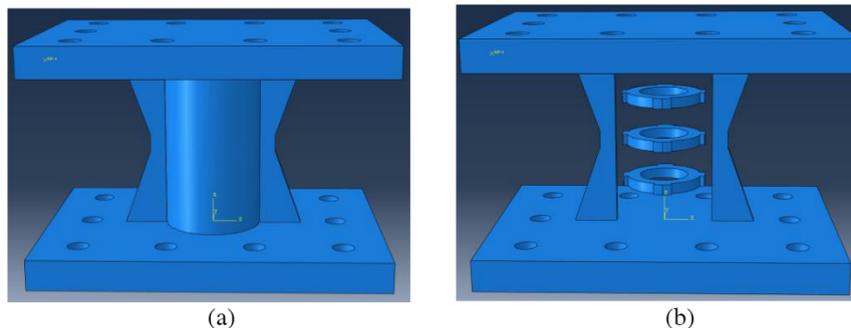


Fig. 1 The vertical steel pipe damper: (a) Front view of the damper; (b) Strengtheners of the damper (the pipe is not shown)

Schedule 80 carbon steel pipe and steel plate were used as the material of the damper. The results of simple tensile tests done to obtain the steel pipe and plate properties are shown in Table I. The properties shown in the table are used as material data for numerical simulation. Steel pipes with diameter greater than 100 mm were considered to be useable as dampers. In this study the steel pipe of 114.3 mm diameter, available in the local market, was chosen. Most part of the pipe is expected to yield due to cyclic loading. Abebe, Kim, and Choi [1] demonstrated that in order the developed stresses caused by both bending and shear occurred simultaneously, the height to diameter ratio of the pipe should be equal to $\sqrt{3}$. Therefore the height of the pipe is equal to $\sqrt{3} \times 114.3 = 197.97 \text{ mm} \sim 200 \text{ mm}$. The thickness of the pipe is 8.6 mm. A trial based on the needed strength of the welded connection at the top and bottom of the damper was done to find the minimum width of the top and bottom of the trapezoidal plate strengthener. The minimum width at the top and bottom was found about 50 mm and the width of the middle part was kept minimum (20 mm). The thickness of the plates was 12 mm. Each ring for stabilizing the cross-section of the pipe was welded at four points to the inner side of the pipe wall (Fig. 1). The thickness of the rings was 12 mm.

Table I: Properties of the steel used in this simulation

Steel	Modulus of elasticity (MPa)	Yield stress (MPa)	Ultimate stress (MPa)	Breaking strain (%)
Pipe	200.000	330	465	37
Plate	200.000	360	500	25

2.1. Finite element simulation

ABAQUS, a suite of engineering simulation programs based on the finite element method, was used to simulate the damper under lateral cyclic loading. A general purpose linear brick element (C3D8R) was used to mesh the model of damper. This element has one integration point located at the middle of the element. Stresses and strains were evaluated at the integration point. For the purpose of simulating hysteretic behavior and fracture prediction of the damper, bilinear model of the material with combined hardening were used for the simulation. The yielding load (Q_y) and the yielding displacement (δ_y) corresponding to the yielding load Q_y were estimated by first applying monotonic lateral load to the damper. $Q_y \sim 430000$ N and $\delta_y \sim 0.821$ mm were obtained. A loading protocol with increasing amplitude was used to simulate the hysteretic behavior of the damper. This protocol consists of : (1) three set of six cycles; the amplitude of the cycle is constant within each set but it is increased for every consecutive set of cycles, following the sequence $0.375\delta_y$, $0.50\delta_y$, and $0.75\delta_y$; (2) one set of four cycles with constant amplitude $1.0\delta_y$; (3) five set of two cycles; the amplitude of the cycle is constant within each set but it is changed for every consecutive set of cycles, following the sequence $0.375\delta_y$, $1.50\delta_y$, $0.375\delta_y$, $2.0\delta_y$, and $0.375\delta_y$; (4) finally the amplitude in each consecutive cycle is increased by $1.0\delta_y$ up until failure if necessary.

Fig. 2a shows the plot of von Mises stresses of the vertical steel pipe damper. It can be seen that most part of the damper yield to dissipate the input energy. It is unlikely the vertical pipe damper can sustain that many cycles, shown in Fig. 2b, due to cyclic loading. Early ductile fracture, that reduced the number of inelastic cycles, was expected to happen. Fig. 2b shows a stable hysteretic behavior. The shape of the hysteresis ($Q - \delta$) curve is close to a rectangle indicates a high energy dissipation capacity of the damper.

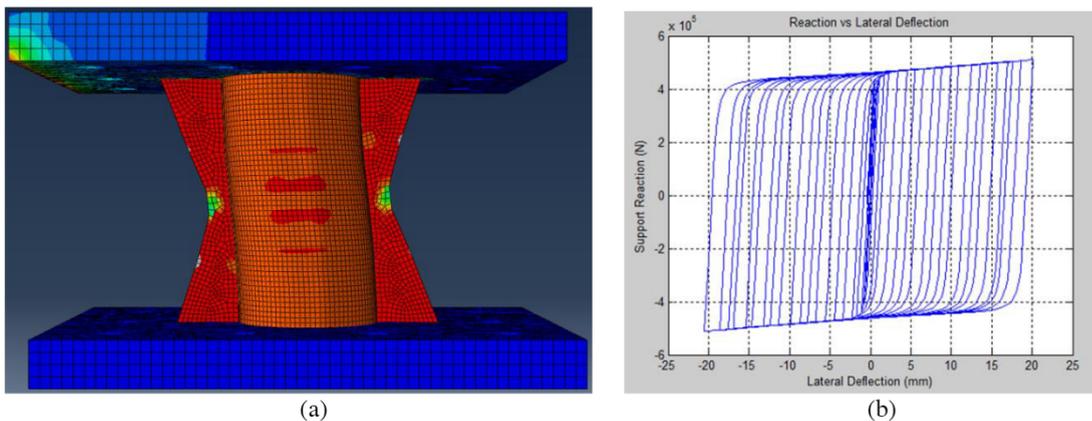


Fig. 2 Simulation results: (a) Plot of von Mises stresses; (b) Hysteresis or ($Q-\delta$) curve of the damper

2.2. Ductile fracture prediction

Sudden failure of critical components of existing structures which are characterized by large scale cyclic yielding due to earthquake was term Ultra Low Cycle Fatigue (ULCF). A simple criterion has been established to predict the failure of the steel pipe dampers due to the ULCF loading. Fracture occurs when micro voids initiating at sulphide or carbide inclusions grow under plastic strains, leading to micro void coalescence. Stress Modified Critical Strain (*SMCS*), developed based on the concept of tracking micro void growth and coalescence, is one of such criteria [2]. In *SMCS* model, a critical value of plastic strain, ε_p *critical*, is related to stress triaxiality T and parameter α by the following equation:

$$\varepsilon_p \text{ critical} = \alpha \cdot \exp(-1.5T) \quad (1)$$

The *SMCS* criterion, defined as the different between the critical plastic strain and the calculated equivalent plastic strain (ϵ_p), is:

$$SMCS = \epsilon_p - \epsilon_{p,critical} \tag{2}$$

Fracture is predicted to occur when *SMCS* = 0. *SMCS* model is simple to be applied to preliminary predict when ductile fracture will occur under ULCF condition. For ductile fracture prediction a circumferentially notched tension bar (*CNTs*), assumed to be extracted from the steel plate, and was simulated. Ramberg Osgood model was used to model the strain hardening of the material. Fracture displacement, which should be obtained from *CNT* test, was needed. However no *CNT* test was done. Therefore base on the *CNT* test result of similar steel done by Myer, Deierlein, and Kanvinde [3], the fracture displacement ($\Delta_f = 0.92$ mm) was used to calculate the equivalent plastic strain and the material resistance to fracture (α). Parameter α was found equal to 1.97. Once α is determined, it can be implemented through finite element simulations to predict facture initiation in steel pipe dampers.

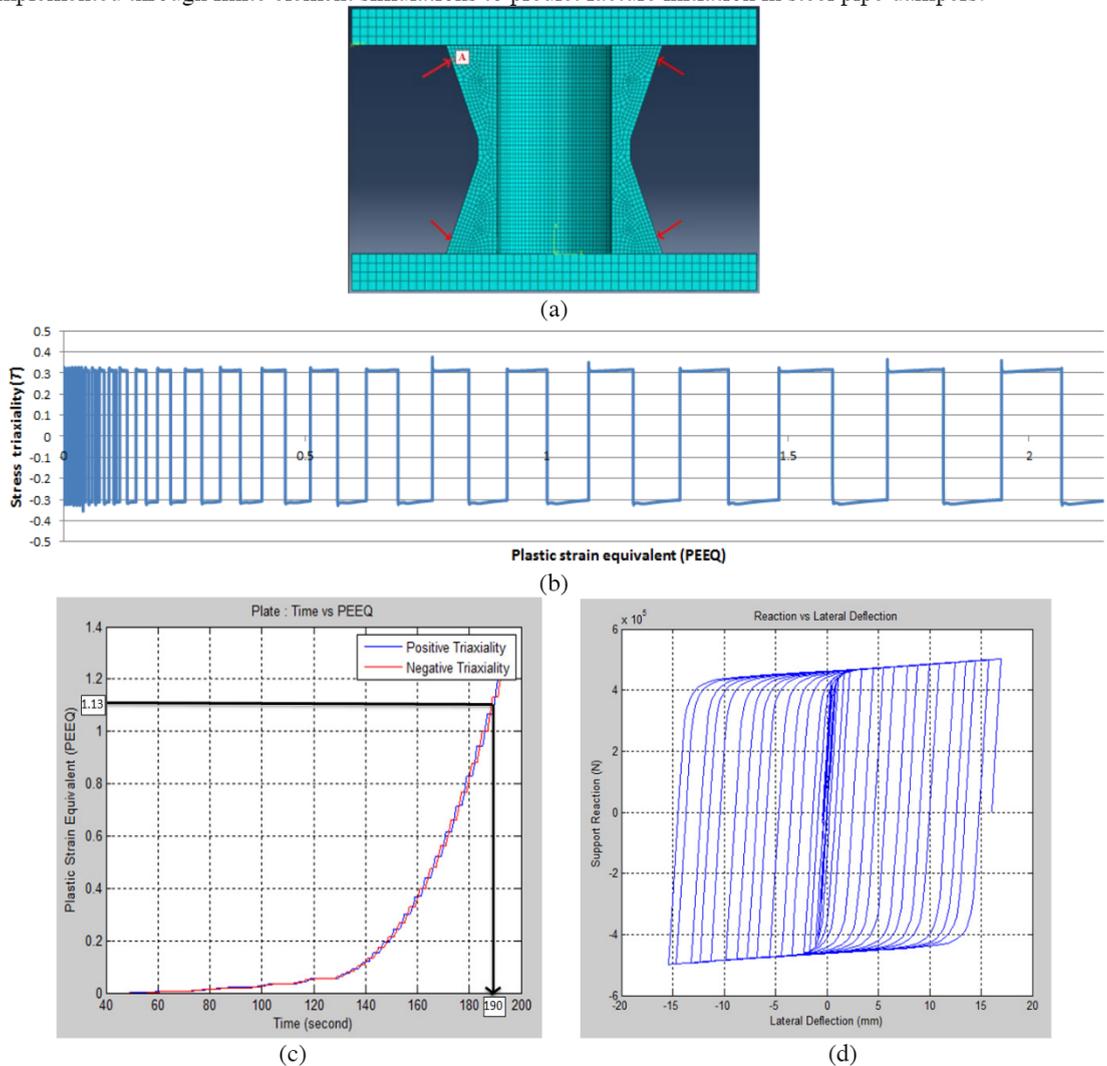


Fig. 3 Ductile fracture prediction: (a) The spots with intense stresses (all spots are represented by point A); (b) The corresponding plot of *T* against *PEEQ* at point A; (c) The plot of positive and negative stress triaxiality at point A; (d) Reduced *Q-δ* curve of the damper\

The von Mises yield criterion was used to identify spots with intense stresses. The identified spots for the vertical steel pipe damper were at the top and bottom of the trapezoidal plate strengtheners as shown in Fig. 3a. During nonlinear simulation, a request was sent to ABAQUS to generate stresses in x, y and z components (*S11*, *S22* and *S33*), von Mises stress (σ_e) and plastic strain equivalent (*PEEQ*) at point A which represents all values at the four spots. The hydrostatic stress was calculated as $\sigma_m = (S11+S22+S33)/3$ and the stress triaxiality was $T = \sigma_m/\sigma_e$. Plot of stress triaxiality *T* vs. plastic strain equivalent *PEEQ* is also shown in Fig. 3b. It can be seen that the stress triaxiality *T* does not change much with the increase of the plastic strain equivalent. Therefore it can be concluded that ϵ_p *critical* in eqn. (1) and eqn. (2) depends on instantaneous *T* so that the loading history can be neglected. The positive and negative stress triaxiality *T* was then separated and the results were shown in Fig. 3c. From eqn. (1), using $\alpha = 1.97$ and $T = 0.37$, the critical plastic strain is ϵ_p *critical* = 1.13. The *SMCS* criterion in eqn. (2) can be applied with the help of Fig. 3c which corresponds to the time $t \sim 190$ second. From loading protocol, the $t = 190$ second corresponds to the amplitude = 20.52 mm.

The location of the spots of intense stress are close to the welded connection meaning fracture is expected to happen at heat affected zone (HAZ). Myers, Deierlein, and Kanvinde [3] have shown that fracture toughness is degrading in the HAZ of a welded connection under ULCF loads. Toughness in HAZ exhibit large uncertainty. Data from CNTs extracted from weldments indicate that fracture toughness in the HAZ is approximately 50% smaller than that of base metal. Using engineering judgement, ductile fracture is expected two or three cycle less than the number of cycle predicted using *SMCS*. Therefore ductile fracture is expected to happen at reduced amplitude corresponding to the amplitude = 17.1 mm. The estimated *Q*- δ curve of the damper before ductile fracture happened is shown in Fig. 3d. The *Q*- δ curve can then be used to estimate the energy dissipation capacity and accumulated plastic deformation of the vertical steel pipe damper.

3. Energy dissipation capacity and accumulated plastic deformation

Based on the researches done in Japan since the mid of 1970, Benavent-Climent [4] proposed an energy-based damage model for seismic response of steel structures. Benavent-Climent, Morillas, & Vico (2011) applied the proposed model for seismic damper design. The processes in applying the proposed model are time consuming if they are applied manually. Therefore some routines were coded using MATLAB to digitalize the proposed model. All data needed by the proposed model were calculated and imported into MATLAB. On the top of the data, some routines that can be used to estimate the energy dissipation capacity and accumulated plastic deformation of the vertical steel pipe damper were built.

Following energy-based damage model proposed by Benavent-Climent [4], the *Q*- δ curve is decomposed into skeleton part and Bauschinger part in the positive and negative domain of loading. An example of the decomposition of a stable *Q*- δ curve is shown in Fig. 4. The paths that exceed the load level attained by the preceding cycle in the same domain of loading are connected sequentially resulting two curves shown in Fig. 5. The skeleton part was approximated by three lines. The first line starting from the origin was the elastic stiffness *Ke*, the second line starting from the end of the first line was the first plastic stiffness *Kp1* and the third line was the second plastic stiffness *Kp2*.

The area enveloped by each segment in the skeleton and Bauschinger part was calculated using a MATLAB function *polyarea*. Parameters can be expressed in non-dimensional form as follows: the first plastic stiffness $k_{p1} = K_{p1} / K_e$, the second plastic stiffness $k_{p2} = K_{p2} / K_e$ and $\tau_B = Q_B / Q_y$ (see Fig. 5). From numerical simulation of the steel pipe damper, the values of $Q_y = 43000$ N, $\delta_y = 0.821$ mm, $Q_B = 466000$ N, $k_{p1} = 0.0434$ and $k_{p2} = 0.0048$ were obtained. If $\epsilon_p \eta$ represents the cumulative plastic deformation ratio (normalized by δ_y) on the skeleton part and η represents the ultimate energy dissipation capacity of the damper (normalized by $Q_y \delta_y$) then η can be calculated using the equations proposed by Benavent-Climent, Morillas, and Vico [5]:

$$\text{for } \epsilon_p \eta \leq \frac{2(\tau_B - 1)(1 - k_{p1})}{k_{p1}} : \eta = 0.25 \epsilon_p \eta^2 \left(\frac{k_{p1}}{1 - k_{p1}} \right) + \epsilon_p \eta(1 + a) + b \tag{3}$$

for $ep\eta > \frac{2(\tau_B - 1)(1 - k_{p1})}{k_{p1}}$:

$$\eta = \frac{(\tau_B^2 - 1)(1 - k_{p1})}{k_{p1}} + \left(\frac{ep\eta}{2} - \frac{(\tau_B - 1)(1 - k_{p1})}{k_{p1}} \right) \times \left[2\tau_B + \frac{k_{p2}}{(1 - k_{p2})} \left(\frac{ep\eta}{2} - \frac{(\tau_B - 1)(1 - k_{p1})}{k_{p1}} \right) \right] + a_{ep}\eta + b \quad (4)$$

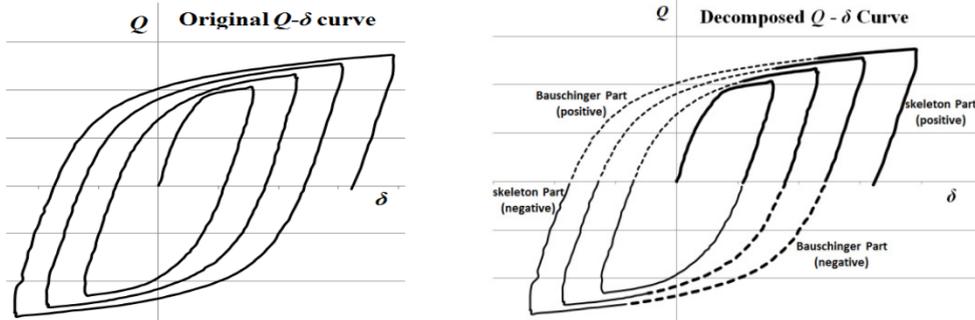


Fig. 4. Original and decomposed $Q-\delta$ curve

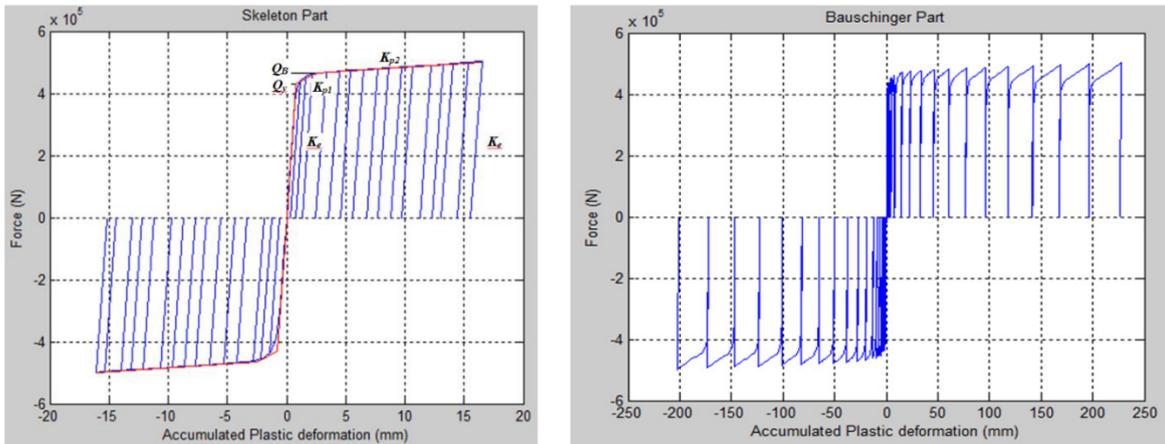


Fig. 5. Skeleton part and Bauschinger part in the positive and negative domain of loading

The last two terms in eqn. (4) represent the energy dissipated on the Bauschinger part. The relation between $ep\eta$ and $B\eta$ is linear and can be expressed as follows: $B\eta = a_{ep}\eta + b$. Benavent-Climent, Morillas, and Vico[5] studied a short wide-flange as a simple energy dissipating device. For comparison purposes, the parameters $a = -12$ and $b = 1140$ obtained in their study was used to draw the eqn. (3) and eqn. (4). Testing two specimens under different patterns of cyclic loading is required to determine the actual values of parameter a and b .

The relation between $ep\eta$ and η is graphically shown in Fig. 6. In non-dimensional form, the values of ultimate energy dissipation capacity and accumulated plastic deformation ratio of the vertical steel pipe damper are predicted as **593.57** and **40.57**. The history of the predicted values at each cycle of loading up to 20 cycles is shown in Fig. 6 as well.

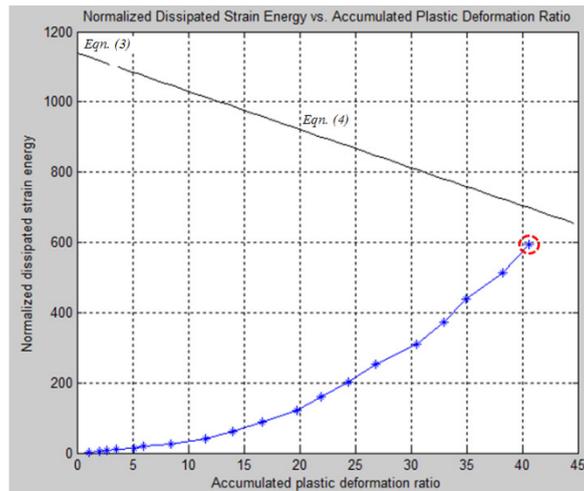


Fig. 6 Normalized dissipated strain energy vs. accumulated plastic deformation ratio

4. Conclusion

Ductile fracture is a limit state which should be considered because it controls the ultimate strength and ductility of the damper. Anticipating damper's failure due to ductile fracture under applied cyclic load, prior to testing the specimen of the damper, is one of the crucial steps in developing damper. The digitalized energy based damage model, which takes into account the accumulated damage resulting from inelastic cycles due to cyclic loading, applied to the Q - δ curve from finite element simulation allows one to predict of the energy dissipation capacity of the damper.

Acknowledgement

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