INTISARI

Topik tentang *run-up* banyak terdapat dalam literatur baik hidrodinamika maupun rekayasa pantai. Pada kasus tsunami, fenomena ini termasuk sulit dimodelkan terutama ketika berinteraksi dengan variabel yang dilewatinya seperti profil pantai dan sistem mitigasi yang ada daratan. Pentingnya pemahaman tentang *run-up* tsunami dikarenakan konstribusinya secara langsung terhadap kerusakan di daratan pantai sehingga menimbulkan suatu tantangan tersendiri secara konseptual dan matematis. Penelitian ini diklasifikasikan dalam tiga skema penelitian, yaitu: 1) Proses evolusi gelombang mulai dari sumber pembangkitan, penjalaran di kedalaman konstan dan transisi, serta *run-up* di pantai berkemiringan seragam. 2) Tinjauan interaksi *run-up* tsunami terhadap model vegetasi hipotetik sebagai sistem mitigasi. 3) Pengembangan dan implementasi *Nested Grid* untuk studi kasus tsunami di Teluk Pacitan, Jawa Timur.

Pada skema penelitian pertama, penelitian dilaksanakan pada sebuah saluran gelombang di Laboratorium Hidraulika dan Hidrologi Pusat Studi Ilmu Teknik, Universitas Gadjah Mada. Gelombang dibangkitkan dengan metode *Dam Break* yang skala dan prilaku gelombangnya ditentukan oleh variasi kedalaman waduk (d_0) dan kedalaman hilir (d_1). Kategori profil pantai adalah *mild slope*, yaitu pantai berkemiringan seragam 1:20. Pengukuran profil gelombang menggunakan empat sensor *wave probes*. Prilaku perambatan gelombang direkam dengan kamera 60 fps (*frame per second*) dan FHD (*Full High Definition*). Pengembangan model numerik tsunami untuk mengakomodasi pembangkitan metode *Dam Break* pada Program TUNAMI juga dilakukan pada kajian ini. Pada skema penelitian kedua, metode pemodelan efek vegetasi pantai dipilih menggunakan Metode ERM (*Equivalent Roughness Model*) dan CRM (*Constant Roughness Model*). Metode CRRM (*Combined Roughness and Reflected Model*) diperkenalkan sebagai penggunaan alternatif pada model numerik tsunami dengan efek vegetasi. Kinerja Metode CRRM dibahas pada kajian parameter *layout* penanaman vegetasi, yaitu seragam dan *zigzag* dengan variasi kerapatan. *Open Gap Type-Z* diusulkan untuk meminimalisir kekurangan dari keberadaan *open gap*. Verifikasi model dilakukan dengan model fisik yang material modelnya terbuat dari *Hollow Galvalum*. Pada skema penelitian ketiga, kunjungan lapangan ke Teluk Pacitan dilakukan untuk *survey* topografi dan inventaris kondisi pertumbuhan vegetasi. Domain simulasi dibagi dalam 7 regional, yaitu dari asimilasi data topografi dan bathimetri baik data primer maupun sekunder. *Coupling* Model Deform dan ERM dilakukan pada model tsunami. Inisiasi tsunami dibangkitkan oleh scenario gempa dengan skala 8.9 Mw yang dislokasinya berada di Segmen Jateng-Jatim. Pengembangan dan implementasi *Nested Grid* dilakukan dengan tahapan interpolasi beberapa level *grid* pada komputasi numerik di Persamaan Konservasi Massa dan Momentum.

Pembangkitan tsunami dengan metode *Dam Break*, pada suatu kedalaman konstan dengan $d_0/d_1 \geq 2.0$ menghasilkan bentuk *bore* dengan kategori *developed bore*. Kategori *undular bore* terbentuk saat $d_0/d_1 < 2.0$. Deviasi hasil *run-up* kedua model mencapai 9.64-20.61% untuk seluruh data dengan hasil model numerik lebih besar. Aplikasi susunan penanaman *zigzag* mampu mereduksi *run-up* tsunami sekitar 45% lebih baik daripada *layout* seragam. Metode CRRM mengakomodasi keseluruhan fisik dari proses refleksi gelombang saat berinteraksi dengan pepohonan. Verifikasi model dari Metode CRRM menghasilkan deviasi berkisar 2.07-19.70% untuk susunan seragam dan *zigzag*. Perbandingan *run-up* melewati *Open Gap Type-Z* dan tanpa *open gap* berkisar 1.30-9.15% dengan dua dimensi *gap* yang berbeda. Selisihnya yang relatif kecil ini menunjukkan bahwa pengaruh keberadaan tipe bukaan ini tidak banyak berdampak negatif saat diaplikasikan pada suatu vegetasi pantai (dengan ada *open gap*) sebagai sistem mitigasi.

Verifikasi dengan model fisik menghasilkan deviasi kurang dari 1% untuk kedua varian *gap* yang disimulasikan. Pengembangan dan implementasi *Nested Grid* mendukung pemodelan tsunami dengan variasi ukuran *grid* atau resolusi data yang beragam dalam sekali komputasi. Proses *run-up* menjadi lebih detail sehingga pemetaan area genangan lebih rinci pada studi kasus tsunami di Teluk Pacitan. Hasil model menunjukkan bahwa tsunami tiba di garis pantai setelah 24 menit dengan tinggi gelombang mencapai 6.9 m. Tingkat keberhasilan hutan pantai dalam mereduksi tsunami berkisar 12.98-51.85% di mana sangat tergantung dengan kondisi pertumbuhan tiap sektor vegetasi.

Kata kunci: gelombang; genangan; numerik; laboratorium; mitigasi.

ABSTRACT

The run-up issue is commonly realized in both hydrodynamics and coastal engineering literature. In the tsunami case, this phenomenon is complex to model, especially when interacting with variables such as coastal profiles and existing mitigation systems on land. The consequence of understanding the tsunami run-up is due to its direct contribution to the damage on the coastal plain then posed a challenge in itself conceptually and mathematically. This study is classified into three research schemes, namely: 1) The process of wave evolution from the source of generation, propagation at constant depth and transition, and run-up on a uniformly sloping beach. 2) Overview of tsunami run-up interaction with coastal roughness was represented by the application of the hypothetic model of coastal vegetation as a mitigation system. 3) The development and implementation of Nested Grid to simulate tsunami run-up in Pacitan Bay, East Java.

In the first research scheme, the study was conducted on a wave at Hydraulics and Hydrology Laboratory of Research Centre for Engineering Science, Universitas Gadjah Mada. The wave was generated using Dam Break method and its scale and behavior were determined by the reservoir depth (d_0) and the downstream depth (d_1). Beach profile was categorized as mild slope, namely a uniformly sloping beach 1:20. The wave profile was recorded by four wave probes sensors. The wave propagation behavior was recorded using a camera 60 fps (frame per second) and FHD (Full High Definition) quality. The development of a tsunami numerical model that accommodated Dam Break system on the TUNAMI Program was also conducted in this study. In the second research scheme, the simulation of vegetation effect was selected using ERM (Equivalent Roughness Model) and CRM (Constant Roughness Model) methods. The CRRM (Combined Roughness and Reflected Model) was introduced as an alternative method of the tsunami numerical model with vegetation effects. The performance of the CRRM method was discussed by the evaluation of layout plantation, i.e. uniform and zigzag arrangements with vary densities. Open Gap Type-Z was proposed to minimize the limitation of existing open gaps. The model verification was conducted by a physical model where the hypothetical vegetation models made by Hollow Galvalume. In the third research scheme, field surveys to Pacitan Bay were conducted for topographic mapping and investigation of vegetation growth conditions. The simulation domains were divided into 7 regions, namely by assimilation of topographic and bathymetry data. Coupled both Deform Model and ERM Method were performed on the tsunami model. Tsunami initiation was generated by an 8.9 Mw earthquake in which the dislocation was located in Central-East Java. The development and implementation of Nested Grid were performed by interpolating stages of numerous grid levels for both Mass and Momentum Conservation Equations.

The tsunami generation by the Dam Break method, at a constant depth with $d_0/d_1 \geq 2.0$ produced a bore form which categorized as a developed bore. The undular bore category was formed when $d_0/d_1 < 2.0$. The deviation of the run-up results for both models reached 9.64-20.61% for all data where numerical results were greater than the physical model. The application of zigzag plantation was explicitly reduced the tsunami run-up approximately 45% better than the uniform layout. The CRRM method was able to accommodate the total process of physical wave reflection when interacting with trees. Model verification of CRRM method produced a deviation around 2.07-19.70% for both uniform and zigzag arrangements. The comparison of Open Gap Type-Z results and without open gap reached 1.30-9.15% for two gaps variation. This slight deviation showed that the implementation of this kind gap has a little negative impact on the application in a coastal vegetation (with open gaps) as a tsunami mitigation system. The model verification by laboratory work resulted that the deviation was less than 1% for both open gap models. The development and implementation of Nested Grid provided its ability to model tsunami with varying in grid size or multiple data resolutions in a single computation. The run-up process became more detailed by determining the small data resolution to support more specific area mapping in tsunami case studied in Pacitan Bay. The model results showed that the tsunami arrived at the coastline after 24 minutes and its height reached 6.9 m. The success rate of coastal forests in tsunami reduction ranges from 12.98% to 51.85% which was highly dependent on the growth conditions for each vegetation sector.

Keywords: wave; inundation; numerical; laboratory; mitigation.