Assessment of the deformation by punching and at the base of an offshore wind turbine jacket impacted by a ship

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Introduction

Renewable energy production systems are expanding very fast to meet the actual energetic issues. Amongst them, offshore wind is a very promising technology as it provides a nearly constant and high electricity power. However, this growing number of offshore wind turbines increases the collision risk with vessels that needs to be considered during the design phase. Finite elements are widely used and provide accurate results, but are time-demanding, especially when thousands collision scenarios are investigated in a full collision risk analysis.

The authors developed analytical formulations in order to compute quickly the crashworthiness of an offshore wind turbine jacket. From numerical simulations, four deformation modes were identified. The methodology and the main developments performed for two of them, namely the punching and the deformation at the base of the jacket, are presented in this poster. These formulations are then integrated in a general algorithm that includes all four modes to compute the total jacket resistance.

Punching deformation

For an impacted OWT jacket, energy is dissipated by the punching of a leg by a compressed brace. Figs. 1 and 2 represent the deformation of the jacket of a 75 MJ collision with the punched connections highlighted and a zoom on a punched connection respectively.

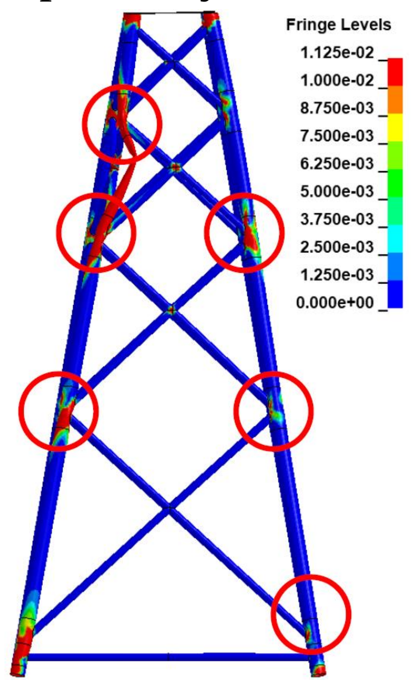

Fig.1: Punched areas on OWT jacket

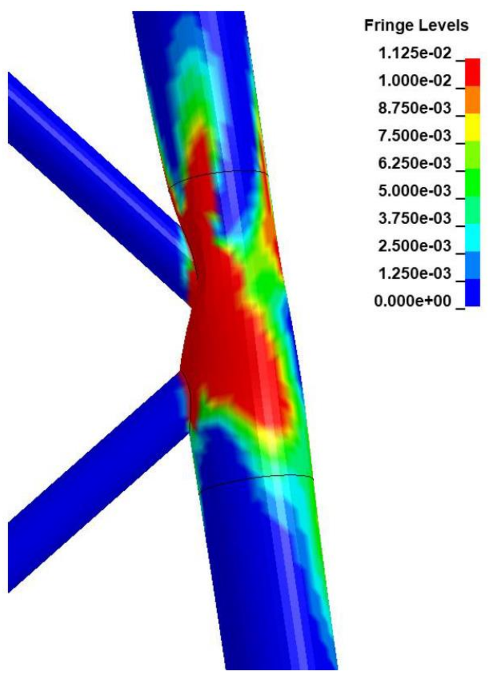

Fig.2: Effective plastic strain on a punched area

Using the upper-bound theorem, written as $F \times \dot{\delta} = \dot{E}_{int}$, and the deformation pattern assumptions described in Fig. 3, analytical expressions providing the crushing force evolution with regard to the penetration are developed for one connection. Validation is performed by comparing the obtained results with finite elements simulation (*LS-DYNA*), as represented in Fig. 4 for a typical Y-joint.

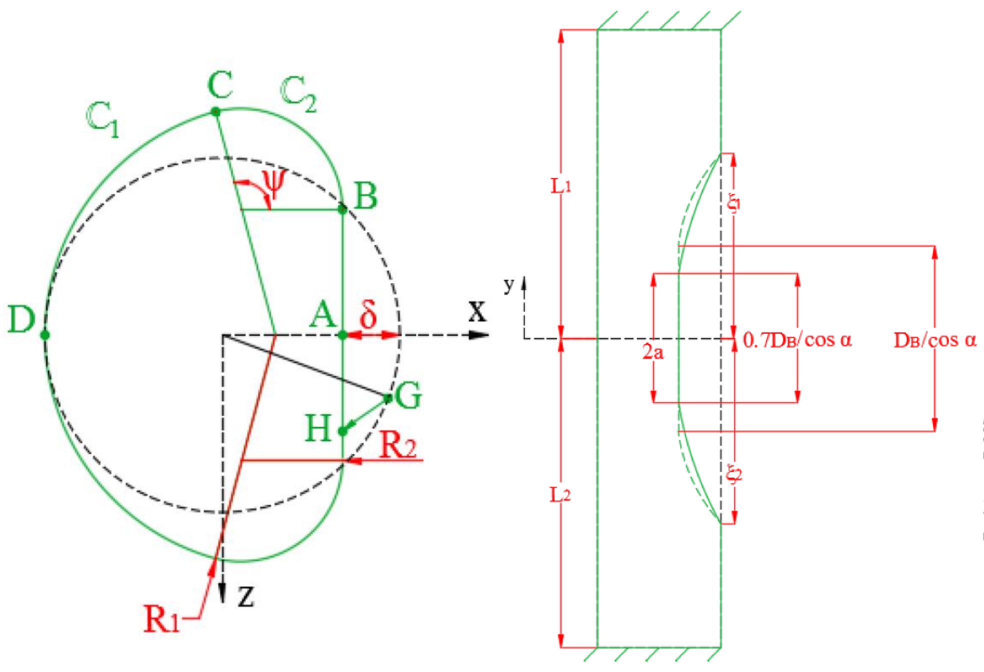

Fig.3: Punching deformation field assumption

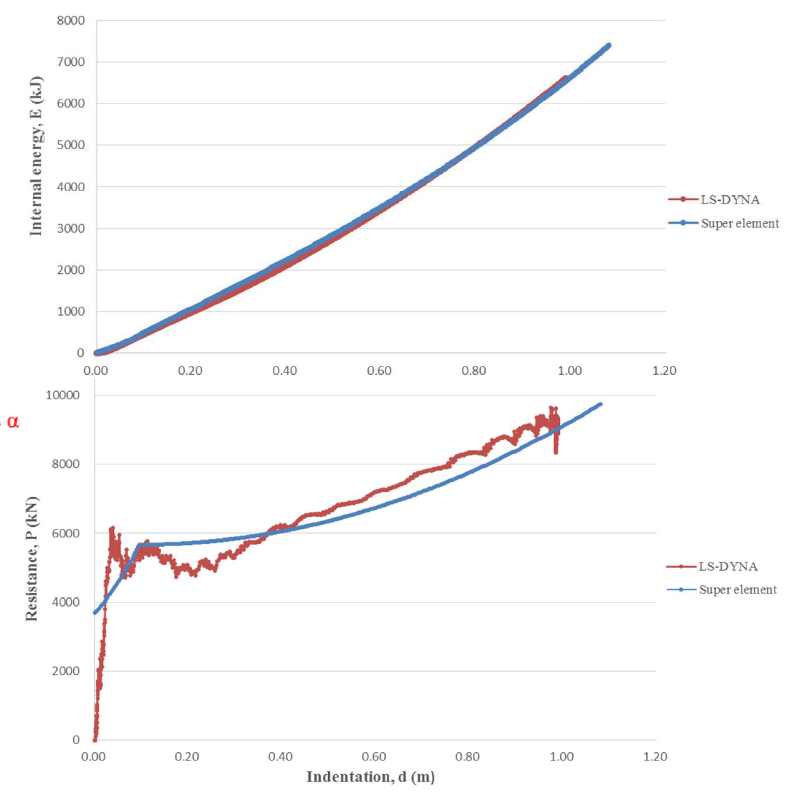

Fig.4: Validation for dissipated energy and punching force

Considering a full jacket, punching may occur on the impacted leg, the rear leg or both. After identifying the braces in tension or compression (Fig. 5), the normal compression force is compared to the connection threshold value. In case of initiation, punching resistant force is computed at the connection, and the force is transmitted to the striking ship (Fig. 6).

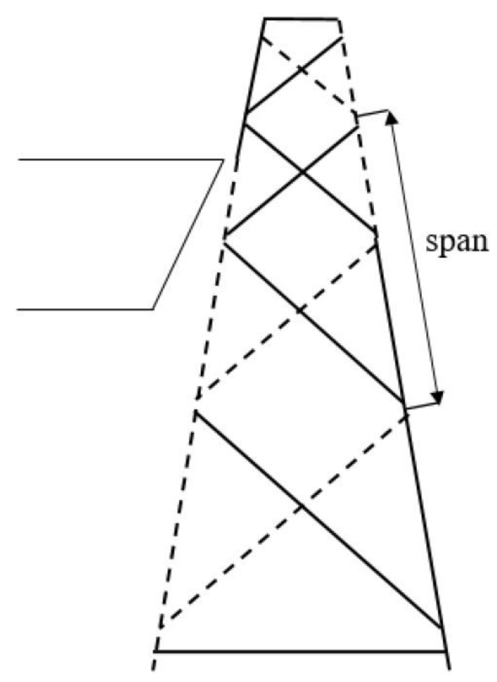

Fig.5: Axial force sign in jacket members

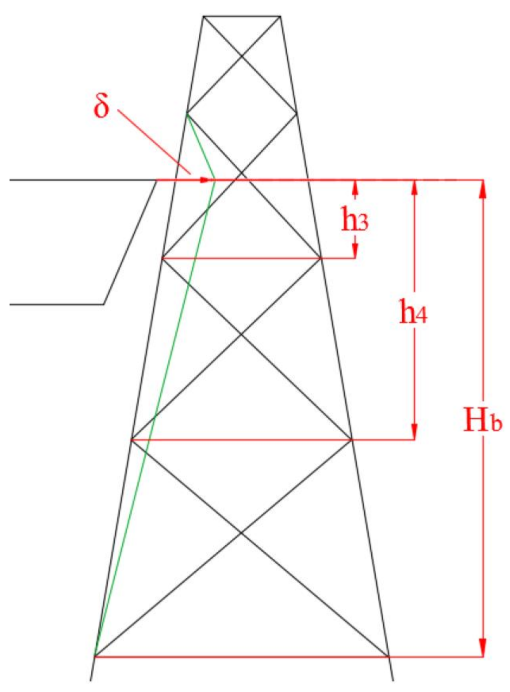

Fig.6: Transmission of punching force to the ship

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Base deformation

Deformation may also occur at the foundation level of the impacted OWT jacket, as represented in Fig. 7 for the impacted and rear leg. The base of the jacket may be divided into 4 zones for which analytical formulations are developed (Fig. 8).

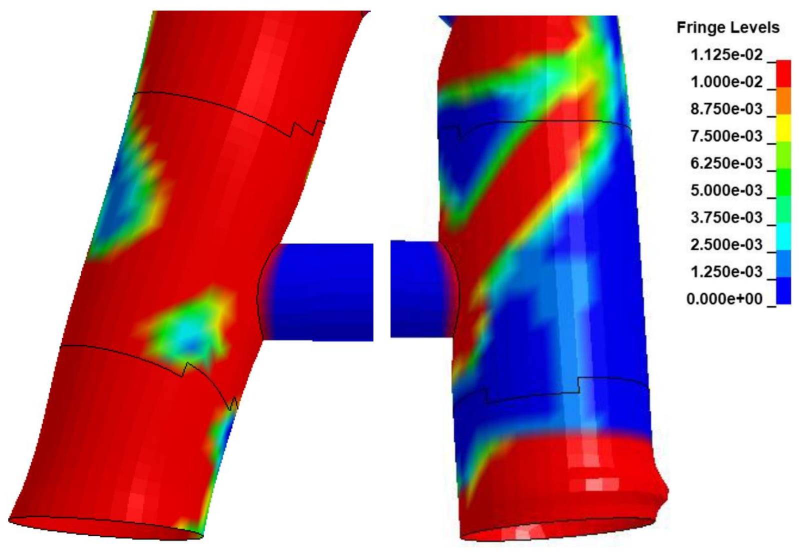

Fig.7: Deformation at the foundation level of an OWT jacket

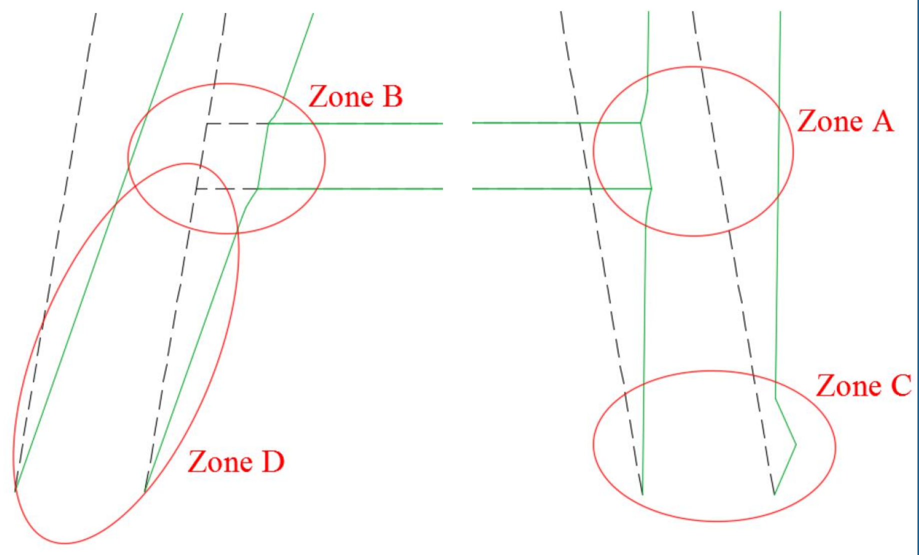

Fig.8: Definition of the 4 zones at the jacket base

For all four zones, assumptions on the displacement field is performed, as represented in Fig. 9. Based on this, the upper-bound theorem is used to get the analytical formulations to compute the resistance and the energy dissipation.

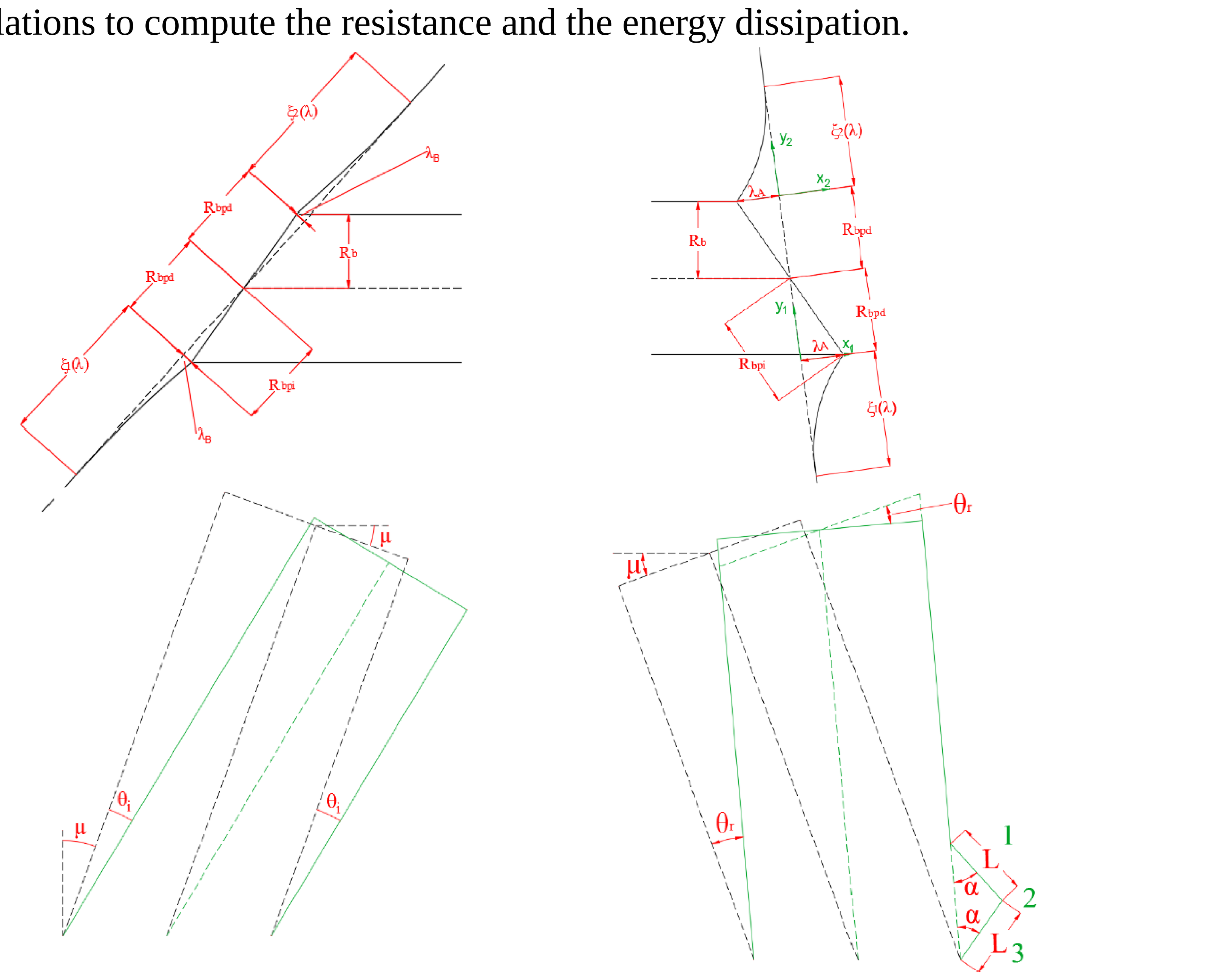

Fig.9: Deformation field assumption for zones *A* to *D* at the jacket base

Validation is performed with a collision on a complete jacket by comparing the analytical results and the numerical ones (*LS-DYNA*). The discrepancy between both models is only equal to 2%. The largest contributions come from zones *C* and *D*, represented in Fig.10.

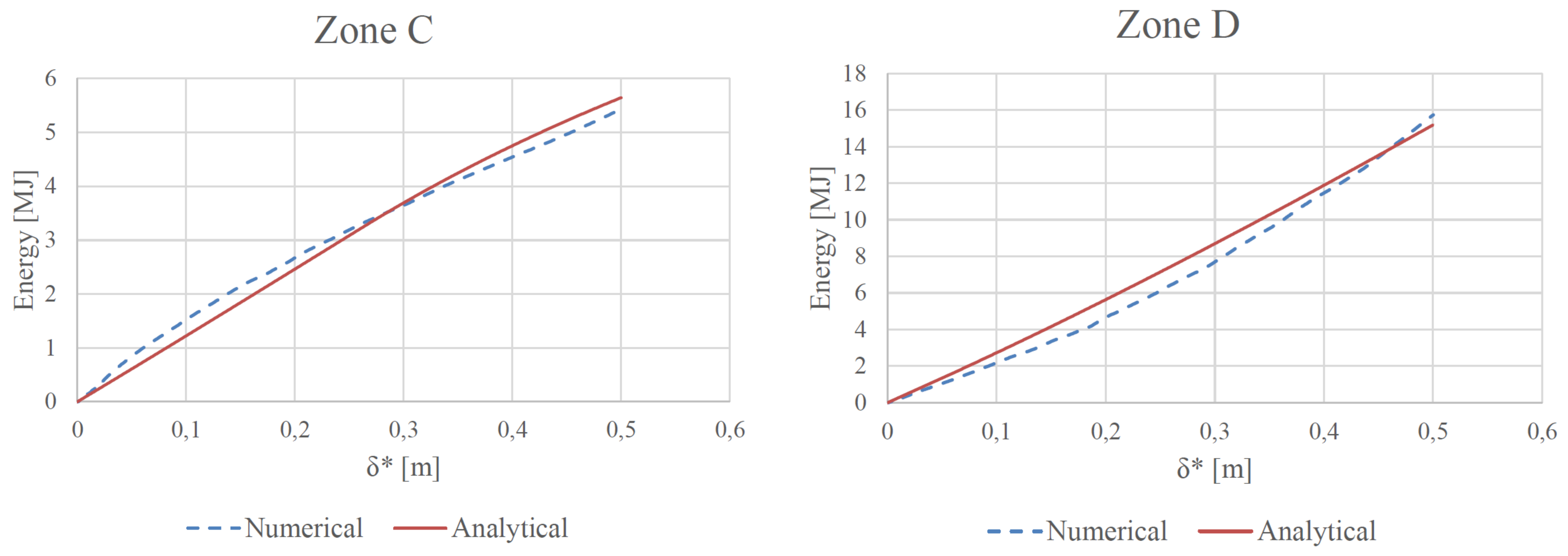

Fig.10: Validation for dissipated energy at zones *C* and *D*

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