Journal of Loss Prevention in the Process Industries 46 (2017) 163–176

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

Recent developments to evaluate global explosion loading on complex systems

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ARTICLE INFO

Article history:
Received 27 October 2016
Accepted 3 February 2017
Available online 6 February 2017

Keywords:
Explosion
Design
Risk
CFD
FLACS®
Global loading
Blast load cases (BLC)

ABSTRACT

During the engineering phase, a “Design Explosion loads Specification” is often developed by the safety discipline in order to provide the necessary explosion response inputs to other engineering disciplines for each individual item part of a safety critical system. This includes the specific targets, the associated performance criteria and the corresponding design explosion loads. This is an efficient way to manage explosion in design for each individual item composing a safety critical system but when combination of items need to be addressed, for instance global loading on complex items (e.g. modules, critical pipework or packages), this approach may result in an overly conservative design if the maximum explosion loads on each item are summed simultaneously. Indeed each component may experience variability in loading time due to the propagation of blast wave during the explosion event. In the opposite, only considering explosion loads on each individual item successively may be not safe enough. An alternative methodology based on Computational Fluid Dynamics (CFD) FLACS® software simulations is presented in the article in order to get more adequate global blast loads for design verification, in particular taking into account potential shielding effects, group effects of elements. It focuses on the development of dedicated blast load cases for the design in order to address both internal and external explosion events related to complex items such as whole onshore units or offshore modules on floating facilities. This method will be favorably implemented on generic typical systems in order to develop blast loads cases combination rule sets on future projects. This will contribute to enhance blast design approaches and promote opportunities for further optimization.

1. Introduction/background

An Explosion (Risk) Analysis (ERA) is usually carried out during the detailing engineering phase of a project as part of the safety studies of Quantitative Risk Assessment (QRA). In addition to the estimation of the risk to people, the ERA also provides also dimensioning explosion loads for the response of safety critical elements (SCEs) such as structures, equipment and piping. Indeed a number of Safety Critical Systems (SCS) which have to fulfil a Main Safety Function (MSF) shall withstand an explosion event. A document called **Design Explosion Loads (DEL)** specification should be issued by the safety discipline in order to provide explosion design inputs to each engineering discipline. That comprises the list of items that shall withstand an explosion event, the associated performance criteria and corresponding effective explosion loads which combine the contribution of overpressure and drag pressure as described in Technical Notes (FABIG, 2008). However for design or verification purpose, the above listed information is not necessary enough and **Blast Load Cases (BLC)** need to be developed in order to justify the design, especially when global loading should be addressed for overall resistance/stability justification as shown in Fig. 1 since directionality effects are significant.

For most of the individual items such as building or equipment, the Design Explosion Loads Specification provides enough information for engineering disciplines to develop their design, since global loading may be easily addressed. But for complex items, such as packages or large items, which may combine both structures, equipment and piping, it is not straightforward to define global loading for designing the supports (e.g. stools). Simply adding the contribution of all the individual items together may be too conservative since the blast wave does not necessarily apply at the

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http://dx.doi.org/10.1016/j.jlp.2017.02.002
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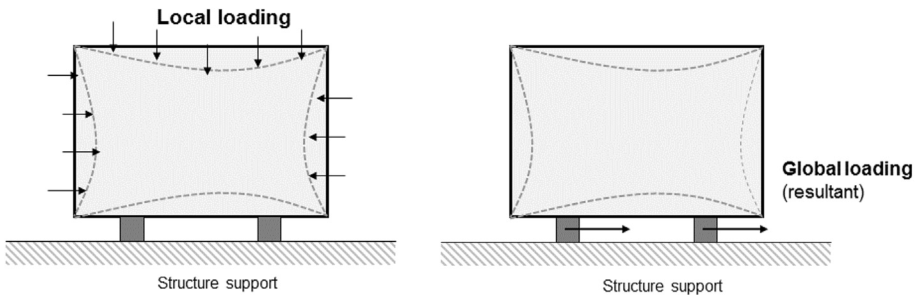

Fig. 1. Local loading and global loading for a typical building.

same time on all components and therefore the resulting loads might not credible. In addition it may also be dependent on the explosion source location. Hence explicit definition of BLCs should be developed for the response in order to take into account blast directions. This requires a close cooperation between engineering disciplines (e.g. structures, equipment, piping, safety) in order to develop credible design explosion scenarios to address these particular issues.

For instance, a flare header on a floating facilities, as shown in Fig. 2, which is a critical part of the depressurization system, comprises structures, equipment, piping, Emergency Shut Down (ESD) or Blow Down (BD) valves, etc. Each item should normally withstand the explosion event with its own performance criteria. But in any case pipework is spanning over several modules and hence will experience a progressive blast load while the blast propagates along the facility as shown in Fig. 3.

Depending on the different blast events location and piping supports location, various design BLCs have to be considered since different part of the system will be loaded successively. In addition the response of pipework is also strongly dependent on directionality loading. As a consequence the blast loads on piping should be detailed into several BLCs for design verification as shown in Fig. 4. BLC shall be derived from "representative" design explosion scenarios. This implies to select representative design explosion scenarios from the Explosion Risk Analysis. Note that a detailed assessment is only possible only for the most safety critical systems such as flare or firewater network.

Another typical example is an offshore module or onshore modularized facility partially grated as shown in Fig. 5. When the blast wave propagates in such an environment, it will load progressively all the decks with different intensity and time arrival. Hence considering loads on each deck successively, once at a time, may be not safe, while considering the loads on all decks at the same time will be overly conservative with potential design issues. Both configurations are related to "internal explosion" cases, within the module or unit itself. Thus it may be necessary to consider the contribution of several decks in order to define the resultant vertical loading for the design of supporting stools or foundations.

Similarly, for a module loaded by an explosion coming from an adjacent module, considered as an external explosion, shown in Fig. 6, the horizontal resultant blast load may be higher than the load resulting from an explosion located in the module and will stress others components of the system (e.g. bracing) and stools in horizontal direction. This should take into account the contribution of blast walls, large equipment such as columns or large cold boxes in the overall loading but not necessary by summing up all the maximum individual contribution.

There is limited available literature and guidance on how to define proper design blast loads cases in order to get a robust design of the system. There is neither rules set available to address the contribution of the different individual items to the overall loading, including those not explicitly designed to blast which provide additional loads up to their failure. On one side, the potential direction of propagation of the "credible" blast wave should be considered in order to derive suitable blast loads. On the other side, the expected dynamic response should be well appreciated in order to select the proper BLCs for which the system will be most stressed (bending moment, shear, etc.). For one DEL, several BLCs may be defined. This requires specific skills

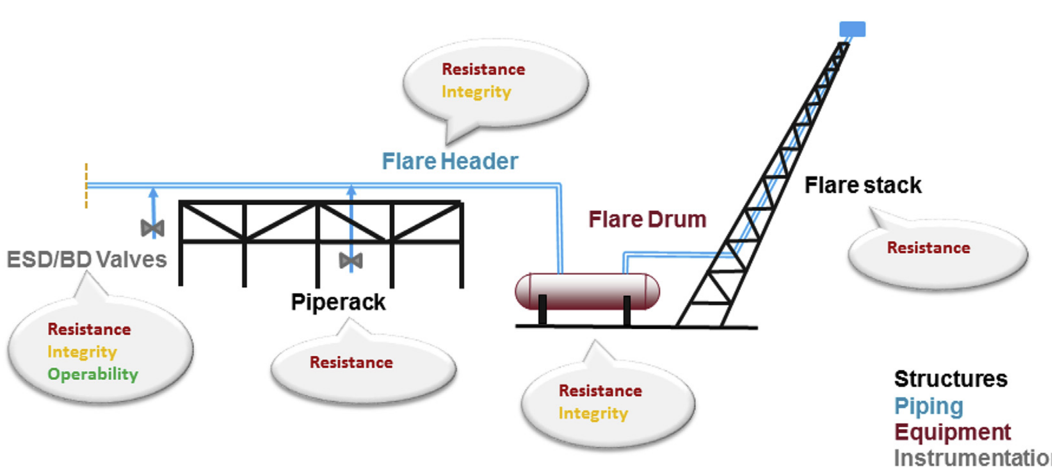

Fig. 2. Example of a complex system: the flare network.