Capability Statement
Structural Performance Under Fire Loading

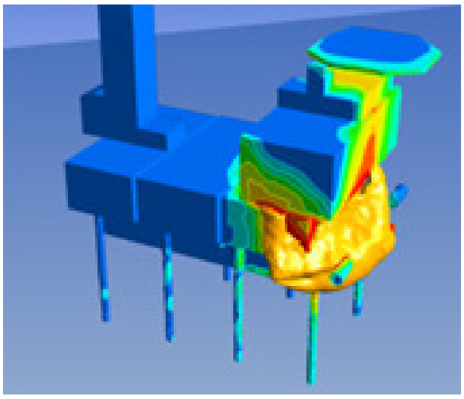
Introduction

MMI are experts in determining the response of structures subjected to fires. The following stages cover the main technical areas of expertise we possess.

Stage 1 - Fire Risk Analysis

The Fire Risk Analysis (FRA) identifies the fire threats posed by the accidental or malicious events to the facility. The identification involves:

- The identification of the type, size & location of hydrocarbon inventories that are ignited
- The likelihood of a release & ignition of the hydrocarbon
- The type of fire (pool, spray, jet, confined or unconfined) produced
- The identification of the areas of the facility that could be impinged upon by the various fire threats
- A criticality ranking of the required performance of the affected areas to determine the need & required survival time of the item. Decisions on element criticality should take into account the facility safety case and the business requirements of the facility's operator



Stage 2 - Fire Characterisation

Once the release is defined, then a computational modelling exercise is performed to characterise the fire. MMI are experienced users of CFD analysis techniques for fire modelling, specifically with respect to hydrocarbon fires. This approach allows an accurate representation of the fire event, capturing all effects, such as structural interaction with the fire, and the impact of under or over ventilated conditions.

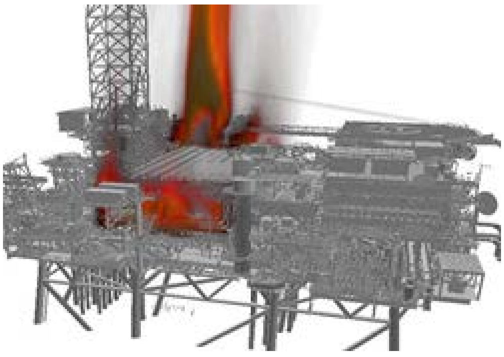
MMI uses a number of specialised tools to undertake the modelling of fires, principally Kameleon KFX or the Fire Dynamics Simulator (FDS).

Where suitable fuels or source terms for the fires are not available, then MMI develops its own source terms from fundamental chemistry and physics, or seeks information from published literature, and can use the generalized CFD code ANSYS-CFX to undertake analyses.

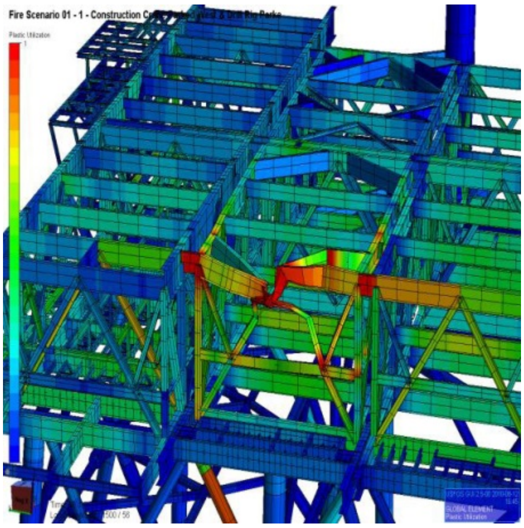
The computational approach can also be undertaken to include the effects of water spray and deluge mitigation. Much of MMI's work relates to the modelling of gas jet, spray, and pool fires associated with ignited hydrocarbon releases. The analysis yields:

- Heat flux contours for the fire threat & the time variation of the contours
- The production of time-varying heat flux or temperature loadings on individual structural elements, both fully engulfed or in close proximity to the fire as the fuel is consumed. The treatment of the problem as a transient is essential to ensure that the effect of the fire is not overestimated
- Additional data on smoke, soot concentration, and Carbon Monoxide levels to assess the impact on personnel

Typical outputs of flame, showing the degree of geometrical complexity that can be included in computational models. A typical computational visualisation is provided opposite.



Stage 3 – Structural Response Analysis



With fire loads defined in terms of time-varying heat flux loads on all structural members for the selected fire case, a structural response analysis can be undertaken. Here, the heat flux loads are used to define the temperature time histories for the members, and then a mechanical analysis is performed to predict how the complete structural system performs under the thermal loads, through the effect that the temperatures generated in the members have on the material strength properties.

MMI uses the USFOS structural analysis package for the structural performance evaluation. USFOS has been developed to capture buckling as the yield strength of material reduces. USFOS interacts with the software tool FAHTS, also developed by ComputIT, which calculates the thermal loads generated within the structure through the applied heat fluxes (calculated from the CFD analysis).

MMI has developed an automated process to enable all 3 elements of the calculation (CFD, temperature loads, structural response) to interface with each other, producing an efficient calculation process. If significant portions of the structure involve the use of stiffened plate, then ABAQUS is the preferred tool, as USFOS is only validated for structural framing.

It may be the case that the cause of the fire has been accidental or malicious, e.g. an explosion or impact, in which the structure has sustained some damage, and the fuel for the fire has been released. The event has therefore escalated beyond the initial event to a fire event.

The analysis process can be undertaken with structural elements in their damaged state.

Stage 4 – Mitigation Measure Determination

One the performance of the structure in its unprotected state has been determined, and compared against the defined structural performance requirements, areas where mitigation are required to meet the performance will be highlighted. The effect of a number of mitigation methods to ensure performance can be explored using the computational process described in Stages 1 to 3. Such methods may include:

- The use of drains systems to remove hydrocarbon liquids from the area of the fire, & thus remove the source of fuel
- Use of firewater systems to provide general area deluge with the view of reducing heat levels from the fire, making it smaller
- Use of foam systems to extinguish the fire and therefore remove the fire threat
- Use of passive systems, such as Passive Fire Protection (PFP) coating, which remain inert until activated by the presence of a fire

Any such system should be robust enough to survive the initiating event, such as an explosion or impact, and be available on demand.