Use of Mesh in Passive Fire Protection coatings

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Fire hazards present a real risk to human lives, asset integrity and the environment. A fire could result in considerable financial loss to the asset owner as a result of downtime, cost of repairs and damage to their reputation. In response, both active and passive fire protection can be used. Active fire protection is a system that seeks to extinguish or control a fire, for example, by using water sprinklers or inert gas. Passive fire protection (PFP) does not extinguish or control the fire but protects the structure. In a fire steel heats up and loses strength which can cause structural failure. PFP protects the steel giving more time for evacuation of personnel and opportunity to control the fire.

PFP coatings are developed with specific fire types in mind. For example, cellulosic fires are found in buildings such as offices and stadiums. Hydrocarbon fires are more commonly associated with the oil and gas and petrochemical industries, although in recent years they have been used on some prestigious high rise buildings. Historically, PFP coatings for hydrocarbon fires required reinforcement with metal mesh and pins to aid fire performance. Using mesh in this way is labour intensive so there has been a drive to develop better solutions such as metal mesh that does not require pins. While these methods remain with cementitious coatings, they have largely been superseded by fabric meshes in hydrocarbon epoxy intumescent coatings. Fabric meshes are composed of glass and/or carbon fibres which are engineered to fit the fire scenarios.

Recent advances have seen new hydrocarbon intumescent PFP coatings that do not require the use of mesh. Claims to reduce complexity, improve productivity and therefore reduce cost are naturally appealing to applicators and construction facilities. Nevertheless there are other aspects to consider when choosing passive fire protection. This article discusses the choices needed to make for good performance.

Why use mesh?

Cementitious coatings provide insulation to the substrate but do not intumesce in the event of a fire. With cementitious products, metal mesh is required to support high thickness application and to provide reinforcement during a fire. It is necessary to weld pins to the steel to support the metal mesh. Using pinned metal mesh is a labour-intensive multistep process. First, spot removal of any primer is required before welding of the pins. After the pins are welded the primer must be touched up and given enough time to cure before the fire protection is applied.

In a fire, epoxy-based fire protection coatings intumesce (swell up) producing a char to protect the steel. When mesh is specified it is normally included at mid PFP coating depth. The mesh is laid over the wet coating and bedded in with paint rollers wetted with solvent. Each manufacturer specifies their mesh materials optimised for their PFP systems. Typically, they are constructed of glass and/or carbon fibre materials. The purpose of mesh is to contribute to the fire performance of the system. Therefore, it needs to be applied as in the design certification.

In a fire, the mesh used in PFP systems provides the following attributes:

- In a hydrocarbon pool fire, it prevents char slumping, detachment and cracking on specimen edges by enabling the formation of a more controlled char. The lack of well-formed expanded char would cause the steel to heat up more rapidly leading to premature structural failure.
- In jet fire scenarios, the mesh is used to protect the char against the erosive forces of the jet fire. Mesh used for this purpose is often thicker and more tightly woven.

The challenges

Formulation

The intumescent reaction is well known with ingredients such as ammonium polyphosphate, melamine and pentaerythritol being common. In the event of a fire the combination of materials in the formulation interact in complex reactions to expand, forming an insulative char, while preventing oxidation and degradation

from the surrounding fire. Every aspect of the system, primer, PFP, mesh and topcoat affect the fire performance. Formulation for fire performance needs to consider the whole system and be developed considering whether mesh is used and what type is chosen.

Application

The mesh application needs to follow the relevant design approval. The certified mesh requirement depends on the type of product, the steel specimen used as well as the fire duration and type of fire involved.

The mesh is applied by hand at a specified PFP thickness

- If the mesh is applied within the PFP scheme at lower thicknesses it will not provide the structural reinforcement to the char during a fire. In a fire scenario this could lead to cracking, slumping and detachment with a reduced protection time.
- If the mesh is applied within the PFP at a higher thickness, the mesh could reduce the ability of the intumescent to expand and reduce the insulation efficiency.

The overlap between pieces of mesh is specified depending on the product designs. Typically, there must be an overlap of adjacent pieces to maintain integrity. While this presents little issue on straight sections of columns or beams it adds complication at joins, corners and abutments. Product improvements have allowed systems that do not require overlaps and instead they use mesh pieces flush to each other without gaps.

The use of mesh within the PFP layers (particularly meshes of a thicker nature associated with jet fire scenarios) may have an impact on inter-coat adhesion if not managed correctly in accordance with the manufacturer's guidance.

In service performance

Exposed mesh can be a route for water ingress and a potential cause of coating failure. The mesh at the edge of any area protected by PFP needs to be fully encapsulated. If moisture is allowed to enter through the mesh layer it could lead to delamination, this is a particular concern in environments where temperatures cycle to below freezing. Any water ingress would also compromise the systems corrosion protection of the underlying substrate.

Maintenance and Repair

Repairs are carried out to defective areas at the installation phase or during maintenance. Consideration needs to be given in maintaining the mesh layers integrity and preventing weak points in the PFP scheme. Coating manufacturers will provide detailed instruction for such repair work.

When does mesh gives advantages?

While important, speed and cost of application are not the only consideration in a coating selection. Fire performance is normally the main consideration. Critically, it may be that a product requiring mesh offers better fire performance for a given design considering duration, fire type, section factor and shape. For example, a lower overall thickness may be possible, reducing the weight load on the structure, and potentially reducing cost.

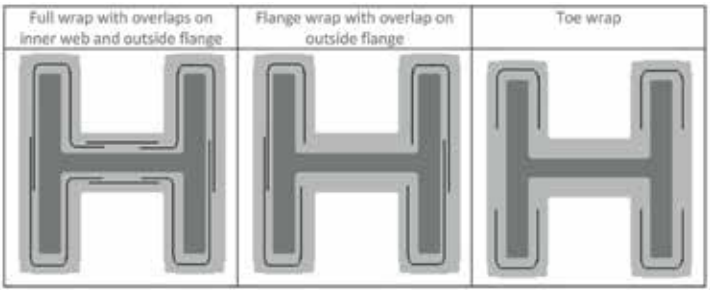
The benefits, in terms of application time, of mesh free systems is more prominent in short fire duration specifications which typically require lower film thicknesses. In specification where a long fire duration is required (a three-hour duration my require 20mm of passive protection) the use of mesh will form a smaller portion of the material costs. As it will take multiple coats to build up the coating thickness, the time taken to install the mesh will be less as a proportion of the overall application time.

If cryogenic spill protection is required, then mesh is almost certainly going to be needed. In duplex schemes of passive fire protection over insulation it is very likely that mesh is specified in one of the coatings. This is because in the event of a cryogenic spill the protective coating will experience some degree of cracking and the mesh is necessary to maintain the systems integrity in any fire that follows.

Mesh free Passive Fire Protection solutions

The fact that mesh free products exist indicates that the hydrocarbon passive fire protection manufacturers understand that application of mesh in PFP is challenging for application. Some new innovative products incorporate fibres to reinforce the system.

Efforts have been made to simplify the mesh requirements for schemes where it is still needed. This is often easier with pool fire products than jet fire products. While most hollow sections will require a full wrap of mesh it is possible to reduce the meshing requirements of I-sections by understanding the challenging areas. Early mesh systems had the full section wrapped. This used more mesh and left more areas to consider overlap. This is being reduced to just wrapping the outer and inner flanges – reducing overlaps and overall mesh use. In some cases, it has been reduced further to simply wrapping the toes of I sections, see the diagram below. This is where the char is under most stress as it expands. This limited meshing provides enough reinforcement but greatly simplifies the requirements.



Potential mesh overlap configurations on a column. The position of overlaps will depend on product specification and size/shape of the column. The overlaps along the length would also need to be considered.

The removal of mesh, a key component in a specific PFP system requires new ways of controlling and reinforcing the intumescent expansion. This is overcome by effectively adding the char controlling elements of the mesh into the formulation. For example, glass, carbon and mineral fibres are already used to reinforce the char so increasing the amounts in the formulation would be an obvious first step. However, the already viscous, mastic nature of the average hydrocarbon fire protection product gives only limited scope before application properties are adversely affected causing issues to the user. Alternative approaches involve controlling the intumescent reaction itself – altering the formulation and adding chemicals to fine tune the char expansion and strength.

Other product selection criteria

Most facilities will fortunately never experience a fire. The PFP coating needs to remain place for 25 years as part of the corrosion protection system to resist the environment. As part of this, the usual considerations would be needed regarding accelerated weathering tests, pre-qualification testing, class approvals and track record. Oil and gas facilities are located in some of the most challenging environments, from offshore platforms in the North Sea to the hot dry environments in the middle east. More recently, several projects have been located in the arctic which has presented other new challenges and issues to overcome. Therefore, the lifetime performance in the specific environment of the structure needs to be carefully considered when selecting a PFP system.

Conclusion

Mesh in passive fire protection coatings is used for preventing char slumping, cracking, detachment and erosion. Mesh free products offer advantages in term of reducing application time, complexity and therefore cost.

Where mesh is used there is a need to rigorously follow the manufacturer's instructions to make sure application is done correctly and is compliant with the certification and standards. Good quality control is important.

In all cases good specification and product selection is essential. Creating a strong specification considering the lifetime environment of the structure and coating will highlight necessary requirements. Coating products should be selected based on all requirements for the project and products that use mesh should not be overlooked.

Experts can help you develop a functional coating specification taking into account what performance is required, under which application conditions, and the operational environments the system will operate.

Editor: *The Institute of Corrosion now has PFP Inspector training courses which can help to improve competence in this safety critical area and ensure that the specified system is applied correctly. These are expected to start in early 2021, and further details can be obtained from the Institute website.*