Figure 1. XHab™ machine and support trailer during commissioning trials in Houston.

PUTTING THE STEEL BACK INTO PIPELINES

Ray Burke, Pipestream Inc., USA, explains how a range of different pipeline anomalies and problems can be permanently repaired using the company's XHab™ technology.

Many thousands of miles of steel pipelines worldwide are suffering from external corrosion due to insufficiently robust external coating protection, or cathodic protection problems. In severe cases, operators are required to lower the operating pressure to remain within a safe working limit for the pipeline. In addition, external damage (e.g. denting) can considerably reduce the fatigue life of a pipeline.

Currently accepted methods of pipeline rehabilitation include composite wrapping, full-encirclement welded sleeves, grouted sleeves and welded patches. These are manual operations and are often limited to repair of relatively short lengths of damaged pipe, although longer lengths (in excess of 200 ft) of manually-applied repair wraps have occasionally been applied.

Novel technology

Pipestream's XHab™ technology enables operators to repair extended lengths of pipe, up to 250 ft of 30 in. pipe in one pass, by helically over-wrapping an ultra-high strength steel (UHSS) strip on the defective region of the pipe, while the pipeline continues to operate. These sections can be overlapped to provide continuous reinforcement and re-rating for an entire pipeline length between valve stations.

The repair can be tailored to the linepipe geometric and mechanical properties, as well as the size and frequency of defects and anomalies. This system is intended to reinstate the pipe to its original design conditions, but may be modified to achieve any desired pressure rating.

The XHab™ system consists of the following components:

- Epoxy defect-filler material.
- UHSS helically wrapped reinforcing strips (FBE-coated for outermost layer).
- Epoxy adhesive.
- End bands.

The end bands prevent the ends of the helical strips from disbonding and also allow adjacent wraps to be tied in, creating one continuous repair.

XHab™ wrapping machine

The current XHab™ machine is intended for repairs on pipelines between 20 - 30 in. OD and is designed to reinforce up to 250 ft (75 m) of 30 in. pipe in one run before reloading. The machine can also be employed to wrap multiple shorter layers without reloading the machine (e.g. five layers over a 50 ft length), and is being further developed for larger diameter applications.

A single trailer transports the equipment to the worksite, including the XHab™ machine, generator, control unit and materials.

A removable plate in the winding head allows the XHab™ machine to be placed on the pipe, with the head fully encircling it. With every rotation of the winding head, steel strip is both wrapped around the pipe and added to an accumulator so that all material is on the machine before half the length is wrapped. An oscillating adhesive assembly applies the structural adhesive to the pipe directly before the strip is wound. The machine is driven along the pipe by a pair of tracks, which can be tilted to allow the machine to remain centred on the 12 o'clock position of the pipe around bends or where the pipe route is uneven. The tracks are synchronised with the winding head and adhesive applicator to enable precise control of wrap pitch and adhesive volume.

A process control system allows online measurement and recording of key operational parameters, such as adhesive flowrate, with alarms tripped if these exceed optimal limits. This Quality Control (QC) record can be verified against the written specification for the repair. The system was designed so that one electrical system can be used to control a range of machine sizes.

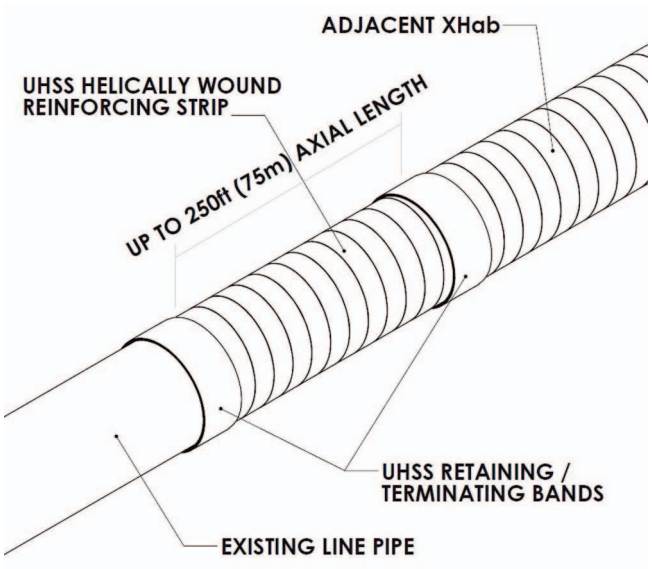

Figure 2. Illustration of the XHab™ system applied on line pipe.

Field application of XHab™

An overview of the pipeline rehabilitation process using XHab technology follows:

Excavation

A key driver in the design of the XHab™ machine was to leave current excavation and rehabilitation techniques unchanged. The machine requires less than 20 in. excavation below a 30 in. pipe.

Pipe preparation

The pipe is prepared in accordance with operator standard pipe cleaning and blasting procedures, similar to those used for recoating operations. This process would remove old coatings and then blast the exposed steel to a near-white finish (NACE no. 2/SSPC SP-10) to ensure a proper adhesive bond.

External defects, such as dents and external corrosion, are filled with a stiff epoxy, profiled to match the pipe circumference. This prevents excessive deformation of the pipe wall. The same material is used to provide a smooth transition over prominent weld caps.

Initiating the repair

After being lowered onto the pipe, the machine is levelled using integrated height adjusters and the tracks are clamped. Operators guide the steel strip through the machine and then attach it to the pipe to initiate the repair.

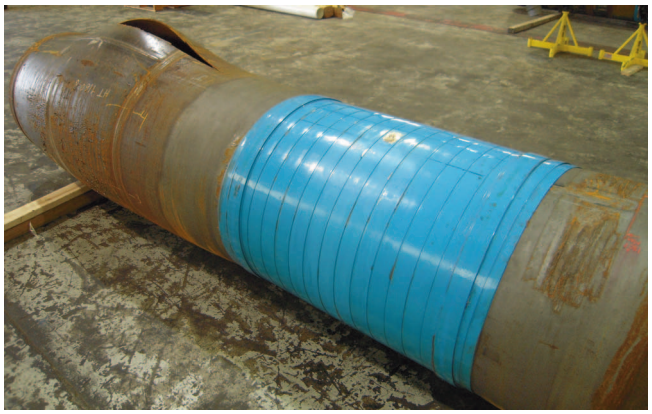

Figure 3. Burst test specimen. The XHab™ repair was wrapped over a machined 80% wall-loss defect. The failure occured in the adjacent 'good' pipe.

The initiation method is by pin brazing the strip directly to the pipe. This has the advantage of creating a permanent connection between the two and in addition, the strip is then electrically connected to the pipeline for cathodic protection purposes. If the pipeline operator does not allow pin brazing, the strip may be secured using a temporary mechanical clamp. In this case, a secondary CP attachment is required to protect the strip via the pipe wall.

Terminating the repair

At the completion of a production run, the operator must cut the strip at the machine and terminate the strip on the pipe using the same method as for initiation.

For multiple layer repairs, the machine is returned to the start of the run and the wrapping process is repeated.

On completion of the overall repair, the terminating bands at either end of the helical wrap are applied. If multiple lengths of XHab™ are being applied adjacent to one another, a terminating wrap is used to bridge and encapsulate the two ends.

Pipe coating

The type of secondary coating and method of application will be agreed with the pipeline operator during the project planning phase. It may be the case that the operator will not require any coating in addition to the FBE already on the outer surface of the outer strip. Suitable coating materials and the associated procedures for application, holiday testing and repair are already well established and operator-qualified. XHab™ can be used with any recognised in-field coating method.

Design of XHab™ repair

For plain dents, the primary objective is to restrain the dented region from excessive cyclic deformation, which could lead to early failure. For external corrosion wall loss, the restoration of pressure capacity becomes important in addition to restraint of the defect.

The thickness of the repair (number of strip layers and thickness of strip) is determined such that the burst strength of the repaired pipe is greater than the burst strength of the adjoining bare pipe i.e., the repaired section should not be a weak point in the system. At the same time, the stress in all layers of the metallic strip is maintained below the strip material SMYS by an appropriate design factor (for example, 72% on hoop stress) at maximum operating pressure.

Regulatory compliance

US Code of Federal Regulation (CFR) Title 49 – Transportation, parts 192 and 195 both use similar high level language for pipeline repairs, requiring that the repair is made "by a method that reliable engineering tests and analyses show can permanently restore the serviceability of the pipe." A request for interpretation has been submitted to the Pipeline and Hazardous Materials Safety Administration (PHMSA) to confirm that the regulations do not limit the repair length or number of adjacent repairs.

The design of bonded wrap repairs in ASME PCC-2 is focused on non-metallic ('composite') repair systems. Although XHab™, as a metallic composite repair, would not strictly apply in this regard, the overall design methodology and qualification process follow the guidance of the ASME standard.

Testing

An ongoing programme of physical testing and finite element analysis underlies the XHab™ qualification programme. Short pipe specimens with external metal loss and dent defects have been repaired on a prototyping machine. Burst tests have been successfully carried out on 10 in. and 30 in. diameter pipes with machined local external metal loss of up to 80% wall thickness.

Cyclic pressure testing of an XHab™ repair on dented pipe has been performed by a third party. Dents were placed in plain pipe, on the ERW seam weld and on girth welds. In all cases, the samples have survived in excess of 100 000 'full range' pressure cycles (to a hoop stress of 72% SMYS) without any sign of fatigue-related failure.

Other testing is ongoing, including long-term performance of the XHab™ repair on buried pipe and long-term behaviour of aged epoxy adhesive.

Conclusion

XHab™ presents operators with a permanent repair for a range of different pipeline anomalies and problems, including various forms of external corrosion, dents, gouges and defective coatings, using FBE-coated steel as a single, robust, technical solution in one operation. This avoids repeated digging and patching campaigns in high consequence areas, or in particularly corrosive environments. Furthermore, for up-rating or class change situations, the option to maintain continuous line operation, while reducing the hoop stress, is compelling - when compared to replacement. WP