White Paper

United States

Effect of Cut Grooving on Pipe End Strength

The Issue

Cut Grooving, the oldest of the pipe grooving techniques, involves machining a narrow circumferential channel of material from the surface of the pipe, in which the grooved mechanical coupling engages the pipe. While this method has an over 85 year track record of success, questions are still asked as to whether cut grooving has a detrimental effect on the strength of the pipe. Empirically and analytically, this has shown to not be the case.

Introduction

Victaulic, (The Victory Pipe Joint Company, as it was then known), pioneered the grooved mechanical pipe technique during World War I as a fast, reliable way to transport fuel and water to the Allied troops. In the years since, Victaulic couplings have become the preferred pipe joining method due to improved reliability, health and safety issues, ease of maintenance and speed of assembly, for all types of piping applications when compared with welding, threading and flanging. The mechanical joint, or coupling (Figure 1), has four elements: the grooved pipe, the gasket, the coupling housings and the fasteners. The pipe ends have a cold formed (roll groove) or machined (cut) groove that provides an engagement point for the coupling and locates the sealing surface for the gasket. The gasket seals the pipe ends, trapping fluid within as it is enclosed by the coupling housings. The housings are held together by bolts and nuts tightened with a socket wrench or impact wrench. The coupling housing encases the gasket and engages the circumferential pipe groove to produce a leak-tight seal in a self-restrained pipe joint.

Figure 1

Cut Grooving

The Victaulic grooved pipe joining method has gained widespread use since the founding of the Victaulic Company, in 1919, but misunderstandings still exist regarding the original cut grooving method, and its effect on the grooved pipe joint's engineering and performance.

Cut grooving is commonly used on pipes of ANSI standard wall or greater and for abrasive applications, where the inside of the pipe wall needs to be as smooth as possible to allow materials to pass without obstruction. The smooth, continuous inside surface remains after the groove is cut, making cut grooving suitable for systems that require plastic coating, rubber lining, cement lining or other protective linings for corrosion or abrasion reasons. The most common uses of cut grooved pipe are in the mining, power, wastewater, and oil field markets. Cut grooving involves removal of approximately one-third of the total pipe wall thickness to provide a point of engagement for the grooved mechanical pipe coupling. Cutting a groove removes less material, to less depth, than threading the pipe (Figures 2 and 3). Cut grooving is free of the stress risers created in threaded joints at the crests and roots of the threads. Cut grooving can be completed manually or by using motorized tools.

Figure 2

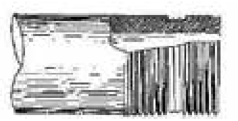

Figure 3

The pressure rating on a grooved mechanical pipe joint is determined in consideration of all the components involved. These factors include the characteristics of the grooved coupling, pipe material and pipe wall thickness. In other words, a grooved mechanical coupling and likewise, grooved pipe itself, have no specific independent pressure ratings, as the pipe joint ratings are a function of both. Victaulic couplings' published pressure ratings are based on standard wall cut groove (or roll groove – they give identical pressure performance) carbon steel pipe, unless otherwise specified. (Style 808 Duo-Lock™ couplings for example are based on heavy wall carbon steel pipe). Our cut groove pipe joint ratings have been qualified through extensive internal and third party hydrostatic proof tests, and validated through over 95 years of experience in the cut groove pipe joining business. Our successful performance history on cut groove pipe takes into account the material that had been machined away in the creation of the groove.

Pipe Stress

If internal pressure creates over stress failures, the Victaulic cut groove will not be the weak point. When under pressure, two basic stresses occur, longitudinal pressure stress and internal pressure stress (hoop stress). Longitudinal pressure stress can be described as the "tensile" stress in the material, trying to pull the pipe apart in the direction of the pipe axis. A failure due to longitudinal pressure stress would cause a circumferential fracture around the pipe (Figure 4). Hoop stress can be described as what may cause ballooning or expansion of the pipe diameter in a radial manner. A failure due to hoop stress would cause the pipe to split lengthwise along the axis (Figure 5).

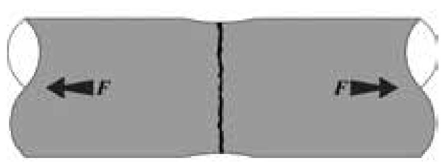

Figure 4

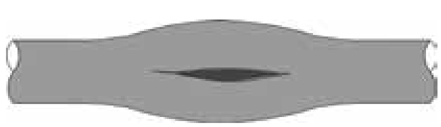

Figure 5

Free body diagrams and balancing forces determine the equations for longitudinal and hoop stresses for thin walled tubes (pipes). Longitudinal and Hoop stress are also derivatives of Hooke's Law. ASME B31.1, 2010 edition, Power Piping Code, contains the mathematical formulas for calculating longitudinal pressure stress (paragraph 102.3.2.A.3) and Barlow's Equation for hoop stress (derived from minimum wall thickness equation, paragraph 104.1.2.A) and are as shown below:

Longitudinal Stress = (Pressure x Outside Diameter) ÷ (4 x Wall Thickness)
Hoop Stress = (Pressure x Outside Diameter) ÷ (2 x Wall Thickness)

Therefore in any given pipe diameter or any given pressure, the hoop stress is twice the longitudinal pressure stress. Analytically, this suggests that pipe failures due to overstress would show up as fractures along the length of the pipe, such as weld seam failures. Empirical or real world data confirms this to be the case.

Cut grooving reduces the wall thickness by removing a narrow circumferential strip of material in the outside surface. The hoop stress remains approximately the same since the groove is so narrow and reinforced by the full wall thickness of pipe on either side of the groove. The groove is also reinforced by the coupling key engaging in the groove, preventing it from expanding diametrically. However, the longitudinal stress will increase proportionally with the decrease in the wall thickness. Mathematically, as long as more than one half of the original wall thickness remains under the groove, longitudinal stress of the pipe under the groove will be greater than or equal to the hoop stress in the pipe barrel.

Since the cut groove depth in standard wall thickness pipe removes only about one-third the original pipe wall thickness, the hoop stress will remain larger than the longitudinal stress. Therefore, any "over-stress" failure will continue to occur along the length of the pipe and not at the groove, demonstrating that the groove area is stronger than the longitudinal barrel of the pipe.

The below photo (Figure 6) shows one 6" (168.3mm) ASTM A53, Grade B Seamless carbon steel ANSI schedule 80 pipe that was used in a hydrostatic pressure test of a Victaulic Style 808 Duo-Lock™ coupling. The internal pressure reached 10,000psi; then the test was stopped prior to catastrophic failure of the coupling or pipe. The photo shows that the hoop stress (calculated at approximately 75ksi (520MPa)), has caused the pipe to yield as noted by the expansion of the pipe at the center portion of the barrel. The diameter of the pipe and groove at the coupling, while still showing signs of yield, are at a much smaller diameter due to the reinforcement of the coupling.

The pre-test and post-test pipe diameters were measured as follows:

	Pre-Test Measurements	Post-Test Measurements
Outside Diameter	6.625" (168.3mm)	6.948" (176.5mm)
Outer Groove (#1) Diameter	6.340" (161.0mm)	6.388" (162.3mm)
Inner Groove (#2) Diameter	6.340" (161.0mm)	6.468" (164.3mm)

Figure 6

Conclusion

In conclusion, cut grooving pipe does not reduce the strength of the pipe joint. Any overstress pipe failure due to excessive over pressurization will occur along the barrel due to pipe strength and not at the pipe end due to metal removal at the cut groove.