Polypropylene Random Copolymer (PPR) for hot water applications

Udeshini A.A.,
R&D Executive, Quality Assurance Department, S-lon Lanka (Pvt) Ltd.

Abstract

A breakthrough in water distribution was the invention of thermoplastic pipes to replace Galvanized iron pipes (GI pipes). Polyvinyl Chloride (PVC) pipes play a major role among the other pipes due to their flexibility, durability, safety, and low cost compared to steel pipes. Despite being a part of everyday life, PVC has the drawback of not being able to withstand higher temperatures . Polypropylene random copolymer (PPR) becomes a solution to the aforementioned issue and also offers additional benefits to the pipe industry such as safety and chemical resistance, low cost, durability, and efficiency. PPR pipes, which have emerged as the preferred option for high-temperature pipe applications, are discussed in this article. Furthermore, the advantages and disadvantages of PVC pipes are covered in this article.

Key words: Polypropylene Random Copolymer, PPR, Hot water, PVC, Polyvinyl Chloride, high temperature

1. Introduction

The invention of thermoplastic pipes to replace the traditional galvanized steel pipes is a revolution in water transportation and distribution. As metal pipes come into contact with static water, it leads to corrosion while giving a metallic flavor to the water. Thus, it leads to health issues, and people tend to find replacements for GI pipes. As a result, the invention of thermoplastic pipes led to rapid public acceptance.

Among generally used thermoplastic materials, polyvinyl chloride (PVC) plays a major role in water pipes. PVC pipes are non-corrosive and light weight. They prevent the growth of bacteria, fungi, algae, and other biological toxins. But Unplasticized PVC is not very flexible, which makes it unsuitable for plumbing networks that need bends and joints. Therefore, plasticized PVC which is more flexible than unplasticized PVC became more popular, replacing the galvanized steel pipes. Despite the above-mentioned benefits, PVC pipes have the disadvantage of not been able to withstand higher temperatures.

Typically, hot water systems have boilers that carry hot water at about 60°C–83°C to various parts of the building via pipes. [1] As the softening point of PVC starts at about 70°C, it is not advisable to use PVC pipes for hot water distribution. [2]With the temperature fluctuations, PVC pipes tend to show some signs of damage in their properties like stiffness, pipe dimensions, pressure ratings, etc.

Therefore, PVC pipes are more suitable to be used in cold water systems and drainage systems for residential and industrial water systems.

2. Effects of temperature on PVC pipes

2.1 Structure

Compared to GI pipes, PVC pipes are flexible and can yield without fracturing under a load. They can comfortably deflect

excess material without putting any strain on the overall structure of the pipe. The PVC pipes can become stiffer with decreasing temperatures and more flexible with increasing temperatures. [3] The research has found that PVC joints lose 80% of their stiffness with an increase in temperature from 23–90%, destroying their natural flexibility. [4] This dramatic loss of rigidity causes a loss of structure and leads the plumbing system to disconnect from the rest.

2.2 Leakages

Like all other materials, PVC which has a thermal expansion coefficient of 3.0 x 10-5 in/in/°F can expands with temperature and contracts with a decreasing temperature. [5] As the PVC pipes have a high length-to-diameter ratio, the change in length is noticeable with temperature fluctuations. The change in pipe dimensions hinders the compatibility, flow rate, pressure rating, and structural integrity of the piping system. Thus, the dimensional changes hinder the tight seal between the pipe fittings that prevents leakage.

2.3 Pressure capacity

The pressure capacity of PVC pipes significantly depends on their operating temperature. As the operating temperature falls, the pressure capacity of the PVC pipe

increases to a level higher than its pressure rating. Despite the fact that the pressure capacity rises as the temperature falls, PVC displays brittle behaviors at low temperatures, leading to low energy brittle failures because of a significant drop in impact resistance. This brittle behavior can result in catastrophic failure. [6]Conversely, with the increase in operating temperature, the pressure capacity of the PVC pipes decreases to a level below its pressure rating.[3]Therefore, PVC pipes are not recommended for low temperature applications and are only recommended for temperatures up to 60°C [7].

Therefore, to address the above problem of inability to use in hot and cold applications, the researchers have found PPR (Polypropylene Random Co-polymer) [8].

3 PPR pipes

Polypropylene random copolymers are thermoplastic resins created by polymerizing propylene with ethylene or butene linkages added to the polymer chain. It is made up of chains of hydrocarbons in such a simple chemistry that allows it to have properties of being tough and long lasting.

During the production process, polypropylene is made flexible by using short chains and stiff by using long chains. Since both long and short chains are used during the manufacturing of PPR, it has both rigid and flexible properties. Because of PPR's flexibility, it helps to protect pipes from external damages such as impact and freezing. Further, it can absorb the stresses, including expansion stresses that can damage other systems. The stiffness shown by PPR helps to improve the system's performance and appearance. [9]

3.1 Properties of PPR

PPR pipes show unique properties that set them apart from other pipe materials. Heat resistance, thermal conductivity, smooth inner surfaces and chemical resistance are some of the properties.

3.1.1 Heat resistance

The PVC is recommended for use at no more than 60 or 65 °C. (With a maximum of 80 °C.) [10] This is because having a low softening point (the temperature at which an amorphous polymer starts to soften) of

approximately 70°C makes it unsuitable for high-temperature applications. [11] But the PPR, which has a softening point of 131.5 °C, has better heat resistance compared to the PVC. [12]Therefore, PPR is more suitable for hot water distribution pipes compared to PVC.

3.1.2 Low thermal conductivity

Traditionally, galvanized pipes are used for hot water distribution. But they have a high thermal conductivity of 52.0 W/mK compared to other plastic pipes. Heat transfer from the environment to the liquid inside the pipe or vice versa is higher with metal pipes compared to plastic pipes. Therefore, a high heat loss or gain occurs during the transfer of hot and cold fluids. Thus, it is advisable to insulate the pipes. But this adds an additional cost for installation of pipes. But PPR pipes, which have a low thermal conductivity of 0.15 W/mK compared to GI pipes, are a solution to the above problem as they can provide high efficiency at a low cost. [13, 8]

3.1.3 Chemical resistance

PPR has better chemical resistance compared to PVC because of its molecular structure. It shows excellent resistance to diluted and concentrated acids, alcohols, and bases and good resistance to aldehydes, esters, aliphatic hydrocarbons, and ketones. [14] In contrast, PVC has a lower chemical resistance because its molecular structure contains chlorine atoms, which can react with certain chemicals and reduce its resistance to chemical attacks. Therefore, though PVC is resistant to many alcohols, fats, oils, aromatic free petrol, and most corroding agents, including inorganic acids, alkalis, and salts, it should not be used with esters, ketones, ethers, or aromatic or chlorinated hydrocarbons as it will lead to swelling and a reduction in tensile strength. [15] Therefore, PPR is better than PVC in chemical resistance. PPR also exhibits better UV resistance compared to PVC. [16]

3.1.4 Non-Toxicity

The random incorporation of ethene units (up to 6% by mass) into polypropylene copolymers increases the flexibility of the polymer chain. Compared to PPR, PVC is a rigid material. Therefore, it must be plasticized to achieve flexibility. Generally, these plasticizers are low in molecular weight. Therefore, they can leach out from the pipe resulting in mechanical degradation and eventual contamination of the surrounding environment. This phenomenon can lead to contamination of drinking water [17, 18]. But as PPR is flexible, the addition of plasticizers is not necessary. Therefore, PPR is known to be safe for the human body as well as the environment. Thus, PPR pipes are suitable to carry purified water since they do not cause any pollution. [8]

3.1.5 Smoother inner surfaces

The PPR pipes have a very smooth inner wall compared to the PVC pipes. Therefore, they are less affected

by frictional resistance and pressure loss during the transportation and distribution of the fluids. Thus, contributing to the energy efficiency of the PPR piping system. [19] Further, PPR pipes are less damaged or cracked compared to PVC and metal pipes. Thus, it has better durability than other piping systems. [14]

3.1.6 Recyclable

PPR pipe can be recycled after being used for a certain time and it has a long life of at least 50 years.

3.2 Installation of PPR pipes

Heat fusion is commonly used to join PPR pipes and pipe fittings. During connecting,

the PPR pipes and fitting ends are simultaneously heated to critical melting points. The pipes are then immediately put in a straight line into the PPR pipe fittings and allowed to cool. Such welded pipes have a high success rate and strong contact performance. [20]

Because of the above properties, PPR pipes are now playing a major role in cold and hot portable water transportation and distribution in industries, residences, and public installations. They are also used to transport beverages, sanitary liquids, assertive chemicals, pressurized air, and highly acidic or alkaline solutions. [21]

4 Conclusion

With the development of plastics, metal pipes were replaced with PVC pipes. They were widely used by people because of their properties like flexibility, durability, safety, and low cost compared to steel pipes. Despite being a part of everyday life, PVC has the drawback of notwithstanding higher temperatures. Polypropylene random copolymer (PPR) becomes a solution to the aforementioned issue because of its higher softening point(131.5°C) compared to PVC (70°c). Further PPR pipes offer additional benefits to the pipe industry like safety, chemical resistance, low cost, durability, and efficiency.

References

[1] "Hot water heating," [Online]. Available: https://www.sciencedirect.com/topics/engineering/hot-water-system#:~:text=Hot%2Dwater%20systems%20typically%20have,located%20in%20the%20various%20rooms..

[2] "Polyvinyl chloride," [Online]. Available: https://en.wikipedia.org/wiki/Polyvinyl_chloride.

[3] "The effect of temperature on PVC pipe," [Online]. Available: https://www.heritageplastics.com/technical-bulletins/effects-temperature-pvc-pipe/#:~:text=The%20maximum%20recommended%20operating%20temperature,pipe%20is%20140%C2%B0F.&text=PVC%20pipe%20and%20conduit%20becomes,73%C2%B0F%20operating%20temperatures..

[4] H. A. A.-H. a. M. A. Al-Naeem, "Effect of Temperature on the Stiffness of Polyvinyl Chloride and Chlorinated Polyvinyl Chloride Joints Under Bending," Science Alert.

[5] "The engineering toolbox," [Online]. Available: https://www.engineeringtoolbox.com/linear-expansion-coefficients-d_95.html.

[6] "Low temperature properties of polymers," [Online]. Available: http://www.appstate.edu/~clementsjs/polymerproperties/plastics_low_temp.pdf.

[7] "Design and engineering data," [Online]. Available: https://www.charlottepipe.com/TechTools/Content/temp_derating_calc_info.pdf.

[8] "What are the main uses of PPR pipes," [Online]. Available: 11. https://en.lesso.com/blogs/ppr-pipes-uses/#:~:text=Also%20known%20as%20Polypropylene%20Random,diameter%20of%2020mm%20to%20110mm..

[9] "Raw material PPR," [Online]. Available: http://ppr.almatherm.de/index.php?option=com_content&view=article&id=%208&Itemid=139.

[10] "Plastics," [Online]. Available: https://www.interempresas.net/Plastics/Articles/19819-PVC-becomes-still-more-hot.html#:~:text=Most%20of%20the%20genus%20PVC,this%20point%20the%20material%20softens..

[11] D. C. DeArmitt, "Rainsing the sofetning point of PVC," Plastics, Additives and compounding, vol. 6, no. 4, pp. 32-34, 2004.

[12] "Get to know about PPR," Rifeng, [Online]. Available: https://www.rifeng.com/article/get-to-know-about-ppr-pipe#:~:text=PPR%20pipe%20has%20better%20heat,pipies%20is%20131.5%C2%B0C..

[13] "Polyvinyl Chloride – Density – Strength – Melting Point – Thermal Conductivity," Nuclear Power-Thermal engineering, [Online]. Available: https://material-properties.org/polyvinyl-chloride-density-strength-melting-point-thermal-conductivity/.

[14] "What' the difference between polypropylene types," Machine design, [Online]. Available: https://www.machinedesign.com/