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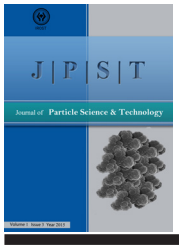

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Review

A Review of Manufacturing Process of Polyethylene Pipes and Connectors for Applying in High-Pressure Natural Gas Pipelines

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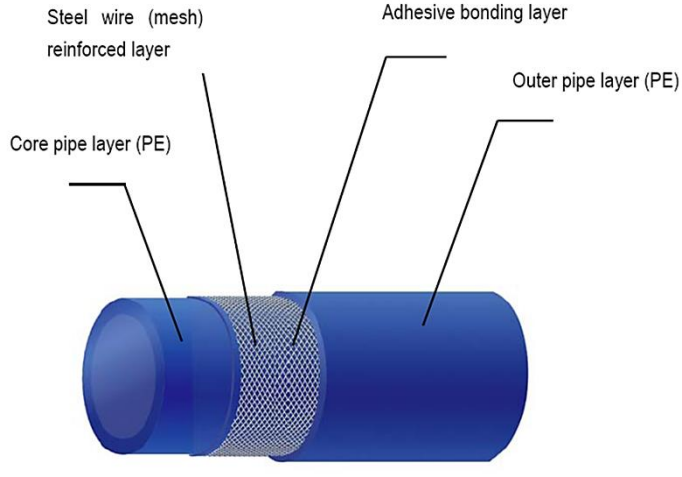
HIGHLIGHTS

- It is possible to use thinner pipes by reinforced pipes instead of unreinforced HDPE pipes.
- The highest nominal pressure for HDPE pipes is 25 bar, according to AS4130 standard.
- Ingredients ratio for Glue, polyethylene and metallic-wire are 3, 57 and 40%, respectively.
- There are several parameters which determine reinforcing level.

GRAPHICAL ABSTRACT



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ABSTRACT

In this article various pipes used for transporting of gas are introduced and pros and cons of each one are elucidated. The pipes are categorized in three different subgroups including metallic, polymeric and metallic-wire reinforced polymeric pipes. Metallic-wire reinforced polymeric pipes are nominated as the best option for usage in high pressure pipelines transporting natural gas. As a result, some information about major manufacturers of this kind of polymeric pipes, raw material, production process and metallic-wire orientation are presented. Finally, from economical point of view, some calculations are done to estimate required amount of polymer and metallic-wire to manufacture such pipes. It is also possible to compare their manufacturing cost with usual metallic and polymeric pipes.

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1. Introduction

Supplying fuel and water is one of the most important issues in every country and transportation of these fluids is also extremely important. Among various existing methods, using pipelines is a facile, trustable and cheap way for natural gas conveying. Thereby, in each country, pipelines are considered as a valuable asset of the country due to ability of such systems for sharing natural and unnatural resources in every part of a country [1,2]. Pipelines pass from different places where salinity or humidity are high enough to degrade and destroy them gradually. To prevent pipelines from such devastating corrosive environments, some techniques like cathode protection or coating of surface of metallic pipes have been practiced. However, such protective methods are not fully successful and decrease in thickness of pipes in comparison with ideal thickness is observed during service life. The usual solution in such cases is replacing the degraded pipes with the new ones. The disadvantage of this repairing method is interruption of natural gas stream during repairing period. Moreover, cutting of degraded pipe and welding of new one is necessary which is associated with wasting of some fuel and also existing possible explosion during welding. Considering such problems, a new solution which is applying metallic-wire reinforced polyethylene pipes is introduced for making high-pressure gas conveying pipelines. The manufacturing process of such pipes is also described in this review.

1.1 Pipes and their various models

Pipe is a cylindrical hollow part with a determined thickness which is used for conveying fluids. A pipe specifications include material kind and dimensions including internal diameter, external diameter, thickness and length. Pipes have standard length and thickness and are manufactured in different length including 6, 12 and 24 meters [3]. Selecting an appropriate material is the most important factor when a pipeline is designed. Pipes can be made from steel, copper, nickel, aluminum, composite and polymers. Among the above-mentioned materials, steel and polymeric pipes are used for natural gas conveying which are discussed in the following sections.

Steel pipes have been used widely in fuel conveying pipelines, especially natural gas, since many years ago. Steel pipes are divided into two groups including seamless and welded ones. Bearing high pressures, wide access to connectors and low leakage are the most important advantages of the steel pipes [2,4]. However, such pipes suffer from high corrosion, high weight and easy oxidation. The latter is a very important problem in pipelines. To overcome this problem, applying coating on the surfaces of the pipes and cathode protection method are utilized. Unfortunately, both of these methods are expensive and time consuming.

Applying coatings and paints on a surface includes different steps which are surface preparation, paint preparation and finally applying the material on the surface [5-9]. Any deficiency in these steps will limit ability of coatings to appropriately protect the pipes from corrosion. It is interesting to know that even inappropriate applying of coatings will accelerate corrosion. Moreover, coatings may be damaged during transportation and installation. All of these deficiencies will intensify corrosion and increase probability of hole creation in the damaged area and failure of the pipe before reaching its expected service life. Cathode protection is widely used all over the world to protect pipes against corrosion. This method is performed in two different ways including apply of sacrificing anode and use of injection flow. Each of these ways needs usage of special devices which is considered as a problem here. Needing electricity current for protecting pipes, manipulating anode medium, establishing cathode protection station and requiring copper wires are necessary components of cathode protection method. The absence of each one will hinder function of the method. Considering that all of these components may be stolen or damaged signifies the difficulty of cathode protection method for protecting pipes. Moreover, in different seasons when the earth resistivity changes, the current amplitude should be regulated. All the instruments should be checked and tuned regularly.

Polymeric pipes not only have low weight, but also do not suffer from corrosion. In other words, problems of steel pipes including high weight and oxidation, are solved by using polymeric pipes. Nowadays, polymeric pipes are used widely for conveying fluids under low or medium pressure. Poly (butadiene), polyvinyl chloride, polypropylene, and polyethylene are widely used for manufacturing of polymeric pipes. Significant advantages of polymeric pipes over conventional pipes have hasten their usage in natural gas and water pipelines. In addition to the above-mentioned benefits, application of polyethylene pipes is associated with easy installation, no gas leakage, resistance to corrosive chemicals, long service life, resistance to sedimentation, high wear resistance, bearing high and low temperatures, having better performance under dynamic loads and low pressure lost due to little friction of the pipes [10]. On the other hand, inability of polyethylene

pipes in high pressures will limit their application in high-pressure natural gas pipelines. For such high-pressure applications, steel pipes are the only candidate. By the advent of reinforced polymeric pipes, benefiting from properties of polymeric and steel pipes simultaneously is possible. Consequently, usage of polymeric pipes in high-pressure pipelines is feasible. In the following sections, properties of metallic-wire reinforced pipes are discussed.

1.2 Polyethylene reinforced pipes

Steel reinforced polyethylene pipes are new generation of reinforced pipes which possess advantages of both polymeric and steel pipes concurrently. Reinforcing polyethylene pipes with metals is a technique to enhance the pipe performance under high internal and external pressures. Diameter of the metal wires, distance between wires, amount of polyethylene, mechanical properties of the wire, adhesion of wire to polyethylene and processing condition are the parameters which determine reinforcing level. Nowadays, metallic-wire reinforced polyethylene pipes are used widely in different areas. For example, their application in natural gas conveying systems, high-pressure water conveying systems, sewage transportation, ore paste conveying, transportation of corrosive materials in mine and metal extraction plant, chemical material transportation, cement slurry transfer and drainage systems are reported [12].

1.3 Comparing steel wire reinforced polyethylene pipes with usual polyethylene pipes

It should be emphasized that this comparison is made by Roobuck Company, Australia. It is one of the most important producers of usual and metallic-wire reinforced polyethylene pipes [13]. From thickness point of view, at equal nominal tolerating pressure, reinforced pipes have lower wall thickness comparing to their usual counterparts and this trend is independent of pipe diameter.

Considering weight, it should be mentioned that weight of steel reinforced polyethylene (SRPE) pipes with diameter above 225 mm is lower than the weight of usual PE pipes. To discuss conveying area, it should be mentioned that due to lower wall thickness of SRPE pipes in comparison with usual unreinforced pipes, the available area and consequently flow rate of fluids in the former is higher.

From pressure point of view, the highest nominal pressure for HDPE pipes is 25 bar, according to AS4130 standard. However, this value increases to 40 bar for SRPE pipes. Considering long term hydrostatic stability, it is worthy to note that reinforced pipes endure most of internal tensions exerted by pressure through their metallic network. As a result, SRPE pipes have enhanced creep resistance in long term. The pipe service life is influenced with three factors including tension, temperature and fluid kind. Considering a fluid in a constant temperature, a longer hydrostatic stability means longer service life or enduring higher pressure by pipe.

Table. 1.
Comparing hydrostatic stability of SRPE with usual PE pipes produced in Roobuck Company [13].

	Loop Stress (MPa)	Time (h)
Usual PE pipe	11.4	15041
Roobuck pipe	31.0	22752

In the SRPE pipes, wires are welded to each other to make a network and this welded network is placed in polyethylene medium. In this structure, the metal network is fixed in the medium firmly and, in the case of crack creation, the metallic core significantly hinders crack propagation.

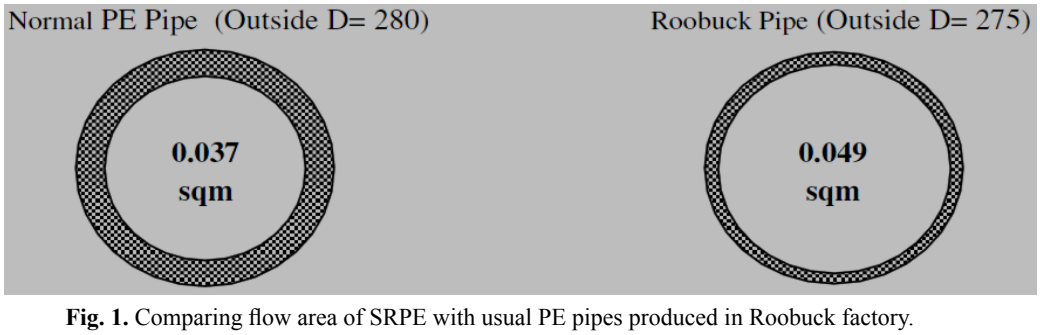

Fig. 1. Comparing flow area of SRPE with usual PE pipes produced in Roobuck factory.

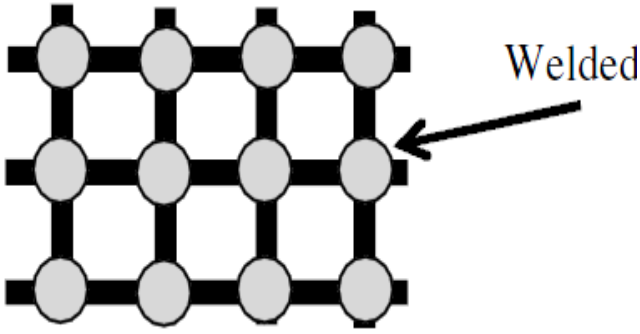

Fig. 2. Illustration of welded points in SRPE pipes [13].

In high temperatures, stability of HDPE decreases sharply, however, steel will face very little change in temperature range between 0 to 100 °C. As a result, stability of SRPE pipes against pressure at high temperatures is just a little decreased.

welding of the pipes needs increasing temperature of HDPE plates and this results in creation of a circular waves on the internal wall surface of the pipes, Figure 3. Exist of such waves not only decreases internal diameter of the pipe, but also causes creation of turbulence in fluid. Consequently, a considerable resistance against fluid flow will exist.

Table. 2.
Comparing long term hydrostatic stability of HDPE pipes reinforced by metallic-wire with usual pipes made in Roobuck Company.

	Inner pressure	Crack length	Outside diameter (mm)
Roobuck Pipe	1	No crack	174
Normal PE pipe	0.89	95 mm	110

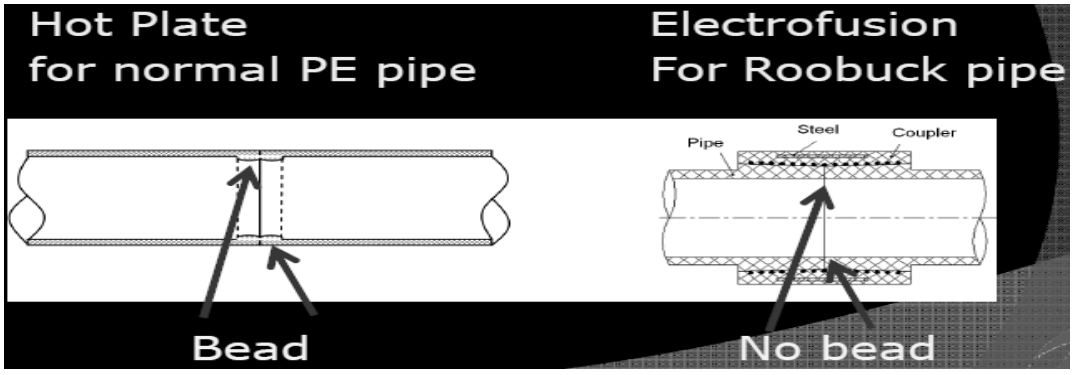

Fig. 3. Electrofusion welding is used in steel wire reinforced HDPE pipes and un-reinforced ones [17].

Considering impact strength and dimensional stability of the pipes, it should be mentioned that elastic modulus of steel is 200 times higher than HDPE. Design of metallic network in SRPE pipes is such that gives the pipe enough flexibility in axial direction. This flexibility along with enough hardness of the pipe enable it to stand against vertical loads and pressure created during transportation and movement of the pipes. According to these features, such SRPE pipes are suitable for using in pipelines which have a little curvature. Moreover, their transportation and installation are easier.

Welding of the pipes needs increasing temperature of HDPE plates and this results in creation of a circular waves on the internal wall surface of the pipes, Figure 3. Exist of such waves not only decreases internal diameter of the pipe, but also causes creation of turbulence in fluid. Consequently, a considerable resistance against fluid flow will exist.

Electrofusion welding of the reinforced pipes leads to creation of a big welding surface whose area equals to πDL (D is outer diameter of pipe and L is width of bushing). However, for a usual HDPE pipe, just the pipe wall is welded and its area is πDW where W is wall thickness of pipe. In the area of installation and repairing, some points should be taken into account which are discussed below. After electrofusion welding, bushing and pipe make a double layer structure at the point of welding. Usually, welding point in unreinforced pipe is 20% weaker than other parts of the pipe, however, welding points in reinforced pipes are stronger than the other parts of the pipe. As it is shown in Figure 4, the bushing has a metal skeleton and this is the reason of reinforcing of the welding area. Metal skeleton of bushing is more powerful than metal network of the pipe and during hydrostatic test, the reinforced pipes are broken from other parts rather than welding points. This ability reduces possibility of leakage from reinforced pipes [13-16].

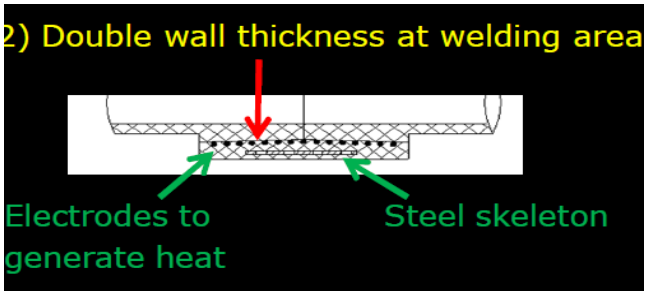

Fig. 4. Steel skeleton of bushing and wire network of HDPE pipe welded by Electrofusion method.

Regarding installation, repairing and connecting of the pipes, the following points should be considered.

1: lower weight of reinforced pipes in comparison with unreinforced ones means easier transportation of the former comparing latter. 2: Roobuck Company uses an electofusion welding machine weighting 20 kg for welding metallic-wire reinforced pipes and it is clear that this machine can be transported just by one person. 3: To install unreinforced HDPE pipes, it is necessary to use welding machine above ground surface. However, to weld reinforced pipes, the welding machine is located on the ground surface and just connection of electrical wires is necessary. 4: In a reinforced pipe with internal diameter of 250 mm, around 10-20 minutes is required to weld the pipe and the total time for installation is about 30 minutes. However, unreinforced HDPE pipes need twice of this time to be welded and installed. 5: For welding of unreinforced pipes with high diameter, a considerable time is required for pre-heating while for SRPE pipes produced by Roobuck Comapny no pre-heating is required. 6: In unreinforced HDPE pipes, the pipes are connected to each other in one or two points and complete cooling of previous welding point is necessary to be able to work on the subsquent point. On the other hand, for welding of reinforced pipes, just a clamp is enough to keep the welded point together and no cooling time is necessary. 7: Welding machine of HDPE pipes is really intricatd. The quality of welding is highly dependent on human factors. In contrast, the welding machine used for reinforced pipes is a smart device. It atumaticly analyzes the pipe and chooses the best parameters to gaint the best result. This machine just connects the wires to the pipe. It can easily control the welding process and all of the welding procedure is performed comfromtably. 8:Welding of unreinforced HDPE pipes is highly dependent on enviromental factors like rain and wind, however, these parameters are not paramount in electrofusion welding of the reinforced pipes. 9: The electrical energy used for welding of the reinforced pipes is lower that their unreinforced counterpart. 10: Welding of the unreinforced pipes needs skillful workers while this issue is obviated in the reinforced ones. Thus, the speed and accuracey of the welding is higher in the latter. 11: Due to existance of metalic networks inside the reinforced pipes, detection of possible defects and their reparing is more facile [18-22]. In the following tables, standard dimensions of the reinforced polyethylene pipes produced by H&T Industrial Developing Co., Taizhou Yisheng Trading Co., Ltd, and Goldstone Orient New Material Equipment Co., Ltd. are presented below.

Table. 3.
information about the reinforced polyethylene pipes produced by different manufactures.

Company	Brand Name	Place of Origin	PN or Working Pressure	Color	Pipe Material	Fittings Material	Website Address
Taizhou Yisheng Trading Co., Ltd.	YS	Jiangsu (China)	1.0 to 3.5Mpa	Black	HDPE, Steel Wire	-	www.tzys.en.alibaba.com
Chengdu Chuangrong Trading Co., Ltd.	CR	Sichuan (China)	-	Black	HDPE, Steel Wire	HDPE	www.cnchuangrong.en.alibaba.com
Shandong Donghong Group Co., Ltd.	Donghong	Shandong (China)	0.8~5 Mpa	Black, green, blue, red, any color as your requirement	HDPE (PE100), Steel Wire	-	www.dhguanye.en.alibaba.com
Qufu Henglian Import & Export Trade Co., Ltd.	HENGLIAN	Shandong (China)	PN:0.4 to 1.25 Mpa	Black and blue strip	PE80, PE100, Steel Wire	-	www.qfhenglian.en.alibaba.com
Nanjing Lejie New Type Material Co., Ltd.	Lejie	Jiangsu (China)	-	Black, white, green	HDPE, Steel Sheet	HDPE	www.ljxxcl.en.alibaba.com
ECETAS Construction Industry Incorporated	EBS	Ankara (Turkey)	Up to 30 bar	Yellow	Thermoplastic, Steel Wire	-	www.ebsboru.com
Roobuck Pty Ltd.	Roobuck	Australia	PN: 10 to 40 bar	Black	HDPE, Steel Wire	HDPE, Steel Sheet	www.roobuck.com.au
Goldstone Orient New Material Equipment Co., Ltd.	Goldstone	Sichuan (China)	16 to 25 bar	Yellow	HDPE, Steel wire	-	www.goldstone-group.com
Shandong Dongbao Steel Pipe Co., Ltd.	DB	Shandong (China)	1.0 to 3.5Mpa	Black	HDPE, Steel Wire	HDPE, Steel Wire	www.sddbgroup.com/en/index.asp
H&T Industrial Developing Co.,Ltd.	Huachuang	Beijing (China)	PN: 0.44 to 1.6 MPa for gas pipe	Black	HDPE (PE80), Low Carbon Content Steel Wire	HDPE (PE80), Steel Skeleton	www.reinforcedpipe.com

Table.4.
specification of the reinforced polyethylene pipes produced by H&T Industrial Developing Co., Ltd selling under trademark Huachuang, China.

Specification			For industry				For water supply				For gas		
			Working Pressure (MPa)			Working temp.	Working Pressure (MPa)			Workin g temp.	Working Pressure (MPa)		Working temp.
Inner Dia	Wall Tickness (mm)	Weight (kg/m)	Standard Class	Class A+	Class A++	℃	Standard Class	Class A+	Class A++	℃	Standard Class	Class A+	℃
DN50	11	3.2	4	4	4	-20-70	2.5	4	2	-20-80	1.6	1.6	-20-40
DN65	11	4.3	4	4	4	-20-70	2.5	4	2	-20-80	1.6	1.6	-20-40
DN80	12	5.5	3.5	3.5	3.5	-20-70	2.5	4	2	-20-80	1	1	-20-40
DN100	12	6.7	3	3	3	-20-70	1.6	2.5	2	-20-80	1	1	-20-40
DN125	12	8.3	2.5	3	3	-20-70	1.6	2.5	2	-20-80	1	1	-20-40
DN150	12	9.5	2	3	3	-20-70	1	1.6	2	-20-80	0.8	0.8	-20-40
DN200	12.5	13	1.6	2	2	-20-70	1	1.6	2	-20-80	0.7	0.8	-20-40
DN250	12.5	15.7	1.25	1.6	2	-20-70	1	1.6	2	-20-80	0.5	0.8	-20-40
DN300	12.5	20.5	1	1.6	2	-20-70	1	1.6	2	-20-80	0.44	0.8	-20-40
DN350	15	30.7	1	1.6	2	-20-70	1	1.6	2	-20-80	0.44	0.8	-20-40
DN400	15	34.3	1	1.6	2	-20-70	1	1.6	2	-20-80	0.44	0.8	-20-40
DN450	16	42.5	1	1.6	2	-20-70	1	1.6	2	-20-80	0.44	0.8	-20-40

Table. 5.
standard dimensions of the reinforced polyethylene pipes produced by Taizhou Yisheng Trading Co., Ltd, which are sold under trademark YS, china [24].

Nominal Outside Diameter (dn/mm)		Nominal Pressure (Mpa)				
		1	1.6	2	2.5	3.5
Basic Size	Deviation (+)	Nominal Wall Thickness (mm) and Deviation (+mm)				
50	1.2		4.5+1.2	5.0+1.2	5.5+1.5	5.5+1.5
63	1.2		4.5+1.2	5.0+1.2	5.5+1.5	5.5+1.5
75	1.2		5.0+1.2	5.0+1.2	5.5+1.5	6.0+1.5
90	1.4		5.5+1.5	5.5+1.5	5.5+1.5	6.0+1.5
110	1.5	5.5+1.5	7.0+1.5	7.0+1.5	7.5+1.5	8.5+1.5
140	1.7	5.5+1.5	8.0+1.5	8.5+1.5	9.0+1.5	9.5+1.5
160	2	6.0+1.5	9.0+1.5	9.5+1.5	10.0+2.0	10.5+2.0
200	2.3	6.0+1.5	9.5+1.5	10.5+2.0	11.0+2.0	12.5+2.2
225	2.5	8.0+1.5	10.5+2.0	10.5+2.0	11.0+2.0	
250	2.5	10.5+2.0	12.0+2.2	12.0+2.2	12.5+2.2	
315	2.7	11.5+2.0	13.0+2.5	13.0+2.5		
355	2.8	12.0+2.2	14.0+2.5			
400	3	12.5+2.2	15.0+2.8			
450	3.2	13.5+2.5	16.0+2.8			
500	3.2	15.5+2.8	18.0+3.0			
560	3.2	20.5+3.0				
630	3.2	23.5+3.0				

1.4 Suitable polyethylene resins for using in metallic-wire reinforced polyethylene pipes

PE80 and PE100 are two grades of polyethylene which are used in manufacturing of the reinforced pipes widely. Usually, high molecular weight polyethylene has better mechanical properties in comparison with lower molecular weight one. HDPE is a high molecular weight polymer which has outstanding properties like high toughness, high ESCR resistance and high resistance against crack propagation. As molecular weight of polymers increases, their processing becomes more difficult. Thus, synthesis of a polymer with wide molecular weight distribution possessing two peaks yields a material with acceptable mechanical and rheological properties simultaneously [25-28]. A suitable polyethylene resin was desingned by Dupire et. Al [25] to be used in manufactruing of metalic-wire reinforced polyethylene pipes. This especial resin consists of around 35-49% high moleculare weight polyethylene and 51-65% of low molecular weight polyethylene. The former polymer is a LLDPE grade with density of 0.93 g/cm^3 and has low melt flow index around 0.6 g/10 min. However, the latter polyemr is a HDPE grade with density of 0.969 g/cm^3 and a MFI value greater than 10 gr/ 10 min. Totally, this especial resin has a density greater than 0.946 gr/ cm3 , melt flow index around 1-100 g/10 min, and a dynamic viscosity exeeding 200000 Pa.S. The ratio of dynamic viscosity at 0.01 to 1 rad/s ($\eta_{0.01}/\eta_1$) is also greater than 10. Extrusion is the most usual process for manufactruing of metalic-wire reinforced polyethylene pipes. The extrusion process used for producing the reinforced pipes is partially similar to one used for producing unreinforced ones. Preparing metalic networks and installing them in pipes are the extra steps in extrusion process of the reinforced pipes. The details and secuqunces of performing these steps are dependent on the kind of pipe and may vary in different pipe grades. In the Figure 5, the manufatring of pipes in an industrial plant is illustrated. At first, an internal polyethyelen pipe is produced and then a wire coil is installed on it. Finally, the system moves toward extruders which produce external pipe. Metal wires can be wound around the pipe in different models.

Fig. 5. Manufacturing plant of the metallic-wire reinforced PE composite pipes which are produced in Goldstone Orient New Material Equipment Co., Ltd , China, and sold under trademark Goldstone [15].

The metalic wires used for manufactruing of the pipes may vary in different layers of the pipe based on parameters like the population and kind of wires, angle of winding in coile, wire tensile resistance and amount of wire in each layer. When metalic-wires are used in manufaturing of the pipes, two morphologies of winding including squar and diamond are commonplace. These morphologies are depicted in Figure 6. In Figure 6-a, which is more easier for manufacturing, the reinforcing wires are located in angles of 45 and 135 degree in respect to pipe axis. Bobbin contaning metalic-wires is installed in two rotating plates where one of them rotates in clockwise and the other vice versa, Figure 6, 7. By this method, metalic-wires are placed on the surface of the pipe in a network-like pattern. In the second morphology which is depicted in Figure 6-b, the morphology of metalic-wires is parallele and prependicular to the pipe axis [29-30]. In contrast to diamaond morphology, in pipes with squar morpholgy which experience vertical loads just the wires which are in the same direction, vertical, tolerate the load and the ones in horizantal direction are uneffective. In fact, in a squar morphology, the horizontal wires do not contribute in rigidity, compressive strength and yeild strength in vertical direction. In diamond morphology, however, both of the crossover wires have similar role in bearing pressure. As in square morpholgy more thicker wires are used, the weight of pipes containing this morpholgy is higher thant the ones contaning diamond morphology. In the Figure 8, the machine used for welding of the wires is also shown.

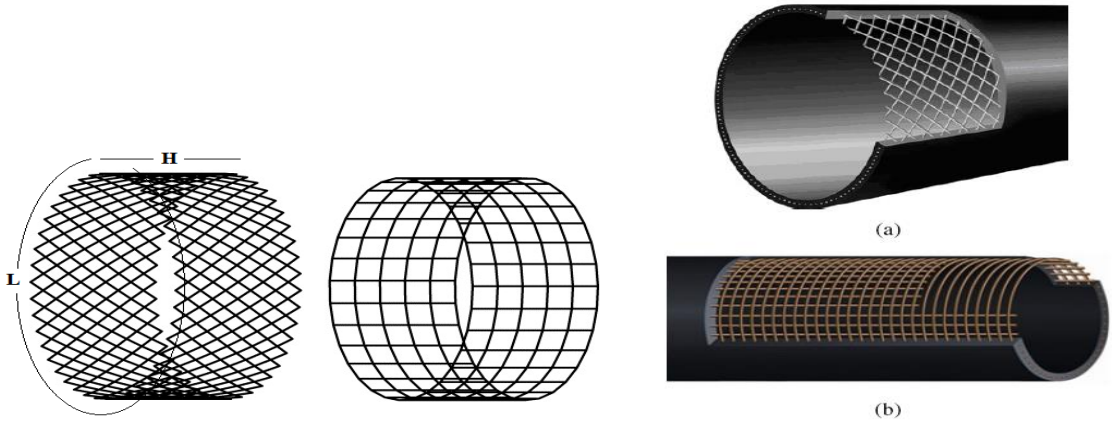

Fig. 6. Two different morphologies of reinforcing wires in pipes [32].

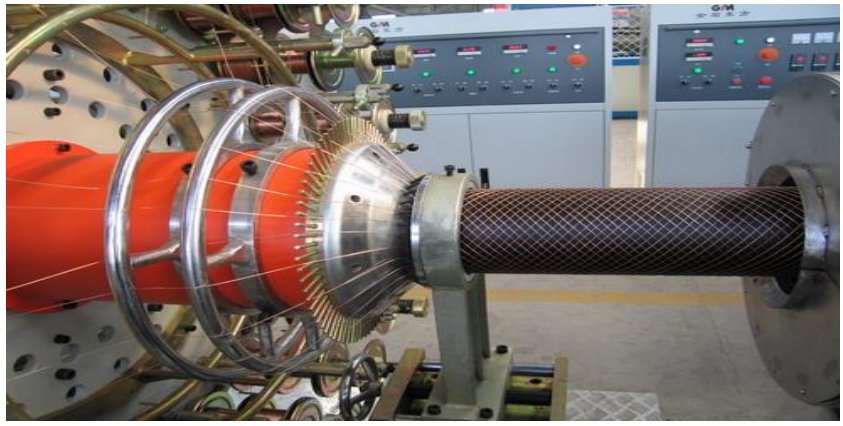

Fig. 7. Unit of wire winding of the reinforced polyethylene composite pipes in Goldstone Orient New Material Equipment Company, China.

Fig. 8. The welding machine of metallic wires (square morphology).

One of the most important problems in reinforced HDPE pipes is absence of any connection in interface of metallic-wire and polyethylene. In other words, the mechanical forces are the only parameter which adhere the wire to polyethylene matrix. As a result, internal tensions and environment thermal fluctuations may create a crack in the interface. Moreover, in the absence of appropriate sealing in cut section, water leakage into composite layer (between two polyethylene layers) is possible. Thus, breakage of pipe even in low pressure is plausible. To solve this problem, an auxiliary extruder which coats metallic-wires with glue-like resin is used in manufacturing line. It is worthy to say that this glue-like resin is compatible with polyethylene. Finally, the outer polyethylene layer will encapsulate all the metallic coils and internal PE pipe [31].

1.5 Manufacturing of Connectors

A pipeline consists of pipes and connectors. It should be emphasized that all parts in a pipeline should bear a pre-determined pressure. Thus, in the case of using the reinforced pipes in a pipeline, it is necessary to use reinforced materials for manufacturing of connectors as well. To produce metal reinforced polyethylene connectors, metallic wires are not used usually. On the other hand, some porous surfaces are used for this purpose. In Figure 9, a metallic reinforced polyethylene connector is shown. Reinforcing wires enhance the part strength just in the wire direction. Thus, the wires are placed in the direction in which maximum load exists. As the tension and flow profiles in connectors like tee water are really complicated, it is not possible to accurately prognosticate the tension direction imposed to the parts. As a result, using wire is not reasonable for reinforcing such parts and it is replaced by a porous continuous metallic sheet [33].

Fig. 9. Picture of a connector made from polyethylene reinforced by metallic porous sheet [13].

1.6 Incipient calculations to compare usual polyethylene pipe with reinforced grades from economical point of view

According to information released by major producers of the reinforced pipes like H&T Industrial Developing Co. Ltd, the ratio of ingredients comes as follows. Glue is 3%, polyethylene is 57% and metallic-wire is 40% [23]. Information of this company also show that weight of one meter of a reinforced pipe with external diameter of 225 mm, is 15 kg, Table 6. As mentioned before, 40% of the weight is wire and 57% is the resin. So, for one meter of the pipe, the weight of each component can be calculated as:

$15\times0.4 = 6\ kg$ (wire)
$15\times0.57 = 8.55\ kg$ (resin)
$15\times0.03 = 4.5\ kg$ (glue)

As price of one kilogram of PE100 produced by Jam petrochemical company, Iran, is about 40000 Rials, price of each kilogram of steel wire is around 80000 Rials and price of one kilogram of hot melt is 20000 Rials, the price of one kilogram of the pipe can be found as:

$(8.55\times40000)+(6\times80000)+(4.5\times20000)=912000$ Rials

Table 6.
comparing weight of the reinforced polyethylene pipes with unreinforced HDPE counterparts produced in China [20].

Inside Diameter	Outside Diameter	kg/m	Outside Diameter	kg/m	Comparts on Result
	SR-PE pipe		ISO4427 PEpipe (PN20/SDR9)		
DN150	DN174	11	160	8	38%
DN200	DN225	15	225	15.8	-5%
DN250	DN275	18	250	19.5	-8%
DN300	DN325	22	315	31	-29%
DN350	DN380	28	355	39.3	-29%
DN400	DN430	32	400	49.9	-36%
DN450	DN482	43	450	63.2	-32%
DN500	DN532	50	500	77.9	-36%

The price of the unreinforced HDPE pipe also can be found as

15.8 × 40000 = 632000 Rials

The price of raw materials for manufacturing of a reinforced pipe is higher than price of its unreinforced counterpart. The prices offered by Pars Ethylene Kish Company, for a single wall polyethylene pipe with outer diameter of 225 mm bearing 20 bar is about 1170685 Rials. According to the information released by Roobuck Company, the price of each meter of SRPE pipe with outer diameter of 225 mm and working pressure of 20 bar is 110 Australia dollars.

Table. 7.
Comparison between price of one meter of HDPE pipe and HDPE reinforced pipe

Pipe	Unreinfroced HDPE	Reinforced HDPE
Price (Rial)	1170685	2820000

2. Discussion and Conclusions

Nowadays, usage of metallic-wire reinforced polyethylene pipes in water and natural gas conveying is growing. This is why such pipes have advantages of both steel and polyethylene pipes simultaneously. Replacing of HDPE pipes with the reinforced grades leads to an economical profit gain. In industrial projects, flow rate is a very important issue. In similar flow condition, by the use of reinforced pipes instead of usual unreinforced HDPE pipes, it is possible to use thinner pipes and subsequently achieve higher flow area. Moreover, by the use of reinforced pipes which have lower diameter in comparison with usual pipes, it is possible to exert higher pressure inside the pipes. So, some costs like pumping expenses and finally the overall cost will be decreased. In addition, easy transportation of pipes, no need to skillful staffs for installation and lower time for installation make it more profitable to build a pipeline with the reinforced HDPE pipes instead of unreinforced grades. According to information released by major producers of the reinforced polyethylene pipes, such pipes are usually used in pipelines conveying water and sewage. However, there are just handful companies producing the reinforced pipes for working in high pressure to convey natural gas. Roobuck is the biggest SRPE producer which is located in Australia. It produces the reinforced pipes with large diameter for working in high pressure to convey natural gas.

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