Korean J. Chem. Eng., **20**(2), 230-234 (2003)

Automatic Heat-Shrink Sleeve Applicator Using the Low-Temperature Catalytic Combustor

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(*Received 5 July 2002 • accepted 14 September 2002*)

Abstract−Catalytic combustion for applying heat shrink sleeves (HSS) to a pipeline in KOGAS was investigated. We used a low temperature catalytic combustor in order to place HSS in the conduit. The surface temperature of the catalytic combustor maintained the conditions at which HSS can become well-adhesive at the conduit. Therefore, the automatic HSS construction provided the chance to establish gas pipeline safety by an automatic catalytic combustor device.

Key words: Catalytic Combustor, Heat Shrink Sleeve, Automatic Device, Adhesive Sheet, Natural Gas Pipeline

INTRODUCTION

Heat shrink sleeves (HSS) have been widely applied to girth weld parts in the construction of utility pipelines. However, it is proven that the performance depends on the attainment of uniform preheating to a certain target temperature and sufficient heating over the HSS backing layer around the pipe when a flame torch is used with LPG. An incomplete application of HSS can lead to a detrimental result, such as a poor adhesion or disbonding resistance, especially in 6 o'clock position. Special care should be taken for pipes with large diameter (>20 in general). In the light of this fact, some machinery using specially mechanized equipment has been recently made to ensure complete and defective-less performance in the HSS application. Typical examples are an electrical resistive heater and a catalytic burner for over-the-ditch application. But these are not applicable to our construction environments due to required utilities or size.

Catalytic combustion is one of the best combustion processes in that the formation of pollutants can be avoided through complete combustion as well as enhancement of combustion efficiency. In addition, catalytic combustion has been known as the only method for both eliminating nitrous oxides and solving an economical problem for clean combustion [Arai and Machida, 1996; Eguchi, 1996; Seo et al., 1999].

The use of a catalytic burner as a heat source for industrial and domestic applications requires some auxiliary functions and safety devices. For example, it is necessary to lighten quickly and to reduce the emission of unburned gases during light-off combustion.

In the catalytic combustion system, the catalysts promote the complete oxidation of the hydrocarbons and improve the energy efficiency of the process. Among the noble metal catalysts, a supported platinum catalyst has been recognized as the most active catalyst for LPG combustion with thermal stability [Farrauto et al., 1992; Ryu et al., 1997].

In this work, we report the development of an LPG-fired catalytic burner for a heater of HSS at low temperature (300-500 °C). A newly designed machine using the catalytic burner has also been assembled and demonstrated to inside-the-ditch application [Kirby, 1991, 1993].

BACKGROUND

Korea Gas Corp. (KOGAS) has been constructing transmission underground pipelines for domestic supply of natural gas since 1983. The backbone of the network is in principle composed of 26 and 30 diameter pipes. All the HSS for the girth weld of the constructed pipes so far were manually installed with the gas flame torch. Even though the pipes are mostly new, incomplete installation of the HSS resulted in some unsatisfactory corrosion. Usually, the corrosion is identified as microbiologically induced corrosion. Thus, an appropriate countermeasure is the need to use HSS continually. The newly designed machine is in principle to utilize the heat radiated from the catalytic combustor.

The domestic environment, characterized by the pipeline construction along main traffic roads, does not allow us to make an over-the-ditch application. Instead, the inside-the-ditch application is a more general type. The rule of thumb in designing the machinery is that it has to be characterized by the smallest width.

An objective of this work is to provide new environmental and operator-friendly equipment for a heat shrink sleeve (HSS) heater. The beneficial point of this equipment is the safety of the natural gas transmission pipeline in Korea.

To heat the HSS by a heating element in the field requires a flameless heater to bond between an adhesive of sleeve and natural gas pipe line. Therefore, we have developed a new type heating apparatus by catalytic burner, which is a flameless, safe and radiative burner.

1. Characterization of the Machinery

The low-temperature catalytic burner or radiant heater (Fig. 1)

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‡This is the article of poster presentation material (P-8) at 5th IWCC in Korea (April 29-May 1, 2002).

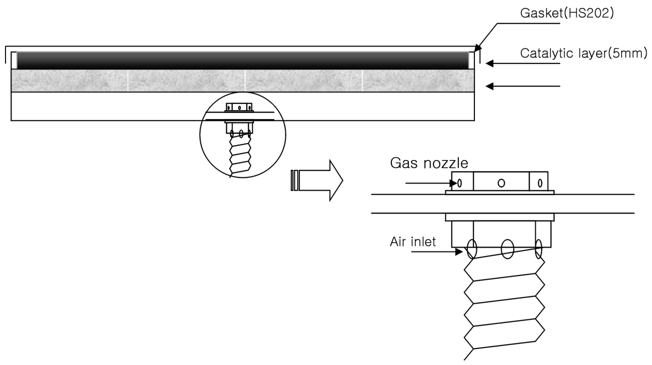


Fig. 1. Schematic design of catalytic burner for HSS heater.

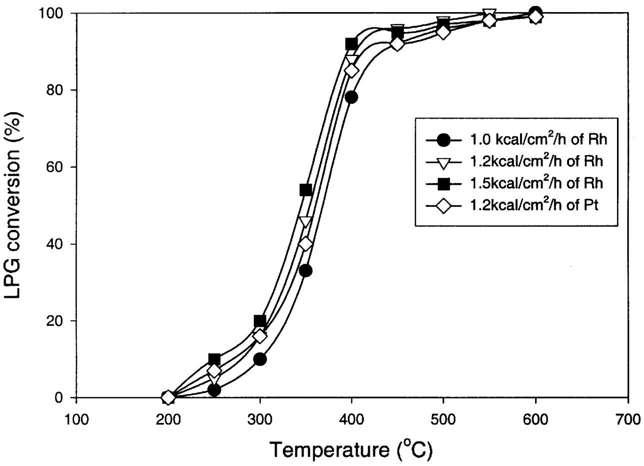


Fig. 3. LPG conversion over Rh/Al_2O_3 and Pt/Al_2O_3 fiber mat with heat flux as a function of temperature.

has already become a commercial product in applications from domestic and commercial space heaters to manufacturing processes where paint is dried or materials are cured. And the heat flux for design ranges in operation giving low heat flux (1.0-2.0 kcal/cm^2·hr). Therefore, a gas-fired catalytic burner is a safe, flameless heating technology that produces a uniform low intensity, non-glowing heat.

In 1997, KOGAS began supplying the first exhibition model of a low temperature catalytic burner in the textile process. The second exhibition model was applied to the artificial leather embossing process. With this technology, HSS applicators have been made for the 12" steel pipe as prototype and for the 30" pipe as target model.

CATALYTIC BURNER PERFORMANCE TEST

1. Catalyst Preparation

The two kinds of catalysts (supported Rh and Pt catalysts) used in this study were prepared by a conventional impregnation method. One Rh catalyst type was synthesized and designed for utilization in the catalytic burner. An appropriate amount of $RuCl_3$ or Rh-CA (Engelhard) was impregnated first into a porous alumina fiber-mat, and excess water was then removed by centrifuge, dried and calcined at 400 °C for more than 3 h.

The other Pt type catalyst was prepared to be used in a residential boiler of 3,000 kcal/hr. An appropriate amount of H_6PtCl_6 (Aldrich Co.) was impregnated first into the support (porous alumina), and excess water was removed by a rotary-evaporation followed by drying at 110 °C for more than 3 h and then calcinating in air at 550 °C for 2 h.

2. Catalytic Activity Test

Some preliminary experiments were carried out for measuring the catalytic activity and estimating the performance of the catalytic burner. For this purpose, a combustion test system was used. The LPG gas controlled by gas flow meter was passed through catalytic burner as shown Fig. 2. The composition of gas mixture after reaction was analyzed with a portable gas analyzer. The main prod-

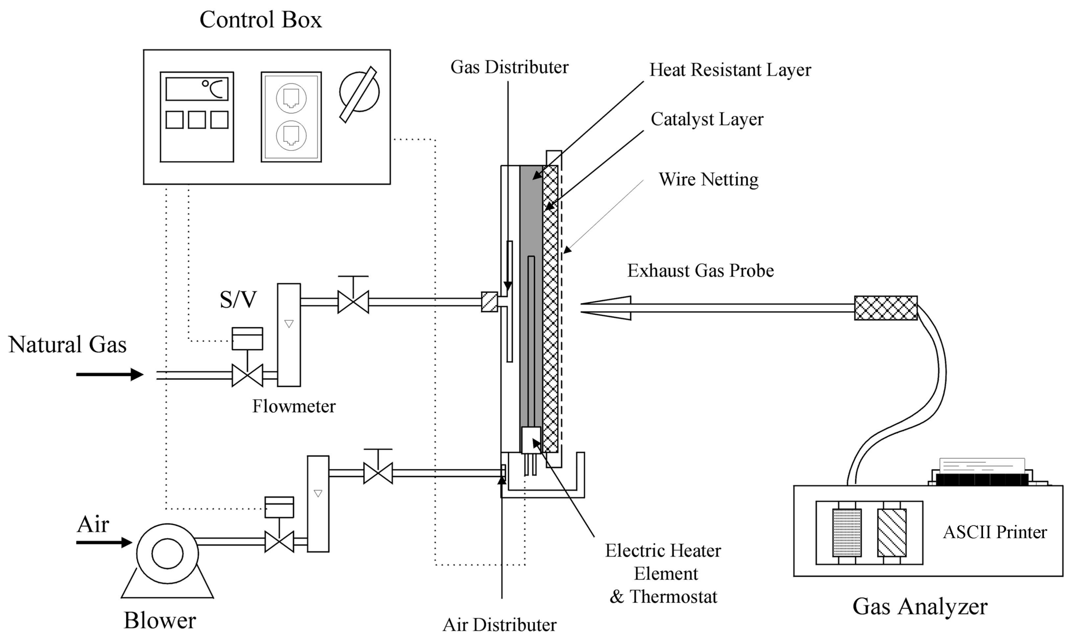


Fig. 2. Schematic diagram of catalytic burner test system.

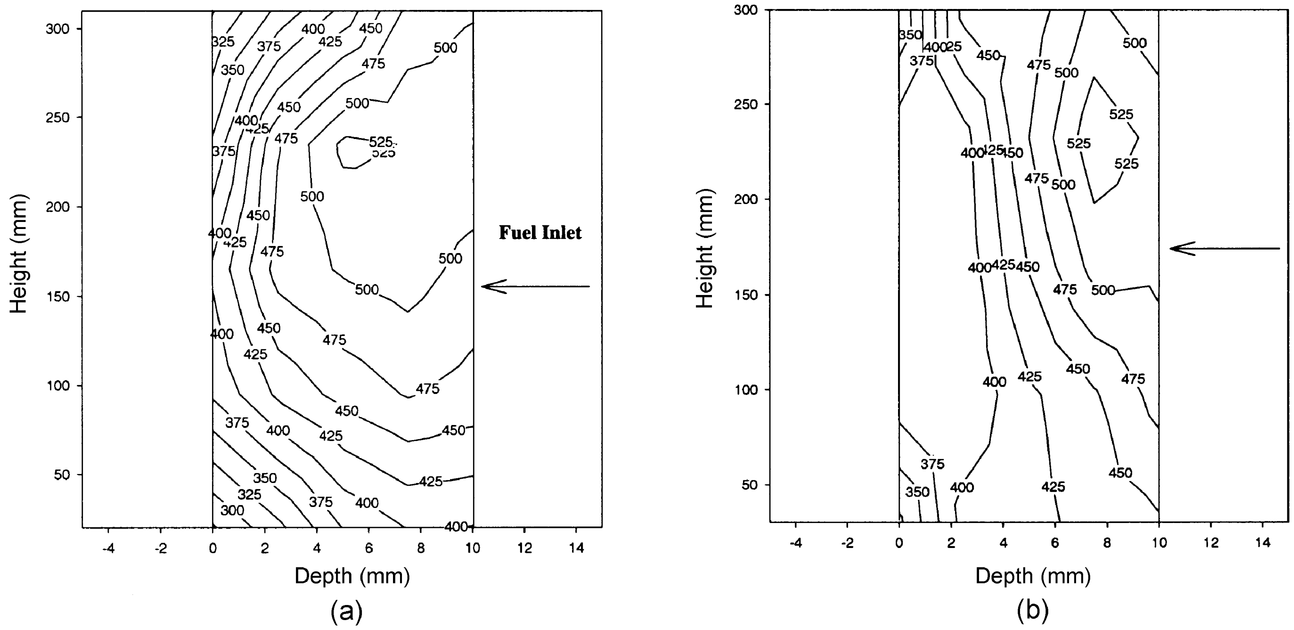


Fig. 4. Effects of the heat flux on the temperature distribution of the catalyst layer [Heat flux: (a) 1.05 kcal/cm^2·hr and 1.2 kcal/cm^2·hr of natural convective diffusion type].

uct gas is CH_4, CO and CO_2. The LPG was supplied to burner at a heat flux of 1.0-1.5 kcal/cm^2·h.

A catalytic burner is usually operated in the natural convective diffusion combustion mode that fuel flows out from the upstream of a catalyst mat, while the combustion air diffuses into the catalyst mat against the bulk flow.

Fig. 3 describes the LPG conversion versus reaction temperature over fresh Pt and Rh-Al_2O_3 catalysts with varying the heat flux. Within the given temperature range between 300 °C and 450 °C, the LPG conversion increases as the heat load increases. Above 450 °C, however, the heat flux of 1.2 kcal/cm^2·h is more stable and reaches complete combustion reaction at 550 °C.

Rh/Al_2O_3 catalyst is more activity for LPG conversion than Pt/Al_2O_3 catalyst as shown Fig. 3. Therefore, the catalytic burner for HSS heater is selected.

Fig. 4 illustrates the temperature profile into the depth of a natural convective diffusive catalytic burner for HSS heater. The temperature of catalyst layer increases with increasing the heat flux when compared between (a) and (b). The surface temperature distribution is nearly uniform at 375 °C at 1.2 kcal/cm^2·hr. It is enough that the sleeve adheres to a pipe in-ditch-application.

THERMAL CHARACTERISTICS OF THE AUTOMOTIVE INSTALLATION FOR HSS

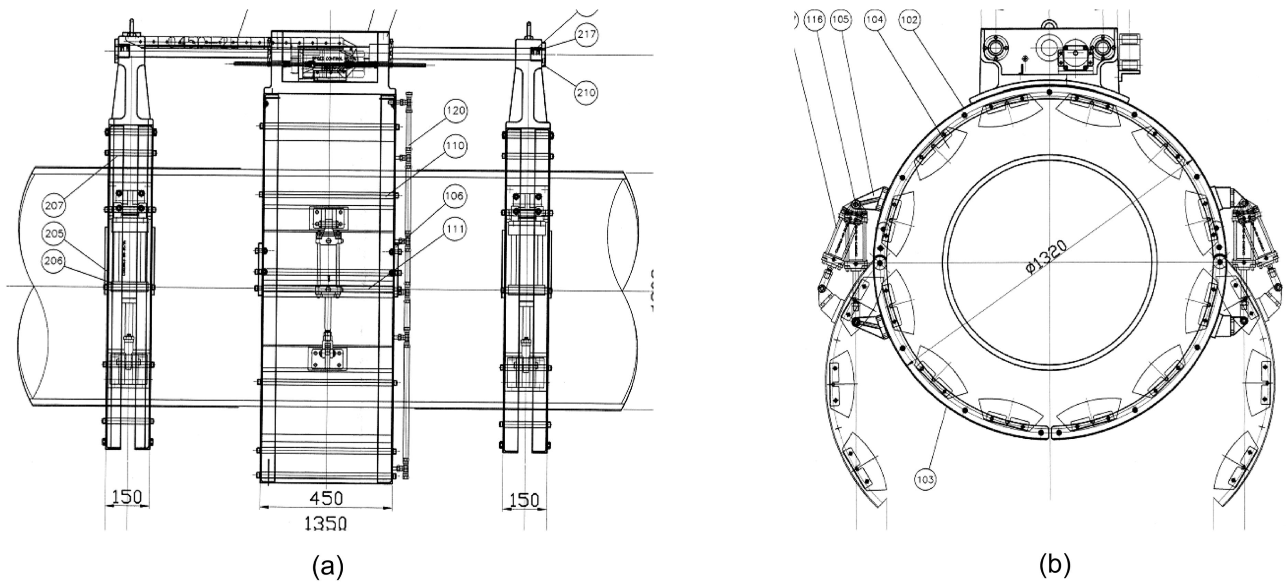


Fig. 5. Detail design of the HSS automotive installation for 30" pipe.

1. Construction of the Automotive Installation for HSS

As mentioned above, the automotive installation for HSS has been constructed to cope with traditional manual installation by using a gas flame torch, which has shown insufficient heat to adherent sleeve and non-uniform heating around the pipe under the ground. Fig. 5 shows the HSS automotive installation apparatus for 30" pipe.

This apparatus constitutes the main frame of three parts: heating equipment used by catalytic burner, automative main frame with catalytic burner supporter and control facility, and the utility; air compressor for supplying utility air, LPG gas cylinder and power supply.

The machine for 30" pipe has 12 unit catalytic burners, and each burner has a radiation area of 200 mm by 400 mm. These burners are supported by a frame, which is composed of members with two hinges. It is operated under a control unit hooked up into microcomputer. The installation is made by round-traveling of the burner frame from one end to the other. A maximum normal speed of the frame is 100 mm/min.

2. Trial Run of the Automotive Installation for HSS

Before a field test, we try to operate the HSS automotive installation apparatus in order to find out the optimum operation conditions. The major factor for operating the HSS automotive installation apparatus is an even-temperature profile according to installation time. Fig. 6 represents the plot of the temperature profile of the sleeve surface during shrinkage operation of the sleeve in the assembly with twelve burner elements for 30" pipe. It is apparent from the temperature profile that uniform heating is fairly done in the assembly.

However, it is somewhat different from real field conditions. Ambient temperature and wind directly do not have an influence upon the HSS automotive installation apparatus.

3. Field Test of the Automotive Installation for HSS

Fig. 7 shows that temperature distribution obtained at pipe surface under ambient temperature of (a) subzero 7 °C, (b) superzero

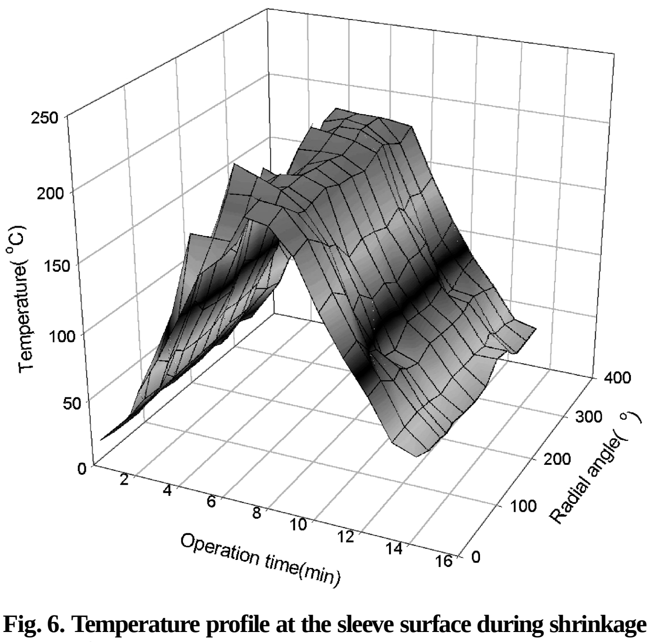
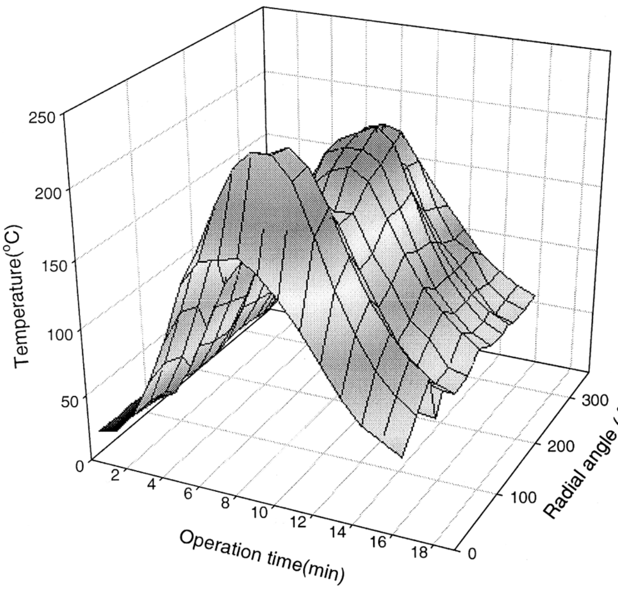
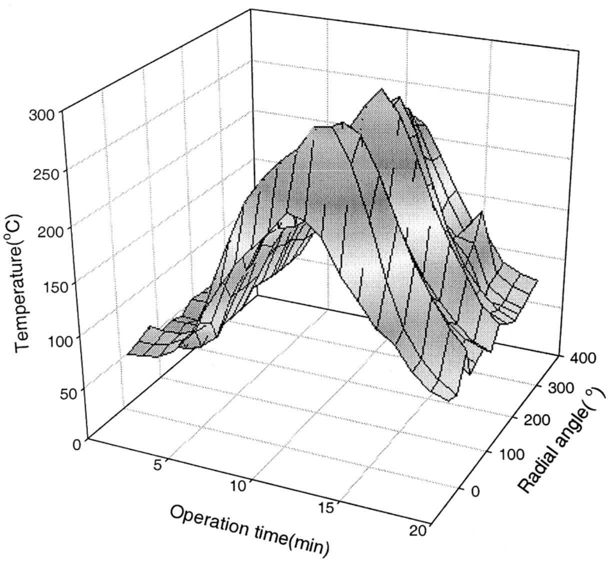


Fig. 6. Temperature profile at the sleeve surface during shrinkage of the sleeve when using the HSS automotive installation apparatus for 30" pipe.



(a)



(b)

Fig. 7. Temperature distribution obtained at pipe surface under ambient temperature of (a) subzero 7 °C, (b) superzero 11 °C.

11 °C. The temperature distribution of (b) condition is better than that of (a), because of ambient temperature difference between mild and cold weather conditions. The adhesive capacity of HSS on the pipe is affected by the good distribution of temperature. Therefore, it is important to heat the pipe up to 60 °C before operation of this equipment for good adhesion between the HSS and the pipe.

4. Appearance and Adhesion for Installed HSS

The developed machine was run together with some specific HSS recommended by HSS manufacturers. The cosmetic appearance after installation of HSS with this machine looks excellent regardless of orientation along the pipe, and, especially, the 6 o'clock (under the pipeline) problem seems to be completely eliminated.

Table 1. Adhesive strengths obtained from flame torch and HSS machinery

Item \ Method	Flame torch		Machinery
	Non-preheating	Sufficient preheating	
Adhesive (N/cm)	17.4	27.2	29.2
Disbonded feature	Water channel	Small cavity	Cohesive

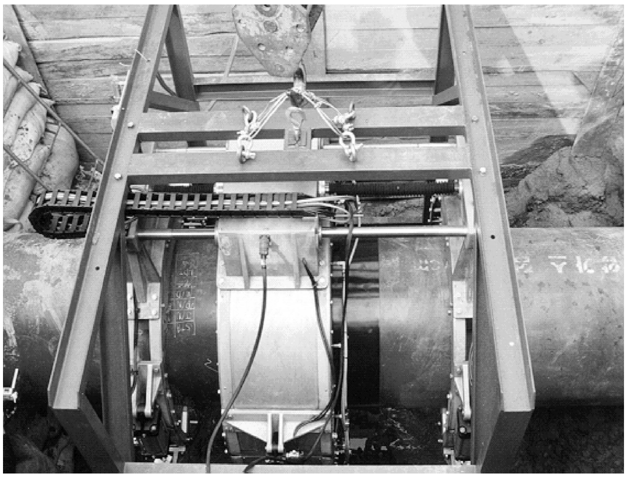


Fig. 8. Photograph of demonstration test of automatic HSS device by low temperature catalytic combustor.

Adhesive strength was measured along the peripheral direction of the pipe and that typically obtained is listed in Table 1. At this moment, the disrupted mode in the peeling process is shown to be a cohesive bonding, which means an excellent bonding of the HSS adhesives.

5. Demonstration of the Machinery On-Site

Test runs have been applied to actual construction sites (Fig. 8). So far the results have been most satisfactory while some of cases gave us essential lessons such as the points to be checked, the application procedure as well as the machine concept.

CONCLUSIONS

Newly designed machinery with a radiating burner using catalytic combustion has been assembled for the inside the ditch application of HSS and successfully demonstrated and run. But a robust design is needed to eliminate the ruggedness while obtaining the simplest manipulation. It is sufficient to heat the pipe up to 60 °C before operation of this equipment for good adhesion between the HSS and the pipe. Of course, this machine in the present design has no limitation for over-the-ditch application. Additionally, this machine can be used to do pre-heat treatment and post-weld treatment in the winter season.

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