Induction brazing technology for pipeline connections of an automated gas metering unit

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Abstract. The article discusses the connection of pipelines of an automated gas metering installation. Welding is considered as the main method of connecting pipelines and an induction pack of heating methods as proposed by the authors. In the work, a threaded connection is calculated according to the method of Anuryev V.I. On the basis of the calculations carried out by the authors using formulas from the designer's handbook, a schematic diagram of the pipe fastening in the process of induction soldering is developed. A schematic diagram of a pipe bend is also being developed. The approach proposed by the authors will repeat the connection of pipelines of oil and gas equipment using induction packs and increase the reliability of brazed structures.

1. Introduction
Welding has found wide application due to the simplicity of the process and the absence of the need to use a large number of additional consumables. This type of equipment connection, like no other, is still the most popular not only in the oil and gas industry, but also in other industries.

The automated gas metering unit “Mera” is designed for automatic and manual measurements of the amount of liquid and gas produced by oil wells. The principle of operation of the installation is based on the hydrostatic method of measuring the mass of liquid. The installation consists of a technological unit, a monitoring and control unit, made in the form of a block of containers.

As for the induction type, high-frequency currents are used for it [1-3]. Electricity is passed through the parts to be soldered, which is why they heat up.

Two methods of soldering are realized here: stationary and with movement of the part or inductor. In the case of joining large-sized workpieces, the second technology is used.

The resistance soldering method is somewhat similar to the induction type [4-6]. It's just that in this technology, the current is passed both through the workpieces and through the soldering element. That is, the parts to be connected become part of the electrical circuit.

Such a process is carried out in electrolytes or in special contact machines, the action of which is very similar to standard electric welding. Contact machines are usually used in industries where it is necessary to solder thin sheet metal products to each other [7-9].
Soldering in electrolytes is not often used today due to the complexity of setting the parameters of the technological process [10-12]. After all, the process takes place according to the principle of the heat effect that occurs between the cathode (parts to be soldered) and the anode. A hydrogen shell is formed around the blanks, which has a very high electrical resistance. Hence the release of large thermal energy.

The purpose of this work is to develop a schematic diagram of fasteners for pipeline connections of an automated gas metering unit (AGMU).

2. Materials and methods
At the initial stage, it is necessary to design the mounts for the inductor. However, for this it is necessary to make calculations. The inductor is fastened using a threaded connection.

The calculation of the threaded connection was carried out according to the method of Anuryev V.I. Handbook of a designer-mechanical engineer in 3 volumes [13]. Calculation of the threaded connection of the inductor in tension (table 1):

Table 1. Thread parameters M12.

| Inner diameter, mm | Average diameter, mm | Hollow diameter, mm |
|--------------------|----------------------|---------------------|
| 11.376             | 12.026               | 11.160              |

The calculation of the threaded connection of the inductor is made according to the formula (1):

$$\sigma_t = \frac{4 \cdot F_t}{\pi \cdot d_1^2} \leq [\sigma_t],$$  \hspace{1cm} (1)

where $F_t$ - tensile force, N; $d_1$ - internal thread diameter M12, m; $[\sigma_t]$ - allowable stretching of the material under tension / compression, MPa.

For copper M2 at constant load $[\sigma_t] = 490$ MPa. The breaking load of a threaded connection is calculated (2):

$$F_t = S \cdot P_w,$$  \hspace{1cm} (2)

where $S$ - cross-sectional area, m$^2$; $P_w$ - operating pressure.

Find the cross-sectional area by the formula, m$^2$:

$$S = 3.14 \cdot 0.012^2 = 0.000314$$

Breaking load of a threaded connection according to the formula, N:

$$F_t = 0.000312 \cdot 2.5 \cdot 10^6 = 0.785 \cdot 10^3$$

For supply, we take a surface pump Vortex PN-650 with $P = 2.5$ MPa. Based on the tensile force acting on the threaded connection of the inductor:

$$F_t = 785,$$

$$\sigma_t = \frac{4 \cdot 785}{3.14 \cdot 0.011376^2 \cdot 4} = 1.2.$$  

As can be seen from the calculations, the condition $\sigma_t < [\sigma_t]$ performed. Next, the shear thread connection is calculated. The actual nature of the distribution of the load along the turns depends on manufacturing errors and the degree of thread wear, which makes it difficult to determine the true stresses. Therefore, in practice, the calculation of the thread strength is carried out not according to the
true, but according to the conditional stresses, which are compared with the allowable stresses established on the basis of experience.

When determining the conditional stresses, it is assumed that all threads are loaded uniformly. It is customary to count the thread:

- By shear stress on the helical surface.
- By shear stresses in the section.

Checking the thread for shear stresses. Probable cut of the threads - by the inner diameter of the thread (3):

$$\tau_{sh} = \frac{F_t}{\pi \cdot d \cdot K \cdot H \cdot K_m} \leq \left[ \tau_{sh} \right]$$

where $K$ – incomplete thread ratio; for triangular threads $K = 0.75$, for rectangular – $K = 0.5$, for trapezoidal – $K = 0.65$;
$H$ – thread height, $H = 90$ mm;
$K_m$ – coefficient considering the uneven distribution of the load on the turns;

$$K_m = \frac{5p}{d}, \left[ \tau \right]_{sh} = 1.5 \cdot \sigma_T$$ – allowable shear stress.

$$K_m = \frac{5p}{d} = \frac{5 \cdot 10^{-3}}{0.015} = 0.333$$

where $p$ – thread pitch.

$$\left[ \tau_{sh} \right] = 1.5 \cdot \sigma_T = 1.5 \cdot 490 = 735$$

$$\tau_{sh} = \frac{F_t}{\pi \cdot d \cdot K \cdot H \cdot K_m} = \frac{785}{\pi \cdot 0.012 \cdot 0.75 \cdot 0.010 \cdot 0.333} = 14154 \leq \left[ \tau_{sh} \right] = 735$$

Checking threads for shear stresses. Calculated if the device is operated with frequent screwing and unscrewing. The condition for operability is the calculation for the deformation of the crushing (4), MPa:

$$\sigma_{cr} = \frac{F}{\pi \cdot d^2} \leq \left[ \sigma_{cr} \right]$$

$$\left[ \sigma_{cr} \right] = 0.85 \cdot \sigma_m = 0.85 \cdot 735 = 625$$

$$\sigma_{cr} = \frac{F}{\pi \cdot d^2} = \frac{150}{\pi \cdot 0.012^2} = 484076 \leq \left[ \sigma_{cr} \right] = 625$$

Thus, it can be seen from the calculations that the necessary conditions of equality are satisfied. This means that it is possible to design an industrial thread.

### 3. Result and discussion

Based on these calculations, it can be assumed that the creation of mounts for large-diameter inductors is possible. This means that it is necessary to develop basic schemes for fastening pipelines. As a result of the calculations, a fastener for pipes (figure 1) and a “mushroom” pipe connection (figure 2) was designed. The authors made schematic diagrams of these structures.
Figure 1. Schematic diagram of pipe fastening. 1. Pipe 90mm; 2. Fastening sleeve; 3. Solder PSr-45.
Figure 2. Schematic diagram of bending pipe connection. 1. Pipe 90mm; 2. Fastening sleeve; 3. Pipe bend 90 mm; 4. Solder PSr-45.
These designs have the following technological parameters: Working pressure, MPa - 0.6; Working temperature, °C from -70 to 300. The designs proposed by the authors will make it possible to rethink the approach to connecting pipelines of an automated gas metering installation. As you can see from the figures above, the collapsible design of the inductors will make it easy to connect any pipelines.

The melting point of the flux must be lower than the melting point of the solder. Fluxes can be solid, pasty and liquid. Soldering of precision joints is carried out without fluxes in a protective atmosphere or in a vacuum.

When brazing with PSr-45 solder, which has a lower melting point than borax, slagging of the flux may occur. Therefore, as a result of numerous experiments, a flux in the form of a liquid paste mixed with water or alcohol has now been developed and used, which has the following composition:

- Borax - 50%.
- Boric acid - 35%.
- Potassium fluoride - 15%.

4. Conclusion
In the course of this work, an analysis of the subject area was carried out, in particular, the soldering method using induction heating was considered. Threaded connections for fastening inductors were calculated using a mathematical apparatus. Current calculations have shown the applicability of the proposed approach. As a result, the construction of schematic diagrams for fastening straight pipes and for connecting a pipe “mushroom” was carried out.

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