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RESULTS OF IMPLEMENTATION OF ORBITAL WELDING IN MANUFACTURE AND REPAIR OF THIN-WALL PIPELINES

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Applied methods were analyzed for producing a permanent joint of thin-wall pipelines of aircraft gas-turbine engines. The peculiarities of application of mechanized and automated joining technologies were noted. The experimental works were carried out for mastering a technology of orbital welding of position butt joints of pipes of up to 0.5–1 mm wall thickness, providing high quality of joints and welding productivity. The developed technology of orbital unsupported pipe welding is used in serial production in JSC «Motor Sich». 5 Ref., 2 Tables, 4 Figures.

Keywords: *aircraft engines, pipe, orbital welding, brazing*

The main problem in designing and production of an aircraft engine (AE) is its service life. The AE service life is determined by durability of its structural elements. Around 7 % of AE rejects [1, 2] comes for AE pipelines of external manifold (due to the damages in zone of welded and brazed seams).

The typical damages of pipelines of engine external manifold are fatigue cracks, fractures, dints, dents, damages related with defects of welded and brazed seams; corrosion damages of brazed structures.

All these defects can be conventionally divided on related with manufacture, operation and design.

The main methods of welding and brazing being earlier used in production and repair of AE pipelines (manual argon arc welding (AAW), induction and gas brazing) have, at that, a range of technological difficulties effecting process stability and weld quality.

● gas brazing is the human factor, need in flux residuals removal and necessity in application of special testing method;

● AAW is the human factor, difficulty of butt welding of pipes of small thickness (0.5–1.0 mm), impossibility of pipe rotation during welding (position joint) due to complex geometry of the most pipes, high labor content of the process;

● induction brazing has significantly limited field of application due to impossibility of brazing of complex geometry parts in steel fixture.

The relevance of this problem is related with production of welded and brazed seams of high strength and stable quality in welding of pipelines of AE external manifold.

The enterprise has made a decision on mechanizing and automation of processes of permanent joint production for solving the problems related with increase of quality stability in welded and brazed joints.

Thus, the technologists faced with the problem of welding and brazing process mechanizing and improvement due to this of product quality, receiving the joints having higher stability to fatigue loads.

Following the conditions of fatigue strength, the most acceptable are the brazed joints and butt welding [2].

It should be noted that mechanization of gas brazing is complicated since it requires bulky and complex in operation equipment and special devices.

Orbital welding [3, 4] is widely used in the world for mechanization of welding of pipe position butt welds. The widespread of this method of pipe welding is related with the fact that this method provides necessary penetration depth and shape, ensures quality formation of weld root, keeps arc in necessary state and guarantees similar welding conditions in any directions. «Orbital welding» concept means performance of the circumferential welds on a fixed part. At that a welding torch moves around the pipe on set circular orbit.

Known in domestic and world practice application of orbital welding for the moment of project creation (2003) is application of unsupported welding of pipe butt joints with wall thickness from 1 mm [3–5].

Aim of the present work is consideration of peculiarities in technology of mechanization of processes of pipe permanent joint production.

At that it was necessary to give proof of relevance of replacement of gas brazing and AAW for automatic

AAW (AAAW) on criteria of strength and workability; outline the main principles for designing the joints in orbital welding at transfer from AAW and brazing as well as repair, propose the main technological approaches in unsupported butt welding of complex geometry pipes providing welded joints of high quality with wall thickness from 0.5 to 1 mm; implement a new technological process into existing pipeline production cycle.

It was assumed that the following would be provided, namely increase of productivity or keeping its previous level, necessary conditions of assembly for orbital welding due to application of modern technologies of facing, calibration, special fixture for centering and assembly; requirements to selection of type of equipment are formed (main and auxiliary) based on determined technological problems.

The technology should provide stable quality and high fatigue strength of welded joints; rise of pipeline service life; expansion of fields of application of automatic orbital welding in manufacture and repair of AE pipelines.

The experiments were carried out on thin-wall parts (pipelines, nipples, connecting pipes) produced of 12Kh18N10T and 14Kh17N2 steels. Welding was carried out using a complex of special equipment including welding power sources (Fronius and Polysoude Companies) with a block of software control and set of heads for welding of different pipe structures and joint types (Polysoude Company). Open type heads (MU IV 38 and MU IV 115) are used for welds with reinforcement and that without reinforcement are made with heads of closed type (MW40 and MW65). Fatigue strength tests were performed in accordance with OST 1.41972–80.

The results of carried experiments allowed developing and implementing a technological process of orbital welding of AE pipelines, the main stages of which are edge preparation for welding, assembly, welding, weld quality control.

The edge preparation and assembly for welding are carried out in accordance with the requirements presented in Table 1.

Cutoff and facing machines (Georg Fisher and Protem Companies) were used for providing a necessary welding gap (see Table 1). They completely eliminate manual edge preparation for welding, at which treatment misalignment of pipe edge should not exceed 0.1 mm relatively to pipe axis.

Assembly and further tack welds were made in special centrators (Figure 1). Displacement of edges of butt joints should not be more than 0.1S.

Table 1. Requirements to edge preparation for orbital welding

Type of welding head	Wall thickness *S*, mm	*b*, mm	l_1, mm	l_2, mm
Open	≤ 1.0 1.0–1.5 1.5–3.0	0–0.1 0–0.15 0–0.2	≥ 100	≥ 5
Closed	≤ 1.0 1.0–1.5 1.5–3	0–0.1 0–0.15 0–0.2	≥ 19	≥ 19

Note. *b* — welding gap; l_1 — length of necessary straight section; l_2 — distance from welded joint to fitting.

Quality control of the welds joints produced by orbital welding was performed by external inspection, hardware check of welding modes, and, depending on importance and designation of pipelines, one of non-destructive methods of testing:

- for fuel pipelines — 100 % X-ray testing, leakage testing;
- for oil pipelines — 20 % X-ay testing, leakage testing;
- for air pipelines — X-ray testing of one part from a batch.

The hardware check lies in verification of current welding modes, which are printed with the modes entered in the technology.

The fatigue strength is the main criterion for providing safe operation of pipeline in AE content. Therefore, the main reason for implementation of orbital welding for a designer is ensuring high strength characteristics of welded joints under cyclic alternating loads. Pilot works on determination of ultimate strength of different configuration pipelines were performed for this. The check was performed in a range of parameters from 10 to 80 mm on OST 1.41972–80.

The results of tests showed that welded joints produced by orbital welding equal on fatigue strength to the joints produced with gas brazing, and significantly exceed ones produced by AAW (Table 2).

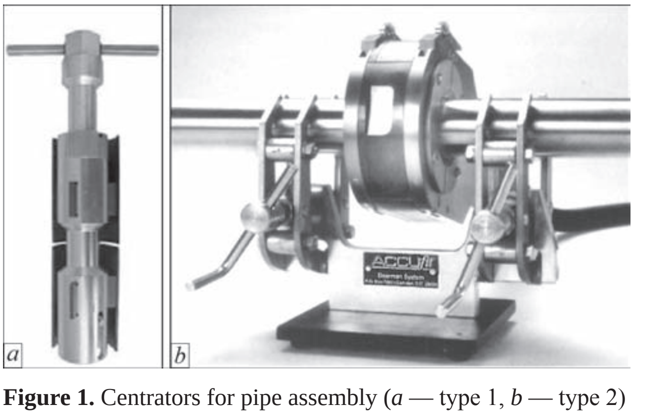

Figure 1. Centrators for pipe assembly (*a* — type 1, *b* — type 2)

Table 2. Comparative analysis of fatigue strength of welded and brazed joints of steel pipelines

Unit design characteristics	Fatigue strength σ_{-1}, kg/mm^2		
	Manual AAW with backing	Gas brazing	Orbital welding (AAAW)
Pipe + pipe 10×1 mm, 12Kh18N10T	–	14	18
Pipe + pipe 14×0.5 mm, 12Kh18N10T	–	16	16
Pipe + pipe 18×1 mm, 12Kh18N10T	–	14	18
Pipe+Pipe 18×0.5 mm, 12Kh18N10T	–	14	14
Pipe + pipe 22×0.5 mm, 12Kh18N10T	–	12	14
Pipe + pipe 25×0.5 mm, 12Kh18N10T	–	10	12
Nipple (12Kh18N10T) + pipe 18×1 mm (12Kh18N10T)	6	16	16
Nipple (12Kh18N10T) + pipe 32×1 mm (12Kh18N10T)	4	–	10
Nipple (12Kh18N10T) + pipe 40×1 mm (12Kh18N10T)	4	–	10
Nipple (12Kh18N10T) + pipe 50×1 mm (12Kh18N10T)	4	–	10
Nipple (12Kh18N10T) + pipe 80×1 mm (12Kh18N10T)	4	–	8
Connecting pipe (14Kh17N2) + pipe 18×1 mm (12Kh18N10T)	6	16	16
Connecting pipe (14Kh17N2) + pipe 32×1 mm (12Kh18N10T)	6	–	14
Connecting pipe (14Kh17N2) + pipe 40×1 mm (12Kh18N10T)	4	–	12

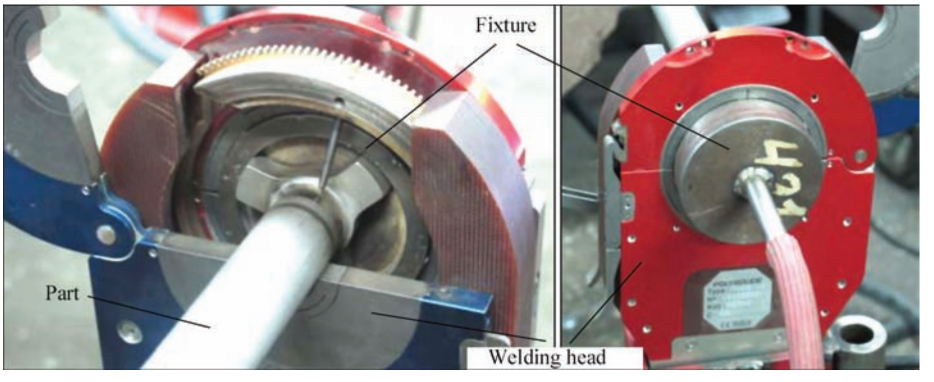

Figure 2. Fixing of closed type welding head to special fixture

The main problems appearing at implementation of orbital welding of pipes and AE parts are the following. The first one is part configuration, location of welded joint directly close to flange or pipe bend radius, at that straight area (l_1, l_2 see Table 2) is necessary for fixing welding automatic units (heads). The second is small thickness of welded edges (from 0.5 mm).

The first problem was solved by production of special fixture, to which welding head was attached (Figures 2, 3).

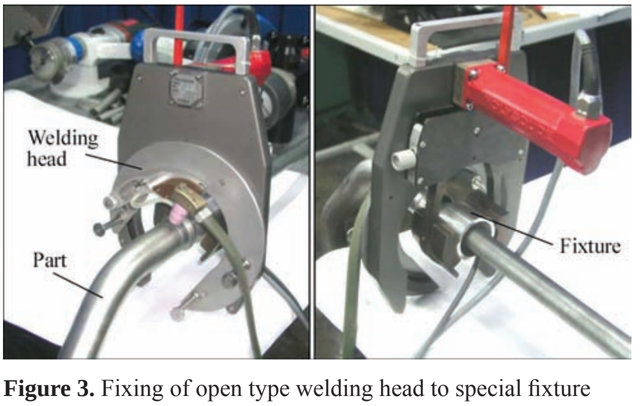

Figure 3. Fixing of open type welding head to special fixture

The second problem was solved due to application of inverter welding power sources from Fronius and Polysoude Companies with microprocessor, synergy control of the key welding parameters (welding current (from 5A), welding rate, wire feed rate and arc

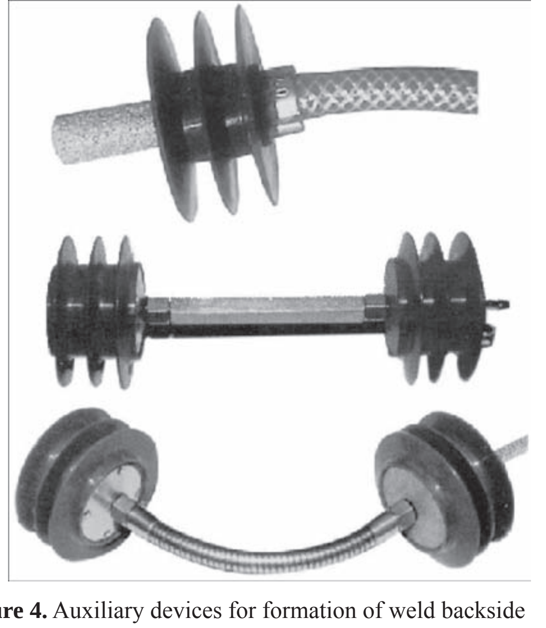

Figure 4. Auxiliary devices for formation of weld backside

voltage) and application of special devices for improvement of formation of weld backside (Figure 4).

The special device was used for argon supply inside the pipe during welding and due to small excessive pressure a weld pool was kept.

Orbital welding is implemented in manufacture of more than 50 dimension types of steel pipelines of up to 0.5 mm wall thickness and 6–90 mm diameter; in repair of steel pipelines of wall thickness up to 0.5 mm and 10–90 mm diameter. Replacement of pipelines for new ones (before that 18–25 pipelines were replaced for new ones in one engine) was virtually eliminated in engine repair and it is used in manufacture of more than 100 dimension types of power assemblies in helicopters and engines of structural steels and titanium alloys of 1–6 mm thickness.

Conclusions

1. Butt joints of pipes produced by orbital welding are not inferior to traditional brazed joints on fatigue strength. This allows their application in new structures designing as well as replacement of existing (brazed) joints.

2. Technological approaches were proposed and equipment and fixture were selected. This allowed welding of pipe-to-pipe, pipe-to-fitting (flange, connecting pipe, nipple) joints in any configuration of pipelines independent on distance of welded joint from flange or pipe bending radius.

3. Technical requirements to edge preparation and assembly for welding were determined and modes were selected. They could provide unsupported welded joints of high quality with wall thickness from 0.5 to 1 mm and 6–90 mm diameter.

4. JSC «Motor Sich» implemented in serial production a welding bench for manufacture and repair of thin-wall pipes of aircraft engineering, design documentation was improved and technological procedures and technological processes were developed.

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