MAGNETICALLY-IMPELLED ARC BUTT WELDING OF PARTS OF AUTOMOBILE RANGE OF PRODUCTS

S.I. KUCHUK-YATSENKO, V.S. KACHINSKY, V.Yu. IGNATENKO, E.I. GONCHARENKO and **M.P. KOVAL**
E.O. Paton Electric Welding Institute, NASU, Kiev, Ukraine

Peculiarities of magnetically-impelled arc butt welding of parts of the automobile range of products, including compact hollow parts of steering rod, shock-absorber and torque rod, are described. Results of metallographic examinations as well as evaluation of mechanical tests, proving the high quality of welded joints, are presented.

Keywords: *magnetically-impelled arc, press welding, automobile parts, joint formation, technology of welding*

High-efficiency and energy-saving processes of welding, assuring the good quality of parts being manufactured, and also allowing achievement of the higher labour productivity find a wide spreading at the automobile plants.

At the E.O. Paton Electric Welding Institute of the NAS of Ukraine the technology and equipment (welding machines MD102 and MD105) have been developed for the magnetically-impelled arc butt (MIAB) welding, which are widely used in the automobile industry of Ukraine. Since 1994 the MIAB-welded pneumatic springs and shock-absorbers (Figure 1) are manufactured at CJSC «Krasnodon Works «Avtoagregat» [1–3]. During this period more than 4 million of welded joints were made.

On the basis of gained multi-year experience of MIAB welding the following main advantages of this technology can be outlined: high efficiency under the conditions of mass production; low time of welding as compared with other processes; minimum consumption of part material for heating and upsetting; air-tightness of welded joints; absence of welding consumables and shielding gas; high strength properties of welded joints at the level of those of parent metal.

Table 1. Technical characteristics of machines for pipe welding

Machine type	Diameter of pipes, mm	Wall thickness, mm	Upsetting force, kN	Consumed power, kV·A	Mass, kg
MD101	10–51	1–4	40	30	230
MD1	18–61	1–6	60	45	190

Over the recent years the technology of MIAB welding of the new generation of parts of automobile industry has been developed at the E.O. Paton Electric Welding Institute. The investigations were aimed at the development of a relatively not expensive high-efficiency process of the MIAB welding for manufacture of automobile parts under the conditions of mass production.

Weldability of compact hollow automobile parts, such as a steering rod of ∅22 × 2.2 mm, shock-absorber of ∅40 × 2.2 mm and torque rod of ∅34 × 6 mm, was investigated. Basic requirements, specified for the work, are to develop the highly-efficiency process of welding for its application in mass automobile production with guaranteed mechanical properties of welded joint at the level of characteristics of the part parent metal.

The works were performed using welding machines MD101 and MD1 (Figure 2), technical characteristics of which are given in Table 1 (the welding efficiency is 60 joint/h), and chemical composition of parts is presented in Table 2.

Main technological parameters of welding the parts of steering rod, shock-absorber and torque rod are presented in Table 3.

Mechanical tests of welded joints were performed in accordance with procedures accepted at the automobile plants. They include full-scale rupture tests and also local bending of segments of circumferential welds.

Metallographic examinations of welded joints of parts of steering rod and shock-absorber were carried out in the LECO device M 400 at 1 N load and 100 μm pitch. To reveal the microstructure of welded joint,

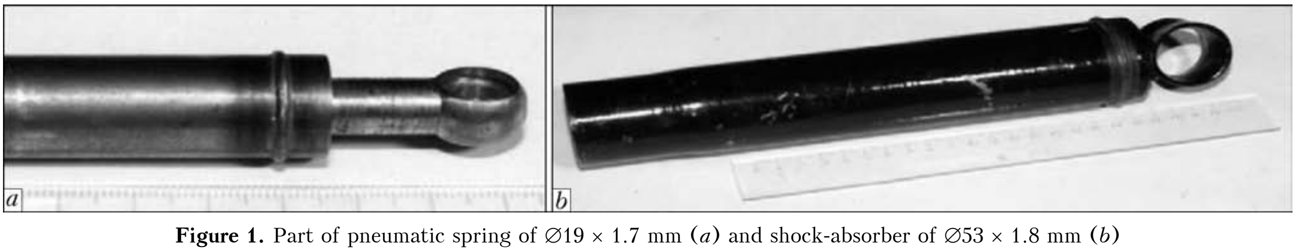

Figure 1. Part of pneumatic spring of ∅19 × 1.7 mm (*a*) and shock-absorber of ∅53 × 1.8 mm (*b*)

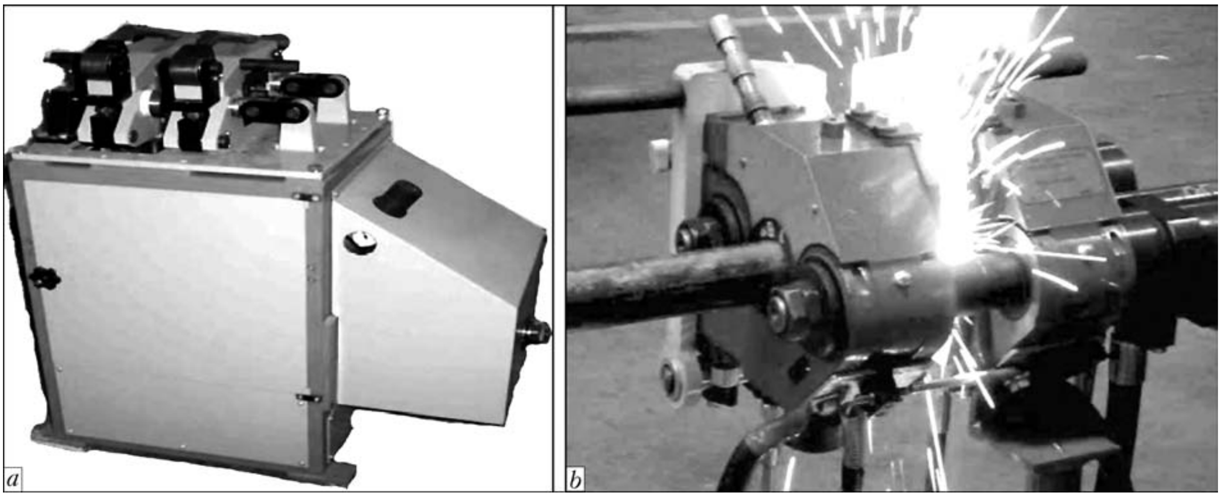

Figure 2. Machine MD101 (*a*) and machine MD1 in operation (*b*)

Table 2. Chemical composition of automobile parts, wt.%

Part	C	Si	Mn	S	P	Cr	Ni	Cu
Steering rod of ∅22 × 2.2 mm:								
pipe	0.194	0.174	1.01	0.004	0.015	0.05	0.04	≤0.02
part of left rod	0.175	0.107	0.91	0.004	0.012	0.17	0.07	0.12
part of right rod	0.170	0.080	0.90	0.004	0.011	0.17	0.07	0.22
Shock-absorber of ∅40 × 2.2 mm:								
pipe	0.146	0.152	1.23	0.004	0.012	0.05	0.04	≤0.02
bushing	0.136	0.162	0.56	0.018	0.011	0.07	0.08	0.08
Torque rod of ∅34 × 6.2 mm:								
pipe	0.18	0.22	0.55	0.010	0.015	0.02	0.01	–
head	0.32	0.20	0.55	0.008	0.006	0.05	0.05	0.1 W

Table 3. Main technological parameters of welding of parts

Part	Diameter, mm	Wall thickness, mm	Time of welding, s	Upsetting force, kN	Part shortening, mm	Consumed power, kW
Steering rod	22	2.2	3.7	21	2.1–2.3	6.1
Shock-absorber	4	2.2	4.8	31	3.7–3.9	6.7
Torque rod	34	6.2	13.2	40	7.0–7.5	7.2

the chemical etching by 4 % alcoholic solution of nitric acid was used.

Steering rods. The part of a steering rod represents a pipe of 300 mm length, to which rod hollow parts with 60 mm long thread are welded-on on both sides. Pilot technology of MIAB welding of pipe with hollow rods has been developed as a result of carried out investigations. Figure 3 shows the MIAB-welded joint.

Welded joints were subjected to rupture and bend tests. The rupture force was 12,900 kg, the fracture occurred on the pipe parent metal at 140 mm distance from the butt that proves the high mechanical strength of the joint. Bend tests showed high ductile properties of the joint.

Macrosections were manufactured from welded joints of the steering rod part (Figure 4). Width of HAZ was 2.2–2.4 mm. Welded joint does not require auxiliary operations after completion of the welding process and flash removal. Method of MIAB welding allows, when necessary, producing the height of weld reinforcement up to 0.5 mm.

The measurement of distribution of metal hardness in the zone of welded joint of the steering rod was

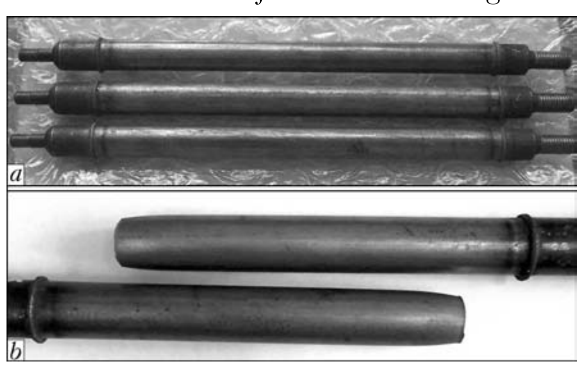

Figure 3. Automobile part of steering rod of ∅22 × 2.2 mm after welding (*a*) and rupture test (*b*)

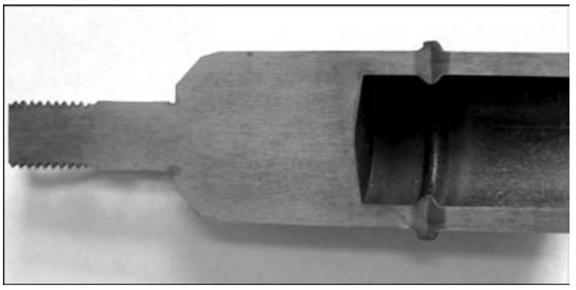

Figure 4. Macrosection (×1) of welded joint of left steering rod

performed in the direction from the pipe to the rod part (Figure 5). The carried out metallographic examinations of welded joint of the steering rod part showed the following results.

The ferrite decarbonized band on the welded joint line is absent (Figure 6). Metal hardness on the joint line is HV 2640–2970 MPa. Defects were not revealed in the joint zone.

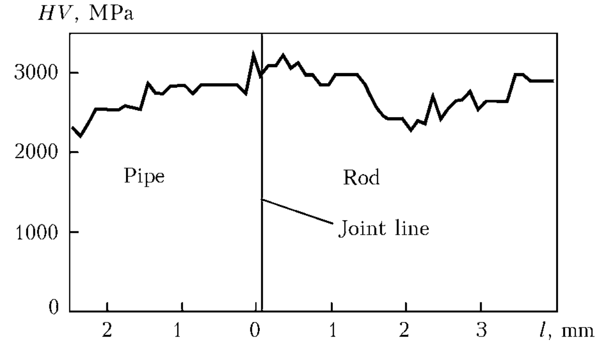

Figure 5. Distribution of metal hardness in the zone of welded joint of steering rod

The structure of HAZ overheating zone represents a mixture of pearlite, bainite (HV 3060–3110 MPa) and a small amount of ferrite (HV 2540–2610 MPa) (Figure 6). The width of overheating zone is 550–600 μm. Then the structure is refined, the amount of bainite is decreased, the amount of a pearlite component is increased.

The structure of parent metal of pipe is fine-grained (number 9–10 by GOST 5639–82), ferrite and pearlite (HV 2020 and 2120–2370 MPa, respectively) with a clearly expressed texture of rolled metal.

The structure of HAZ overheating area of rod part is bainite-ferrite (HV 2710–3210 MPa), width of overheating area is 700 μm. The structure of rod part parent metal is bainite-ferrite with hardness HV 2790–3090 MPa.

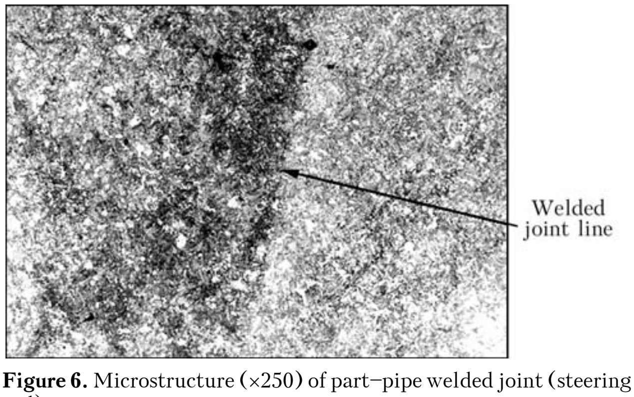

Figure 6. Microstructure (×250) of part–pipe welded joint (steering rod)

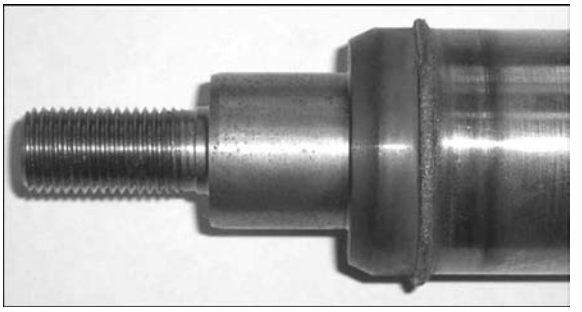

Figure 7. Welded joint of automobile part of shock-absorber

Shock-absorbers. The part represents a pipe of 300 mm length, the inner part of which is coated by chromium of 0.02 mm thickness, a hollow tail piece with 60 mm long thread is welded-on on one side. Figure 7 shows a welded joint made by MIAB method.

Mechanical tensile and bend tests showed that the joint strength is at the level of characteristics of the parent metal of the tail piece part. The tensile force up to fracture was 122 kN. Bend tests showed the high ductile properties of the welded joint.

Mechanical tensile and bend tests of welded joints of a torque rod and shock-absorber prove strength and high ductility of the joints, equal to those of the parent metal of parts. Bend tests are severe for this type of joints. The performed full-scale mechanical bend and rupture tests of parts of steering rod and shock-absorber showed that ductile properties of the welded joint are at the level of properties of the parent metal.

As a result of carried out investigations the pilot MIAB technology for the shock-absorber part has been developed.

Macrosection (Figure 8) was manufactured of the shock-absorber welded joint. Width of HAZ was 2.2–2.4 mm. Welded joint does not require auxiliary mechanical operations after completion of the welding process.

Metallographic examinations of welded joint of parts of shock-absorber of ∅40 × 2.2 mm showed the following results. Measurement of metal hardness distribution in welded joint zone was made in the direction from pipe into part (Figure 9). The ferrite decarbonized band on the line of joint of pipe and tail piece is absent (Figure 10). Metal hardness on the joint

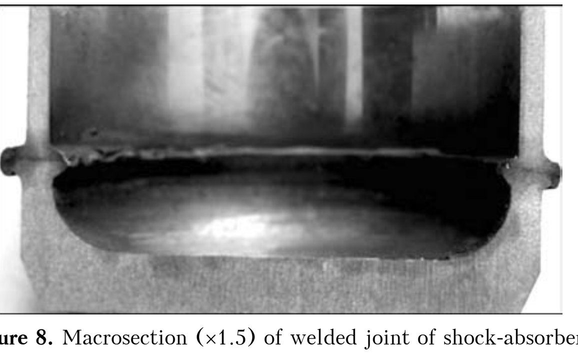

Figure 8. Macrosection (×1.5) of welded joint of shock-absorber

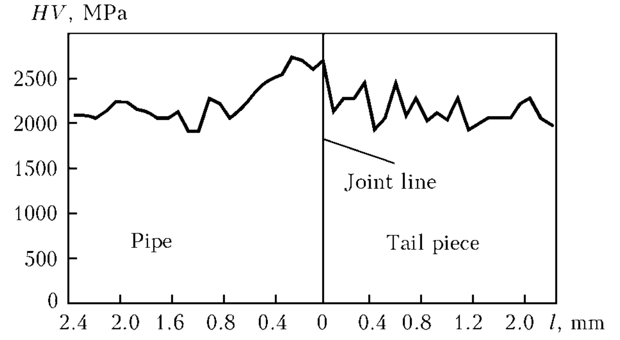

Figure 9. Distribution of metal hardness in the zone of welded joint of shock-absorber part

line is HV 2700–2850 MPa. Defects in the joint zone were not revealed.

The structure of HAZ overheating area of pipe metal consists of pearlite (HV 2570–2650 MPa), bainite (HV 3030–3210 MPa) and a small amount of ferrite. Width of overheating area is 500 μm.

The pipe parent metal has a ferrite-pearlite structure with a clearly expressed texture of rolled metal and HV 2210–2320 MPa.

The structure of HAZ overheating area of metal of tail piece part represents a mixture of ferrite with HV 2190–2210 MPa and pearlite with HV 2340–2390 MPa. Ferrite of different morphological forms is observed in the structure. Width of overheating area is 500 μm, HAZ length is 1200 μm.

The structure of parent metal of tail piece part is ferrite-pearlite (HV 1990–2210 MPa) with a great domination of a ferrite component.

It was found as a result of investigations that the welded joints of parts of steering rod and shock-absorber have no structures, changing significantly the properties of metal as regards to the parent metal. The bainite-ferrite structure is dominated in the structure of welded joints. The peculiar feature of structure of welded joints is the absence of a coarse-grain area.

Torque rod. The torque rod consists of a pipe and two heads. Pipe material is steel 20, heads are of steel 30. As-welded parts of the torque rod were subjected to fatigue tests in a special stand at tension–compression symmetric cycle. Results of tests are given in Table 4.

Table 4. Results of testing four torque rod parts at tension–compression symmetric cycle

Load, kN	Specific load, MPa	Number of cycles before fracture	Place of fracture
±70	133.0	914,000	In head body
±60	114.0	2,480,100	Same
±50	95.0	3,027,500	»
±45	85.5	10^7	Without fracture

The fracture of the torque rod part after tension-compression tests was in parent metal of a tip (Figure 11). The tests of welded joints at symmetric cycle

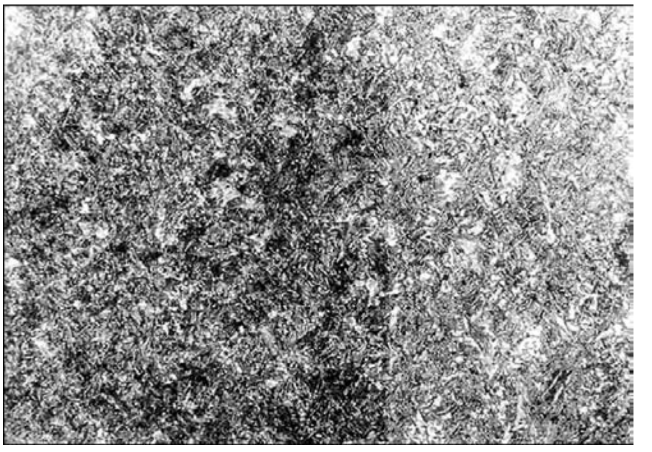

Figure 10. Microstructure (×320) of pipe–part welded joint (shock-absorber)

Figure 11. Part of torque rod after cyclic tests

of tension–compression were performed using joints with a flash. The presence of flash, causing the concentration of stresses, did not decrease the values of cyclic tests. This is stipulated by the fact that the fine-grain structure with high tough properties is observed in the place of an increased concentration of stresses at the boundary of weld reinforcement.

As a result of carried out investigations the pilot technology of MIAB welding of part of the ∅34 × × 6.2 mm torque rod of trucks has been developed.

Thus, the carried out full-scale mechanical rupture tests of parts of steering rod and shock-absorber, welded by MIAB method, prove the high mechanical strength, ductility and resistance to fatigue fractures of welded joint at the level of main characteristics of the parent metal.

The pilot technology of MIAB welding the automobile parts of ∅22 × 2.2 mm steering rod, ∅34 × × 6 mm torque rod and ∅40 × 2.2 mm shock-absorber has been developed. The developed technology can be used in mass production where the high labour productivity is required.

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