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FORGE WELDING OF BIMETALIC AXE

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Abstract: Today, we used to say that bimetalic products belong to the new era, produced only by a high- tech procedure. Here will be shown one product manufactured on a really primitive but successful way, made from one structural and tool steel. Joining of two different steels here is explained by forge welding. For the body of an axe commonly is used a kind of softer structural steel, about 0,30%C, while for a cutting edge must be used an insert from high carbon tool steel with more than 0,70%C. The practice of this kind of welding needs very skill forgers. Another disadvantages of this technology is in very low productivity. But, instead of these, the forging and forge welding were applied over centuries ago in producing very qualitative tools and arms (*cold weapons*). The skills and technical demands from this kind of producing are not fully known to the contemporary welders or engineers, especially the benefits from a protective atmosphere that charcoal could provide. In fact, forge welding does not need an electrical current (direct or alternate), induction heating up, laser beam, shielding atmosphere (argon or vacuum), etc., but only a wood charcoal, coke or gas fuel, and many practical experiences in temperature determination during heating up, handy strikes and speedy movements. The using of an appropriate flux also is needed. At the end, some knowledge and experience are desired in heat treating of tool or an axe, it means in quenching and tempering. After forge welding is done, very qualitative joint is achieved, first of all it means the fusion and interface lines, which here are approved by metallographic view.
Keywords: tool, axe, low- and high carbon steel, forge welding

INTRODUCTION - HISTORICAL BACKGROUND ON FORGING

Forging is undoubtedly the oldest deformation process. At the beginning, the noble metals as silver and gold were deformed, firstly by forging and further by drawing and/or rolling. Very few works were dedicated to the forge welding on the engineering manner, even today.

Forging welding was used in past for producing the wheels for vagons: the steel strip is heated up, bended and forge welded into ring shape, then is mounted on a circular wooden wheel structure. The heat affected zone is present in almost of contemporary welding techniques, but it could be said to be unknown term in forge welding.

Forging and generally fire have taken a very important role in almost civilizations all over the world. One of the most known gods is Hephestus, from ancient Greek, Figure 1a).

Figure 1. Hephestus - ancient Greek's god of forging & fire a) and forging fire b)

The principle of forging in its nature is very simple: the shaping of metal is provided by using localized forces, almost. Traditionally, forging is performing by using hammer and anvil, earlier is provided by hand strikes. The most valuable pieces from industry and elsewhere (hand tools, jewelry, etc.) still are producing by forging, because they are stronger than casted and machined piece.

FORGING FIRE

Forging fire has a pretty long history. Small number of steels may be forged in the cold state; it means that almost of steels should be forged in the warm or hot state. Heating up was provided by using a forging fire by using a charcoal. In nowadays the heating up is rather provided by using a coke or gas fuel (propane or propane mix) for easier achieving the high temperatures. The most important advantage of forging fire lies in ability for producing much desired reduction atmosphere, for preventing the decarburization of steel.

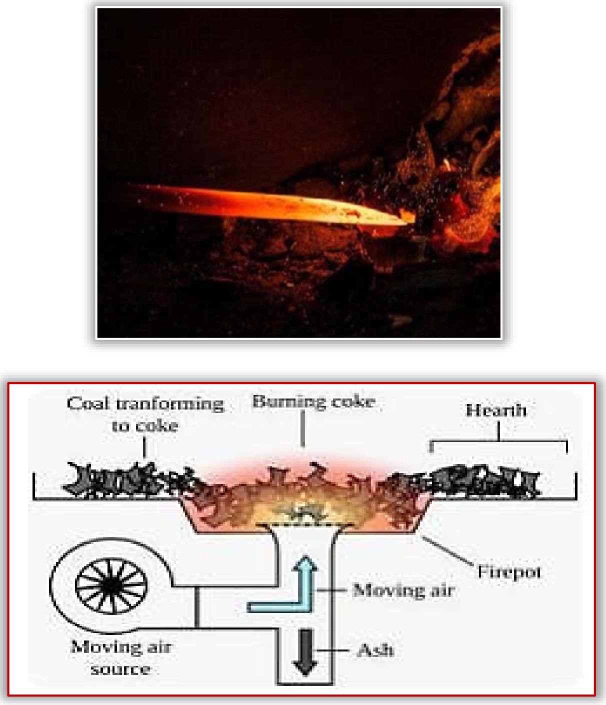

Figure 2. Partially heated up end of a part to be forged a) and air supplying into forging fire b)

The disadvantages of using a forging fire are in limited length (or volume) of heated part, Figure 2a), and at low productivity for the contemporary sense of production. The equipment for forging fire is pretty simple, Figure 2b).
The vertical cross section through the forging fire is given in Figure 2b). Charcoal was used over millennia but now the coke and or propane/butane gas mixture are more desired for heating up for forging. Water power was introduced into iron production in the XII century, allowing the use of large hammers in forging processes.
Pretty long time the forging process (—drop forging) is provided when hammer (raised and dropped by hand) strikes and deforms the workpiece – it is so called open-die forging. For these operations is needed a well skillful operator. It also valids for forge welding.

PRINCIPLE OF FORGE WELDING

In forge welding the pressure and temperature have play crucial role. By using only a pressure many welding methods were developed, from those the most important are:

≡ friction welding,
≡ ultrasound welding,
≡ explosion welding and
≡ stir welding.

Today, the pressure welding is applying in producing some of avio- and auto pieces, thanks to the high quality of those technologies. The real problem in forge welding is limited dimensions.
If the forging force is great than is needed the lower temperature for heating up. In past, the temperature of heating up of a piece is determined only by naked eye, as bright yellow or white. Those temperatures are about 0,9Ts, (between 1200-1300^{0}C), as approved by contemporary methods of temperature measurement. Sketch of three principal stages during forge welding of an axe is shown in Figure 3.

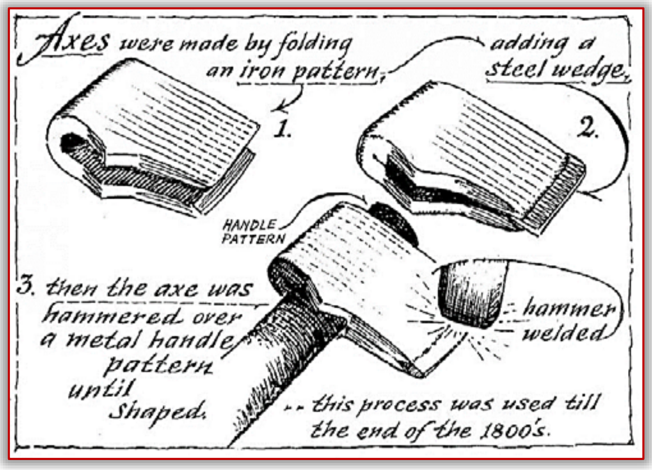

Figure 3. Principal operations in forge welding of an axe with insert

After the piece, from a moderate carbon steel (≈0,30%C), is heated up to desired temperature, next operation is the folding (1) at Figure 3. The second operation (2) is adding the insert from high carbon steel (≥0,70%C), position (2). Then, the juncture is ready to forge (3).

In industrial practice is well known the impossibility of welding when the high carbon steel is used. The critical moment in producing the axe with an insert is the moment of welding, two views are shown in Figure 4. The forge welding starts when the pieces are heated up near to white color, it means to the pretty high temperature, say about 1300^{0}C, Figure 4a). Overheating is not allowed, from the metallurgical reasons. After few strikes the pieces are going to cooling down, as could be see from Figure 4b). In that case, it means that the forging procedure must be stopped and reheating is needed. The number of reheatings is not determined in advance, it depends from the kind of used steels, dimensions of forged parts (here an axe), further from the used energent (fuel), and however from the skillfull of blacksmith.
The process of forge welding must be stopped after pieces are cooled, it could be noticed by changing the color, say at orange color, Figure 4b).

Figure 4. Critical moments in hand forge welding:
a) beginning (bright color) and b) at the end (pieces were cooled to orange color)

In situation as in Figure 4b) the reheating of cooled pieces bust be provide.

RESULTS AND DISCUSSION

— Microstructure of forge welded joint

The microstructural review is one reliable method for observation the state at the weld zone. Many thin cracks in metallic materials could not be registered by ultrasound or gamma-ray techniques, but are available by microscopic monitoring. The presence of eventually imperfections or nonmetallic inclusions will be seen in metallographic view. Microstructures of both materials, low and high carbon steel after forge welding is done, are shown in Figure 5.

Figure 5. Microstructures of two steels obtained in forge welding: left – low carbon and right – high carbon steel [11]

The existence of two different materiaal clearly is visible. The binding zone is homogenous and free of microcracks, those were the aim of welding.

Figure 6. Some steps in hand forging/forge welding of an axe with insert of high carbon steel

After the forge welding is finished, the axe further is heat treated (quenched and tempered) and at the end of processing the edge is sharpened by grinding, sometimes polishing. Picture of some steps in producing an axe is shown in Figure 6.

Forging and forge welding require really simple tools: hammer, anvil and forge fire, it means without electrical current, plasma, laser, shielding gas/mixture, etc. Forge welding is available by hand strikes, but in last centuries for this purpose are used hydraulic or air hammers.

Forge welding is, however, based on forging technology. The pieces to be joined must be heated up to the higher temperatures than for ordinary forging. For successful forge welding the pieces must be heated up to 0,9T_s. The strong strikes lowering the temperature. The forge welding must be done by pretty fast strikes, sometimes with two blacksmiths if needed, with synchronized moves. Even though the high temperature is applied; the strong strikes enable obtaining the fine grain structure of deformed metal. For the body of an axe commonly is used a kind of softer structural steel, about 0,30%C, while for the cutting edge must be used an insert from high carbon tool, steel with more than 0,70%C. The greater content of carbon is needed for achieving the great hardness and strength at the cutting edge after quenching and tempering.

Today, the handy forging is rarely in using, because for its providing are needed both great skillfull and fast moves, so the production periode becomes long. It is clear that many welding methods with using an electric current (on different ways) are faster than handy forging techniques, but the forging usually gives better properties of finished product, also in aesthetic appearance, than mentioned welded products.

CONCLUSION

The axe from the ancient times was an useful tool for man. Pretty early, such man achieved to produce this very qualitative product, even from two different materials/steels. The welding of diversed steels, if one is low and another high carbon steel, represents the problem even today. On the empirical way, the man discovered the production schedule of forging and forge welding, which are approved by contemporary methods of investigations. However, this principle is also available for production of very qualitative goods, as for chains, etc. Handy forging does not require expenses for machinery, tooling and high-temperature furnaces, but the workers must be very skilled. By inserting a high carbon steel at the cutting edge, in a body of an axe from a low carbon steel, is achieved very good connection between these different materials, as could be seen from metallographic view. The microstructures of this forge weld shows pretty good adhesion of two kinds of steels in the fusion zone.

Note:

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