Air Products shielding gases for additive manufacturing

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Abstract

Additive manufacturing methods are considered suitable for technical processes in the manufacture of complex mechanical parts. WAAM together with 3D metal printing are the basic technologies used for additive production. WAAM (Wire and Arc Additive Manufacturing) technology is characterized using welding to create whole structure of mechanical part by cladding weld passes. The WAAM process is characterized by a number of variables, among others the MIG/MAG protective gas shield effects. The aim of this paper is to evaluate the influence of individual components of protective gases supplied by Air Products, Inc. used for welding the whole structure. Especially both to the resulting component geometry and to the efficiency of the welding process.

Key words: WAAM, Air Products, additive manufacturing, shielding gases

1. Introduction

Additive manufacturing is increasingly used in engineering practice to create machine parts of complex shapes. Among the best-known additive manufacturing technologies are 3D printing by sintering of metal powder using laser beam and WAAM (Wire and Arc Additive Manufacturing) technology using welding. 3D printing is used to create small parts with very difficult internal geometry that cannot be manufactured using conventional production methods. WAAM is used for the rapid production of relatively large components with the main purpose of avoiding large waste material such as those arising from the machining of large semi-finished products.
Since the welding process is defined by many variables affecting the stability of WAAM, this work deals with one of them – the effect of shielding gases used for welding technology.

1.1. Additive manufacturing

3D metal printing works on the principle of sintering the additive material as a metal powder. With this method it is possible to create extremely geometrically complex structures without any further modifications. However, the disadvantage of this technology is the cost of manufacturing equipment and add-on material and long production times.

Fig. 1 – Product made by Laser Sintering

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WAAM technology uses welding technology to lay the individual weld passes up to the final shape. For WAAM can be used conventional welding robots and CNC gantry machine installed with a welding torch, which moves according to the programmed path. This technology, rather than small components, can effectively produce large machine components. Currently, WAAM is being developed for use in the aerospace industry to reduce BTF (Buy to Fly). The idea is to reduce the amount of waste material generated during production and thereby reduce aircraft sales prices. [1]

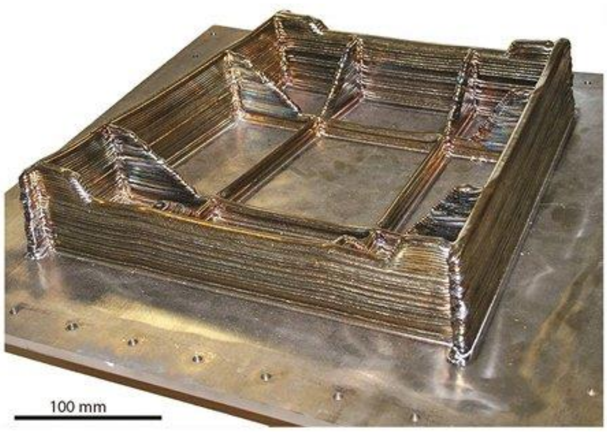

Fig. 2 – Part of the 24 kg chassis of Bombardier made from Ti-6Al-4V [2]

$$BTF = \frac{\text{raw material used for a component}}{\text{weight of the component itself}} \quad (1)$$

1.2. Shielding gases for welding

The main role of shielding gas in welding is to prevent the surrounding atmosphere from entering the weld pool, maintaining arc stability and protecting the electrode. Shielding gases also have a major impact on the type of weld metal transfer, thermal energy transfer, welding speed, etc.

The shielding gases are usually divided into active and inert gases according to their chemical reaction with the weld pool

Representative of inert gases:

argon Ar – single atomic gas, has low thermal conductivity and low ionization potential, does not form any element of chemical compound

Representative of active gases:

carbon dioxide CO_2 – it has a high thermal conductivity and thus causes a high heat transfer to the weld pool

oxygen O_2 – greatly increases the fluidity of the weld pool and increases its surface tension, which improves the degassing of the weld pool

Fig. 3 – Integra cylinders with shielding gases from Air Products [3]

2. Experimental part

The object of the experiment is to weld the structures using a programmed circular path with a total of 50 layers. For each continuously welded structure, Air Products, Inc. shielding gas was used, but with a different composition each time. The wire feed speed parameter was constantly set for each process of cladding. CMT was used as a welding process to reduce the heat input during the welding process.

2.1. Experimental workplace

The main part of the experiment took place in the interfaculty Laboratory of Welding Technologies situated at Department of Manufacturing Technologies CTU Prague, which has, among other things, a robotic workplace for arc welding. This workplace contains the universal 6-axis FANUC Arc Mate 100iC robot with a maximum reach of 1420 mm. There is also a one-axis positioner FANUC P250, welding source for MIG/MAG and TIG welding, with additional wire feeders and Integra cylinders with shielding gases from Air Products, Inc.

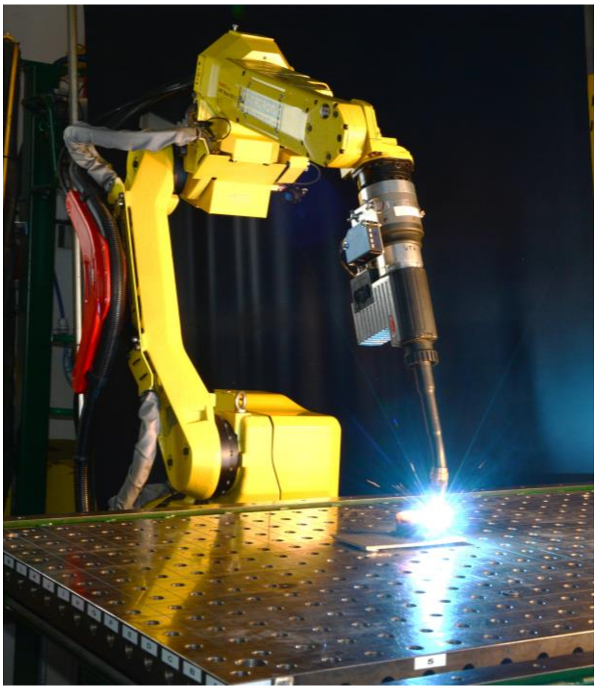

Fig. 4 – Experimental workplace

2.2. Parameters of experiment

The welding parameters set for each sample were the welding wire feed rate of 2.4 $m.min^{-1}$ and the shielding gas flow of 15 $l.min^{-1}$. As filler material was used G 42 3 C G3 Si1 with diameter of 1 mm. Maxx® shielding gases with the composition given in Table 1 were used.

Table 1 - Composition of used shielding gases [4]

Maxx Gases®	**Composition in %**		
	Ar	**CO_2**	**O_2**
Ferromaxx®7	90,5	7	2,5
Ferromaxx®15	82,5	15	2,5
Inomaxx®2	98	2	-

3. Evaluation of experiment data

The evaluation of the experiment was carried out by measuring the EWT and SW parameters on the transverse metallographic section of welded structure together with their overall effective height. The results are reported in in Table 2.

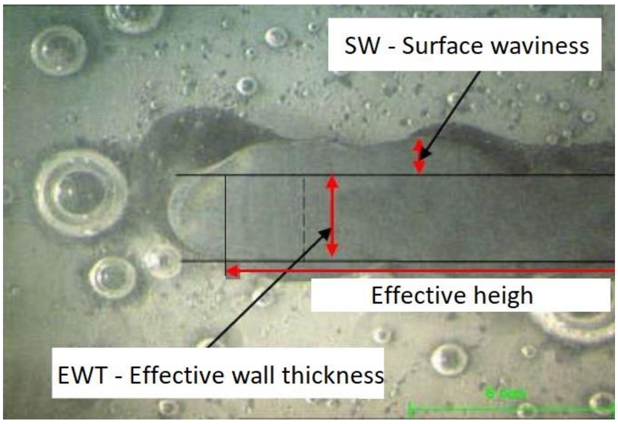

Fig. 5 – A preview of the methodology for measuring EWT, SW and effective weld height parameters [5]

Table 2 - Measured parameters of samples in millimeters

Maxx Gases®	Geometrical parameters			
	Heigh	**EWT**	**SW left**	**SW right**
Ferromaxx®7	58,2	2,4	1,6	1,5
Ferromaxx®15	59,6	2,9	2,4	2,3
Inomaxx®2	57,5	2,9	1,2	1,2

From the obtained data it can be assumed that the gas with the lowest CO_2 content has the lowest thermal conductivity of all used shielding gases. Thus, together with the CMT process, it ensures that the weld does not shrink significantly due to high temperature. The effective wall thickness of the Ferromaxx®15 shielding gas containing 15 % CO_2 is the same as that of the Inomaxx®2 protective gas containing only 2 % CO_2. At the same time, it can be observed that by reducing the CO_2 content, regular surface waviness has been achieved on both the inner and outer surfaces of the weld even half the value of the Ferromaxx®15 shielding gas.
From previous experiments (2018, Gurcik, Stability of WAAM process, Master thesis, CTU in Prague) it can be concluded that the use of a protective atmosphere with 2 % CO_2 together with copper-plated wire for refined and thermomechanically reinforced fine-grained steels could achieve better results. With a protective atmosphere of 18 % CO_2, EWT values of 4.3 mm and SW values of 1 mm on both sides were measured with an effective weld height of 65 mm at the same parameters as in this experiment.

4. Conclusion

The aim of the experiment was to determine the influence of various shielding gases used in welding on the geometric quality of the structure made by the additive WAAM technology. According to theoretical assumptions, it has been confirmed that the atmosphere with the lowest CO_2 content is best suited to the geometric stability of the welded structure from all the shielding gases used.
The experiment helped establish another of the many variables in the process WAAM. Furthermore, it is already possible to monitor the integration of the sensor systems of the robotic device for monitoring the entire process and correcting the movement of the welding torch during the WAAM process.

Acknowledgment

This way I would like to thank Air Products Ltd. for the provision of sufficient quantity and types of protective atmospheres for the realization of this experiment.

Terminology

WAAM	Wire and Arc Additive Manufacturing
BTF	Buy to Fly ratio
EWT	Effective Wall Thickness
SW	Surface Waviness
CMT	Cold Metal Transfer

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