ÓBUDA UNIVERSITY

PHD THESES

ATTILA ZSOLT KENÉZ

Applicability of joining technologies for fixing drill bit segments

Supervisor:
Dr. Gyula Bagyinszki

DOCTORAL SCHOOL ON MATERIALS SCIENCES AND TECHNOLOGIES

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1. Background

There is an increasing demand from the construction industry for tools (for the planned or improvised machining of concrete on site), typically used for chiselling, drilling, channelling, surface finishing and wall breaking. Such machining operations are effectively carried out with diamond edge tools manufactured by powder metallurgy. The segments containing diamond grains are mounted on replaceable inserts or steel tool bodies for cost-effectiveness. The joining technology used must meet technical requirements, as the joining zone is subjected to high mechanical and significant thermal stresses during use. In the event of a defective bond, the segments may detach from the base structure.

Diamond segments are fixed by various methods of welding or soldering. The evolution in the composition and geometry of the segments also requires the development of bonding technologies.

In the first part of my research, I examined the laser welded joint of the powder metallurgy segment and the steel tube in detail to obtain information about the hardness of the joint, the microstructure and possible joint defects. I compared the test results with those reported in scientific publications [1-6]. In addition, I developed an in-device fracture test based on a materials testing machine to replace the manual fracture test. I considered the results obtained as the baseline condition and performed these tests in the technological experiments for comparability.

In the second part of my research, I looked at how different joining methods affect the bond. Among the different welding and brazing processes, I selected capacitor discharge welding [7] and flame brazing [8]. I compared the results of the investigations on the joints with the results of the laser welded joint and selected the joint process for further experiments based on the series production criteria.

In the third part of my research, I investigated the effects of laser welding process parameters [9] and different surface cleaning methods [10-14] on the properties of laser welded joints to improve the strength of the joint. The results were compared with the investigation results of the first part.

In the fourth part of my research, I examined the measured hardnesses in the weld and compared them with values determined by known hardness prediction equations [15-18].

2. Objectives

Based on the literature of the powder metallurgy segment and steel tube joints, I have defined the research objectives in the following thematic areas.

2.1 Investigation the laser beam welded seam

To understand the initial condition before welding, it is necessary to examine the two components, the tube and the segment. For the tube I planned to perform geometric and spectrometric tests, while for the segment I planned to perform density, shrinkage and hardness measurements, followed by transverse bending tests and fabric structure tests. I will use the results for the weldability test.

I planned to perform a CT scan before laser beam welding, then after sectioning and embedding I will look for weld defects, perform microstructure, scanning electron microscopy, energy dispersive studies and conclude with hardness measurements. I will compare these results with those obtained in the technological experiments.

2.2 Developing the fracture test

To complement the tests planned in the previous subsection, I also planned to carry out a fracture test. I aimed to develop a fracture test that could be carried out in a materials testing machine to reduce the variance of the manual torque wrench fracture test. This new fracture test is also use in the technological experiments.

2.3 Testing the effect of different joining methods

I have mapped out the bonding processes that drill bit manufacturers use in their products, and I plan to conduct technological experiments with these processes. I will compare the results with the test results obtained in the previous sub-chapters. My aim is to determine the binding technology to be used in further tests.

2.4 Investigation of factors affecting the properties of laser welded seams

My aim was to investigate the effects of welding process parameters, i.e. laser power, welding speed, defocus and weld position on the break out value. Using an experimental design method, I would like to determine the individual effect of each process parameter and then also the effect of the process parameters on each other.

I also aim to compare the effect of several different laser sources on the break out value and to investigate how different chemical, mechanical and laser surface cleanings affect the weld and break out value. The results obtained will be compared with the test results obtained in the previous subsections.

2.5 Hardness testing in laser beam welded seams

My aim is to find hardness prediction equations for the measured hardness values in laser beam welded seams based on the literature and compare the measured and calculated values.

3. Test methods

After visual inspection of the specimens produced during the technological experiments, I subjected them to computed tomography scanning, looking for seam defects in the resulting images.

During the fracture test (I performed in-device according to the new method), the force-displacement diagram was recorded, from which, in addition to the average breaking force and average deflection, the minimum breaking force and the work done in fracture could be determined. These values were compared with the test results of the standard product and the percentage of deviation was determined. In the case of a significant effect (+20% or more), it is worth examining the sample in more detail.

I cut a section at predetermined positions and after embedding, I continued to look for seam defects by microscopic examination. I used these embedded samples for further scanning electron microscopy and energy dispersive studies, which provided an even more detailed picture, and an elemental map.

I used the embedded specimens for the microstructure tests and then for the hardness measurements, so I examined the same area using different methods.

I summarised the results by test method and by technological experiment to get an overall picture of the sample.

4. New scientific results

1. In the case of the mixed bond tests of the E235+C steel tube and the powder metallurgical segment, the fracture test carried out by the material testing machine I developed for the 100 mm OD replacement module reduced the standard deviation of the fracture values in terms of breaking force to 1.64 compared to the standard deviation of the fracture value of 2.24 for the manual fracture test, while the minimum, average and maximum fracture values showed very similar values in the two fracture tests. [S1]

2. Based on comparative technological experiments carried out on a 100 mm OD replacement module to form a mixed joint between the E235+C steel tube and the powder metallurgical segment, I found that laser beam welding is the most suitable for series production as opposed to capacitor discharge welding and flame welding. [S2], [S3], [S4]

3. In laser beam welding process parameter experiments on the E235+C steel tube and powder metallurgy segment for the 100 mm OD replacement module, I demonstrated that reducing the laser power from 2800 W to 2400 W increases the breaking force, further reducing the laser power also reduces the breaking force. In addition, changing the weld position in the range 0...-0.3 mm gives a good fracture value, at lower position values the fracture value falls below the minimum fracture torque of 9 Nm. Furthermore, I have also demonstrated that defocus in the range +0.25 ... -1.25 mm has no effect on the fracture value when the laser power and the weld position value are not changed. [S1], [S5]

4. Based on the microstructure studies of the laser welded joints of the E235+C steel tube and the powder metallurgical segment, I found that the number of gas seals at the segment-weld interface can be significantly reduced and the microcracks originating from them can be eliminated by surface cleaning in the 100 mm OD replacement module. Furthermore, it also eliminates gas inclusions in the weld and improves the fracture toughness of the joint, regardless of the type of process. [S6], [S7]

5. Utilization possibilities of the results

The need for research from industry arose to see if there was another joining technology besides laser beam welding that could produce drill bits with the same throughput capacity but at a lower cost.

In addition, what methods can be used to increase the strength of laser welded seams if the composition of the powder metallurgy segment changes according to environmental regulations or development trends.

Furthermore, it has also become necessary to develop a testing method that is more stable and more accurate in determining the breaking force by excluding human force.

Both the seam strength improvement procedures and the new testing method can be immediately integrated into the production of the drill bit series based on the results obtained.

Research can be continued with a more detailed study of surface cleaning procedures, which focusing on possible changes in the composition of the seam, and the effect of the amount or composition of the shielding gas on the weld.

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