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Apparatus for Bulge Testing Metal Foils using a Laser Scanner

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Abstract

A fast, cost effective and simple methodology and testing apparatus was developed for testing basic material properties of thin (up to 0.05 mm) metal sheets during production. The method is based on the bulge test method. Air is used as a pressurizing medium and specimen deformations are measured using a 2D laser scanner. Test control and software for evaluating results was programmed in MATLAB using the GUI feature. The testing procedure and test assembly were developed with the accent on simplicity and obtaining fast results, which are both necessary for fast product testing during the manufacturing process.

Keywords: metal foil; material testing; bulge test; laser

1. Introduction

The demand for a simple and fast method for testing the material properties of thin metal foils during the manufacturing process has arisen from one of our industrial partners. The requirements for such a method were:

- must be fast – results within a maximum of a few minutes from obtaining the sample of the foil to be tested
- easy setup and no special skills or special training for operator required – only fast and simple training
- testing assembly must be compact, no need for special tools or facilities
- very low test price per tested sample (no need for special consumables, etc)

Based on these requirements, a normal tensile test method is not acceptable. The main problem faced was the preparation of proper specimens with equal quality (repeatability) for tensile testing. Cutting out a specimen of metal

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foil with a thickness less than 0.05 mm can be very difficult when the quality of the borders of the cut specimen is crucial for further results. Especially when specimen preparation must be fast and simple as required for on side testing. Any imperfections in the borders of such a thin foil specimen would dramatically affect tensile test results. Also, tensile testing such thin foils would be very dependent on applying exactly axial forces. Therefore testing equipment and all operations must be very accurate.

Based on this, the bulge test method [1,2,3,5] was chosen. One advantage of this method is that the borders of a test sample do not affect the results, so sample preparation is simpler. This is because the diameter of the specimens is larger than the tested area, see Fig. 1.

2. Bulge test

The bulge test method is used for testing sheet specimens. It is based on applying pressure on one side of the specimen while measuring its deflection [1], see Fig.1. Specimens are in most cases circular so deformations and stresses are axis symmetrical and therefore easy to calculate or simulate.

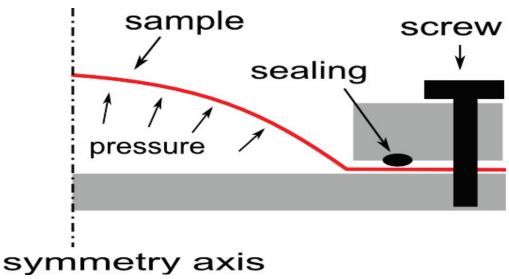

Fig. 1. Bulge test diagram.

Material properties are calculated from applied pressure and resulting deflection relation. Various methods exist for measuring and evaluating deflections. Most of them are based on capturing a series of images of the deflecting specimen followed by analysis of the images. An example of a commercially available system is ARAMIS [4]. These systems require one or two cameras and sophisticated algorithms for image analysis, therefore ready to use systems are very expensive. Contact measurement of deformations is also not possible due to the very thin, light and soft specimen made of thin foil. Anything attached to such a foil specimen, even paint (often used for easier image analysis), would devaluate the measurement results. Length measurement by laser was chosen from all the available non-contact methods..

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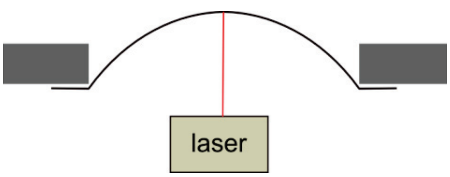

Fig. 2. 1D laser sensor.

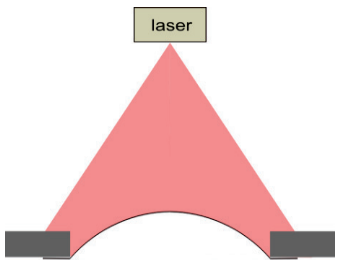

Fig. 3. 2D laser scanner.

Firstly a 1D laser sensor was tested. It measures only one point, so was focused in the middle of the test sample where the highest deformation occurs. No other data are available, therefore the profile of the deformed specimen must be approximated for further calculation. Therefore many assumptions and approximations must be applied.

A 2D scanner provides a whole profile – line of points, see Fig. 2, Fig. 3. No approximation is needed and also it allows measuring the material properties of metal sheets with orthotropic behavior (specimens from the same tested sheet are measured when turned to different angles).

3. Test platform

The test platform was made compact for easy transport as was demanded by the client. The support plate is made of 5mm thick stainless steel and holds all the necessary equipment. Pressure is controlled by a needle valve located close to a pressure sensor to minimize the volume of the air in the pressurized parts of the system. This is necessary in order to minimize explosion effects due to air expansion after the test specimen breaks. A needle valve is needed for precise air flow and therefore proper control of the applied pressure. A manual needle valve can be exchanged for an electromechanical one for precise time dependant pressure control.

The specimen holder is based on a flange design. It is made of stainless steel rings with six bolts for proper tightening. Bolts are oriented upwards so they also work as rails for the upper part of the holder. Proper alignment during holder locking is very important because any side movements of the upper part of the holder against the lower one while the tested specimen is present could damage that specimen.

Displacement of the specimen is measured by a Micro-Epsilon scanCONTROL 2700-100 laser scanner. It has a measuring range from 350mm to 450mm (distance from measured object – z-axis) with resolution 40µm and provides up to 640 points per profile providing resolution in x-axis approximately 0.16mm (100mm profile width, which depends on the exact distance of the measured object from the laser base). Its sampling rate of up to 100Hz is sufficient even for tests with a fast increase of loading. The developed software stores all the profiles during the test, providing the possibility for determination of load speed behaviour and further analysis.

The design of the platform (see Fig. 4) provides the possibility for easily switching from using air as a pressurizing medium to oil, which is more suitable for measuring with higher levels of pressure. Based on pretesting, using air for pressure levels above 0.5MPa is not recommended due to explosion effects after the specimen rips apart (mostly due to operator safety).

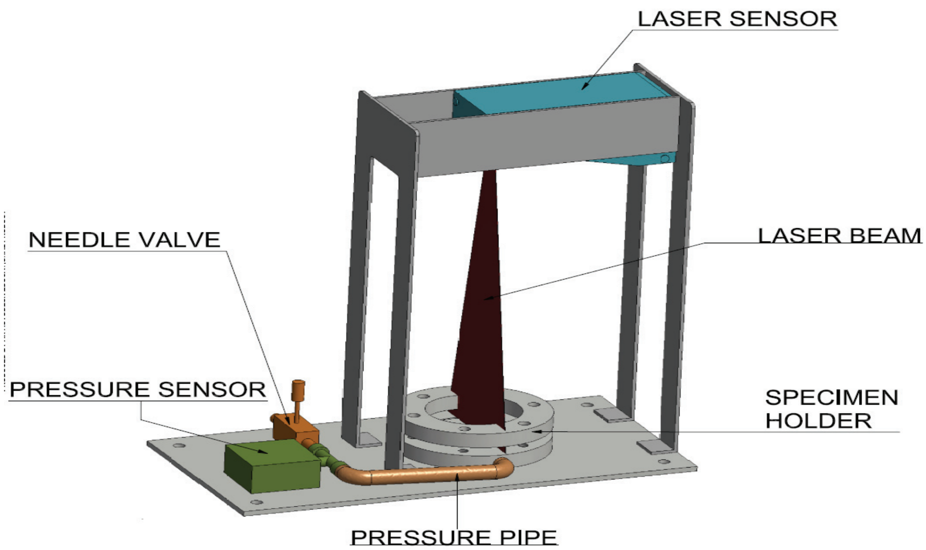

Fig. 4. Test platform.

4. Specimen preparation

As mentioned above, specimen preparation is crucial for proper test results. It was also one of the most important reasons to choose the bulge test as a testing method. The working area of the apparatus is 8 cm in diameter (area of the specimen where pressure is applied). Specimens are made with a diameter of 10cm, therefore the borders of the specimen do not influence the test, see Fig. 1. For easier handling and faster specimen preparation, a tool for cutting the specimen was made, see Fig. 5.

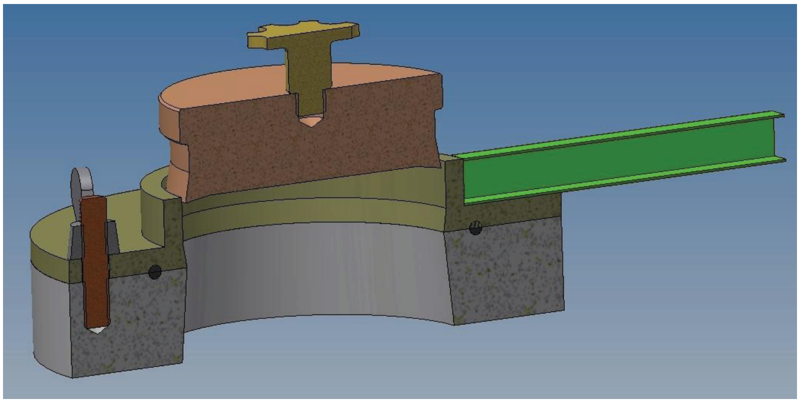

Fig. 5. Die for specimen preparation.

5. Conclusion

Bulge test apparatus for testing thin metal foils was developed because regular tensile testing of the metal foils faces many difficulties especially during specimen preparation. Preliminary testing validated its design and proved it is appropriate for obtaining proper material data. Using air as a pressurizing medium proved simple and easy to use but it limits the pressure levels due to operator safety. The apparatus also allows use of oil or water as pressurizing medium allowing testing tougher samples. Switching the manual needle valve for a computer controlled electromagnetic one will allow precise testing of material properties based on different load speeds. Further improvement of the methodology and testing will follow.

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