Plastic Deformation of Reinforced Aluminum Plates with Polyurea Coating under Impulsive Loading

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ABSTRACT

A single-stage gas detonation apparatus was used for the free forming of metallic-polymeric structures. In the experimental section, to improve the performance of aluminum plates under gas mixture detonation loading, a layer of polyurea material was sprayed onto the back surface of the metallic plate. To investigate the effect of the thickness of the metallic and polymeric layers on the dynamic response of the structure, aluminum plates with different thicknesses of 1, 1.5, 2 and 2.5 mm, as well as polyurea coatings with different thicknesses of 3, 4, 5 and 6 mm, were used. Experimental results showed that spraying the polyurea coating onto the back surface of aluminum plates can significantly reduce the maximum permanent deflection of the structure and also prevent the rupture of the aluminum specimens. In the numerical modeling section, the Group Method of Data Handling (GMDH) neural network was used to present a mathematical model based on dimensionless numbers to predict the maximum permanent deflection of metallic-polymeric structures under impulsive loading. To increase the prediction capability of the proposed neural network for this process, the experimental data were divided into two training and prediction sets. The results showed that good agreement between the proposed model and the corresponding experimental results is obtained and all data points are within the ±10% error range.

KEYWORDS

Aluminum, Polyurea, Gas detonation forming method, Neural network, Modelling.

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1. Introduction

Up to now, a high energy rate sheet forming against impulsive loads is mostly performed using a ballistic pendulum method with the aid of plastic explosive charges [1, 2]. In the last decades, the gas mixture detonation approach [3-9] has been used to sheet and tube forming processes instead of using the ballistic pendulum. The main advantages of gas detonation forming methods are easy automation, clean combustion, higher safety in comparison with using plastic explosive charges, little requirement for external devices and good formability for different materials. So, it seems necessary to track investigations on possible utilization of this method concerning forming technology to design an economic appliance. It is noteworthy to mention that less experimental investigations have existed in the literature about the forming of metal plates using gas detonation method.

The influence of polyurea coatings on the dynamic plastic response and failure mechanism of polyurea-coated metallic plates under extreme dynamic load has been an interesting research topic in recent years. Several investigations on the dynamic behavior of polyurea-coated steel plates subjected to impulsive loading have been conducted, whereas no experimental study has been reported on polyurea-coated aluminum plates using gas detonation forming technique. To this end, eight different types of PU-Al plates with the same layering configuration have been tested under five different loading intensities. Furthermore, experimental data are used to find an equation for predicting the deflection thickness ratio using the GMDH-type neural network and SVD method.

2. Methodology

To investigate the large transverse deformation and performance of polyurea-coated aluminum plates, a total of 40 specimens were designed and fabricated. Different layering thicknesses were used. The tests were conducted by using a single-stage gas mixture detonation apparatus, which was designed and manufactured at the Impact and Blast Laboratory of the University of Guilan (IBLUG). The dynamic plastic response quantities including maximum permanent transverse deflection of polyurea-coated aluminum plates, the pre-detonation pressures of the gas mixture, and pressure-time history after detonation were measured and documented.

The gas mixture detonation testing apparatus used for studying the free forming of polyurea-coated aluminum plates has been schematically demonstrated in Figure 1, which was placed in the explosion-protected area of IBLUG.

Figure 1. Gas mixture detonation apparatus at the University of Guilan

This experimental setup includes four main units: 1) ignition unit, 2) gas flow control unit, 3) pressure measurement unit, and 4) forming unit. The ignition unit consists of a seamless steel combustion chamber with 120 mm inner diameter, 40 mm wall thickness and with a length of 530 mm which is filled with acetylene and oxygen cylinders using two controlling valves for adjusting the pre-detonation pressure of each gas inserted into the chamber. The gas mixture is detonated at the closed end of the combustion chamber using a spark plug. The detonation wave is generated, and moves forward through the combustion chamber and then applies to the specimen. In this experimental setup, the length of the chamber in comparison to specimen dimensions is great, and as a result, the distribution of gas mixture detonation load can be assumed uniform over a plate [3-9].

3. Discussion and Results

To investigate the resistance of polyurea-coated aluminum plates subjected to gas detonation loads, all configurations were tested under five different pre-detonation pressures of acetylene and oxygen mixture with progressively increasing detonation pressure. To better understand and explain the effects of polyurea and aluminum layer thicknesses on the maximum permanent transverse deflection of polyurea-coated aluminum plates, the clustered column charts have been used in Figures 2 and 3. To present the GMDH-type neural networks for conducted experiments, two different sets of data were generated, namely the training set and the testing set. It is clear that the training set that contained 25 data pairs out of 33 input-output data, is used to train the GMDH-type neural network models by employing the SVD approach. The data for the training set was selected randomly, and to demonstrate the ability of the neural network in finding the optimal coefficients of quadratic polynomials, 8 unforeseen testing input-output data was used through the training process. The obtained quadratic polynomial based on the GMDH-type neural network were presented in the Persian format of this paper. Figure 4 shows the modelling and prediction mid-point deflection thickness ratio, using the GMDH-type network model constructed with a singular value decomposition approach for the coefficients of the quadratic polynomials. It is evident from Figure 4 that all experimental data points were located between the less than 10% Error lines.

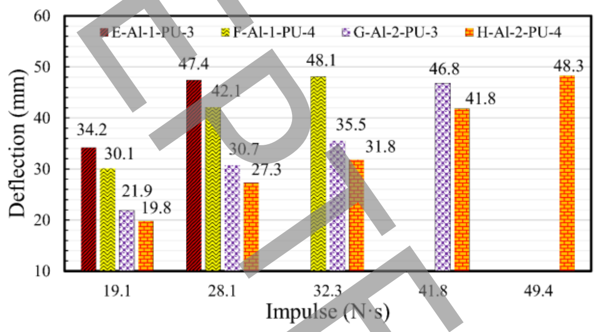

Figure 2. Variation of the maximum permanent deflections of coated aluminum plates versus impulse (Experimental groups: E, F, G, and H)

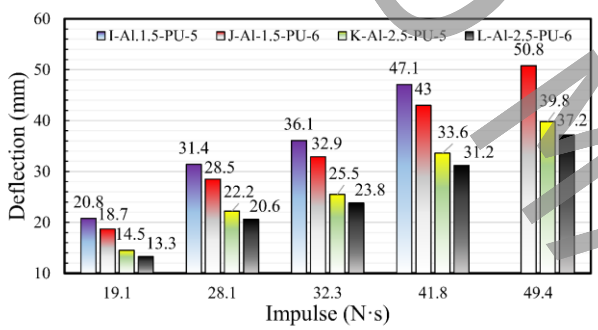

Figure 3. Variation of the maximum permanent deflections of coated metallic aluminum versus impulse (Experimental groups: I, J, K, and L)

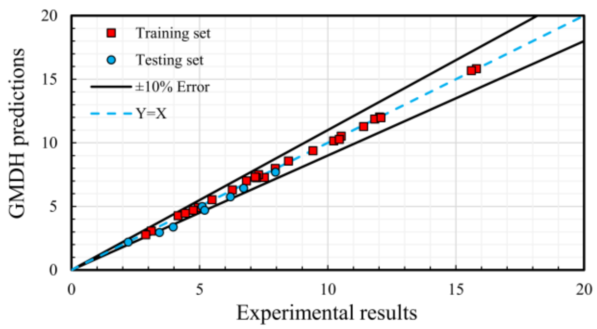

Figure 4. Comparison of experimental results and mathematical model presented by GMDH neural network

4. Conclusions

In this paper, 40 experiments were performed to evaluate the influence of polyurea coatings on the dynamic plastic response of coated aluminum plates under gas mixture detonation loading. The experimental results showed that the polyurea coating significantly improved the resistance of aluminum plates due to increasing the tangent modulus while it is sprayed onto the rear side of metallic specimens.

5. References

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