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Research Article

Study on the Ultimate Strength and Stability of Food Stiffened Plate

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Abstract: Based on the buckling strength of food stiffened plate as the breakthrough point, this study explores the elastic-plastic stability and conducts the stability series analysis of food stiffened plate by virtue of the analysis of longitudinal in-plane load and lateral pressure load of the food stiffened plate frame. The stress state of the food stiffened plate structure is very complex, which is subject to not only the longitudinal pressure caused by the longitudinal bending, but also the lateral pressure of the water. Therefore, it is necessary to consider the full load suffered, in order to calculate the buckling strength of stiffened plate more accurately.

Keywords: Buckling strength, food stiffened plate, stability

INTRODUCTION

When the stiffened plate is subject to local buckling, the buckled plate can be counted into the beam profile and the overall buckling is calculated according to the intersecting beam system. Betten and Shin (2000), Maiorana *et al*. (2009a) calculated the critical stress of the intersecting beam system in the case of overall buckling of the plate frame under different circumstances, of which (Shanmugam *et al*., 1999) converted the intersecting beam system to the continuous beam supported by a series of springs and adopted the vibration analogy method to seek its natural frequency of vibration, thereby gaining the critical stress.

In practice, the stress state of the food stiffened plate structure is very complex, which is subject to not only the longitudinal pressure caused by the longitudinal bending, but also the lateral pressure of the water. Therefore, it is necessary to consider the full load suffered, in order to calculate the buckling strength of stiffened plate more accurately. Maiorana *et al*. (2009b) have done a lot of work in these aspects. In addition, due to the processing and manufacturing, etc., the food structure is bound to have initial defects, including welding residual stress, initial deflection and eccentricity, which tend to make the bearing capacity of the structure decreased. Therefore, the influence of initial imperfections must be considered as far as possible in the case of the study of the buckling strength and ultimate strength of the stiffened plate.

MATERIALS AND METHODS

Elastic-plastic stability of food stiffened plate frame: In the case of instability of the actual plate frame, the compression stress of some materials is near to the nonlinear state, which needs to calculate the elastic-plastic stability. The traditional commonly-used calculation method introduces the idea of stress modification for the compressive stress entering into the nonlinear state, which means after the Euler stress is obtained by analytic formulas or finite element method according to the elastic analysis, the critical stress is obtained through the correction of table, map or formula. Generally, $\sigma_E/\sigma_y \sim \sigma_{cr}/\sigma_y$ curve is used to calculate this effect. For the steel, if $\sigma_E/\sigma_y \geq 2.5$, then the stability is guaranteed; otherwise, the corresponding σ_{cr} should be found out according to the value of σ_E/σ_y; the pressure suffered by the structure is required to not greater than σ_{cr} and have sufficient stability reserve. As the correction curves of various materials are different, the complex structure makes the distribution of internal

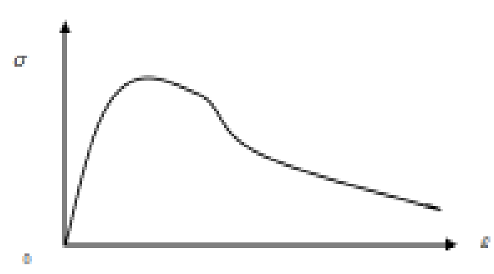

Fig. 1: The compressive stress-strain curve

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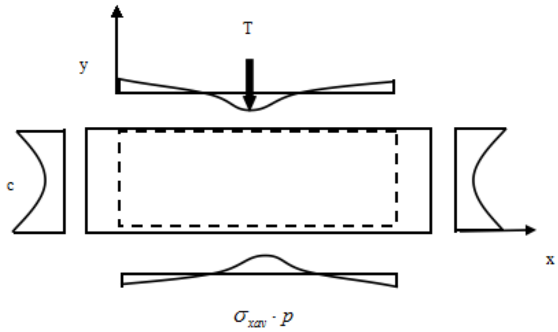

Fig. 2: Stress distribution of food stiffened plate

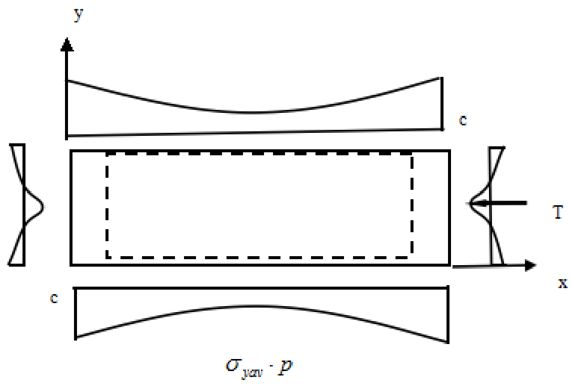

Fig. 3: The stress distribution of food stiffened plate

stress for each component unbalanced, the tangent modulus change is different and it is similar to conduct simple processing with unified correction method. The more accurate solution can be obtained only by directly using the compressive stress-strain curve to describe the nonlinear effect of the material. The compressive stress-strain curve obtained based on empirical formula is shown in Fig. 1. The curve matches the test structure well, which has been widely used in practice.

Longitudinal in-plane load and lateral load: The ultimate strength formula of the longitudinal in-plane load and lateral load model was put forward in 1995. At that moment, the stress distribution of food stiffened plate is shown in Fig. 2. The longitudinal ultimate strength of the failure mode I is σ^{I}_{xu}; the plate is mainly subjected to the longitudinal in-plane load σ_{xav} (σ_{yav} = τ_{av} = 0) and the lateral load p is the minor load. In the present study, we consider that the orthotropic plate has been damaged if the edge of the plate is yielded.

With the increase of deflection displacement of the plate, the initial yield will occur on the central part of the upper and lower edge of the plate due to the deflection. However, the plate will not be destroyed as long as the load along the linear edge of the plate is redistributed under the stress of the thin wall. When most of the pressure edges are yielded, the plate has been destroyed, because the plate edge can not be kept in a straight line, resulting in a rapid increase in the lateral deflection of the plate as well as resulting in plastic point. Therefore, in the Paik's ultimate strength formula, it is assumed that the plate is destroyed when plasticity occurs on the plate edge.

Transverse in-plane load and lateral load: When the plate is mainly subjected to the transverse in-plane load σ_{yav} (σ_{xav} = τ_{av} = 0), the lateral load p is the minor load. The stress distribution of food stiffened plate is shown in Fig. 3.

RESULTS AND DISCUSSION

Local buckling of food stiffened plate: During the local buckling of the stiffened plate between reinforcing bar (failure mode II), it is assumed that if the plate between reinforcing bar is yielded at the junction of the stiffened plate with maximum stress, with the increase of the stress at the junction of the stiffened plate, the yield strength of the plate is reached ultimately and then it is considered that the structure is collapsed. Thus, such failure mode should consider enhancing the diagonal yield of the plate grid between reinforcing bar. Limited experience indicates that the failure mode occurs when the stiffened plate is mainly subjected to the in-plane load. In this case, it is ideally considered that the plate grid between reinforcing bar is mainly subjected to four kinds of load: the maximum compressive stress in x plane, the maximum compressive stress in y plane, the average shear stress τ_{av} and the lateral pressure load. The effect of initial deformation and welding residual stress as the parameter should be also considered. The stress distribution of the cross-section can be obtained by using the nonlinear control differential equation of the plate's large deformation theory.

Buckling strength of the food stiffened plate: There has been a lot of calculation formula of ultimate strength for the beam-column buckling of food stiffened plate (failure mode III) in literature and engineering practice, such as (Pellegrino *et al*., 2009). In these studies, however, the plate is only subject to one-way pressure, in which a series of complete a series of related load must be considered in the design of food stiffened plate and the effect of effective ribband width must be considered. The failure modes caused by the failure of the plate and the rib should be calculated. If the food stiffened plate is mainly subjected to the in-plane pressure, the beam-column theory can be used for analysis. It can be considered that the structure reaches its ultimate strength in the case of beam-column type buckling of the rib and its accompanying ribband at the place with maximum compressive stress in the cross section. Obviously, the width of its effective accompanying ribband decreases gradually before the complete loss of bearing capacity of the whole plate.

It is ideally considered that the plate grid between reinforcing bar is mainly subjected to four kinds of load: in-plane stress σ_{xM}, σ_{yM}, shear stress τ_{av} and lateral pressure load p. When discussing the effective ribband, the welding residual deformation and residual stress should be considered. For the rib reinforcement, the effect of these initial imperfections is not considered. Because if the effect of these initial imperfections is considered, the strength of the rib reinforcement will be smaller and then the calculation of the model is converted to the calculation of model one.

Stability series analysis of food stiffened plate: In the structural safety, in addition to the strength of the structure, the stability of the structure is also an important problem in the structural design, which has always attracted the attention from the majority of scholars. The modern structure trends to be large and light and the stability is more and more prominent. Structural instability is a deformation problem, which refers to the sudden change of the structure from the initial shape to other shapes. At that time, the average stress is called buckling stress, which is closely related to the structural size, type, boundary conditions and distribution form of load.

According to the analysis results of the buckling of special values, the effect of the opening holes on the elastic buckling strength of stiffened plate can be expressed through plotting. The round hole can reduce the buckling strength of stiffened plate. With the increase of the hole diameter, the buckling strength decreases gradually. With the increase of the plate thickness, the reduction of the buckling strength increases, namely with the increase of plate thickness, the buckling strength trends to be decreased more obviously, which is consistent to the distribution law of elastic buckling strength under different holes displayed. With the increase of the plate thickness, as the buckling strength caused by the round hole decreases slowly, this is just the opposite to the tendency of elastic buckling strength. With the increase of plate thickness, the instability of stiffened plate transits gradually from elastic buckling to plastic buckling.

The change laws of the decrease percentage of buckling strength caused by the opening holes with the flexibility of the rib are as follows. The larger the flexibility coefficient of the stiffener is, the weaker the stiffener will be and the larger the decrease of the buckling strength caused by the round holes, namely the decrease percentage increases with the increase of the flexibility coefficient of the stiffener.

CONCLUSION

The effect of the lumbar round hole on the stability of food stiffened plate is similar to that of the round hole. The opening hole can reduce the buckling strength of stiffened plate. With the increase of hole size, the buckling strength decreases gradually. For the stiffened plate with different plate thickness but identical rib, with the increase of plate thickness, the reduction of the buckling strength caused by the hole decreases more obviously. For the stiffened plate with same plate thickness but different rib, with the increase of rib flexibility coefficient, the reduction of the buckling strength caused by the opening hole increases gradually.

REFERENCES

Betten, J. and C.H. Shin, 2000. Elastic-plastic buckling analysis of rectangular plates subjected to biaxial loads. Forsch. Ingenieurwes., 65: 273-278.

Maiorana, E., C. Pellegrino and C. Modena, 2009a. Non-linear analysis of perforated steel plates subjected to localised symmetrical load. J. Constr. Steel Res., 65: 959-964.

Maiorana, E., C. Pellegrino and C. Modena, 2009b. Elastic stability of plates with circular and rectangular holes subjected to axial compression and bending moment. Thin Wall. Struct., 47: 241-255.

Pellegrino, C., E. Maiorana and C. Modena, 2009. Linear and non-linear behaviour of steel plates with circular and rectangular holes under shear loading. Thin Wall. Struct., 47: 607-616.

Shanmugam, N.E., V. Thevendran and Y.H. Tan, 1999. Design formula for axially compressed perforated plates. Thin Wall. Struct., 34: 1-20.