OPTIMAL DESIGN OF COMPOSITE THIN-WALLED LAMINATED BEAM BY RANKING

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SUMMARY

We can get the maximum buckling load of an assigned materials, web thickness, weight, size and structure of composite laminated beam with sublaminates designed by Laminated Ranking Method. By comparing two kind of beams, the buckling load of optimal beam is greater than the quasi-isotropic beam 28.5% by experiments and 28.4% by analysis. That means we can reduce at least one-fourth the weight of the optimal beam by decreasing the number of piles to endure the same buckling load as quasi-isotropic beam. It will greatly increase the velocity and decrease the energy exhausted of industrial products with composite structure, such as airplane, automobile, marine, rail transportation system and so on.

INTRODUCTION

Currently many accepted facts show the composite thin-walled laminated structural beam tended to substitute metal beam because of keeping excellent strength and stiffness weight ratio. Therefore such kind of beam has been widely used especially in aeronautical and astronautical product application as well as used in civil industrial products. The main purpose of this paper is trying to enhance the anti-buckling ability of the composite thin-walled laminated beam by Laminated Ranking Design. In other words, we intend to increase the structural efficiency of the beam, and make the behavior of the industrial products improved.

PROBLEM STATEMENT

In order to express the main concept, an example of assigned materials, web thickness, weight, sizes and structure of composite thin-walled laminated beam is shown in Fig 1.

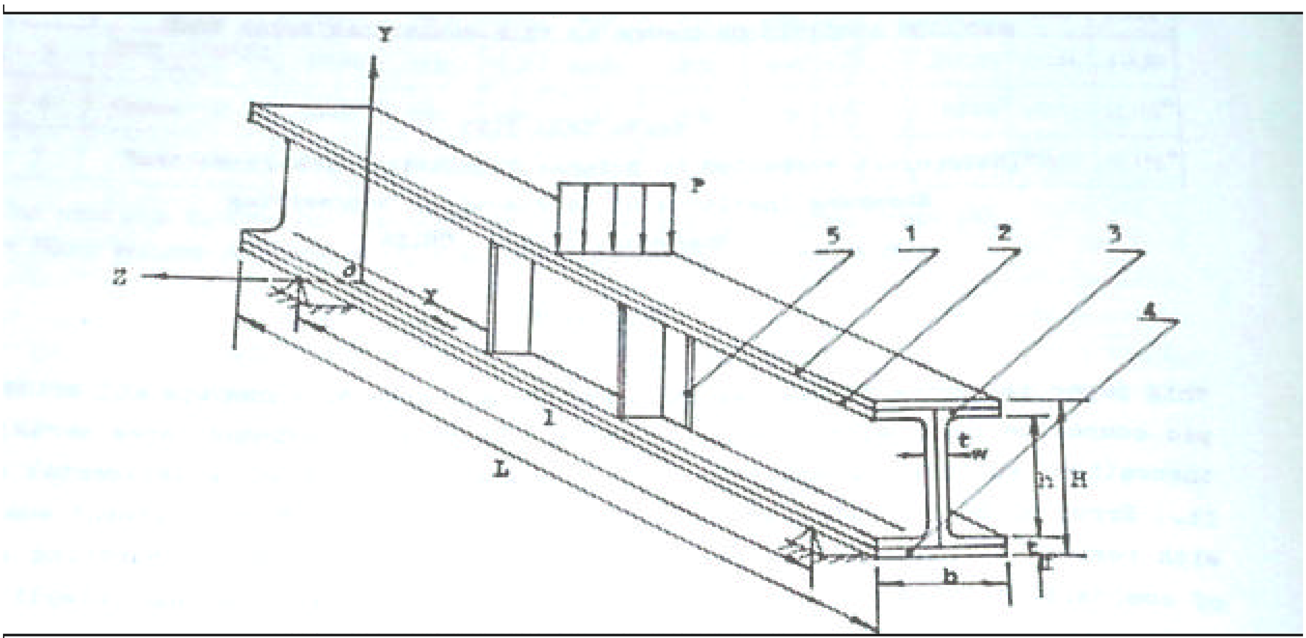

Fig 1. Composite thin-walled laminated beam
1------upper cover laminate 2------left web laminate
3------right web laminate 4------lower cover laminate
5------stiffeners

The beam has uniform cross section along its length, under the load of Three Points Bending Moment. Its size is list in Table 1.

Table 1. Geometrical size of thin-walled laminated beam

Length of Beam	L=0.84m	Web thickness	t_w=0.0055m
Span	l=0.794m	Flange thickness	t_f=0.0059m
Outer beam height	H=0.1364m	Flange width	b=0.0801m
Inner beam height	h=0.1246m	Beam weight	w=7.5kg

The beam structure is composed of five parts: upper cover laminate 1, lower cover laminate 4, left web laminate 2, right web laminate 3 and stiffeners 5. The assigned laminated beam with thirty-two piles either in flange or in web must be symmetrical about the beam axes. The beam is supported on MTS-810 material testing machine and load P is applied gradually from initial value to global buckling failure. In order to prevent from local buckling, it is necessary to cohere four stiffeners on the web near both sides of load P. Then the web is subjected bending and shearing, but there is no torsion induced in laminates, because P is acting in the symmetrical plane of beam structure.

Optimal design of beam laminate by Laminated Ranking

Beam laminate either in flange or web is assembled by sublaminates which is one kind of sublaminate families with two piles, four piles and four angles orientations i.e. 0, 90, 45, -45 degree in relative to the beam's main axis. In order to simplify analytical calculations, the family selected should be orthotropicly with each other, so that the components of flexural stiffeners of laminate such as D_{16},D_{26},D_{61},D_{62} will be vanished. According to <<THE COMPOSITE DESIGN>> [1] (Tsai's 4 Th edition). There are forty-five groups of sublaminates in above two kind families. Two piles family groups include [0 0 0 2], [0 0 1 1], [0 0 2 0], [0 1 0 1] …… [1 1 0 0] and [2 0 0 0]ten groups. Four piles family groups include [0 0 0 4], [0 0 1 3], [0 0 2 2], [0 0 3 1] …… [3 0 0 1], [3 0 1 0], [3 1 0 0] and [4 0 0 0] thirty-five groups. After a series of buckling analysis two kind of sublaminate code [0 0 1 1] and [0 0 2 2] are the best to get the same maximum buckling load among those sublaminates families groups. It is of course more reasonable to select [0 0 1 1] code as the sublaminate of the beam's laminate. So $(45/-45)_{8}$s is the actual selecting laminate code which can satisfy all conditions indicated of thin-walled laminated beam.

EXPERIMENTAL AND ANALYTICAL RESULTS

It is reasonable to compare two kind of laminated beams with same size, materials, weight and structure. The one is optimal designed beam and another is quasi-isotropic beam code $(0/90/45/-45)_{4s}$. The paper " Buckling Analysis of Composite Thin-Walled Laminated Beam " [2] might be applied to compute the buckling load of these beams. The optimal beam is 46.06 KN and the other one is 38.85 KN. The situations of applied load are shown in the Fig 2. And Fig 3.

Fig 2. State of applied load on testing machine

Fig 3. State of applied buckling load on testing machine

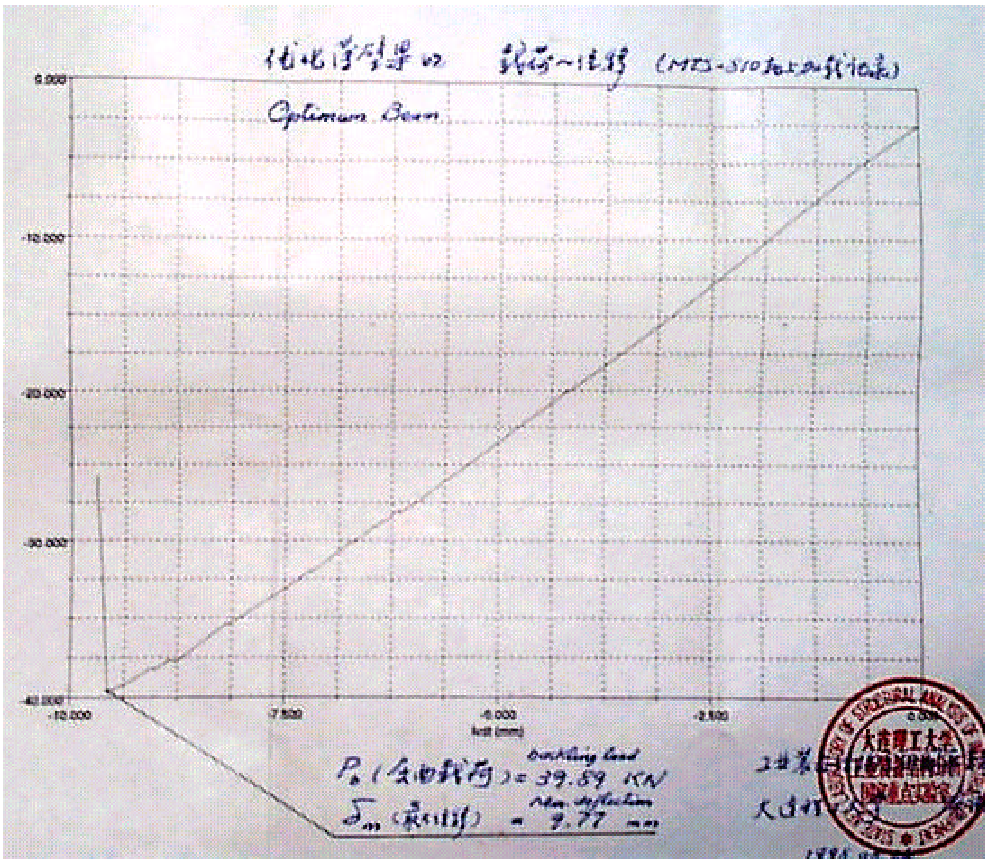

Fig 4. Record of buckling load & maximum deflection of optimal beam by machine computer

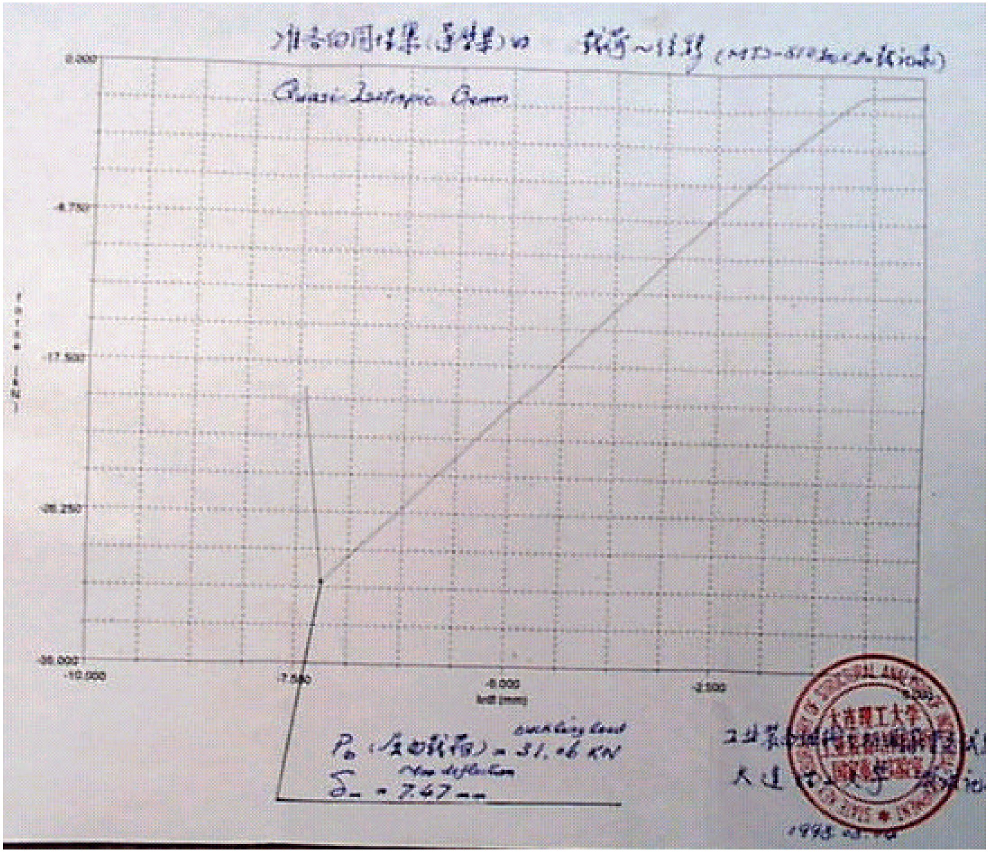

Fig 5. Record of buckling load & maximum deflection
Of quasi-isotropic beam by machine computer

The buckling loads and maximum deflections of experimental results of optimal and quasi-isotropic beams are 39.89KN & 31.06KN and 9.765mm & 7.470mm respectively. The records from the MTS-810 machine computer are expressed in Fig 4. and Fig 5. The comparison of two beam results is listed in the Table 2.

Table 2. Comparison of two beams' results

Beams with same materials,sizes,weight & structure	Theoretical results	Experimental results	Maximum deflections
Quasi-Isotropic	35.85KN	31.06KN	7.470mm
Optimal design	46.06KN	39.89KN	9.765mm
Anti-bucking ability increased by	28.5%	28.4%	

from Table 2. It is obviously expressed that the buckling load of optimal beam is greater than the quasi-isotropic beam 28.5% by experiments and 28.4% by buckling analysis. That means the optimal beam can be reduced at least one forth the original weights of the laminate to support the same buckling load as the quasi-isotropic beam.

It will greatly increase the performance of the industrial products such as airplane, marine, automobile and rail transportation system and so on.

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