Reply by the Authors to Bernard Etkin

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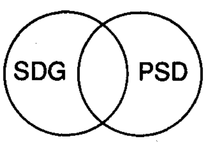
PROFESSOR Etkin's Technical Comment is very insightful. It 1) identifies an ambiguous statement we made in the Introduction to our paper[1]; 2) puts into sharper focus the potential usefulness of the SDG method; and 3) goes on to discuss some recent turbulence-simulation work at the University of Toronto. This reply addresses the first two items and then ties in some related work in the area of time-correlated gust loads recently conducted at NASA Langley.

In the second paragraph of his Technical Comment, Professor Etkin states that our judgment regarding the PSD method (conventional random process analysis) is not strictly true. The judgment he is referring to is contained in the second paragraph of our Introduction and states that the PSD method is not capable of computing a set of physically-realizeable loads. Then, in his third and fourth paragraphs, Professor Etkin proves that, for linear systems subjected to a Gaussian input, such physically realizeable loads may, indeed, be computed. Professor Etkin is correct.

Our statement is true, however, when interpreted in the following manner: For an airplane modeled as a linear system subjected to one-dimensional Gaussian atmospheric turbulence, assume that root-mean-square (RMS) values of shear force (SF) and bending moment (BM) are computed (using conventional random process analysis) at many locations along the span of the wing. The integral of this RMS SF distribution along the span from the wing tip to any inboard location y_i in general, will not be equal to the RMS value of BM at y_i. In this sense, the loads from a conventional random process analysis are not physically realizeable.

Also in his second paragraph, Professor Etkin states that the main advantage SDG has over PSD is the ability of the former to use non-Gaussian turbulence inputs. J. G. Jones, the developer of the SDG method, has expressed the same thought when he says indirectly "A principal objective of the SDG method is to cover, in a unified approach, the cases of encounters with relatively isolated severe to extreme gusts and flight in more extensive patches of continuous turbulence of generally less intensity."[2]

The patches of continuous turbulence referred to here are Gaussian, and it is for this condition that the SDG-PSD overlap has been shown to exist. For this condition, specific values of gust intensity parameter, U_0 [Eq. (1) of Ref. 1], fractional exponent, k [Eq. (1) of Ref. 1], and amplitude reduction factors, p_i [Eqs. (4) and (5) of Ref. 1] are required. The Venn diagram in the following sketch depicts schematically the SDG-PSD overlap.[3] Within the overlapped area Jones claims[2,3] that both analysis methods yield essentially the same results; Ref. 1 confirms that, within a scatter of about ±10%, the claimed 10.4 factor can be expected.



The isolated gusts referred to above are non-Gaussian. This condition is depicted in the sketch by the portion of the SDG circle not overlapped by the PSD circle, and may be accounted for in the SDG method by choosing different values of U_0, k, and p_i. In fact, values of these quantities have been derived from measurements of atmospheric turbulence and subsequently used in SDG calculations.[4]

Until recently, the SDG method had been relatively untried and had an air of mystery and uncertainty about it outside the United Kingdom. The ad hoc international committee mentioned in Reference 1 wanted confirmation that the SDG method performed as claimed in the overlapped area before accepting the method in the nonoverlapped area. The significance of the SDG-PSD overlap, then, is that it "calibrates" the overlapped area of the SDG circle and, thereby, lends credibility to the nonoverlapped area.

References 5–7 describe the results of recent research at NASA Langley and all are outgrowths of the original SDG work discussed in Ref. 1.

Reference 5 shows that, for linear systems with Gaussian inputs, maximized and time-correlated gust loads (TCGL) may be computed using matched filter theory (MFT). MFT yields the shape of the critical gust pattern exactly and directly, avoiding the computationally costly search required by the SDG method. The TCGL computed by MFT are proportional to auto- and cross-correlation functions from conventional random process analysis. Thus, correlation functions of conventional random process analysis can be interpreted as scaled time responses to certain excitations from MFT. Furthermore, the maximum load from MFT is identically equal to the RMS value of the corresponding load from conventional random process analysis, meaning that the constant of proportionality between MFT and PSD is 1.0, with no scatter.

Reference 6 shows that TCGL computed by the SDG method are strikingly similar to TCGL computed by the MFT method. Thus, referring back to the Venn diagram in the sketch, one can conclude that, within the overlapped area, the SDG method provides a very reasonable approximation to auto- and cross-correlation functions.

Finally, Ref. 7 makes use of the joint probability density function [Eq. (3) in Professor Etkin's Technical Comment] and goes on to show that when maximized TCGL computed by MFT are plotted as parametric functions of time the resulting curve is tangent (at one point) to the corresponding equiprobable loads design ellipse. It can be shown that the parametric load plot cannot extend beyond the limits of its corresponding design ellipse.

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