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PRELIMINARY RESULTS OF UNSTEADY BLADE SURFACE PRESSURE

MEASUREMENTS FOR THE SR-3 PROPELLER

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SUMMARY

Unsteady blade surface pressures were measured on an advanced, highly swept propeller known as SR-3. These measurements were obtained because the unsteady aerodynamics of these highly loaded transonic blades is important to noise generation and aeroelastic response. Specifically, the response to periodic angle-of-attack change was measured for both two- and eight-bladed configurations over a range of flight Mach numbers from 0.4 to 0.85. The periodic angle-of-attack change was obtained by placing the propeller axis at angles up to 4° to the flow. Most of the results are presented in terms of the unsteady pressure coefficient variation with Mach number. Both cascade and Mach number effects were largest on the suction surface near the leading edge. The results of a three-dimensional Euler code applied in a quasi-steady fashion were compared to measured data at the reduced frequency of 0.1 and showed relatively poor agreement. Pressure waveforms are shown that suggest shock phenomena may play an important part in the unsteady pressure response at some blade locations.

INTRODUCTION

Realization of the attractive fuel savings potential of an advanced turboprop aircraft could be hampered by a cabin or community noise problem. Noise can result from both steady and unsteady loading. Noise due to steady loading sources has been investigated in both wind tunnels and in flight tests (refs. 1 to 3), while that due to unsteady loading has received less attention. Unsteady loading noise can be a significant source for single rotation propellers in cases where there is distorted inflow or the propeller axis is not aligned with the flow (refs. 4 and 5). Installation effects due to such items as wings and struts result from their associated flow distortions. For counter-rotating propellers the unsteady loading due to rotor-rotor interaction is a major source.

In this investigation the blade surface pressure response on a single rotation, transonic, highly swept propeller, known as SR-3, was measured. The aerodynamic performance of the SR-3 propeller is presented in reference 6. The purpose of these measurements was to obtain a better understanding of the unsteady aerodynamics with the hope that this will lead to noise reductions, as well as solutions to aeroelastic problems. It is further anticipated that once the pressure response of the blades is known, it could then be used as a diagnostic tool to measure inflow distortion. The unsteady pressure measurements were made for both two- and eight-blade configurations in order to obtain cascade effects. In addition, quasi-steady results from an Euler code written by Denton (ref. 7) are compared to the measured data.

Experience with blade mounted pressure transducers (BMT's) on the fans of turbofan engines led us to extend their use to propellers. In the past, BMT data were used in a qualitative fashion to investigate inflow distortions and relate these to noise generation (refs. 8 to 10). In this investigation an attempt to use the BMT's in a quantitative manner was made, with the goal of relating the unsteady pressure amplitudes to change in upwash angle on the blades. The propeller axis of rotation was set at various angles to the flow in a wind tunnel, thus subjecting the blades to a periodic (one per rev.) variation in angle of attack. Much of the unsteady pressure response data presented in this paper is in terms of the pressure coefficient as a function of relative Mach number. For all the data shown the propeller advance ratio, J, was held at the design value of 3.06 thus, keeping the velocity diagrams geometrically similar.

TEST DESCRIPTION

Tunnel Installation and Running Conditions

The propeller was installed in the Lewis 8 by 6 ft supersonic wind tunnel as shown in figure 1. The full eight-bladed propeller is shown here. The SR-3 propeller has a diameter of 0.622 m. The angle the axis of rotation makes with the tunnel flow can be changed by pitching the axis up. The pitch angle of the model for this test was varied in 1° steps from 0° to 4°. Tunnel Mach number was varied from 0.4 to 0.85 while the propeller advance ratio, J, was held at the design value (J = 3.06) by varying the rpm.

Instrumentation and Data Processing

Several Kulite miniature pressure transducers were mounted on two different blades in positions shown in figure 2. At 0.75 radius both 0.1 and 0.5 chord stations are measured. At 0.88 radius the same chordwise stations were used with the exception of the 0.5 chord pressure surface station. The BMT's measuring the suction surface were all mounted on one blade while the pressure surface measurement were made on a second blade. The two instrumented blades were always mounted in the hub next to each other so as to measure both sides of the same blade passage. The transducers were mounted so that they sensed the pressure through a 1.55 mm diameter hole drilled through the blade as shown in figure 3. An RTV silicone adhesive was used for bonding in order to insure that the transducers are strain isolated from the blade. The RTV adhesive was also used to fair the BMT into the blade surface. Mounting the transducer at the bottom of a hole was considered necessary based on a previous test when the transducers were bonded directly on the surface to be measured. Even though the BMT's in this previous test were only 0.33 mm thick, and were faired into the blade surface, in many cases the measurements seemed to be affected by the change in surface contour. These BMT installation effects were greater on the suction surface near the leading edge and at higher Mach numbers.

The signals from the BMTs are taken off the rotor through a rotary transformer. Transducer excitation is a 30 kHz signal brought across the rotory transformer. The transducer output amplitude modulated the 30 kHz carrier which is demodulated, amplified, and put on FM tape. The system

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frequence response was 10 kHz or 65 to 130 shaft orders (P orders) depending on rpm.

Dynamic pressure calibration was accomplished through the use of an electromagnetic driver with a tube and sealing fixture. The sealing fixture is placed on a flush mounted reference transducer while the driver voltage level is adjusted to obtain a known pressure. In this case, the calibration pressure was 2 kPa (160 dB SPL) at 450 Hz. This pressure is then applied to the BMT and the gain for the channel is adjusted so that full scale, 20 kPa (180 dB SPL) equals 1 V/rms. All BMT's are adjusted to have the same sensitivity. When pressure signals are low during testing an additional gain of 10 is applied to improve the signal to noise ratio.

The taped BMT signals along with the once-per-revolution pulse were digitized at rate of 128 samples per revolution. The digital information was then processed on a mainframe computer to produce time ensembles ten revolutions in length. These were averaged (time domain averaging), and Fast Fourier Transforms (FFT's) were taken to produce enhanced spectra and phase (spatial) angles. In addition, FFT's were taken of the individual time ensembles of data and then averaged in the frequency domain. All spectra produced are in terms of shaft orders (P).

RESULTS AND DISCUSSION

Typical Data

With the propeller axis pitched up 4°, each blade undergoes a sinusoidal angle of attack, α change of very nearly ±4°. A typical blade surface response to this change in α is shown in figure 4. Here, the change in pressure is plotted as a function of transducer spatial (circumferential) angle. The convention used for spatial angle is that 0° is at the top center and increasing angle is in the direction of rotation (clockwise viewed looking downstream). The data presented here is for an eight-bladed rotor at a location of 0.75 radius and 0.1 chord. Both pressure and suction surfaces are shown at a tunnel Mach number of 0.6. These curves represent the synchronous average of 100 ensembles of data. Averaging in the time domain provides an increase in statistical confidence and smoothes the curves a bit, but the revolution-to-revolution differences were small. Also included in figure 4 is the forcing function: a curve showing the change in α as a function of spatial angle. The pressures on opposite surfaces are roughly 180° out of phase and the magnitude of the suction surface pressure is higher. These results are consistent with what might be expected based on steady state pressure profiles. Both surfaces exhibit a significant phase lag with respect to the angle of attack curve. The phase lag for the suction surface is 41° while for the pressure surface the lag is 58°. Only a very limited amount of phase angle data will be presented since this paper emphasizes the magnitude of the pressure response. Although the waveforms shown in this example are fairly sinusoidal, there are many that are more unusual. Where these waveforms help identify phenomena they will be presented.

The spectra for the two BMT waveforms presented in figure 4 are shown in figure 5. The suction surface pressure has considerably more harmonic content than the pressure surface, particularly in the second and fourth shaft orders. (2 and 4 P). The suction surface pressure for some locations and conditions

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has a highly nonsinusoidal response. This will be discussed later. The rest of the discussion of pressure response in this paper will be centered on the fundamental frequency. The magnitude of the fundamental shaft order (1 P) RMS pressure was divided by the dynamic pressure, q for the radial station of the BMT to obtain a pressure coefficient, C_{p1}. The relative Mach number, M_r for the radial location of the BMT and tunnel static pressure were used to calculate q. This one P pressure coefficient was plotted against the RMS magnitude of the angle-of-attack change. An example of one of these plots is shown in figure 6. Here the response of the 0.75 radius locations for the eight-bladed rotor are shown as a function of $\Delta\alpha$. The pressure surface BMT's usually show a much more linear response to angle of attack than the suction surface locations particularly near the leading edge. The nonlinear response of the 0.1 chord suction surface BMT is fairly typical of this location and the nonlinearities tend to increase with Mach number. Mach number effects will be discussed in some detail later in this paper.

Denton Code Quasi-Steady Comparison

It was felt that a quasi-steady approach might be useful in explaining some of the pressure response data even though, this data may be too far removed from the steady case. The Denton Code is a three-dimensional Euler formulation of the equations of mass, momentum and energy conservation (ref. 7). The code is able to handle nonlinear effects of shocks which are important to turboprop applications. Modifications of this code to handle the turboprop case have been made operational on the Cray XMP computer and are described in reference 10.

In order to simulate the periodic angle-of-attack changes in the propeller data, the Denton code was run with inflow swirl. The cases run for this comparison were 0°, 1°, 2°, and 4° of swirl in both the direction of rotation (negative α) and opposite to rotation (positive α). It should be noted, that in this quasi-steady simulation, the variation in inflow angle across a passage in the actual flow at any instant in time is not handled in the code. Figures 7 and 8 show a comparison between the data and code for a 0.1 chord location. Both radial locations and surfaces are shown for 0.6 and 0.8 tunnel Mach number. In figure 7 the very high unsteady loading at 0.1 chord on the suction surface for a tunnel Mach number, M_∞, of 0.6 is totally unpredicted. At a Mach number of 0.8 there is fair to good agreement. The reverse is true for the pressure surface. There is good agreement at $M_\infty = 0.6$ while at $M_\infty = 0.8$ there is a substantial underprediction of the pressure coefficient. There may be very different flow conditions present on the suction surface between the 0.6 and 0.8 Mach number data. This is suggested by waveform differences and will be discussed later. The situation is somewhat different at the 0.5 chord location as shown in Figure 8. Here there is good to fair agreement on the suction surface for both radial locations and Mach numbers. The pressure surface is greatly underpredicted.

In general there is not enough agreement for the quasi-steady approach to be very useful. The reduced frequencies (based on semicord) for the 0.75 and 0.88 radius locations are 0.15 and 0.11 respectively. There are phase lags for most of the data in the range 30° to 60°. This suggests that the data may be too far removed from the quasi-steady condition to get good agreement. In addition, there is evidence in terms of pressure waveforms suggesting that the code may not be modeling all the important flow phenomena present on the

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suction surface. Although the overall blade loading is fairly well predicted by the code, the pressure profiles may not be the same.

Mach Number and Cascade Effects

In this section the unsteady pressure response to a sinusoidal angle of attack change will be shown by plotting the magnitude of the pressure coefficient at 1 P against relative Mach number, M_r. Data for both two- and eight-bladed rotors will be shown on the same figures to make comparisons easier.

Figure 9 shows the pressure response of the BMT's on both the suction and pressure surfaces, for 0.75 radius and 0.1 chord location. One of the most obvious features of this figure is the large difference in response between the two- and eight-bladed configurations on the suction surface. Both the two- and eight-bladed rotors have similar response at the lowest M_r. As M_r is increased to approximately 0.9, the two-bladed rotor shows an increasing response while, there is a decrease in the eight-bladed case. Above M_r = 0.9 there is an abrupt drop in pressure coefficient for both configurations. In the next section the waveforms near this abrupt change in response will be examined. The pressure surface response is very similar for both blade numbers, and has no pronounced trends with Mach number. The amplitude of the pressure surface response is much lower than that of the suction surface. This is consistent with the expected steady pressure profiles. In the simplest case (incompressible, and no separation or shocks) it might be expected that C_p would not vary with Mach number and there would be a linear increase with angle of attack. This is the behavior of the data on the pressure surface (figs. 9(c) and (d)).

The response at 0.88 radius and 0.1 chord is shown in figure 10. As in the previous figure for 0.75 radius, there are large differences in the suction surface response between the two- and eight-bladed cases. Here again, the two-bladed rotor, in particular has an abrupt change in response beyond a certain relative Mach number. In this case, when M_r = 0.95 there is a rapid loss of response for most of the data at higher Mach numbers. The onset of this behavior for the 0.75 radius data is at M_r = 0.9 or at a tunnel Mach number, M_∞ = 0.7. This is approximately the same M_∞ where this behavior begins for the 0.88 radius data. There is a suggestion here that this behavior might better correlate to M_∞ than M_r, and that this occurs along much of the blade span simultaneously.

All the pressure surface data in figures 9 and 10 is similar. This indicates there is little effect of blade number or radial location between the data sets.

The response at 0.5 chord and 0.75 radius is much different than the 0.1 chord data, as shown in figure 11. The suction surface shows very little unsteady loading for either the two- or the eight-bladed cases. In fact, the pressure surface shows a higher response for most of the data. An interesting feature of the pressure surface data is the sharp peak in the eight-bladed rotor response at M_r = 1.04 (fig. 11(d)). Except for this peak, the two- and eight-bladed configurations have nearly the same response.

Figure 12 shows the unsteady response at 0.5 chord and 0.88 radius for the suction surface only. The differences between the two- and eight-bladed

rotors are very large. The sudden drop in response at $M_r = 0.94$ is accompanied by a change in waveform.

Examples of the phase angles in terms of lead or lag relative to the forcing function (change in angle of attack) are shown in figure 13. As discussed in connection with figure 4, on the pressure surface the forcing function has a spatial phase angle of 90°. The suction surface forcing function is 180° out of phase with the pressure surface and has a spatial phase angle of 270°. The data shown in figure 13 is for 0.75 radius stations and a change in angle of attack of ±2°.

Most of the data for the two-blade case has a lag of approximately 20° at the low end of the Mach number range increasing to approximately 40° at the high end. It should be pointed out here that the reduced frequency does not change with Mach number since the propeller was run at a constant advance ratio. The corresponding phase angles for the eight-bladed data has a lag generally 10° to 40° higher. The abrupt change in phase angle for the eight-bladed rotor at 0.5 chord on the pressure surface at $M_r = 1.04$ corresponds to the peak in the magnitude data shown in figure 11(d).

The suction surface data at 0.5 chord for both blade numbers has completely different characteristics than the other stations. This data shows large lead angles at low Mach numbers that eventually turn to lags at higher Mach numbers. Although the magnitude of the pressure surface data shows very little effect of blade number, there is a definite increase in lag angle in the eight-bladed case.

The figures in this section indicate large cascade effects (difference between two and eight blades) on the suction surface at 0.1 chord. Also at this location, large changes in response with Mach number were observed, some of them abrupt. The magnitude of the pressure surface data with one exception shows little cascade or Mach number effects.

Pressure versus Angle Waveform

An examination of the pressure versus angle waveform can provide clues to some of the unusual behavior seen in the pressure response versus Mach number curves (figs. 9 to 12). In this section a brief look at some of the waveform data will be taken and some speculation as to the underlying phenomena will be made.

In the previous section of this paper, an abrupt drop in pressure response with Mach number was observed for the suction surface at 0.1 chord. This behavior seems to start at a tunnel Mach number around 0.7. Figure 14 shows a series of waveforms for 0.75 radius 0.1 chord suction surface location at $M_\infty = 0.7$. The top waveform is for a change in angle of attack of ±1°. This is a typical, nearly sinusoidal waveform and is similar to all the waveforms at this location at lower Mach numbers. When ,the $\Delta\alpha$ is increased to ±2°, there is a significant change in waveform typified by a sudden leveling of pressure around 90°, with an upward displacement of the original waveform, then a sudden drop in pressure around 210°. The lower portion of the curve connected by dashed lines is attempt to reconstruct the waveform without the sudden pressure changes. The last waveform is for $\Delta\alpha = \pm4°$. The sudden leveling of pressure seems to occur slightly earlier (lower angle) and the pressure drop later than the ±2° curve. Some candidate phenomena suggested by this behavior are:

periodic shock formation, a shock transiting the measuring station, a periodic separation bubble and a combination of shock formation and separation bubble. Since this change in waveform is Mach number dependent, it seems likely that a shock is involved in some way. It also seems likely that, if a shock occurred at a highly loaded location near the leading edge, a separation bubble would result. A complete separation was not considered since, the overall performance was uneffected and downstream stations show no large changes. Whatever the exact phenomenon, it seems to occur at both 0.1 chord stations on the suction surface for both blade numbers.

The peak in the pressure response curve for the eight-bladed data at 0.75 radius and 0.5 chord, pressure surface (fig. 11(d)) is illuminated further in figure 15. Here a series of waveforms for $\Delta\alpha = \pm3°$ shows a progression with Mach number. The middle waveform is at the peak in the response curve shown in figure 11(d) while the top and bottom waveforms are at Mach numbers just below and above the peak. It should be noted that, at lower Mach numbers than shown here, the waveform is nearly sinusoidal. The steep pressure rise in these curves moves to progressively higher angles with increasing Mach numbers. Here again, a shock seems to be responsible. In this case, since these measurements are on a pressure surface, it seems likely that the shock is originating on the suction surface of the preceding blade. The shock may be moving across the measuring station periodically with the change in angle of attack. It would be expected that the shock would be swept back with increasing Mach number thus explaining the trend in the data to appear at higher angles as M_r is increased. The behavior at this measuring station is very normal for the two-bladed configuration. The pressure response with M_r is flat and the wave forms are sinusoidal. Only the eight-bladed case shows the unusual behavior. This tends to support the idea of shock from the preceeding blade being responsible.

Another case where there is unusual behavior in the pressure response with Mach number is in figure 12(a). Here an abrupt drop in response with M_r is seen for a station at 0.88 radius, 0.5 chord, suction surface and two blades. The progression of waveforms for this case is shown in figure 16. Here again the middle waveform has a sudden pressure rise suggesting a shock. There seems to be no second event where the shock disappears or recrosses the measuring station. There is a drop in all parts of the waveform with increasing Mach number.

The waveform and phase angle data obtained in this investigation may hold the answers to many questions. Further effort in this area is required and is being pursued.

CONCLUDING REMARKS

The unsteady blade surface pressures on an advanced high-speed propeller were measured using blade mounted transducers. Unsteady aerodynamics was investigated here because it is the source of much loading noise, as well as being a concern in the area of aeroelastics. Specifically, the response to an angle of attack change at a frequency of the first shaft order was studied.

A comparison was made between the data and quasi-steady calculations using the Denton code. This three-dimensional Euler formulation is able to handle nonlinear effects including shocks. However, its invisid nature means

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separations are not modeled. The agreement between the code and the data is not good enough to be very useful. There are large differences on the suction surface near the leading edge suggesting that the code may not be able to model all the important flow phenomena when applied in a quasi-steady fashion. The data may be too far removed from the quasi-steady condition as indicated by phase lags of 30° to 60°.

A comparison between the two- and eight-bladed configurations was made to obtain cascade effects. In some cases very large cascade effects were observed. Locations at 0.1 chord on the suction surface showed the largest differences. At these same locations, Mach number effects on the pressure response were also very large and complicated. Most pressure surface measuring stations showed little Mach number or cascade effects. For this reason the pressure surface stations would be good candidates for use as a diagnostic tool to measure inflow distortion. They also had linear pressure response to angle of attack.

The brief investigation of pressure waveforms revealed some unusual and interesting features. There are strong suggestions that shocks contribute to some of the more unusual behavior observed. Some of these shocks may be formed periodically on the suction surface while others might originate on on neighboring blade and be observed on a pressure surface.

It was hoped that among the Mach number effects observed, evidence of acoustic waves traveling across blade passages would be found. These waves might lead to cancellation and reinforcements of surface pressure. This phenomenon has been called acoustic resonance. Although, no obvious effects of this phenomenon were observed, it is still possible that they were masked by some of the more powerful phenomena, some of which may be associated with shocks. A more complete study of the data is needed, particularly the waveform and phase angle information, to better identify important contributors to the observed results.

REFERENCES

1. Dittmar, J.H.; Jeracki, R.J., and Blaha, B.J.: Tone Noise of Three Supersonic Helical Tip Speed Propellers in a Wind Tunnel. NASA TM-79167, 1979.

2. Dittmar, J.H.: Preliminary Measurement of the Noise from the 2/9 scale Model of the Large-scale Advanced Propfan (LAP) Propeller. SR-7A NASA TM-87116, 1985.

3. Lasagna, P.L.; Mackall, K.G.; and Cohn, R.B.: In-Flight Acoustic Test Results for the SR-2 and SR-3 Advanced Propellers. AIAA Paper 83-1214, June 1983

4. Tanna, H.K.; Burrin, R.H.; and Plumblee, H.E.Jr.: Installation Effects on Propeller Noise. J. Aircraft, vol. 18, no. 4, Apr. 1981, pp. 303-309.

5. Dittmar, J.H.; and Jeracki, R.J.: Noise of the SR-3 Propeller Model at 2° and 4° Angle of Attack. NASA TM-82738, 1981.

6. Rohrbach, C., et al.: Evaluation of Wind Tunnel Performance Testings of an Advanced 45° Swept Eight-Bladed Propeller at Mach Numbers From 0.45 to 0.85. NASA CR-3505, 1982.

7. Denton, J.D.; and Singh, U.K.: Time Marching Methods for Turbomachinery Flow Calculation. Application of Numerical Methods to Flow Calculations in Turbomachines. VKI-LEC-SER-1979-7, Von Karman Institute for Fluid Dynamics, 1979.

8. McArdle, J.G.; et al.: Comparison of Several Inflow Control Devices for Flight Simulation of Fan Tone Noise Using a JT150-1 Engine. AIAA Paper 80-1025, June 1980.

9. Homyak, L.; McArdle, J.G.; and Heidelberg, L.J.: A Compact Inflow Control Device for Simulating Flight Fan Noise. AIAA Paper 83-0680, Apr. 1983.

10. Schoenster, J.A.: Fluctuating Pressure Measurement on the Fan Blades of a Turbofan Engine During Ground and Flight Tests. AIAA Paper 83-0679, Apr. 1983.

10. Clark, B.J.; and Scott, J.R.: Coupled Aerodynamic and Acoustical Predictions for Turboprops. NASA TM-87094, 1986.
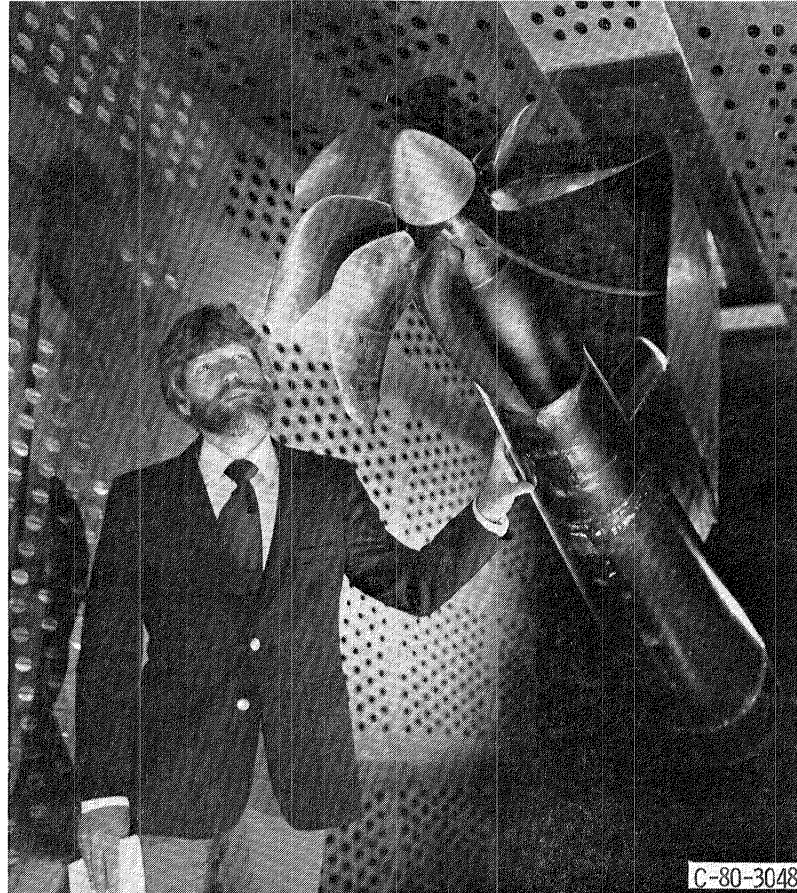
Figure 1. – The SR-3 propeller installed in the 8x6 Foot Supersonic Wind Tunnel.

0.5
CHORD

0.1 CHORD

0.1
CHORD

0.5 CHORD

0.75
RADIUS

0.88 RADIUS
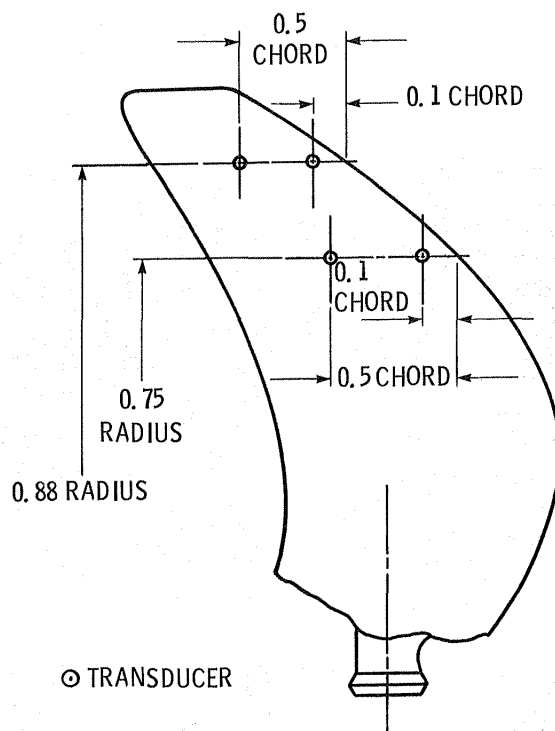
⊙ TRANSDUCER

(a) Blade 1, transducers measuring the suction surface.

0.1 CHORD

0.1
CHORD

0.5 CHORD

0.75
RADIUS

0.88 RADIUS
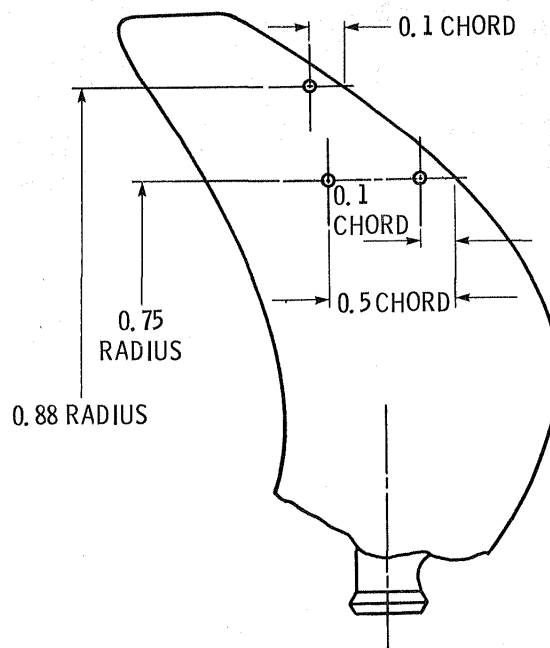
(b) Blade 2 or 5, transducers measuring the pressure surface.

Figure 2. - Locations of the transducers on the blades.
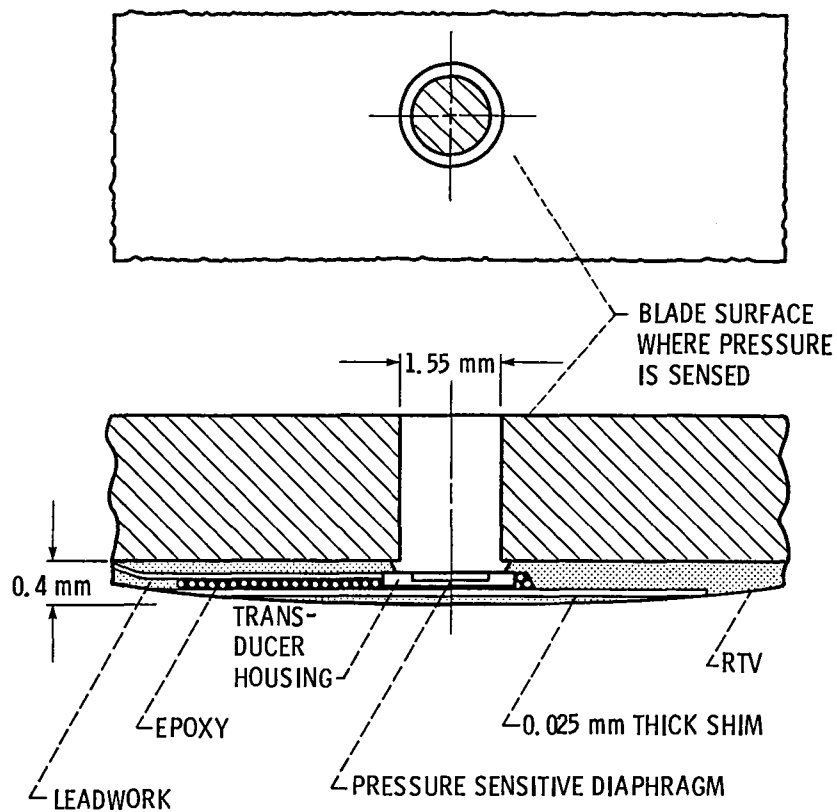
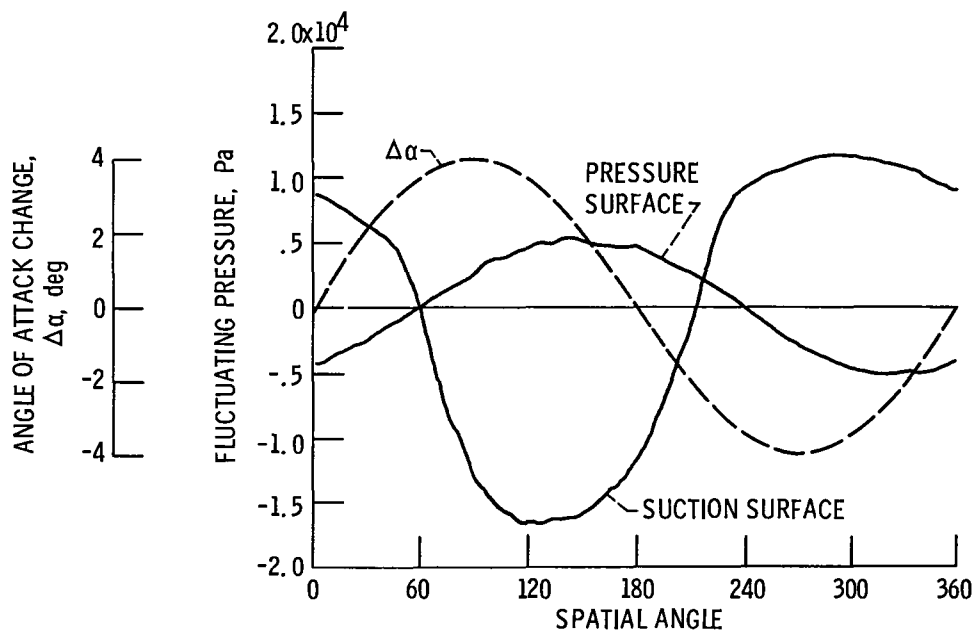Figure 3. - Typical installation of a blade mounted pressure transducer sensing through the blade.

Figure 4. - Pressure waveform for a location of 0.75 radius and 0.1 chord at a tunnel Mach number of 0.6, propeller axis pitch angle 4 degrees up, 100 averages, eight blades.
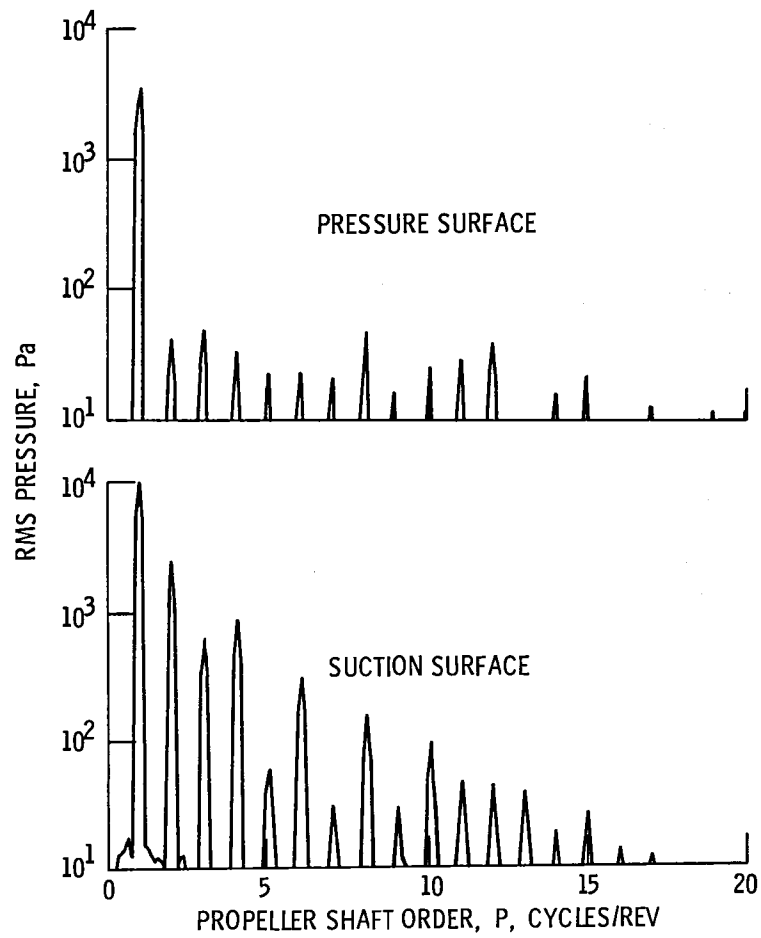
Figure 5. - Spectra of pressure waveform at 0.75 radius and 0.1 chord, $M_\infty = 0.6$, propeller axis pitch angle 2 degrees up, 100 averages in the time domain, eight blades.
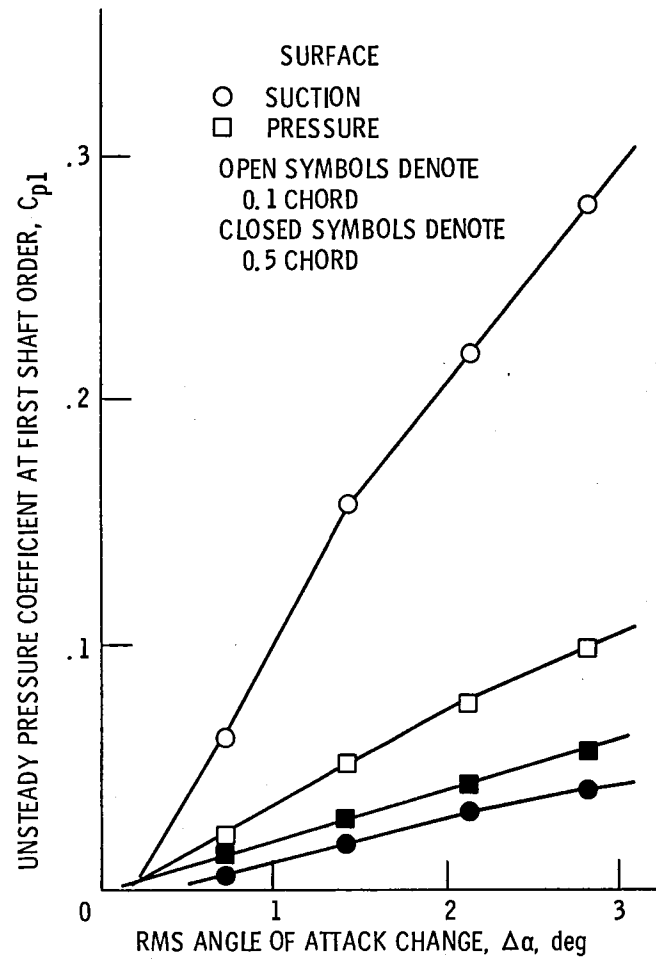
Figure 6. - Pressure response as a function of
angle of attack change for an eight-bladed
propeller, M_∞ = 0.6.
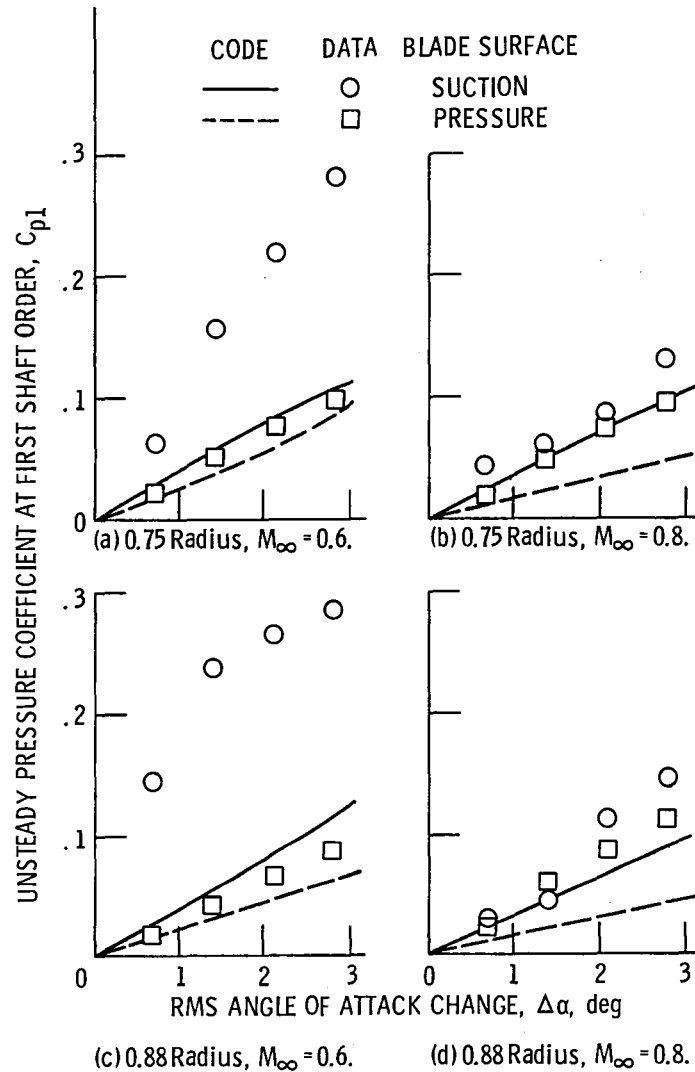
Figure 7. - Comparison between quasi-steady application of Denton code and data at 0.1 chord for an eight-bladed propeller.
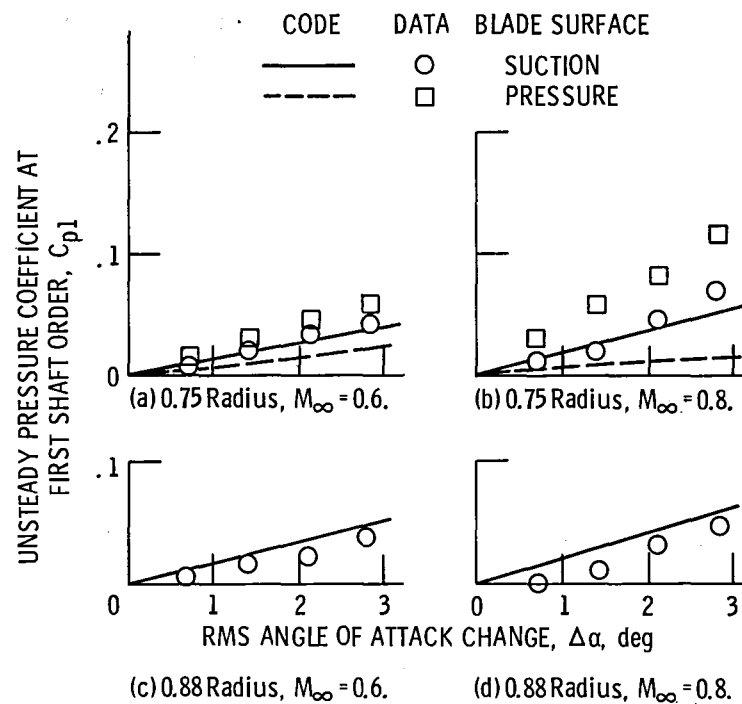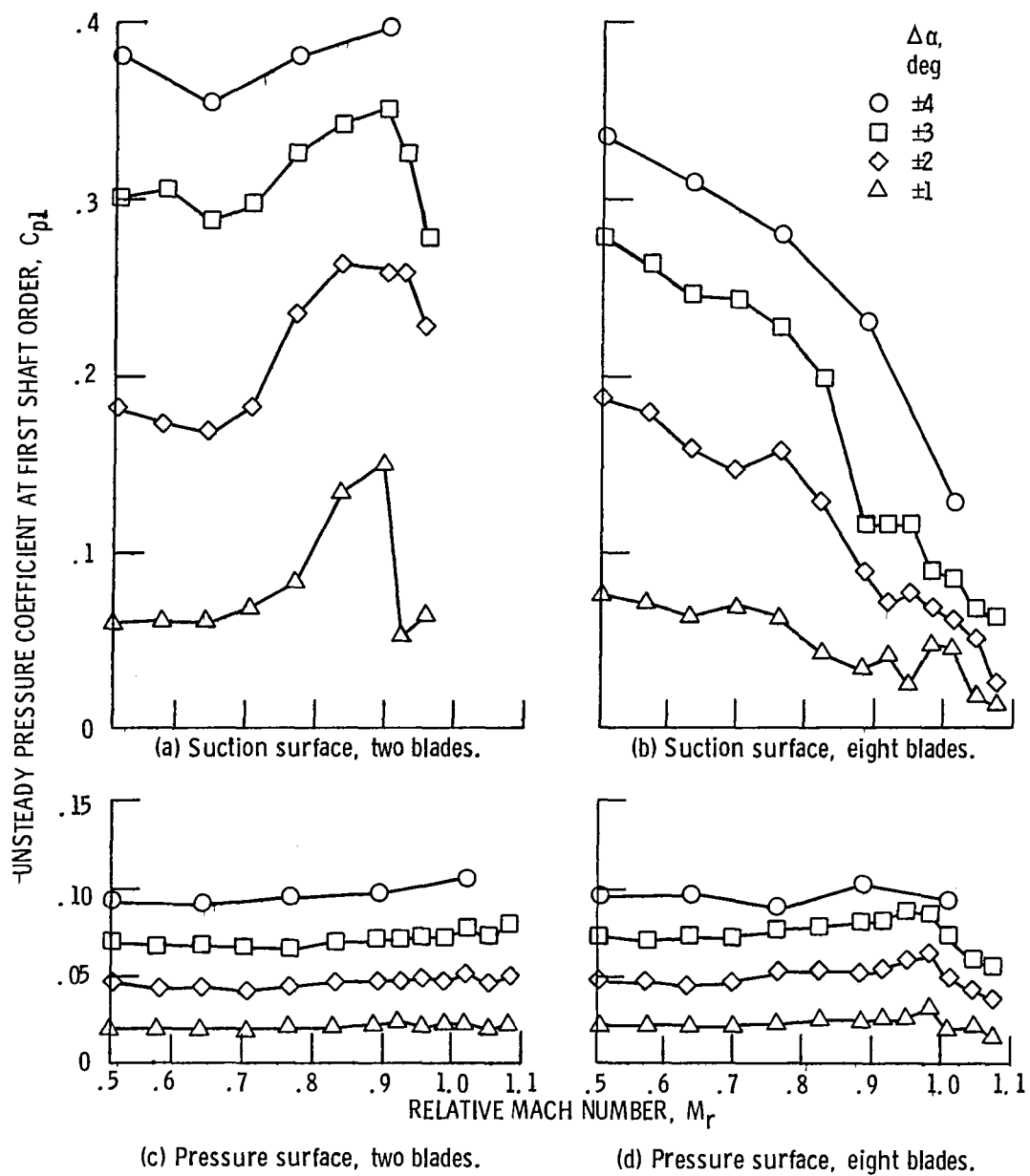
Figure 8. - Comparison between quasi-steady application
of Denton code and data at 0.5 chord for an eight-
bladed propeller.

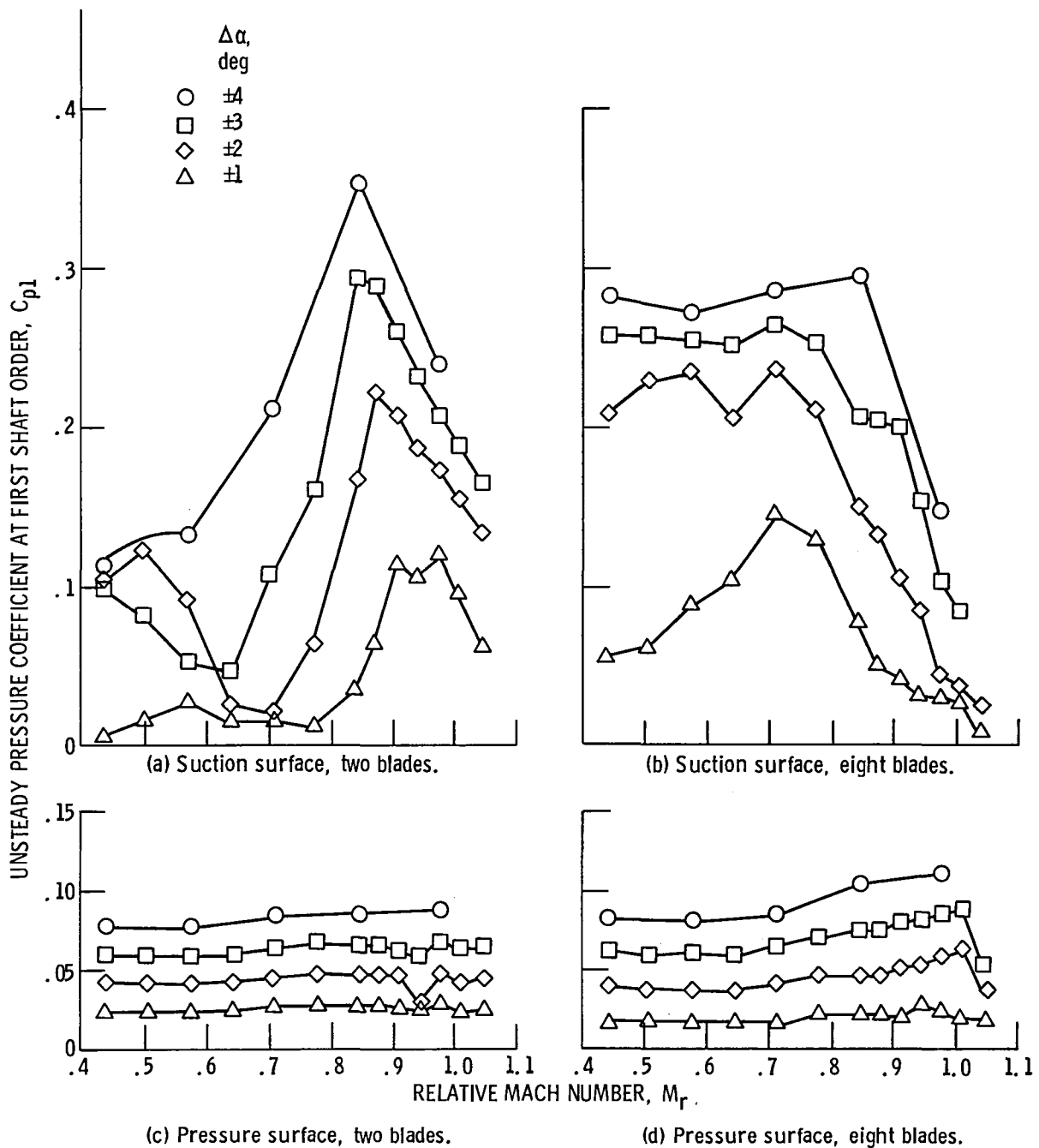Figure 9. - Pressure response as a function of relative Mach number for 0.75 radius and 0.1 chord.

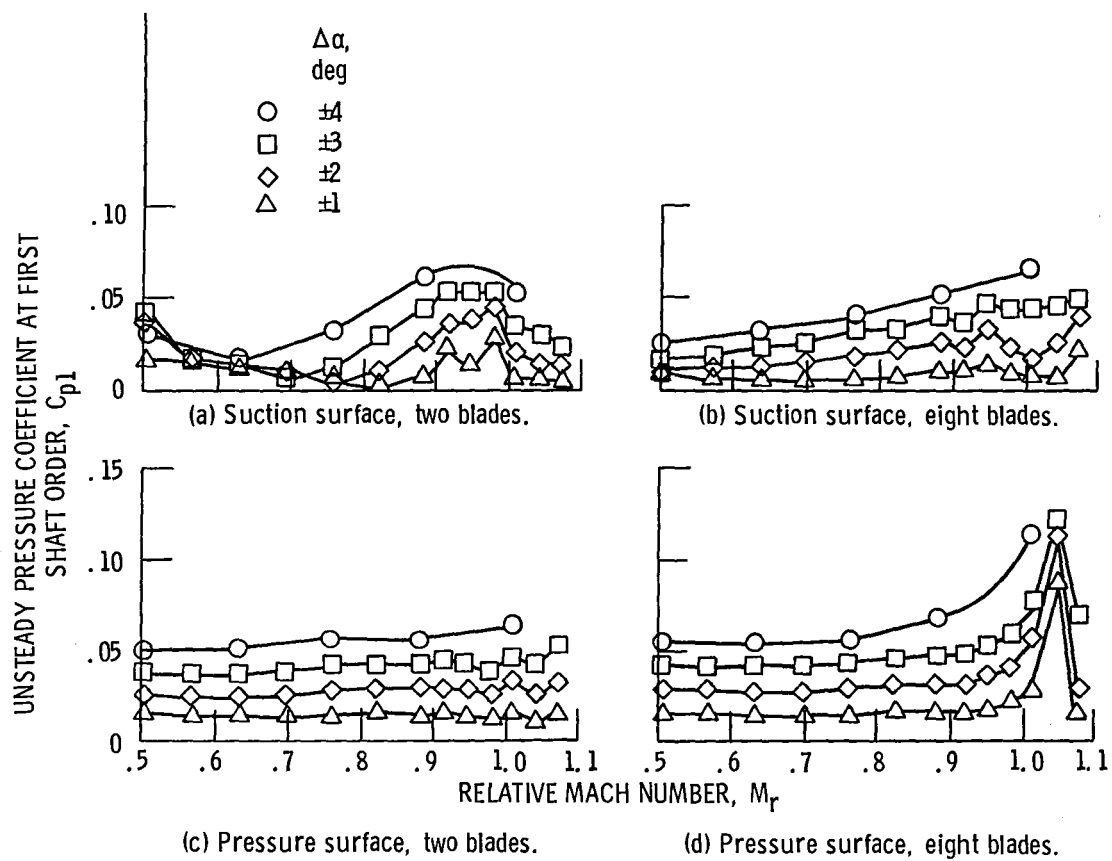Figure 10. – Pressure response as a function of relative Mach number for 0.88 radius and 0.1 chord.

Figure 11. - Pressure response as a function of relative Mach number for 0.75 radius and 0.5 chord.
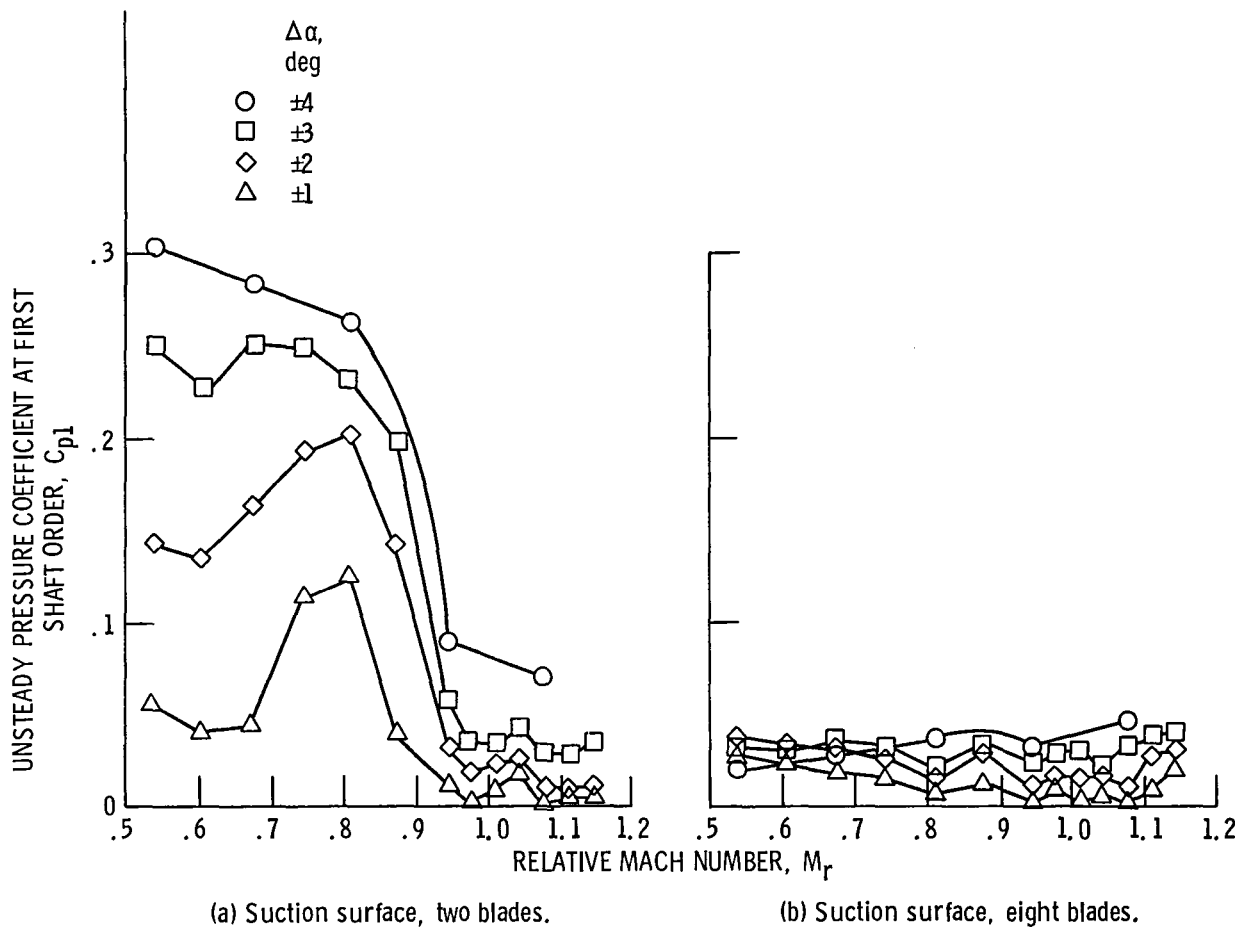
(a) Suction surface, two blades.

(b) Suction surface, eight blades.

Figure 12. – Pressure response as a function of relative Mach number for 0.88 radius and 0.5 chord.
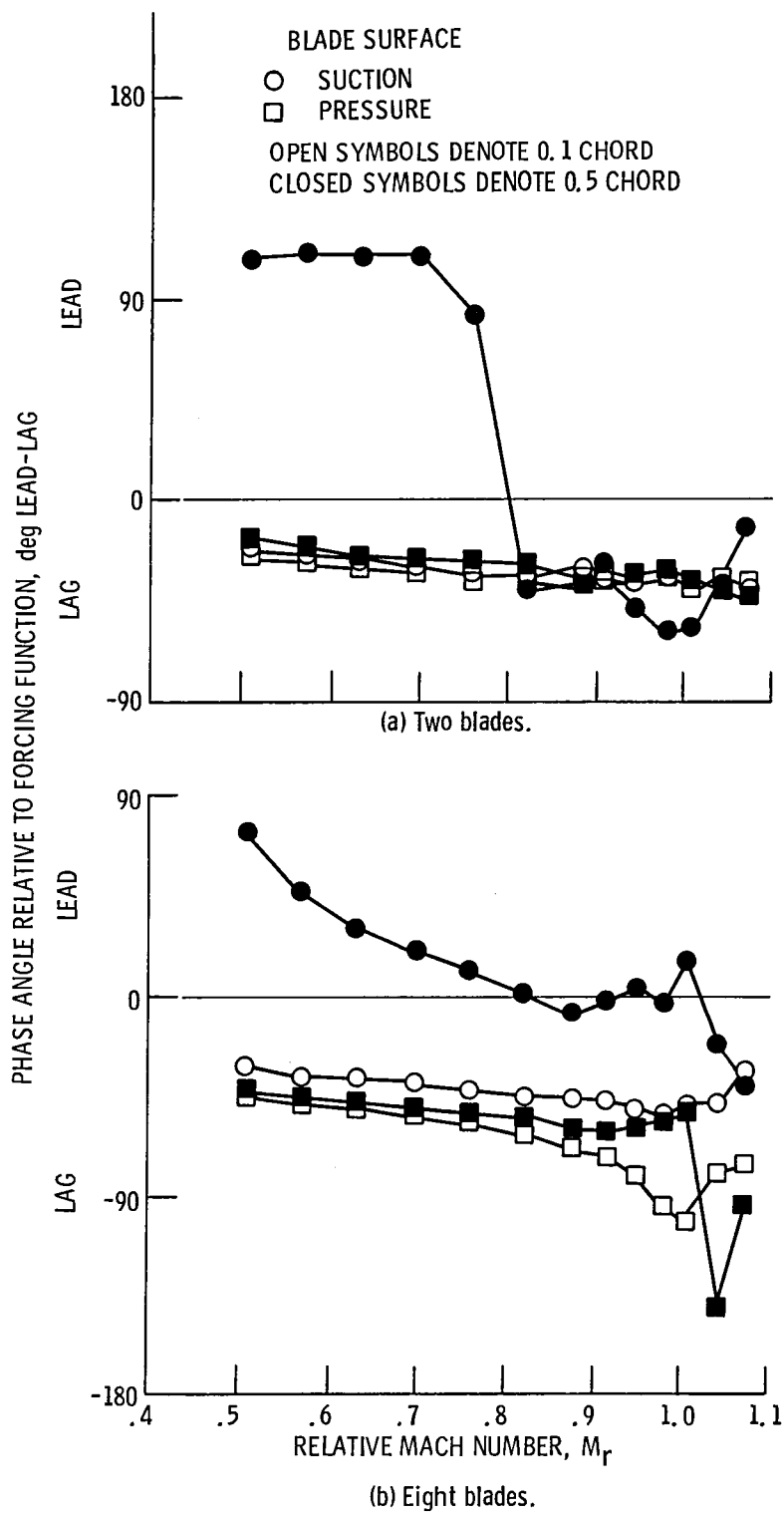
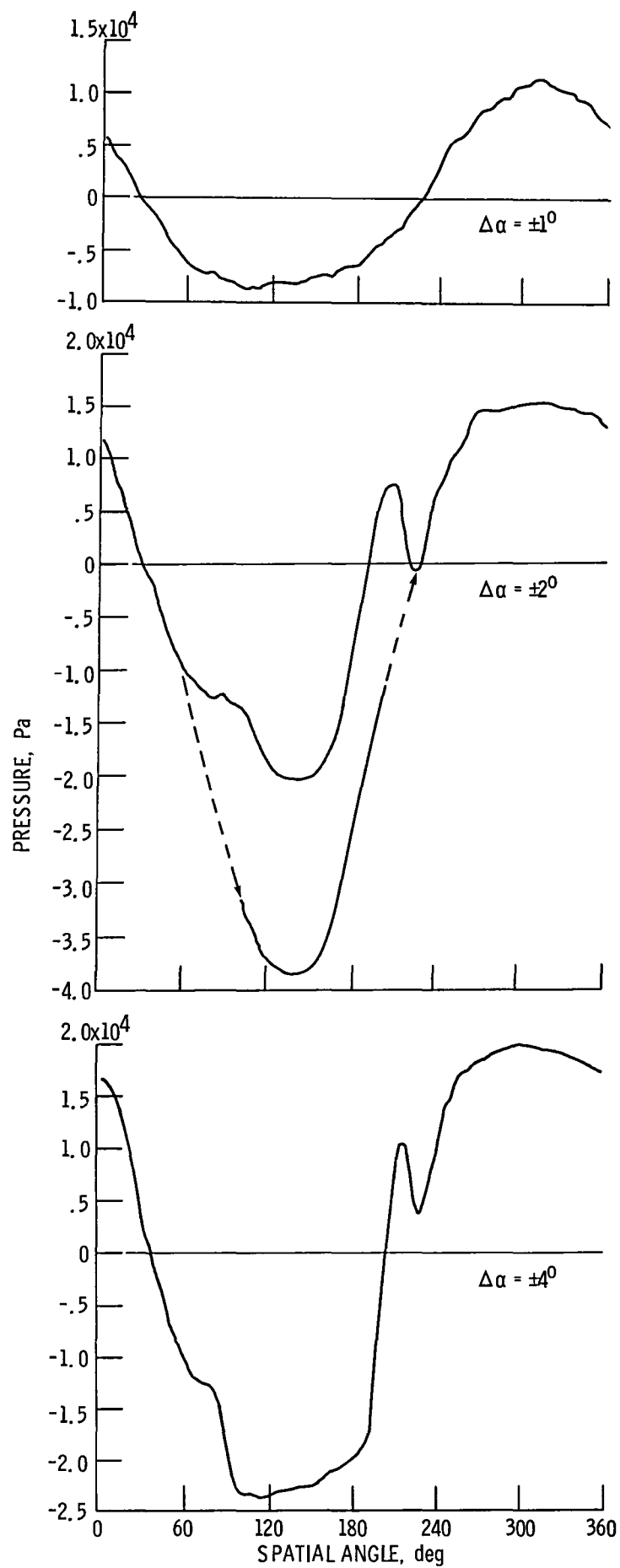Figure 13. - Phase angle as a function of relative Mach number for 0.75 radius.

Figure 14. - Pressure waveforms for the suction surface
at 0.75 radius and 0.1 chord, $M_\infty = 0.7$, $M_r = 0.885$,
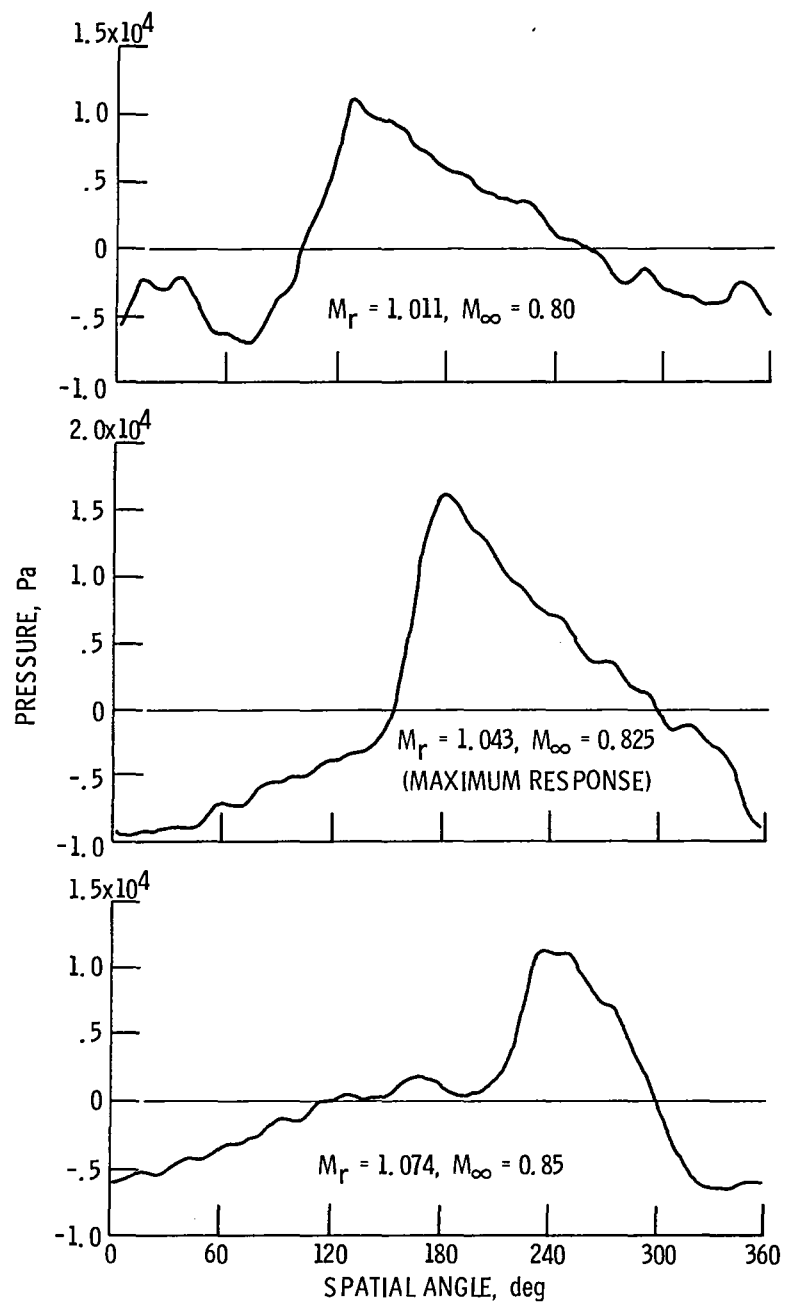two blades.

Figure 15. – Pressure waveforms for the pressure surface at
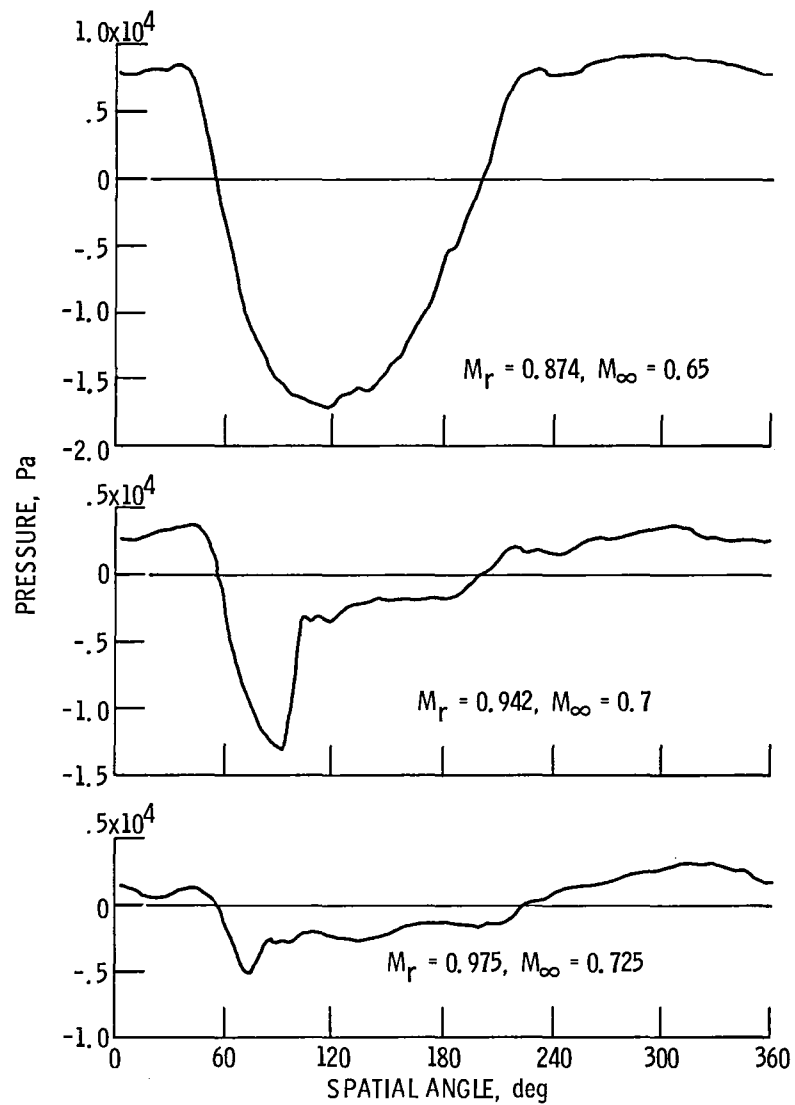0.5 chord and 0.75 radius for eight blades, $\Delta\alpha = \pm3^0$.

Figure 16. – Pressure waveforms for 0.88 radius, 0.5 chord, suction surface, two blades, and $\Delta\alpha = \pm 3^0$.

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16. Abstract

Unsteady blade surface pressures were measured on an advanced, highly swept propeller known as SR-3. These measurements were obtained because the unsteady aerodynamics of these highly loaded transonic blades is important to noise generation and aeroelastic response. Specifically, the response to periodic angle-of-attack change was measured for both two- and eight-bladed configurations over a range of flight Mach numbers from 0.4 to 0.85. The periodic angle-of-attack change was obtained by placing the propeller axis at angles up to 4° to the flow. Most of the results are presented in terms of the unsteady pressure coefficient variation with Mach number. Both cascade and Mach number effects were largest on the suction surface near the leading edge. The results of a three-dimensional Euler code applied in a quasi-steady fashion were compared to measured data at the reduced frequency of 0.1 and showed relatively poor agreement. Pressure waveforms are shown that suggest shock phenomena may play an important part in the unsteady pressure response at some blade locations.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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