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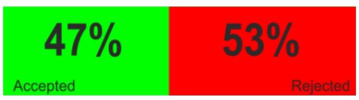

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Issue **Article**

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REFERENCE DATA OF PRESSURE DISTRIBUTION ON THE SURFACES OF AIRFOILS HAVING THE NAMES BEGINNING WITH THE LETTER H (THE FIRST PART)

***Abstract**: The results of the computer calculation of air flow around the airfoils having the names beginning with the letter H are presented in the article. The contours of pressure distribution on the surfaces of the airfoils at the angles of attack of 0, 15 and -15 degrees in conditions of the subsonic airplane flight speed were obtained.*

***Key words**: the airfoil, the angle of attack, pressure, the surface.*

***Language**: English*

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***Scopus ASCC**: 1507.*

Introduction

Creating reference materials that determine the most accurate pressure distribution on the airfoils surfaces is an actual task of the airplane aerodynamics.

Materials and methods

The study of air flow around the airfoils was carried out in a two-dimensional formulation by means of the computer calculation in the *Comsol Multiphysics* program. The airfoils in the cross section were taken as objects of research [1-22]. In this work, the airfoils having the names beginning with the letter *H* were adopted. Air flow around the airfoils was carried out at the angles of attack (α) of 0, 15 and -15 degrees. Flight speed of the airplane in each case was subsonic. The airplane flight in the atmosphere was carried out under normal weather conditions. The geometric characteristics of the studied airfoils are presented in the Table 1. The geometric shapes of the airfoils in the cross section are presented in the Table 2.

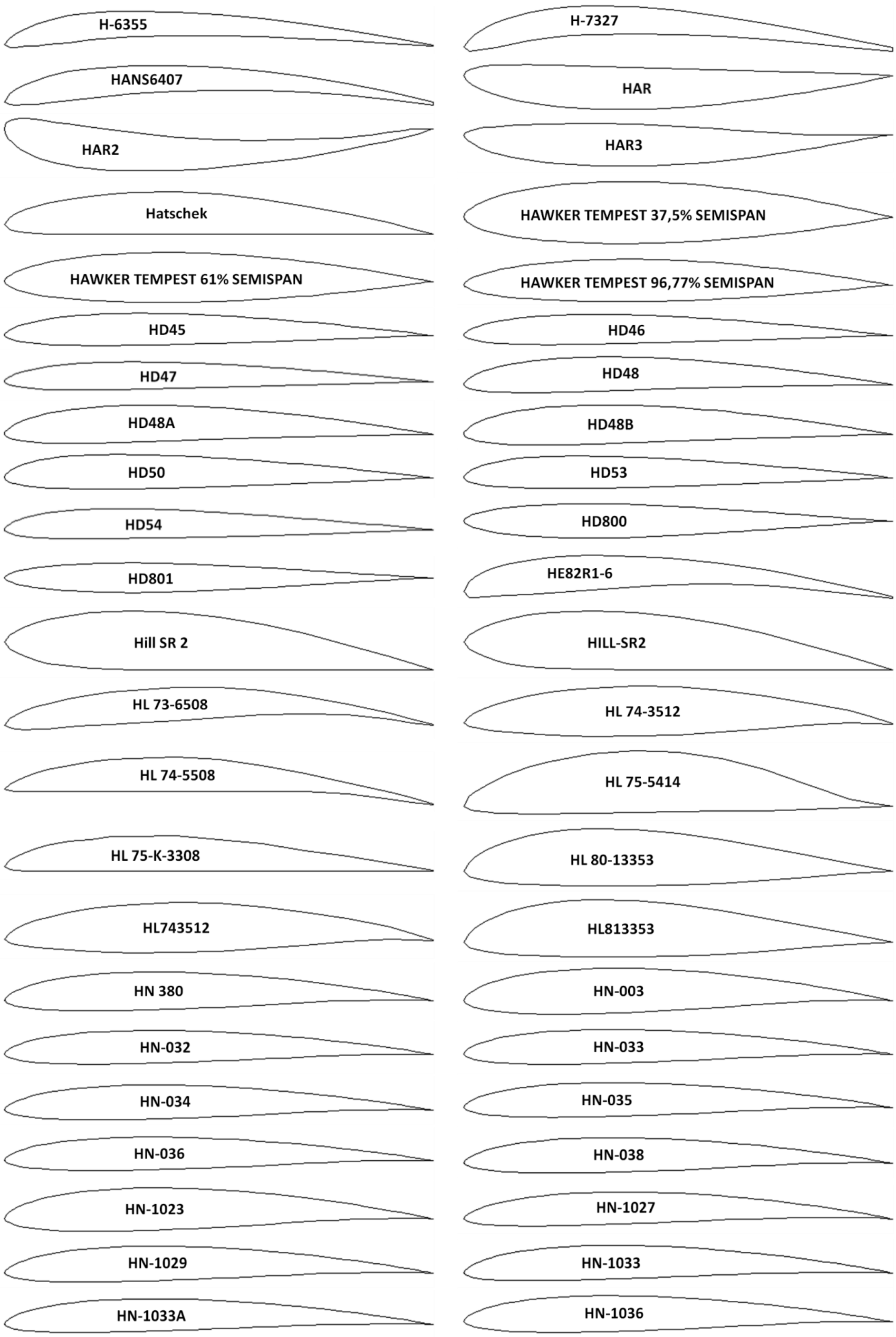
Table 1. The geometric characteristics of the airfoils.

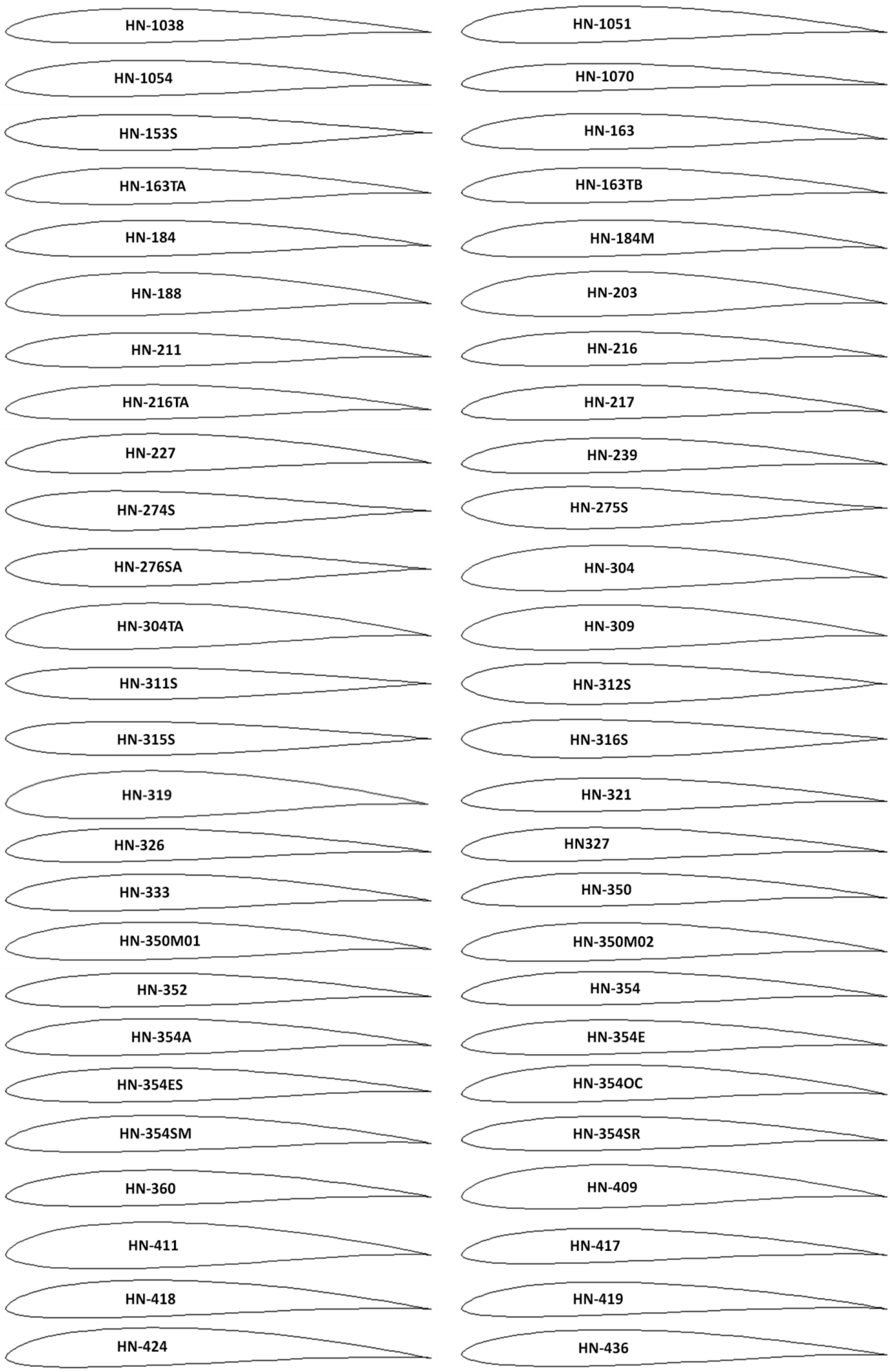
Airfoil name	Max. thickness	Max. camber	Leading edge radius	Trailing edge thickness
H-6355	6.1% at 15.0% of the chord	5.05% at 40.0% of the chord	0.6824%	0.2%
H-7327	6.8% at 30.0% of the chord	7.4% at 30.0% of the chord	0.8095%	0.9%
HANS6407	6.85% at 20.0% of the chord	6.15% at 40.0% of the chord	0.7646%	0.7%
HAR	10.0% at 30.9% of the chord	0.0% at 0.0% of the chord	0.8482%	0.0%
HAR2	10.0% at 17.0% of the chord	0.01% at 0.1% of the chord	2.8877%	0.0%
HAR3	10.0% at 33.9% of the chord	0.0% at 0.0% of the chord	0.6624%	0.0%
Hatschek	10.0% at 40.0% of the chord	5.0% at 40.0% of the chord	0.9514%	0.0%
HAWKER TEMPEST 37,5% SEMISPAN	14.5% at 37.6% of the chord	1.03% at 39.7% of the chord	1.0736%	0.0%
HAWKER TEMPEST 61% SEMISPAN	11.99% at 38.8% of the chord	0.93% at 40.8% of the chord	0.7444%	0.0%
HAWKER TEMPEST 96,77% SEMISPAN	10.0% at 38.0% of the chord	1.03% at 40.1% of the chord	0.5025%	0.0%
HD45	7.5% at 28.2% of the chord	1.4% at 37.7% of the chord	0.5712%	0.0%
HD46	7.0% at 26.4% of the chord	1.4% at 37.8% of the chord	0.553%	0.0%
HD47	6.5% at 26.6% of the chord	1.39% at 38.0% of the chord	0.5234%	0.0%
HD48	8.0% at 27.2% of the chord	2.5% at 42.6% of the chord	0.6361%	0.0%
HD48A	8.5% at 28.6% of the chord	2.5% at 42.3% of the chord	0.6981%	0.0%
HD48B	9.0% at 28.2% of the chord	2.3% at 41.9% of the chord	0.7646%	0.0%
HD50	8.0% at 26.0% of the chord	1.3% at 29.9% of the chord	0.8086%	0.0%
HD53	7.5% at 24.8% of the chord	1.2% at 30.6% of the chord	0.7049%	0.0%
HD54	7.0% at 24.3% of the chord	1.4% at 30.0% of the chord	0.6044%	0.0%
HD800	8.0% at 30.3% of the chord	0.14% at 0.0% of the chord	0.5781%	0.0%
HD801	7.0% at 30.9% of the chord	0.14% at 0.0% of the chord	0.5433%	0.0%
HE82R1-6	8.33% at 25.0% of the chord	6.34% at 45.0% of the chord	1.4517%	0.35%
Hill SR 2	13.7% at 30.1% of the chord	6.85% at 20.0% of the chord	1.0525%	0.0%
HILL-SR2	13.6% at 30.0% of the chord	6.9% at 30.0% of the chord	1.0525%	0.0%
HL 73-6508	7.9% at 40.0% of the chord	5.35% at 50.0% of the chord	0.7345%	0.25%
HL 74-3512	11.9% at 40.0% of the chord	2.7% at 50.0% of the chord	0.7862%	0.2%
HL 74-5508	7.8% at 40.0% of the chord	3.9% at 40.0% of the chord	0.5828%	0.2%
HL 75-5414	14.4% at 40.0% of the chord	5.54% at 40.0% of the chord	1.1155%	0.1%
HL 75-K-3308	8.03% at 40.0% of the chord	4.01% at 40.0% of the chord	0.6275%	0.25%
HL 80-13353	13.4% at 30.0% of the chord	3.15% at 30.0% of the chord	1.1886%	0.1%
HL743512	11.9% at 40.0% of the chord	2.7% at 50.0% of the chord	0.7862%	0.2%
HL813353	13.45% at 30.0% of the chord	3.17% at 30.0% of the chord	1.1898%	0.1%
HN 380	9.15% at 31.6% of the chord	2.33% at 46.9% of the chord	0.6286%	0.0%
HN-003	10.84% at 31.6% of the chord	2.44% at 46.9% of the chord	0.7959%	0.0%
HN-032	7.83% at 28.7% of the chord	1.74% at 46.9% of the chord	0.5471%	0.0%
HN-033	8.05% at 28.7% of the chord	1.85% at 46.9% of the chord	0.5724%	0.0%
HN-034	8.05% at 31.6% of the chord	1.85% at 46.9% of the chord	0.4503%	0.0%
HN-035	8.05% at 28.7% of the chord	1.85% at 46.9% of the chord	0.5318%	0.0%
HN-036	7.85% at 28.7% of the chord	1.65% at 46.9% of the chord	0.5107%	0.0%
HN-038	8.05% at 31.6% of the chord	1.85% at 46.9% of the chord	0.4634%	0.0%
HN-1023	10.2% at 31.6% of the chord	2.38% at 46.9% of the chord	0.711%	0.0%
HN-1027	7.5% at 31.6% of the chord	2.55% at 46.9% of the chord	0.4284%	0.0%
HN-1029	8.06% at 28.7% of the chord	2.21% at 46.9% of the chord	0.5121%	0.0%
HN-1033	7.85% at 28.7% of the chord	2.47% at 43.7% of the chord	0.5203%	0.0%
HN-1033A	7.55% at 28.7% of the chord	2.15% at 43.7% of the chord	0.4917%	0.0%
HN-1036	8.54% at 28.7% of the chord	1.83% at 43.7% of the chord	0.572%	0.0%
HN-1038	8.14% at 28.7% of the chord	1.52% at 43.7% of the chord	0.5299%	0.0%
HN-1051	8.55% at 28.7% of the chord	2.0% at 50.0% of the chord	0.6137%	0.0%

HN-1054	8.55% at 28.7% of the chord	1.65% at 46.9% of the chord	0.587%	0.0%
HN-1070	6.55% at 25.9% of the chord	1.74% at 43.7% of the chord	0.4334%	0.0254%
HN-153S	8.34% at 28.7% of the chord	0.0% at 0.0% of the chord	0.5507%	0.0%
HN-163	8.55% at 31.6% of the chord	1.78% at 43.7% of the chord	0.5297%	0.0%
HN-163TA	8.65% at 31.6% of the chord	1.65% at 43.7% of the chord	0.541%	0.0%
HN-163TB	8.35% at 31.6% of the chord	1.85% at 43.7% of the chord	0.5096%	0.0%
HN-184	8.55% at 31.6% of the chord	1.78% at 46.9% of the chord	0.5264%	0.0%
HN-184M	8.55% at 31.6% of the chord	2.38% at 46.9% of the chord	0.5236%	0.0%
HN-188	10.38% at 31.6% of the chord	2.38% at 46.9% of the chord	0.7573%	0.0%
HN-203	10.8% at 31.6% of the chord	2.34% at 43.7% of the chord	0.7077%	0.0%
HN-211	8.14% at 31.6% of the chord	1.65% at 46.9% of the chord	0.4997%	0.0%
HN-216	8.08% at 31.6% of the chord	1.94% at 43.7% of the chord	0.4905%	0.0%
HN-216TA	8.25% at 31.6% of the chord	1.78% at 43.7% of the chord	0.5071%	0.0%
HN-217	8.08% at 31.6% of the chord	2.34% at 43.7% of the chord	0.4827%	0.0%
HN-227	8.99% at 31.6% of the chord	2.35% at 46.9% of the chord	0.5287%	0.0%
HN-239	8.12% at 31.6% of the chord	2.14% at 46.9% of the chord	0.4835%	0.0%
HN-274S	9.14% at 25.9% of the chord	0.0% at 0.0% of the chord	0.584%	0.0%
HN-275S	10.27% at 25.9% of the chord	0.0% at 0.0% of the chord	0.7112%	0.0%
HN-276SA	8.85% at 28.7% of the chord	0.35% at 46.9% of the chord	0.6743%	0.0%
HN-304	10.85% at 31.6% of the chord	2.38% at 46.9% of the chord	0.8014%	0.0%
HN-304TA	11.05% at 31.6% of the chord	2.41% at 46.9% of the chord	0.8285%	0.0%
HN-309	10.85% at 31.6% of the chord	2.08% at 46.9% of the chord	0.8021%	0.0%
HN-311S	7.65% at 28.7% of the chord	0.0% at 62.4% of the chord	0.5144%	0.0%
HN-312S	9.55% at 28.7% of the chord	0.0% at 65.5% of the chord	0.756%	0.0%
HN-315S	7.99% at 25.3% of the chord	0.0% at 0.0% of the chord	0.6083%	0.0%
HN-316S	8.85% at 25.3% of the chord	0.0% at 0.0% of the chord	0.7171%	0.0%
HN-319	11.48% at 31.6% of the chord	2.38% at 46.9% of the chord	0.8918%	0.0%
HN-321	7.85% at 31.6% of the chord	1.55% at 43.7% of the chord	0.4912%	0.0%
HN-326	7.84% at 25.9% of the chord	1.65% at 43.7% of the chord	0.5586%	0.0%
HN327	7.84% at 25.9% of the chord	1.85% at 43.7% of the chord	0.5516%	0.0%
HN-333	8.44% at 31.6% of the chord	2.01% at 46.9% of the chord	0.5146%	0.0%
HN-350	7.84% at 31.6% of the chord	1.94% at 43.7% of the chord	0.4605%	0.0%
HN-350M01	8.99% at 31.6% of the chord	1.94% at 43.7% of the chord	0.5739%	0.0%
HN-350M02	8.84% at 31.6% of the chord	2.33% at 43.7% of the chord	0.5562%	0.0%
HN-352	7.98% at 31.6% of the chord	1.54% at 43.7% of the chord	0.4829%	0.0%
HN-354	7.88% at 31.6% of the chord	1.93% at 43.7% of the chord	0.4716%	0.0%
HN-354A	8.5% at 31.6% of the chord	2.0% at 43.7% of the chord	0.5381%	0.0%
HN-354E	8.05% at 31.6% of the chord	1.93% at 43.7% of the chord	0.4911%	0.0%
HN-354ES	8.05% at 31.6% of the chord	1.55% at 43.7% of the chord	0.4969%	0.0%
HN-354OC	8.55% at 31.6% of the chord	2.65% at 43.7% of the chord	0.5392%	0.0%
HN-354SM	8.38% at 31.6% of the chord	2.34% at 43.7% of the chord	0.5174%	0.0%
HN-354SR	8.05% at 31.6% of the chord	1.64% at 43.7% of the chord	0.4805%	0.0%
HN-360	8.33% at 31.6% of the chord	2.15% at 46.9% of the chord	0.5031%	0.0%
HN-409	10.48% at 31.6% of the chord	2.55% at 46.9% of the chord	0.7466%	0.0%
HN-411	11.14% at 31.6% of the chord	2.38% at 46.9% of the chord	0.7799%	0.0%
HN-417	8.04% at 25.9% of the chord	2.28% at 43.7% of the chord	0.5662%	0.0%
HN-418	8.55% at 28.7% of the chord	2.48% at 43.7% of the chord	0.5975%	0.0%
HN-419	7.77% at 25.9% of the chord	2.38% at 43.7% of the chord	0.5432%	0.0%
HN-424	8.85% at 28.7% of the chord	2.63% at 43.7% of the chord	0.6335%	0.0%
HN-436	8.5% at 28.7% of the chord	1.65% at 46.9% of the chord	0.581%	0.0%
HN-446	7.84% at 28.7% of the chord	1.71% at 46.9% of the chord	0.5164%	0.0%
HN-450	8.32% at 31.6% of the chord	1.88% at 40.6% of the chord	0.497%	0.0%
HN-450S	8.54% at 31.6% of the chord	1.85% at 40.6% of the chord	0.5181%	0.0%
HN-462	8.08% at 31.6% of the chord	1.34% at 43.7% of the chord	0.4933%	0.0%

Note:
Hatschek (J. Hatschek (Czechoslovakia));
HD45, HD46, HD47, HD48, HD48A, HD48B, HD50, HD53, HD54, HD800, HD801 (Hannes Delago);
Hill SR 2 (M. Hill (USA));
HL 73-6508, HL 74-3512, HL 74-5508, HL 75-5414, HL 75-K-3308, HL 80-13353 (B. Horeni – J. Lnenka (Czechoslovakia));
HN 380 (F3B – RCM 205 de 1998);
HN-003, HN-1023, HN-188, HN-203, HN-304, HN-304TA, HN-309, HN-319, HN-409, HN-411 (Planeur>3.5m, Norbert Habbe);
HN-032, HN-036, HN-038, HN-1038, HN-321, HN-326, HN-354ES, HN-354SR, HN-436, HN-446, HN-462 (F3F Norbert Habbe);
HN-033, HN-163, HN-163TA, HN-163TB, HN-184, HN-216, HN-216TA, HN327, HN-350, HN-354, HN-354E (F3B Norbert Habbe);
HN-034, HN-035 (F3 Norbert Habbe);
HN-1027, HN-1029, HN-1033, HN-1033A, HN-1070, HN-419 (HLG Norbert Habbe);
HN-1036, HN-1051, HN-1054, HN-184M, HN-418, HN-424, HN-450, HN-450S (Planeur Norbert Habbe);
HN-153S, HN-274S, HN-275S, HN-276SA, HN-311S, HN-312S, HN-315S, HN-316S (Aile volante Norbert Habbe);
HN-211 (F3F-F3B Norbert Habbe);
HN-217, HN-227, HN-239, HN-333, HN-350M01, HN-350M02, HN-352, HN-354OC, HN-354SM, HN-360, HN-417 (F3J Norbert Habbe);
HN-354A (BASIC Norbert Habbe).

Table 2. The geometric shapes of the airfoils in the cross section.





HN-1038
HN-1051
HN-1054
HN-1070
HN-153S
HN-163
HN-163TA
HN-163TB
HN-184
HN-184M
HN-188
HN-203
HN-211
HN-216
HN-216TA
HN-217
HN-227
HN-239
HN-274S
HN-275S
HN-276SA
HN-304
HN-304TA
HN-309
HN-311S
HN-312S
HN-315S
HN-316S
HN-319
HN-321
HN-326
HN327
HN-333
HN-350
HN-350M01
HN-350M02
HN-352
HN-354
HN-354A
HN-354E
HN-354ES
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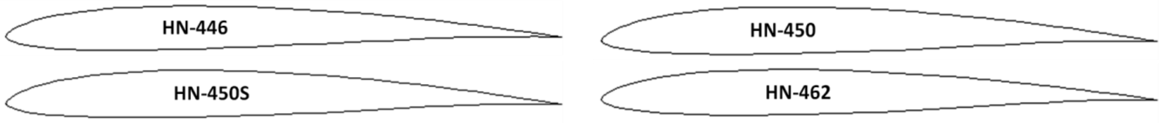
HN-436



Results and discussion

The calculated pressure contours on the surfaces of the airfoils at the different angles of attack are presented in the Figs. 1-102. The calculated values on the scale can be represented as the basic values when comparing the pressure drop under conditions of changing the angle of attack of the airfoils.

102 airfoils of the HN, HL, HD, HAR, etc. series were studied in this work. The airfoils are represented by asymmetrical geometries and symmetrical geometries (HN-153S, HN-274S, HN-275S, HN-311S, HN-312S, HN-315S and HN-316S) in the cross section.

The greatest drag value was determined on the leading edge of the Hill SR 2 airfoil. The drag coefficient was calculated from the calculated value of positive pressure (6.63 kPa) that occurs on the leading edge of the airplane wing flying horizontally. Similarly, the lowest drag value (3.75 kPa) was obtained on the leading edges of the HN-1027 and HN-311S airfoils. Thus, the drag value of the airfoils of the HN series is almost 2 times less than that of the airfoils of other series. This decrease in the drag is noted for the HN-038 – HN-462 airfoils. The analysis of the calculation results showed that at the positive angles of attack, maximum negative pressure is formed on the surfaces of the airfoils. In particular, the negative pressure value is -82 kPa for the HN-035 airfoil. The action of positive and negative pressures of the small value (from 4 to -15 kPa) on the surfaces and the edges is observed at the negative angles of attack of the most airfoils of the HN series.

Let us consider in detail some airfoils that have the special geometric shapes in the cross section. The HAR2 airfoil, compared to the other two airfoils in this series, is subjected to less negative pressure during the airplane descent. The camber of the airfoil leads to the formation of areas of positive and negative pressures along the entire length of the upper surface. The descent and horizontal flight of the airplane with the HL 74-5508 wing airfoil are characterized by a minimum difference (about 1.0 kPa) of positive and negative pressures arising on the surfaces and the edges. The asymmetrical shape of the Hill SR 2 airfoil ensures the formation of the pressures areas of almost the same value during the airplane maneuvers.

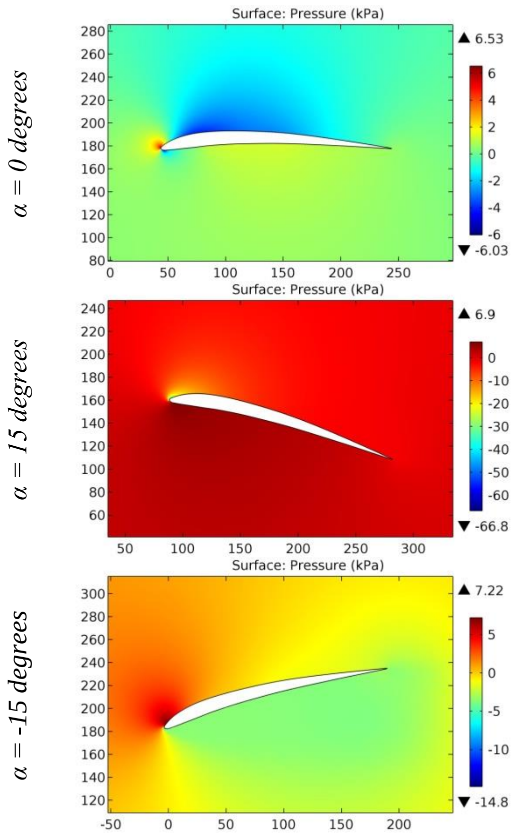


Figure 1. The pressure contours on the surfaces of the H-6355 airfoil.

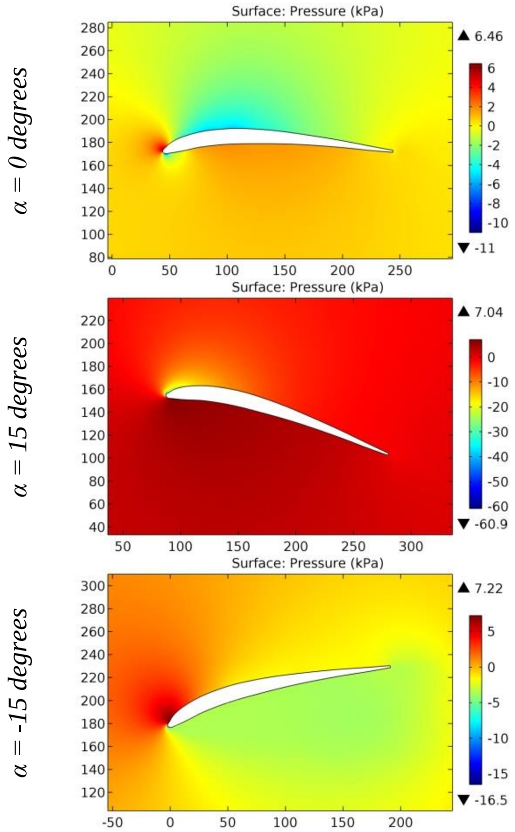


Figure 2. The pressure contours on the surfaces of the H-7327 airfoil.

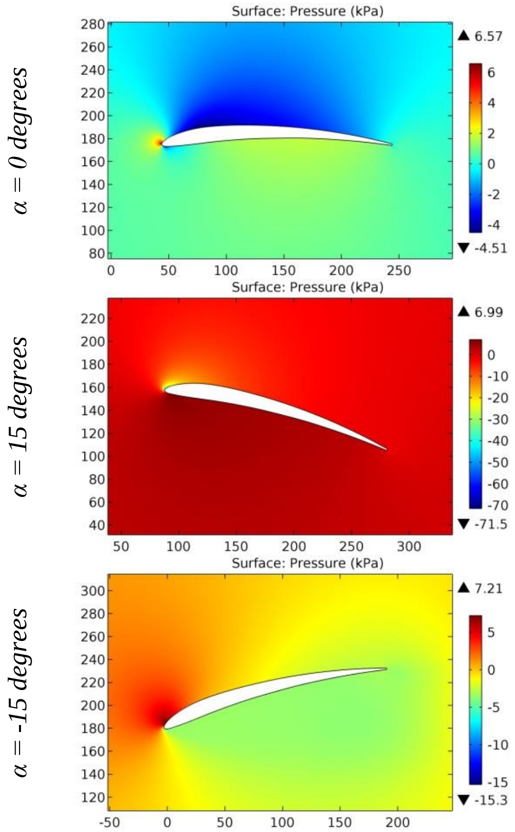


Figure 3. The pressure contours on the surfaces of the HANS6407 airfoil.

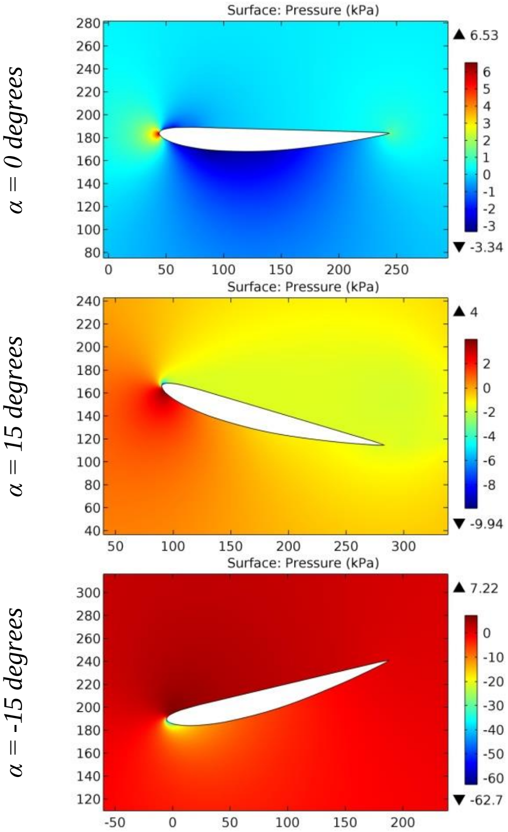


Figure 4. The pressure contours on the surfaces of the HAR airfoil.

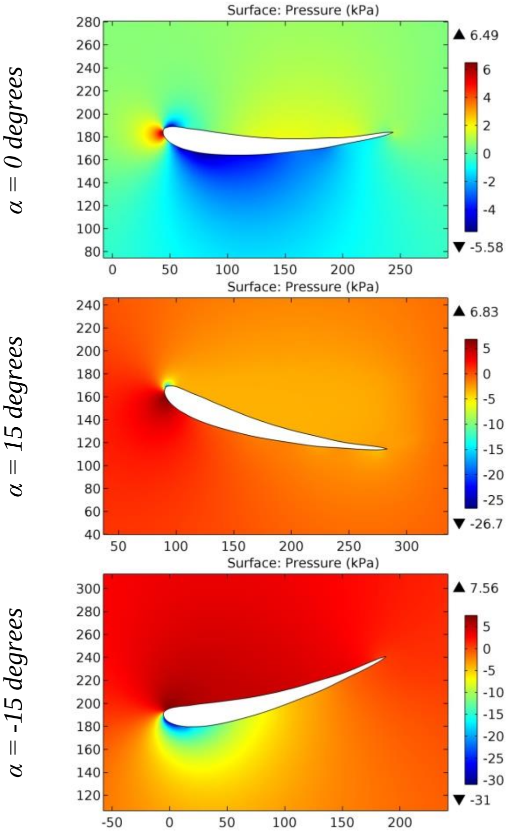


Figure 5. The pressure contours on the surfaces of the HAR2 airfoil.

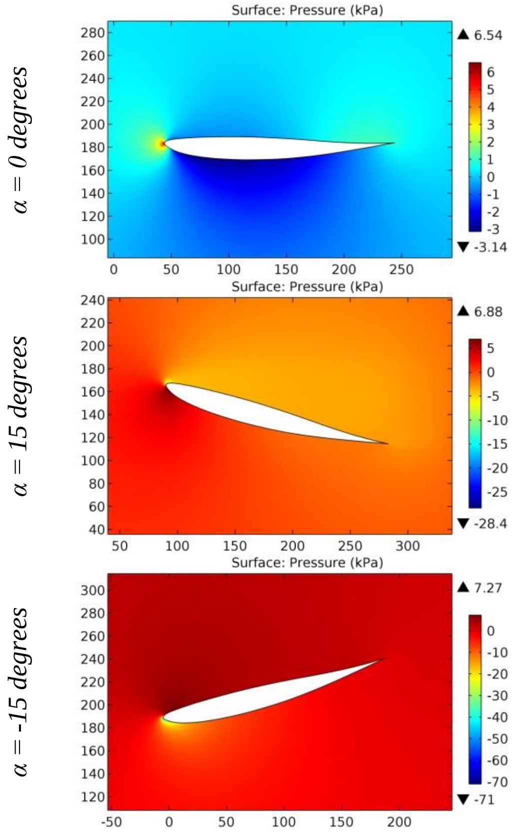


Figure 6. The pressure contours on the surfaces of the HAR3 airfoil.

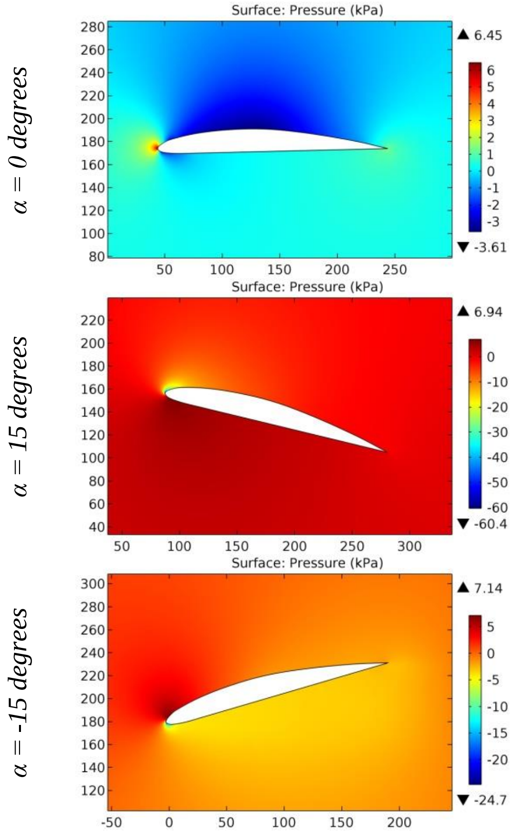


Figure 7. The pressure contours on the surfaces of the Hatschek airfoil.

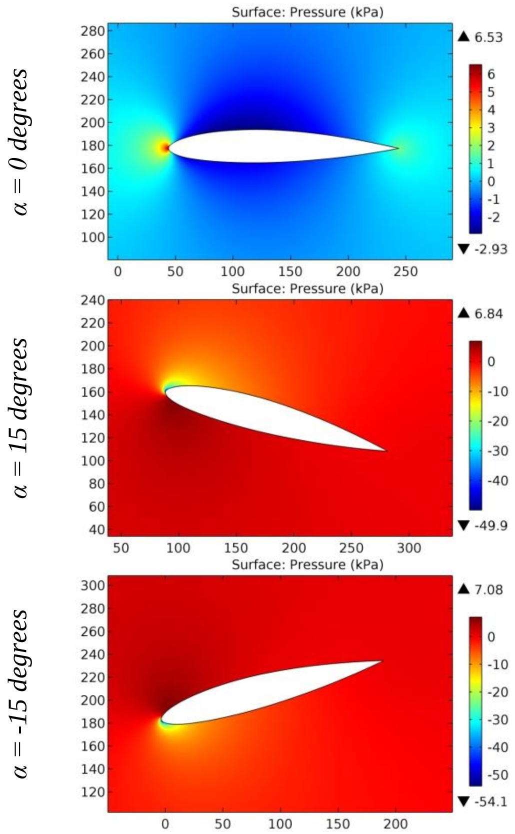


Figure 8. The pressure contours on the surfaces of the HAWKER TEMPEST 37,5% SEMISPAN airfoil.

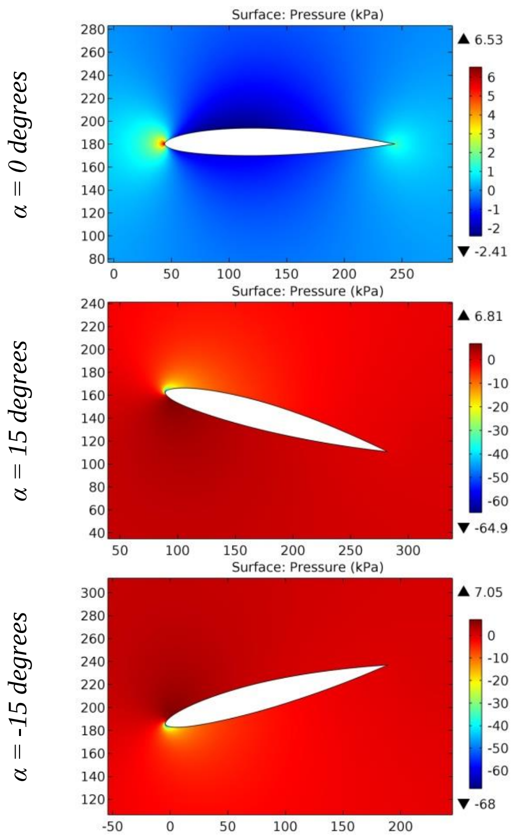


Figure 9. The pressure contours on the surfaces of the HAWKER TEMPEST 61% SEMISPAN airfoil.

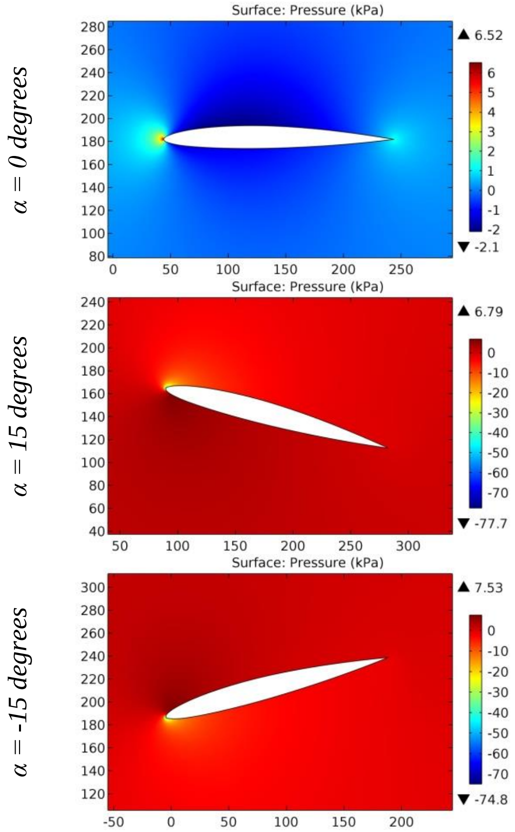


Figure 10. The pressure contours on the surfaces of the HAWKER TEMPEST 96,77% SEMISPAN airfoil.

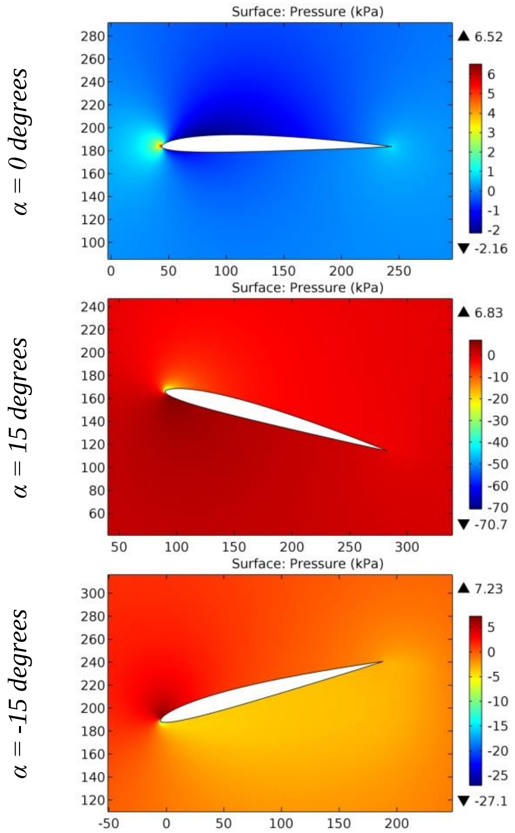


Figure 11. The pressure contours on the surfaces of the HD45 airfoil.

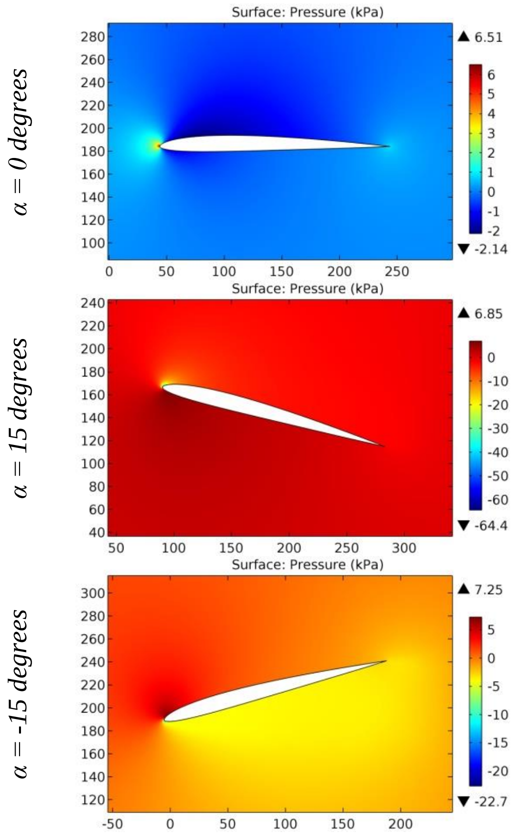


Figure 12. The pressure contours on the surfaces of the HD46 airfoil.

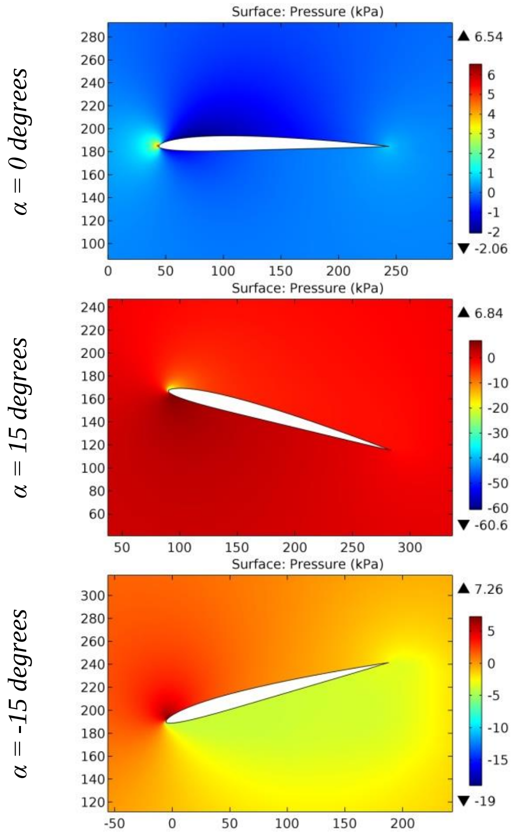


Figure 13. The pressure contours on the surfaces of the HD47 airfoil.

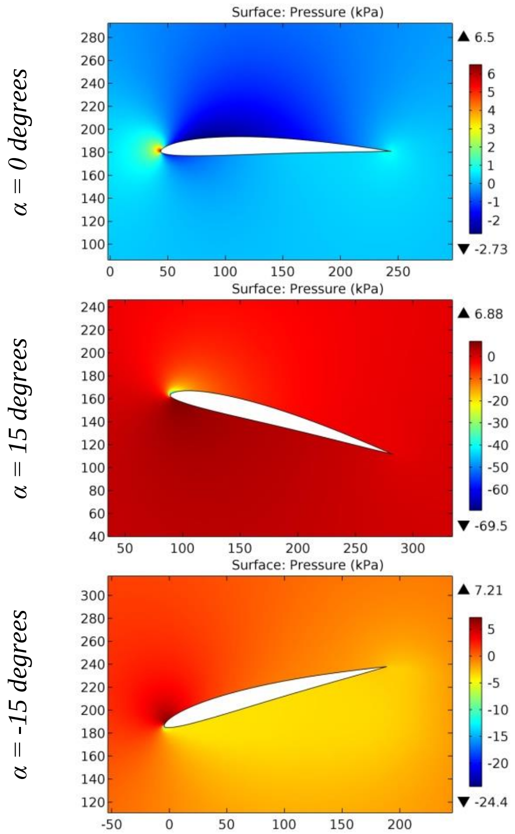


Figure 14. The pressure contours on the surfaces of the HD48 airfoil.

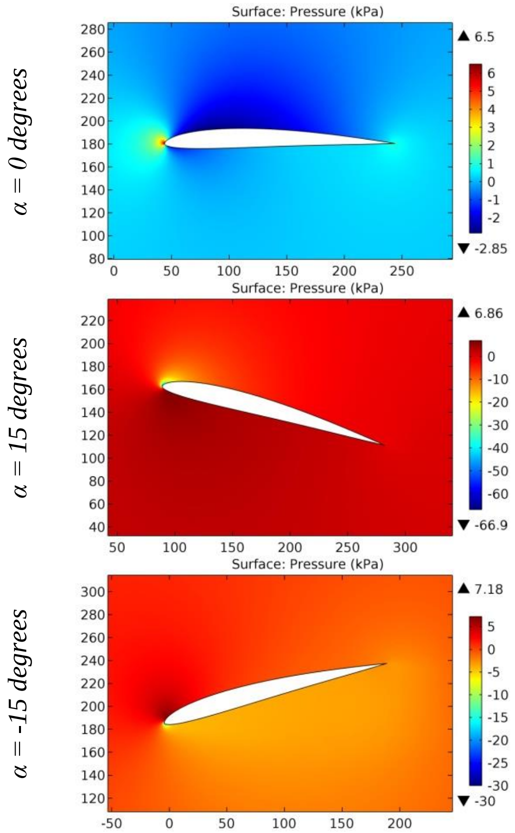


Figure 15. The pressure contours on the surfaces of the HD48A airfoil.

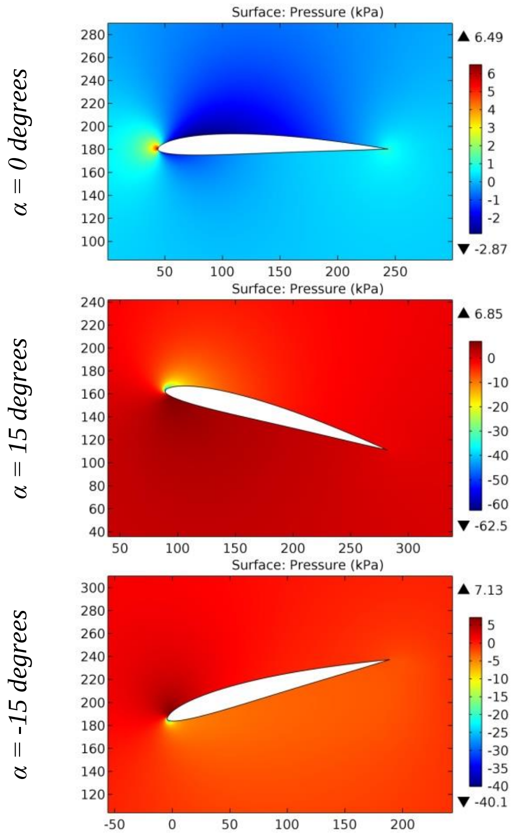


Figure 16. The pressure contours on the surfaces of the HD48B airfoil.

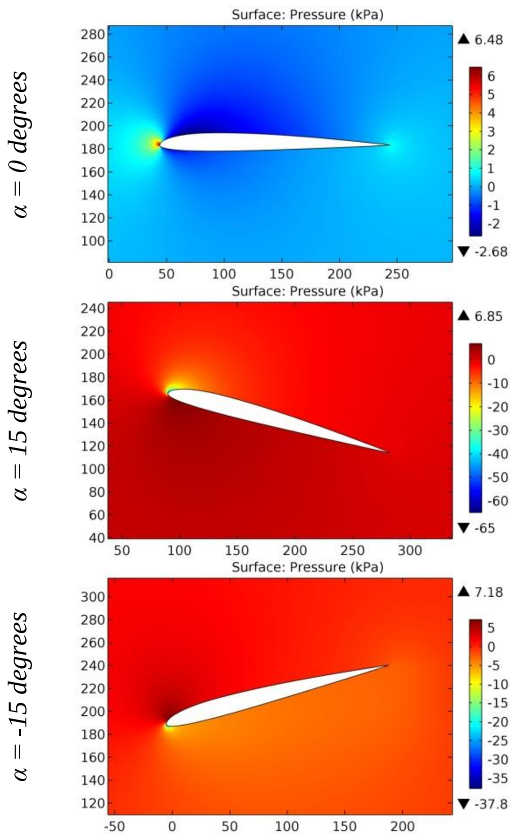


Figure 17. The pressure contours on the surfaces of the HD50 airfoil.

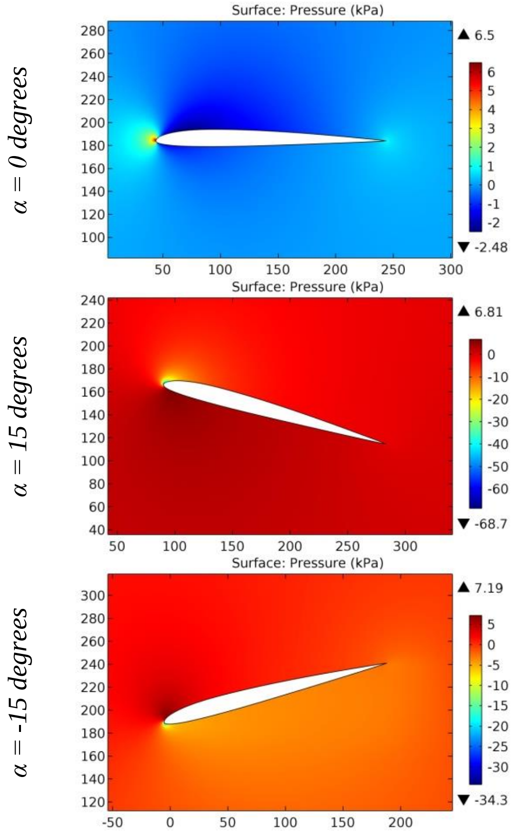


Figure 18. The pressure contours on the surfaces of the HD53 airfoil.

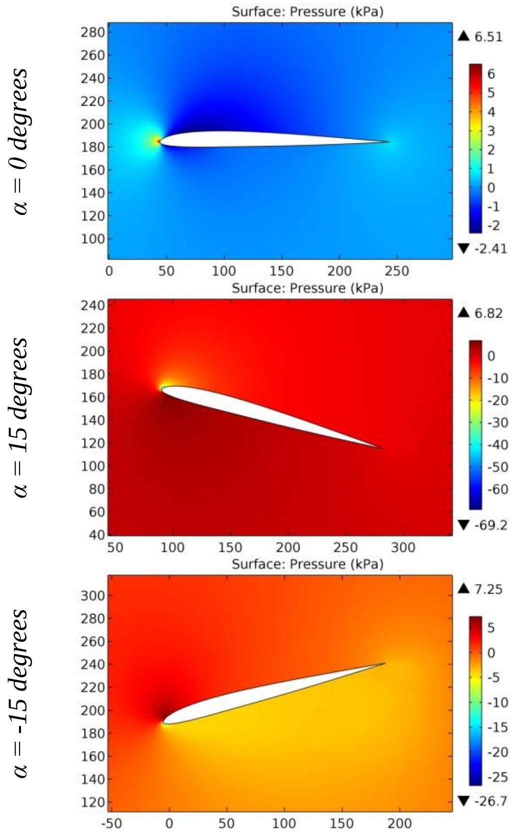


Figure 19. The pressure contours on the surfaces of the HD54 airfoil.

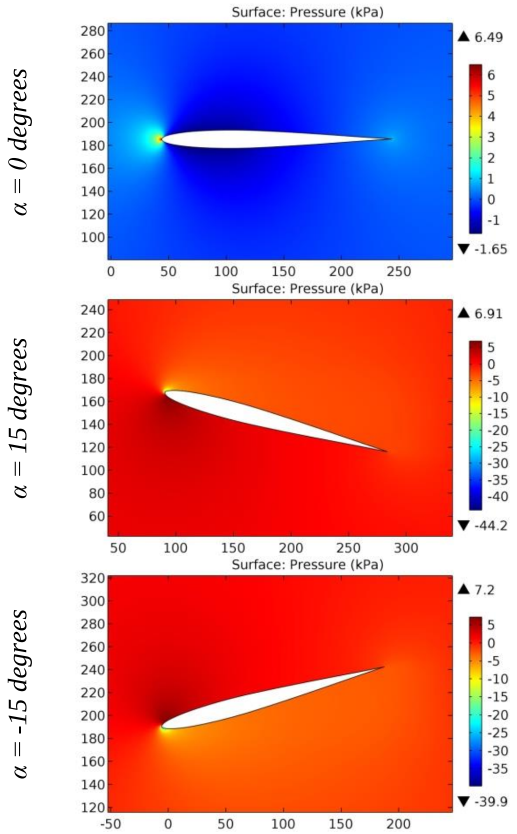


Figure 20. The pressure contours on the surfaces of the HD800 airfoil.

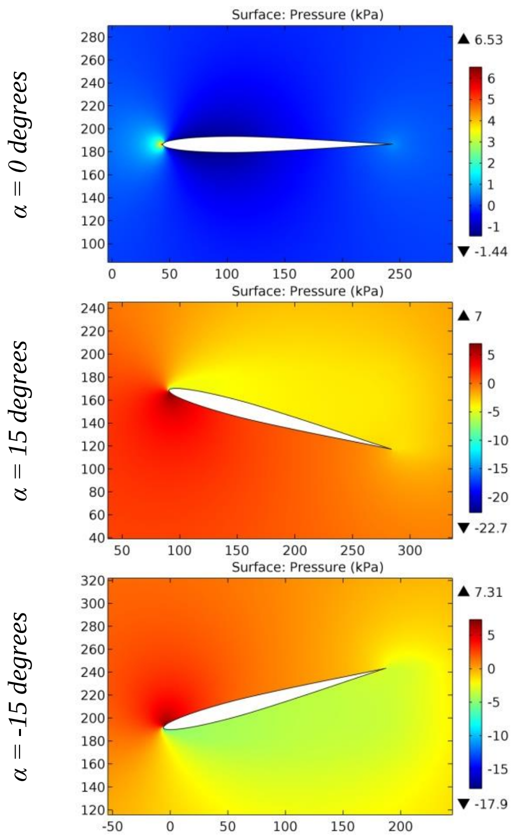


Figure 21. The pressure contours on the surfaces of the HD801 airfoil.

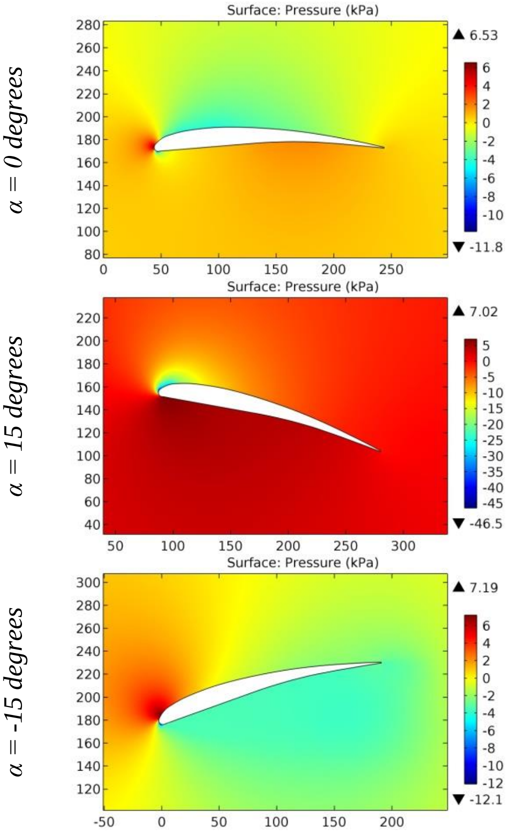


Figure 22. The pressure contours on the surfaces of the HE82R1-6 airfoil.

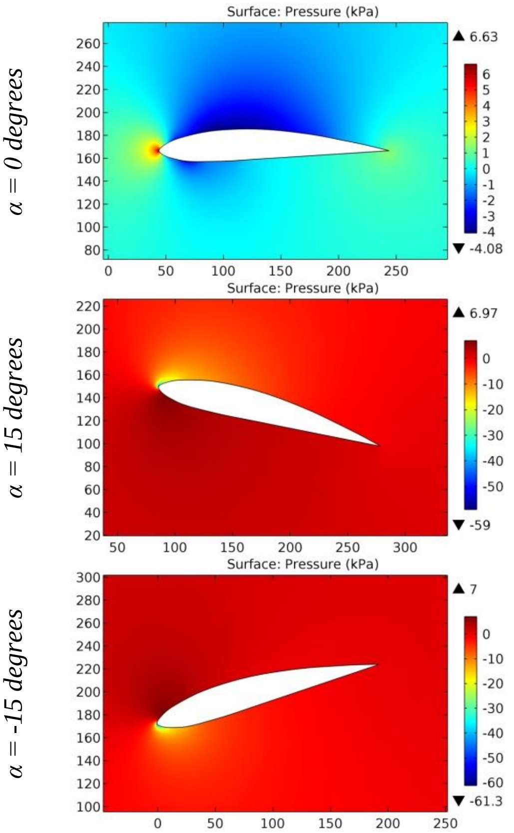


Figure 23. The pressure contours on the surfaces of the Hill SR 2 airfoil.

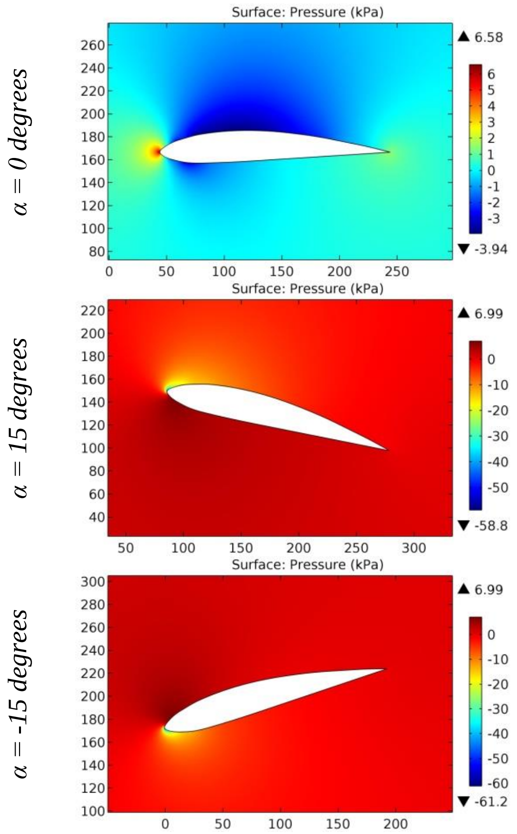


Figure 24. The pressure contours on the surfaces of the HILL-SR2 airfoil.

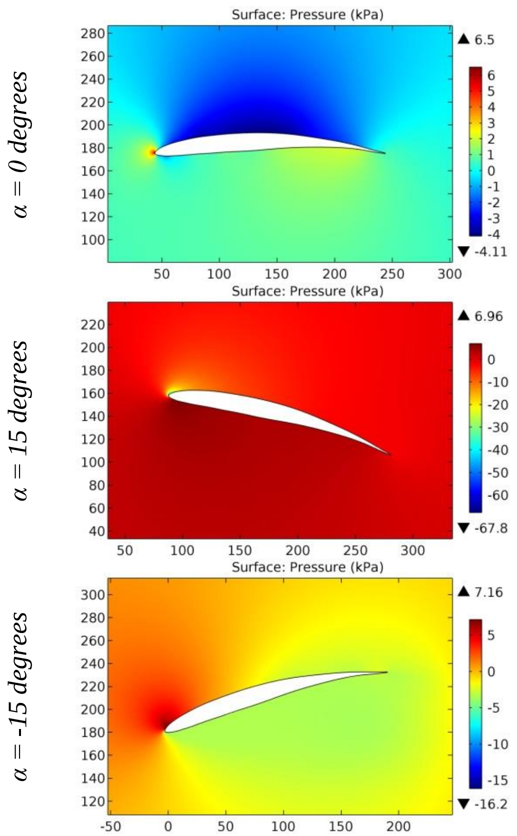


Figure 25. The pressure contours on the surfaces of the HL 73-6508 airfoil.

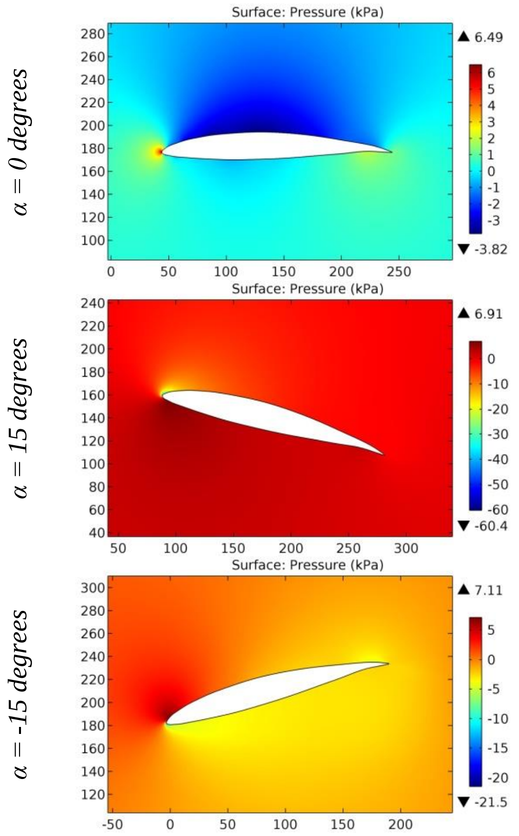


Figure 26. The pressure contours on the surfaces of the HL 74-3512 airfoil.

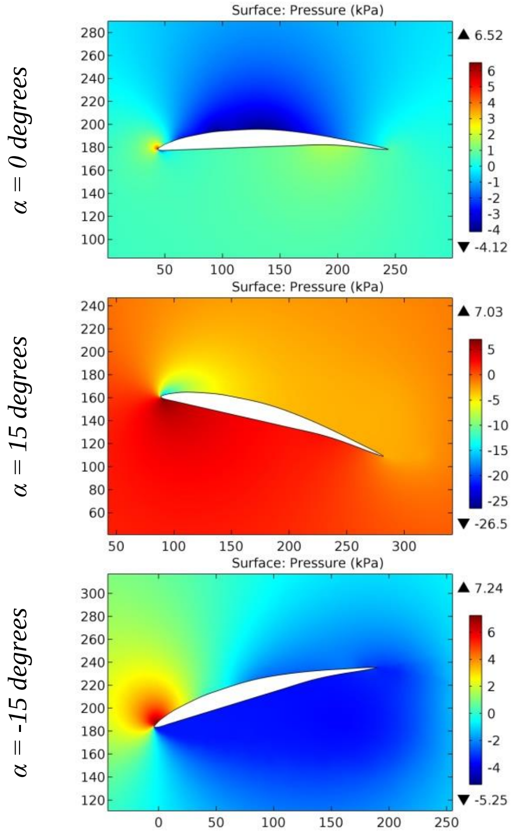


Figure 27. The pressure contours on the surfaces of the HL 74-5508 airfoil.

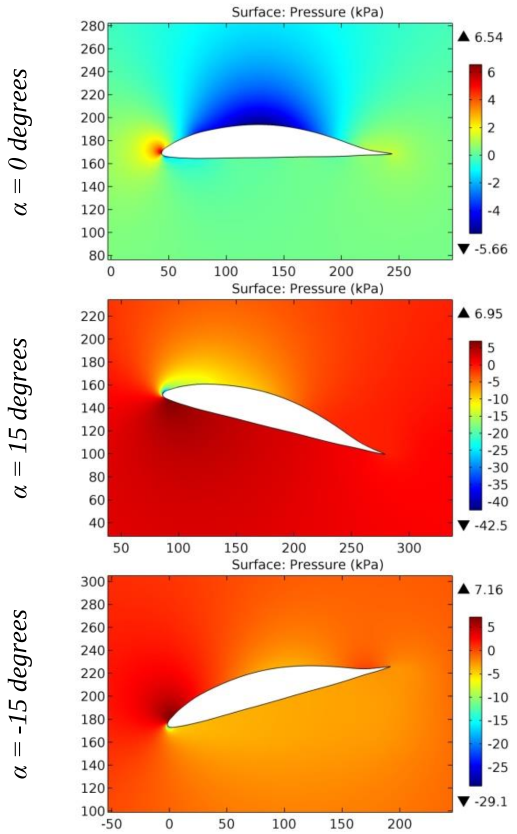


Figure 28. The pressure contours on the surfaces of the HL 75-5414 airfoil.

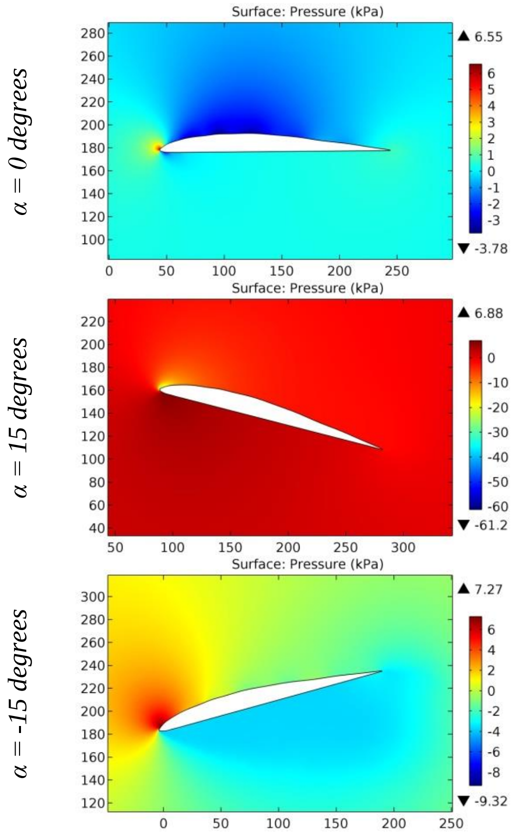


Figure 29. The pressure contours on the surfaces of the HL 75-K-3308 airfoil.

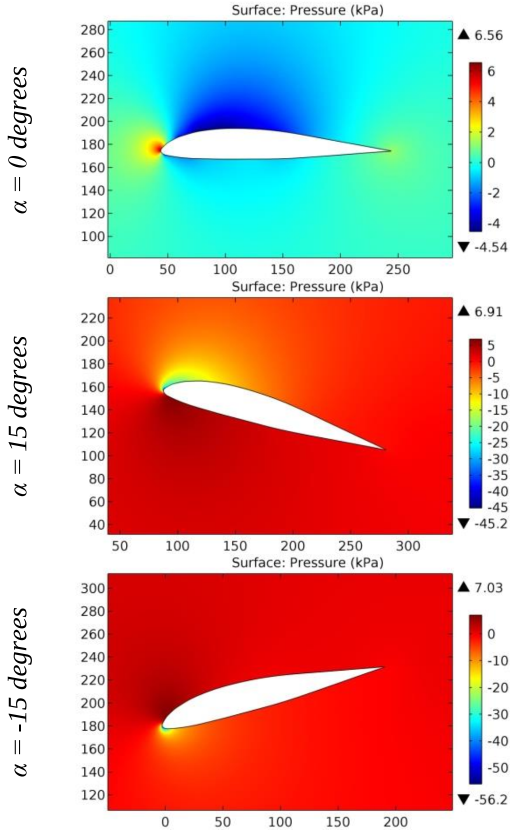


Figure 30. The pressure contours on the surfaces of the HL 80-13353 airfoil.

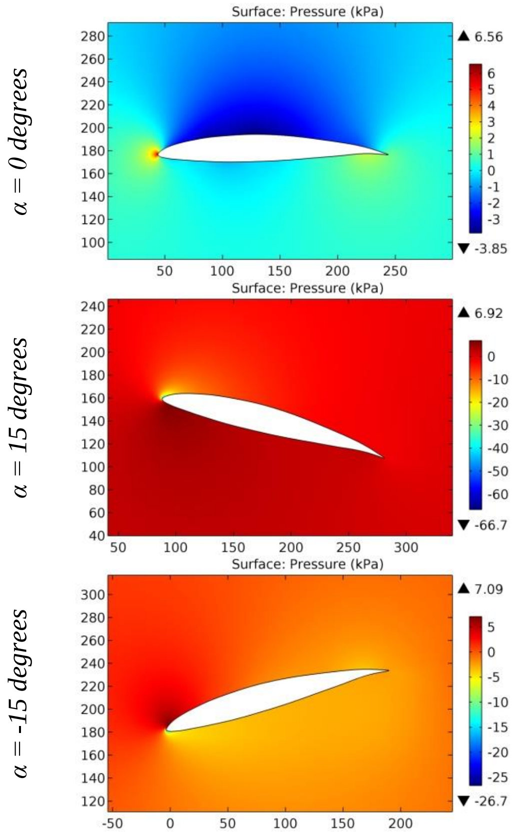


Figure 31. The pressure contours on the surfaces of the HL743512 airfoil.

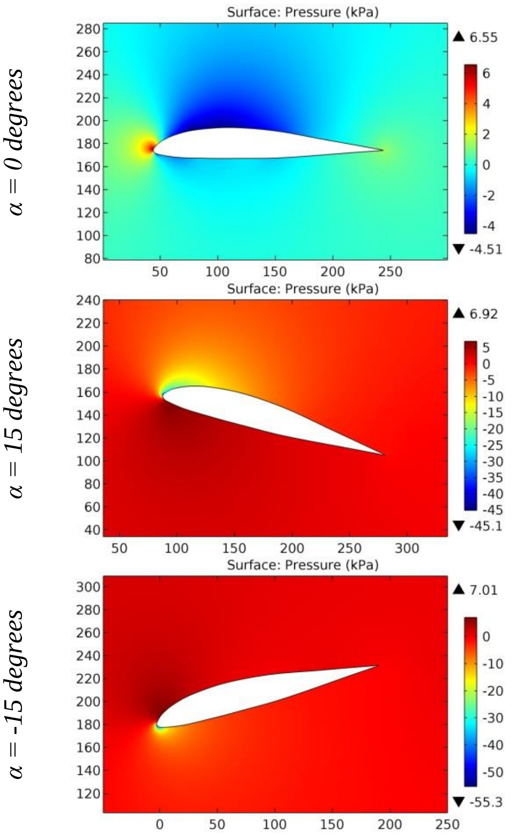


Figure 32. The pressure contours on the surfaces of the HL813353 airfoil.

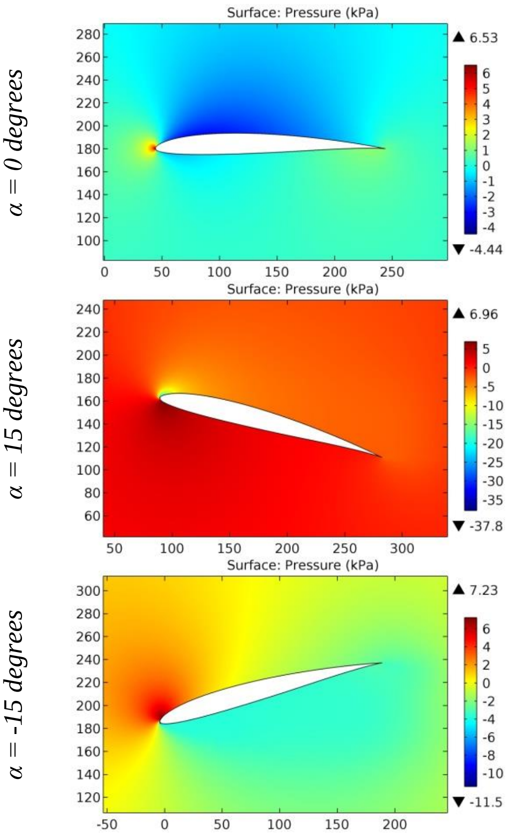


Figure 33. The pressure contours on the surfaces of the HN 380 airfoil.

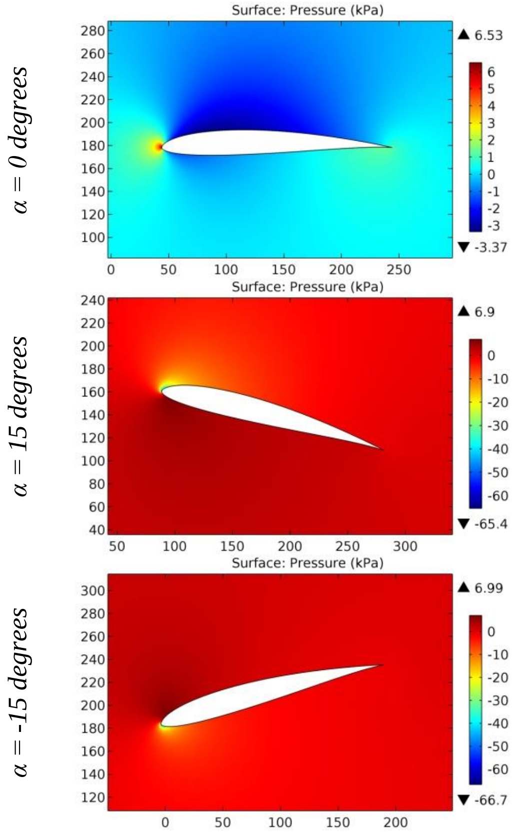


Figure 34. The pressure contours on the surfaces of the HN-003 airfoil.

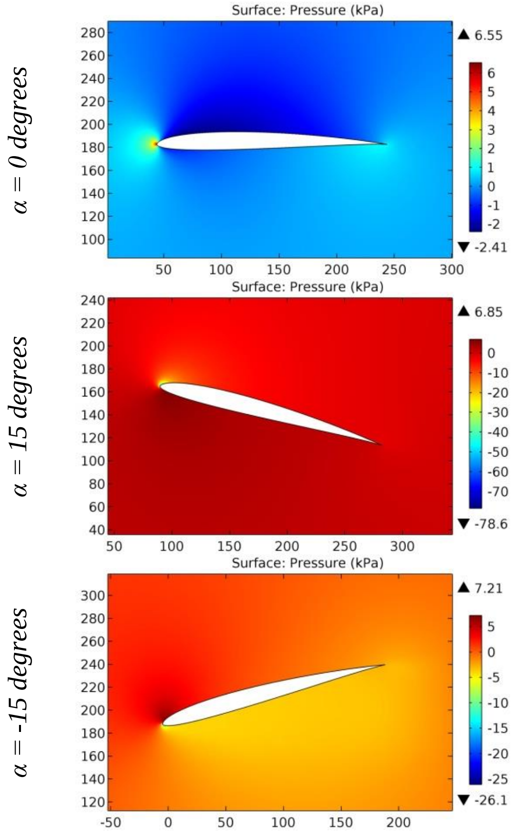


Figure 35. The pressure contours on the surfaces of the HN-032 airfoil.

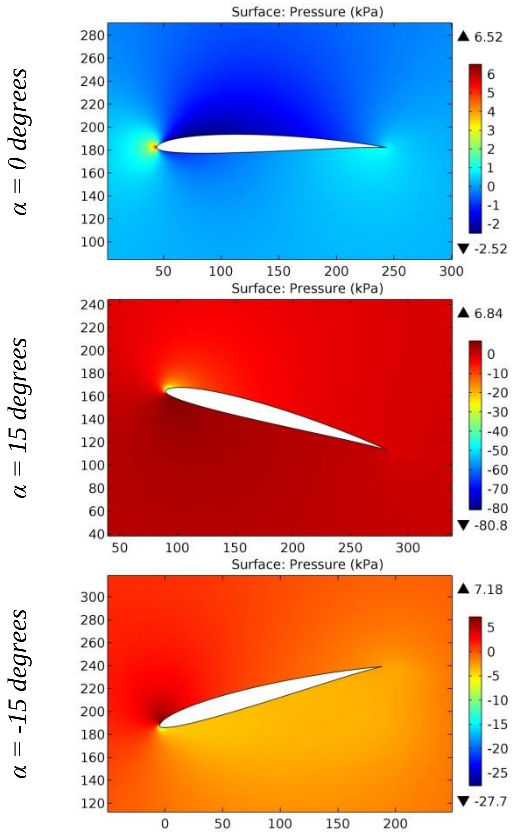


Figure 36. The pressure contours on the surfaces of the HN-033 airfoil.

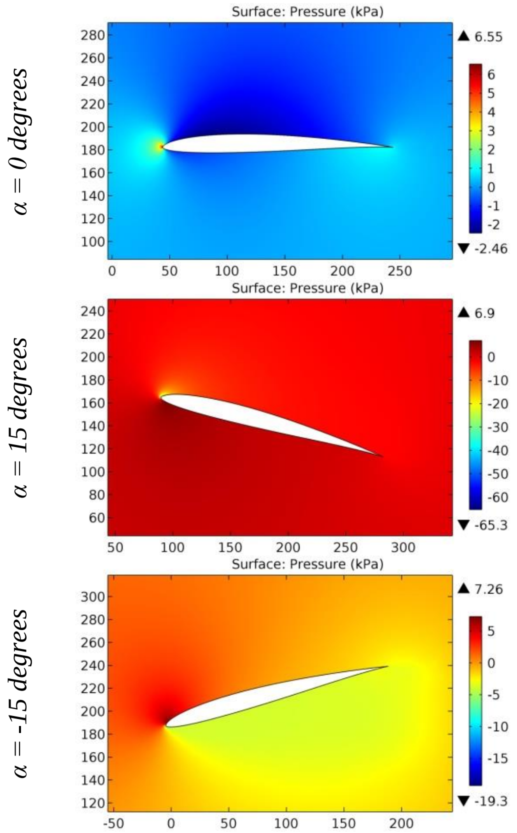


Figure 37. The pressure contours on the surfaces of the HN-034 airfoil.

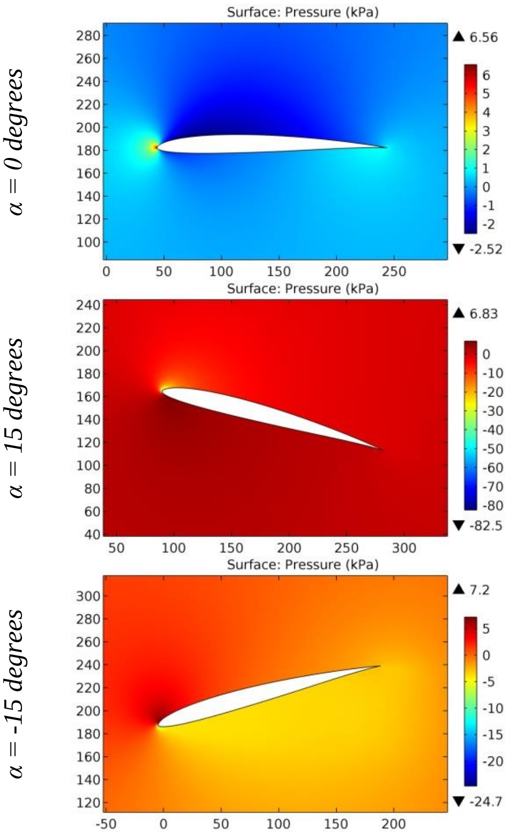


Figure 38. The pressure contours on the surfaces of the HN-035 airfoil.

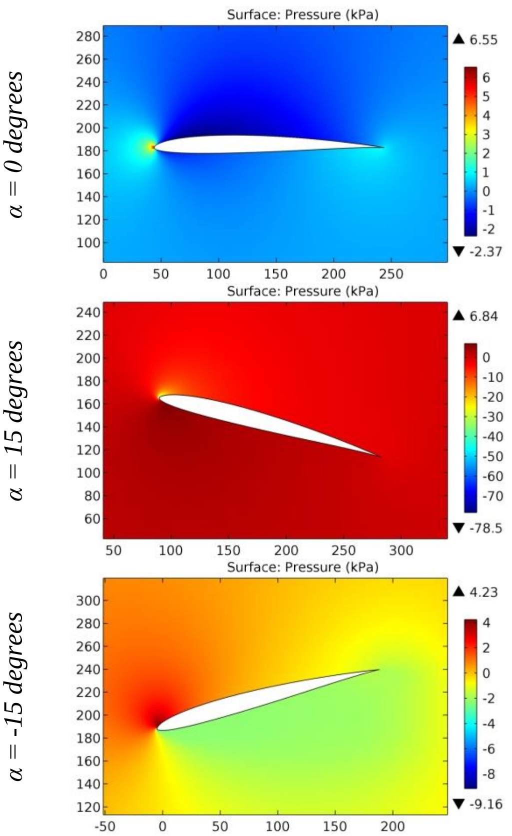


Figure 39. The pressure contours on the surfaces of the HN-036 airfoil.

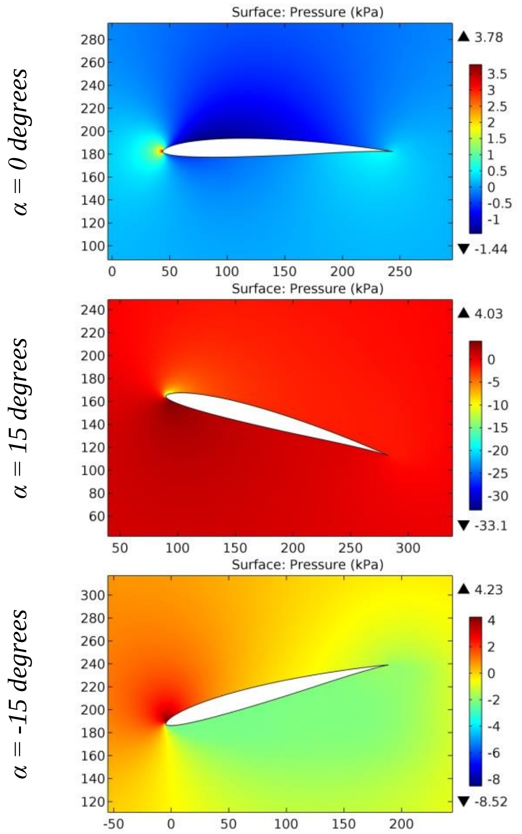


Figure 40. The pressure contours on the surfaces of the HN-038 airfoil.

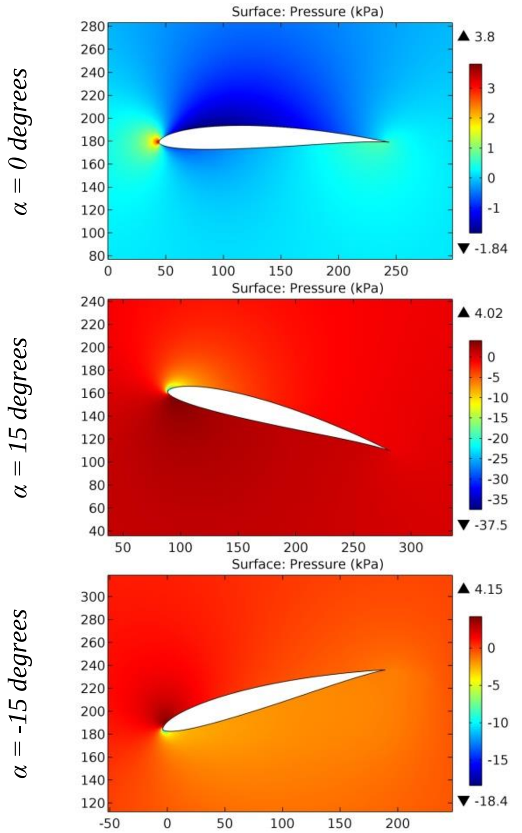


Figure 41. The pressure contours on the surfaces of the HN-1023 airfoil.

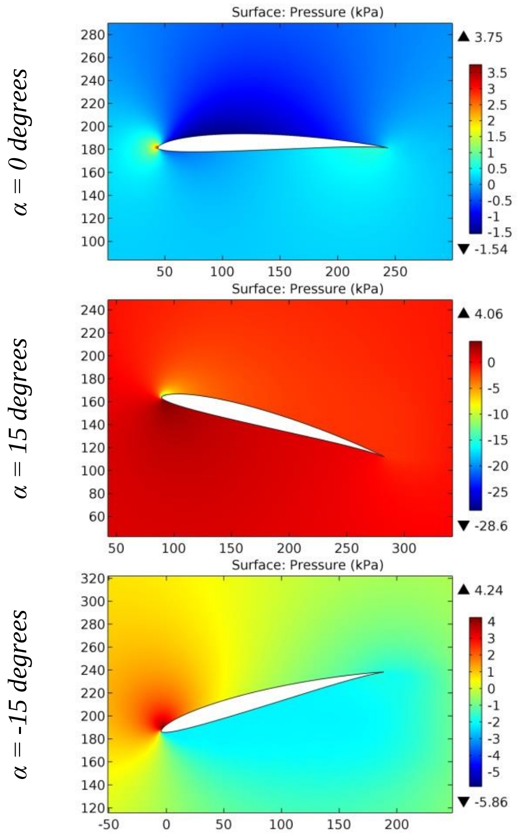


Figure 42. The pressure contours on the surfaces of the HN-1027 airfoil.

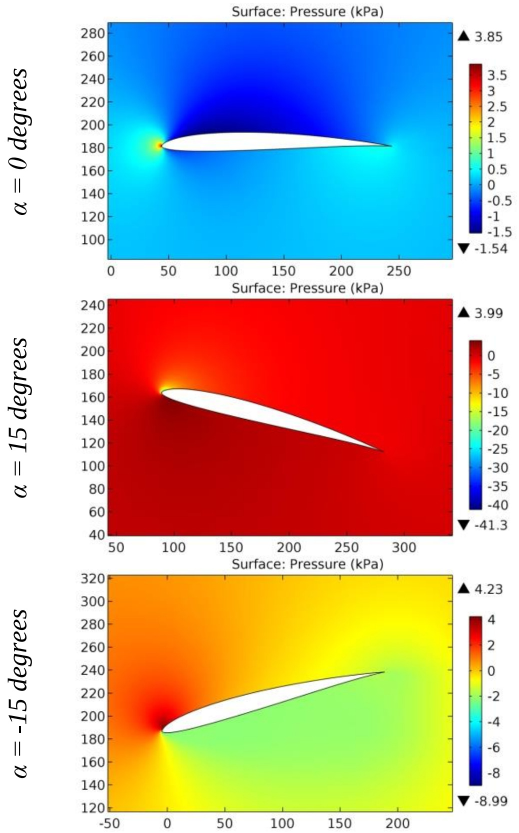


Figure 43. The pressure contours on the surfaces of the HN-1029 airfoil.

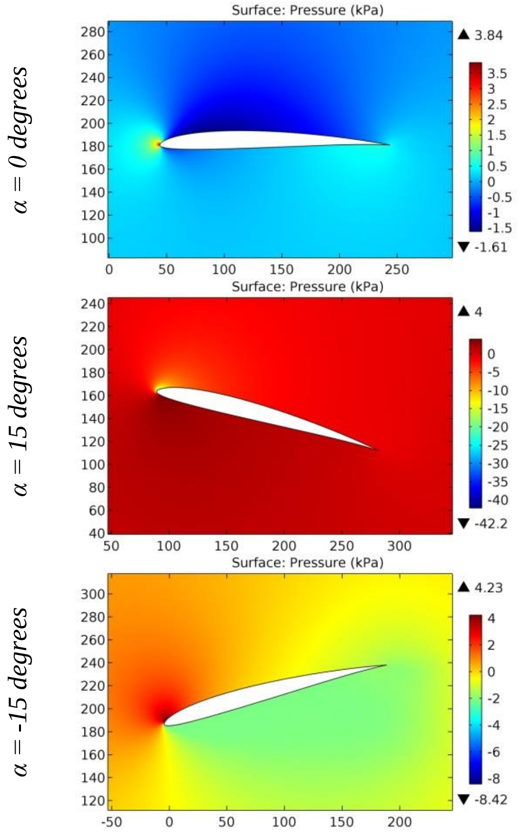


Figure 44. The pressure contours on the surfaces of the HN-1033 airfoil.

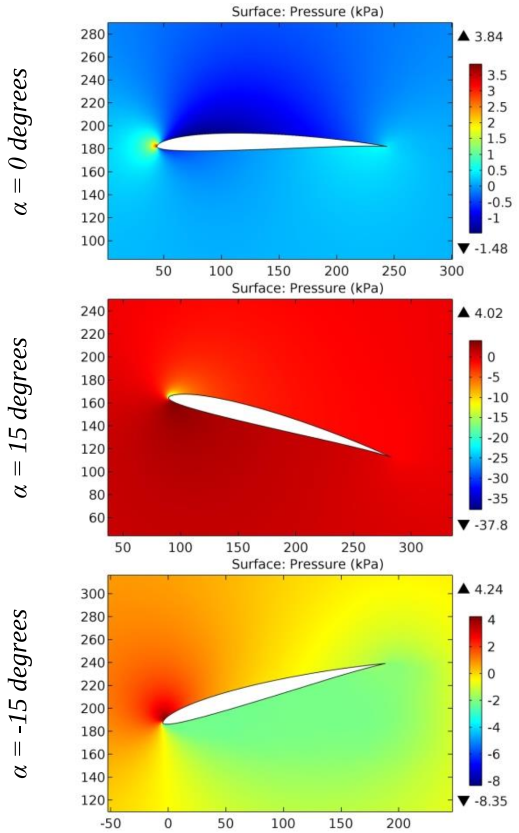


Figure 45. The pressure contours on the surfaces of the HN-1033A airfoil.

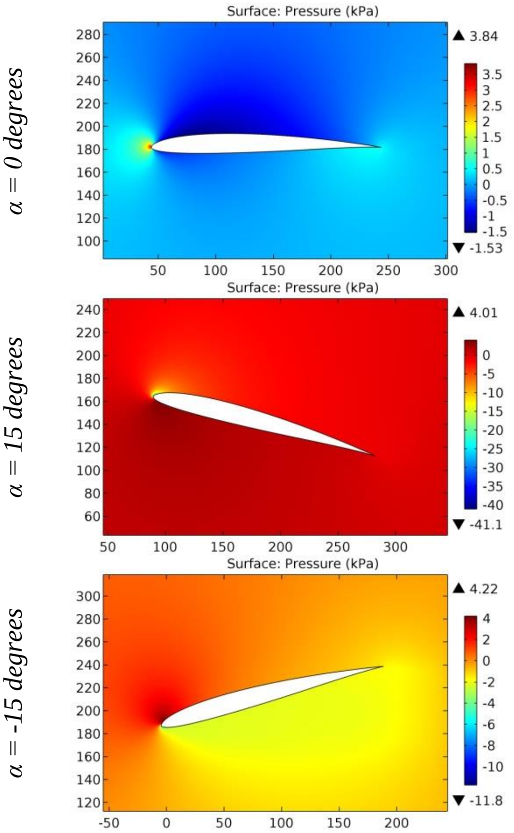


Figure 46. The pressure contours on the surfaces of the HN-1036 airfoil.

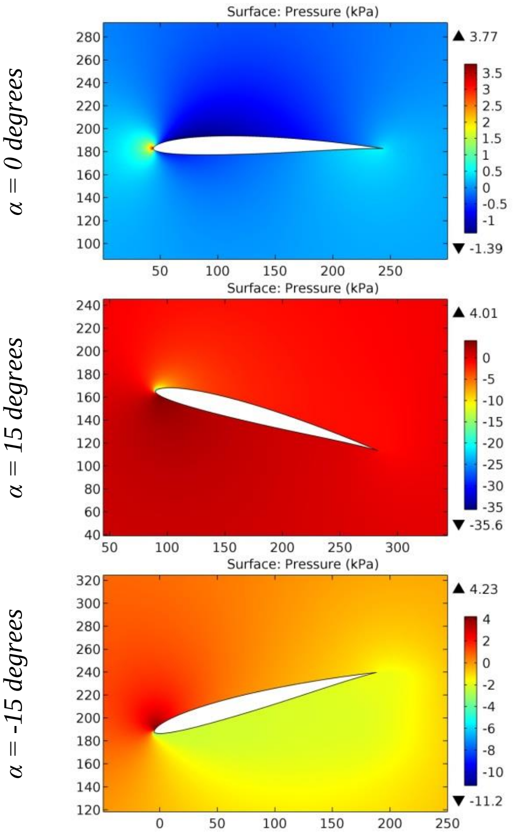


Figure 47. The pressure contours on the surfaces of the HN-1038 airfoil.

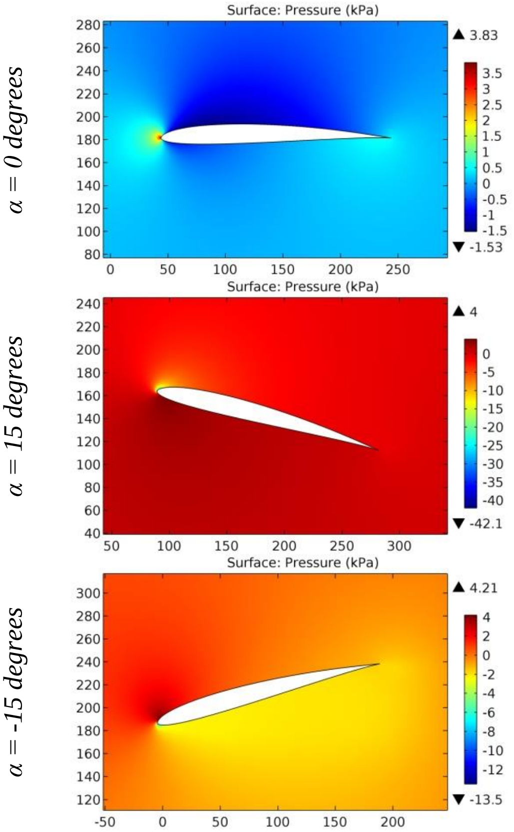


Figure 48. The pressure contours on the surfaces of the HN-1051 airfoil.

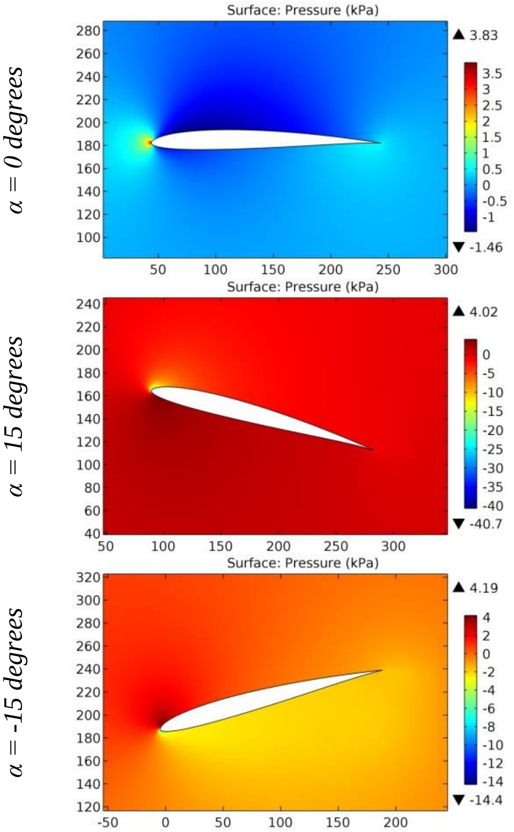


Figure 49. The pressure contours on the surfaces of the HN-1054 airfoil.

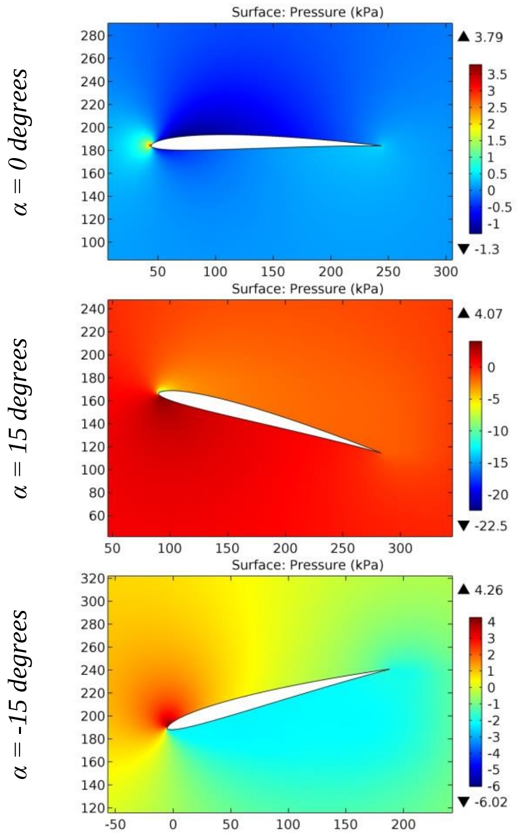


Figure 50. The pressure contours on the surfaces of the HN-1070 airfoil.

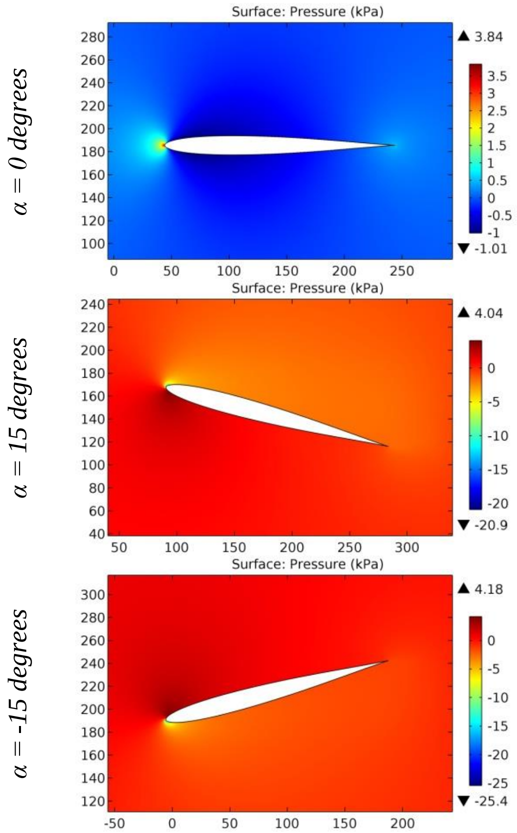


Figure 51. The pressure contours on the surfaces of the HN-153S airfoil.

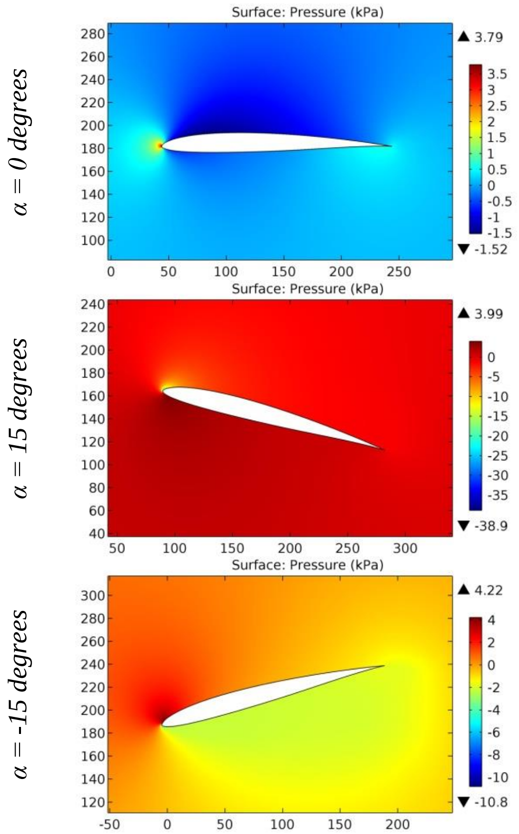


Figure 52. The pressure contours on the surfaces of the HN-163 airfoil.

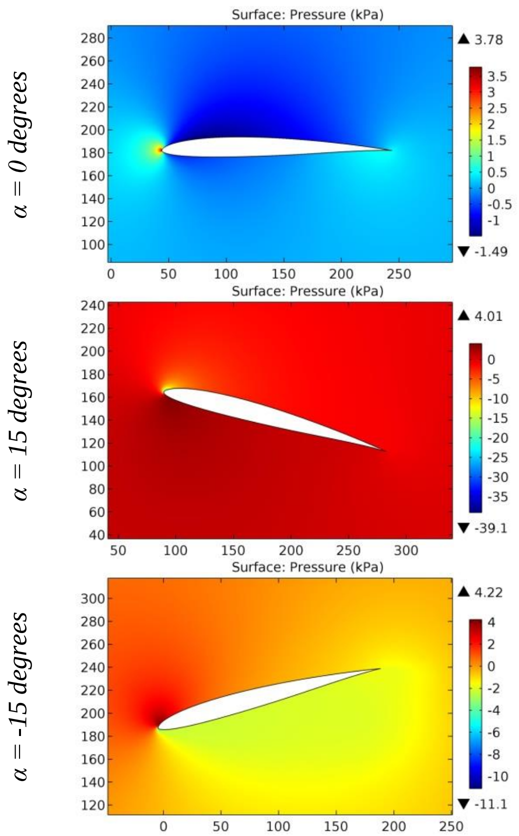


Figure 53. The pressure contours on the surfaces of the HN-163TA airfoil.

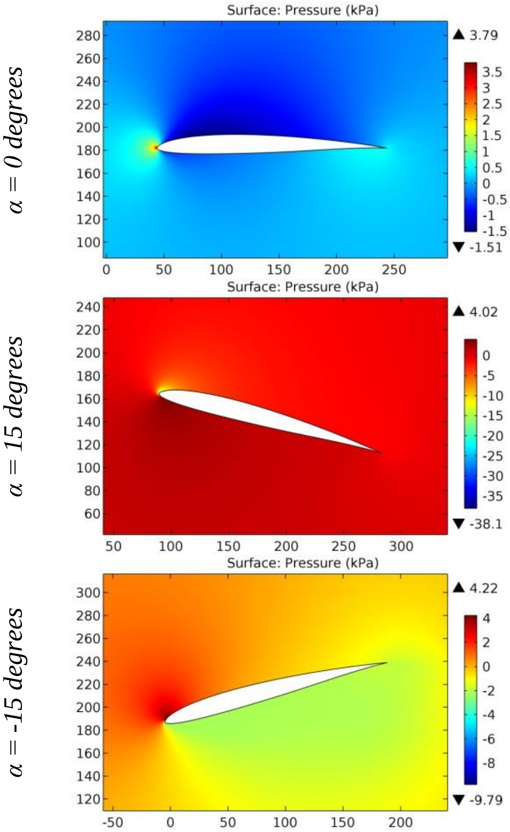


Figure 54. The pressure contours on the surfaces of the HN-163TB airfoil.

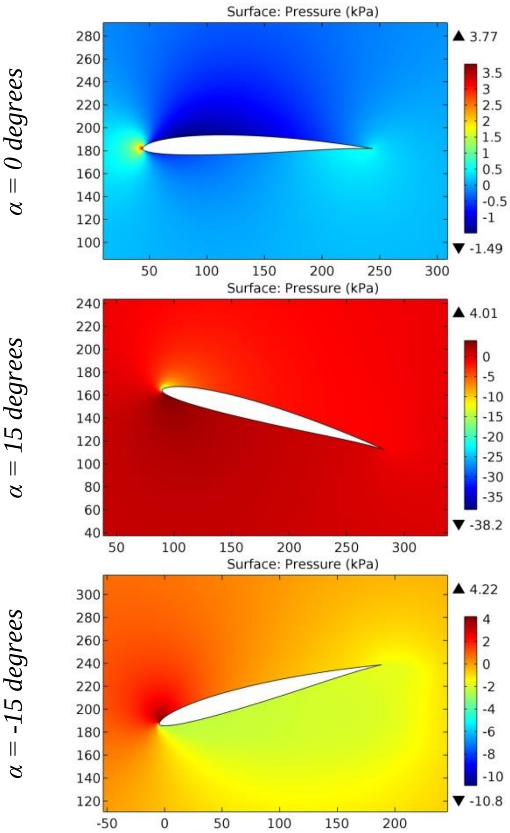


Figure 55. The pressure contours on the surfaces of the HN-184 airfoil.

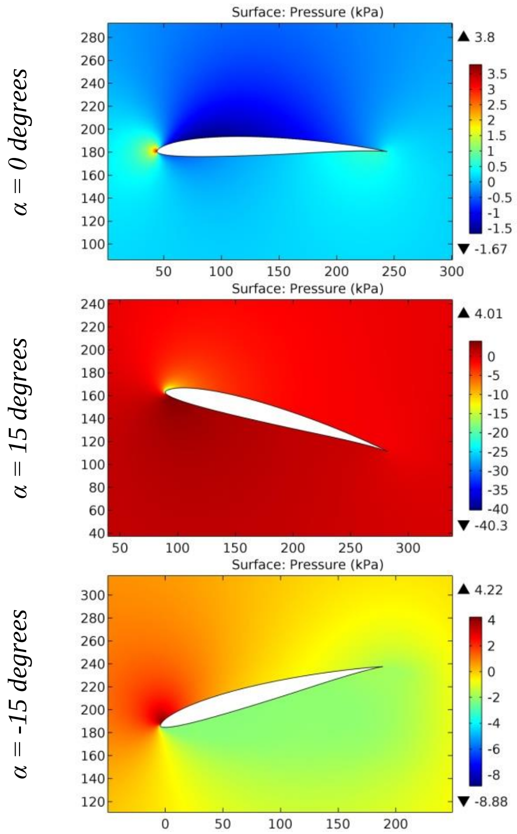


Figure 56. The pressure contours on the surfaces of the HN-184M airfoil.

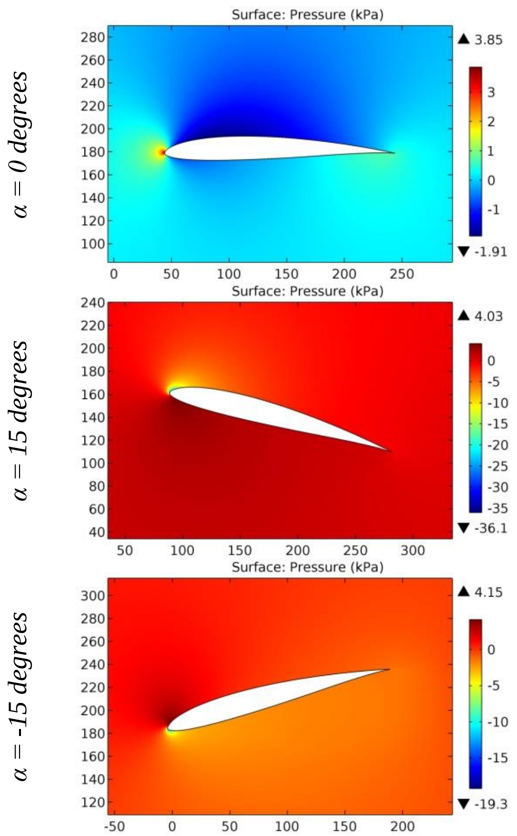


Figure 57. The pressure contours on the surfaces of the HN-188 airfoil.

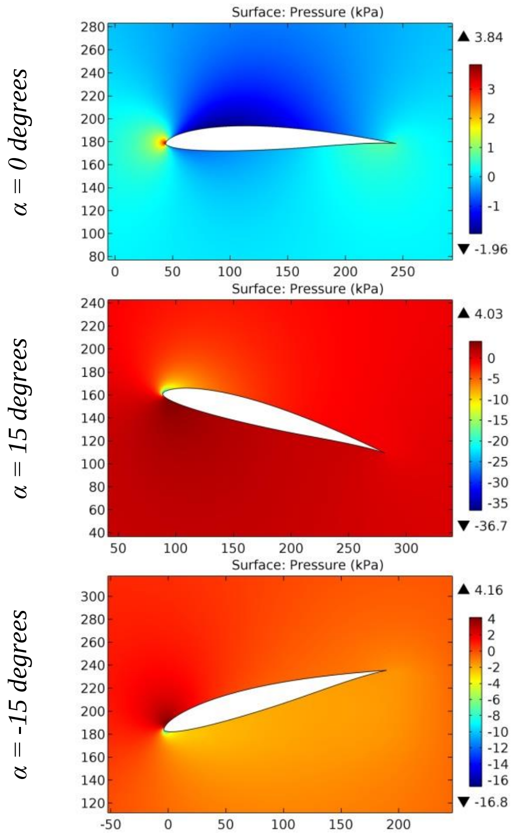


Figure 58. The pressure contours on the surfaces of the HN-203 airfoil.

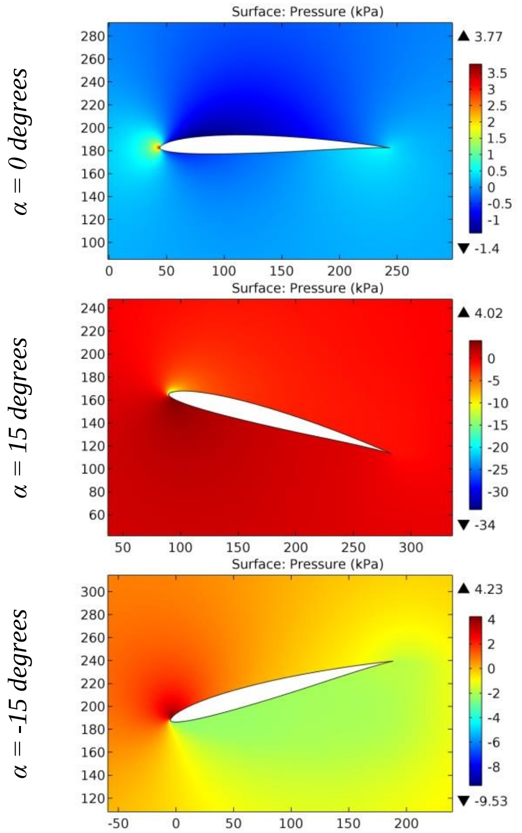


Figure 59. The pressure contours on the surfaces of the HN-211 airfoil.

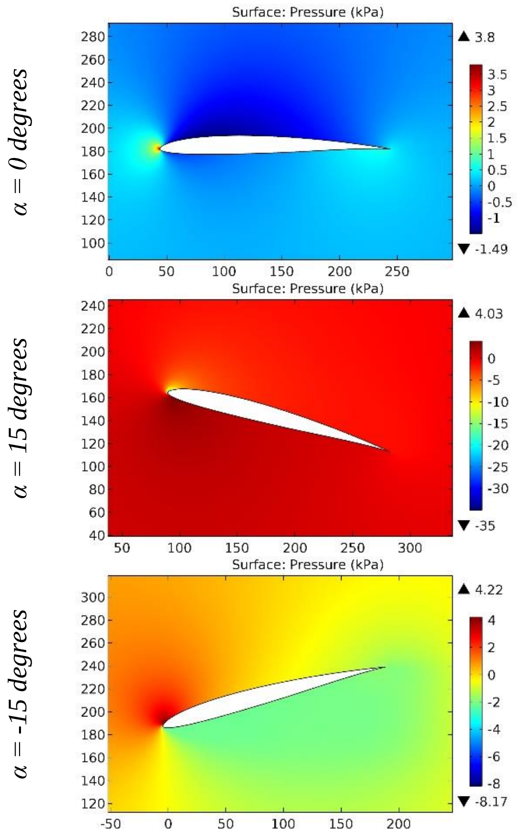


Figure 60. The pressure contours on the surfaces of the HN-216 airfoil.

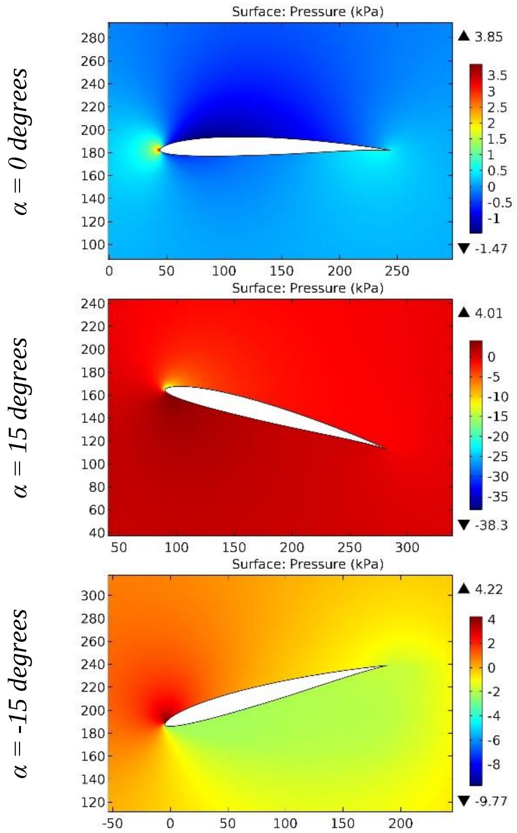


Figure 61. The pressure contours on the surfaces of the HN-216TA airfoil.

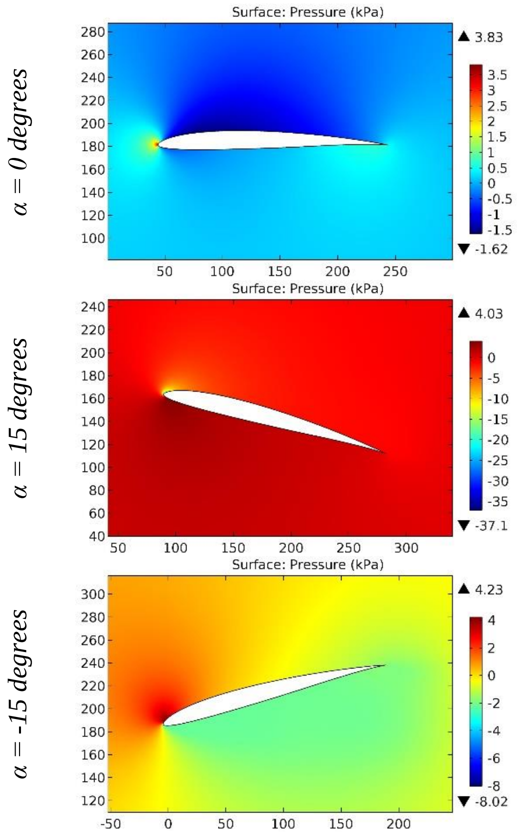


Figure 62. The pressure contours on the surfaces of the HN-217 airfoil.

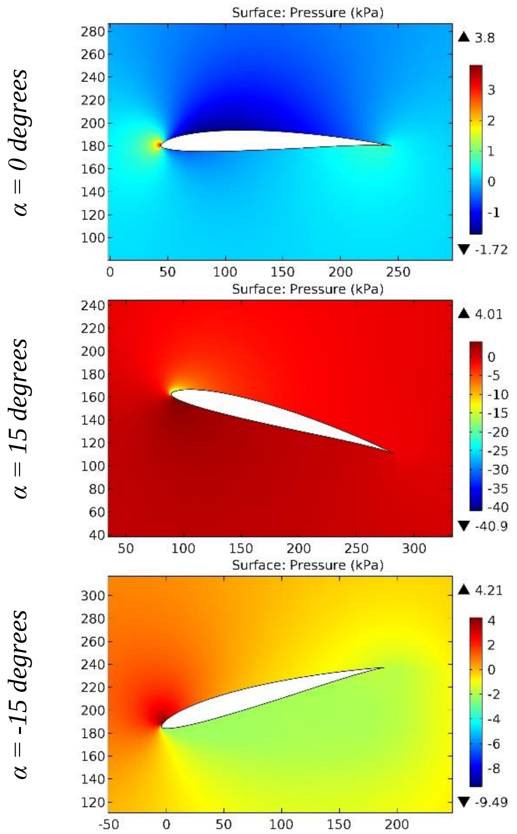


Figure 63. The pressure contours on the surfaces of the HN-227 airfoil.

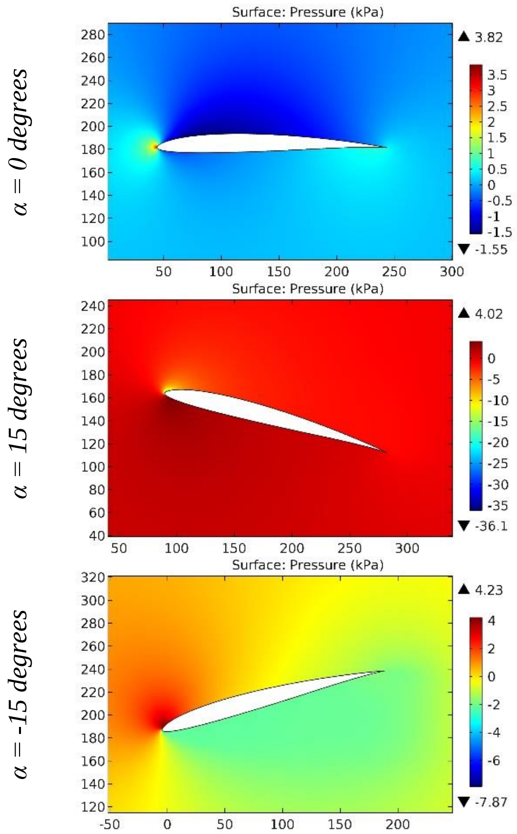


Figure 64. The pressure contours on the surfaces of the HN-239 airfoil.

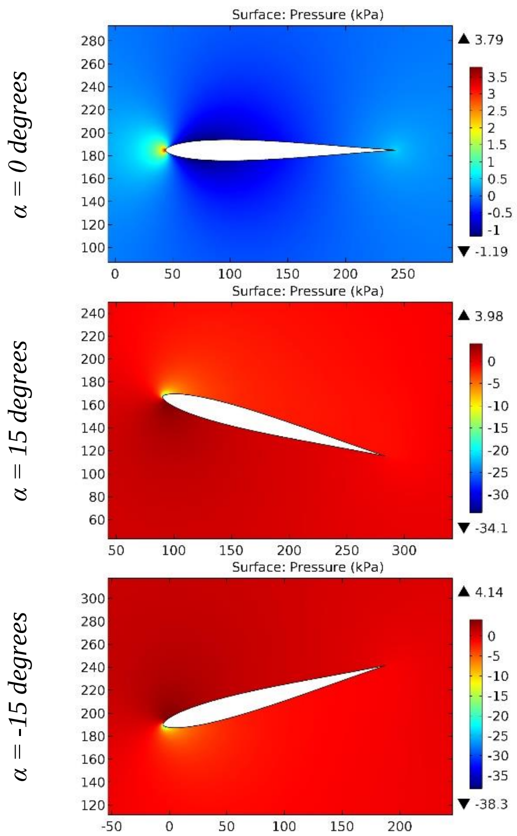


Figure 65. The pressure contours on the surfaces of the HN-274S airfoil.

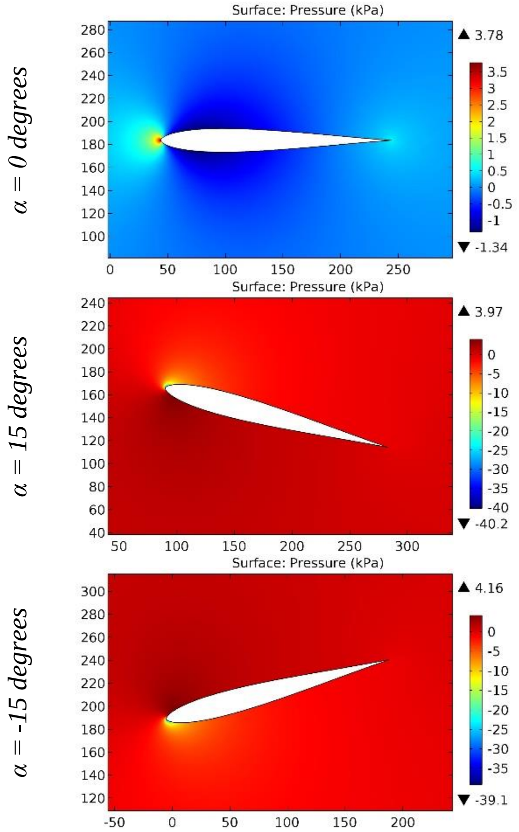


Figure 66. The pressure contours on the surfaces of the HN-275S airfoil.

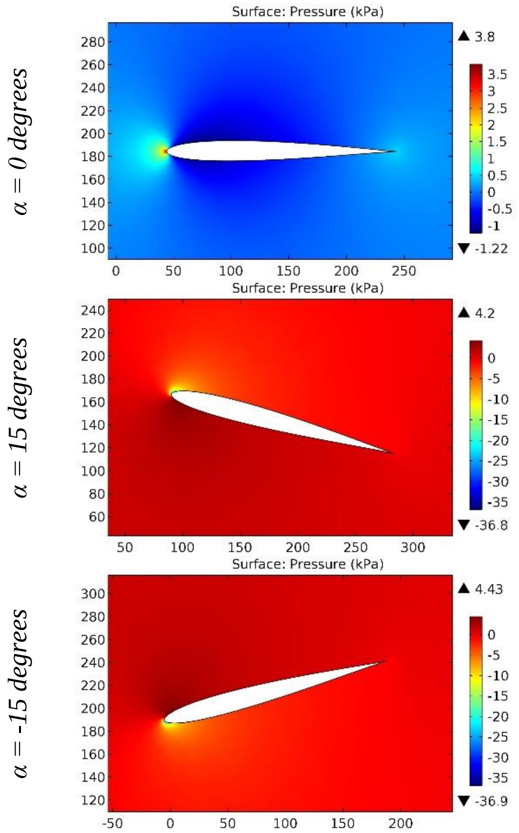


Figure 67. The pressure contours on the surfaces of the HN-276SA airfoil.

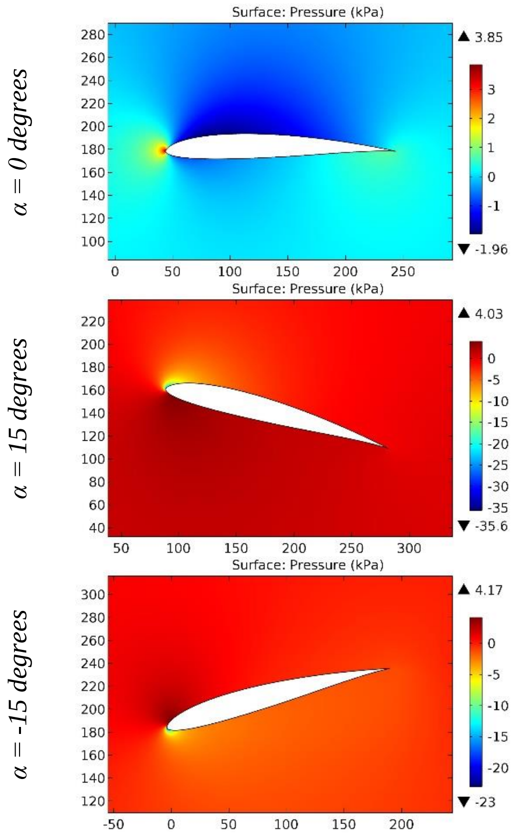


Figure 68. The pressure contours on the surfaces of the HN-304 airfoil.

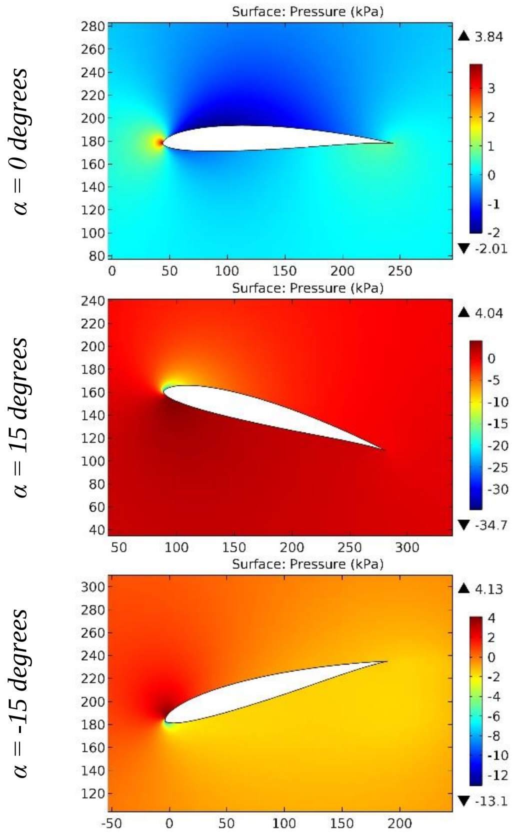


Figure 69. The pressure contours on the surfaces of the HN-304TA airfoil.

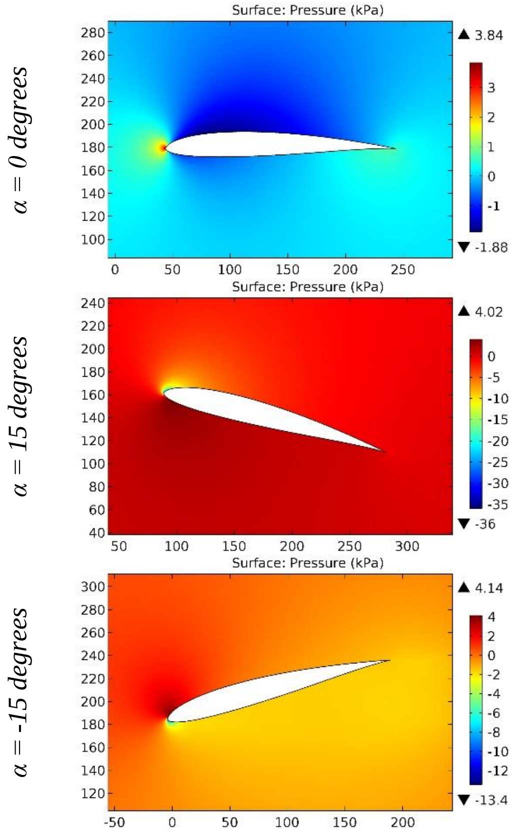


Figure 70. The pressure contours on the surfaces of the HN-309 airfoil.

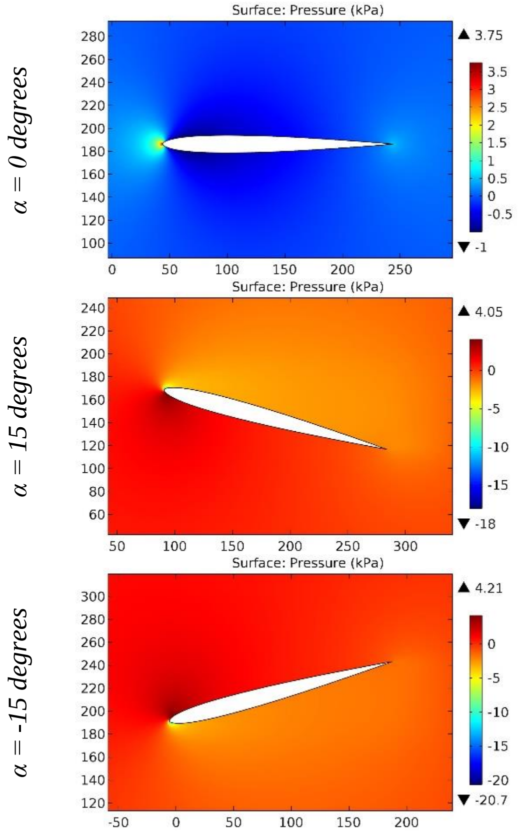


Figure 71. The pressure contours on the surfaces of the HN-311S airfoil.

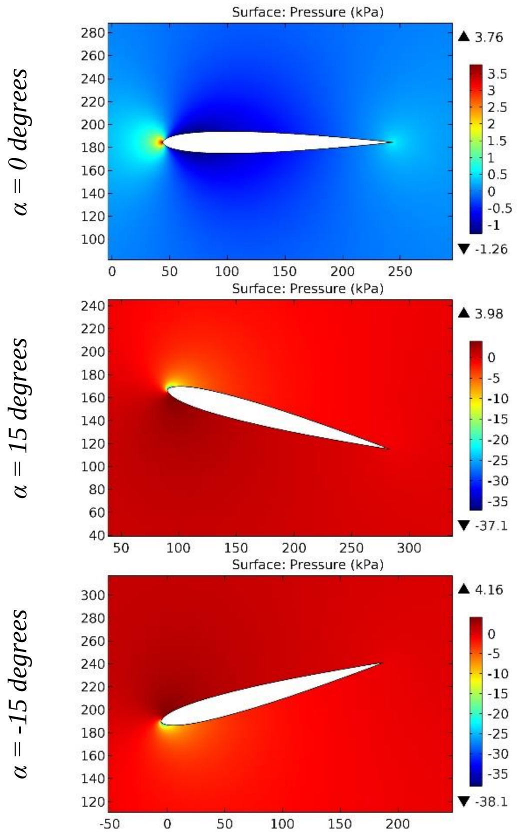


Figure 72. The pressure contours on the surfaces of the HN-312S airfoil.

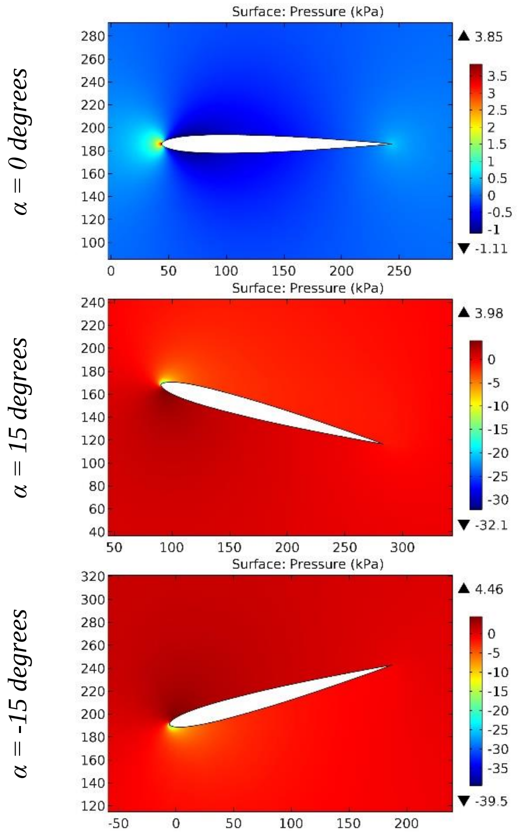


Figure 73. The pressure contours on the surfaces of the HN-315S airfoil.

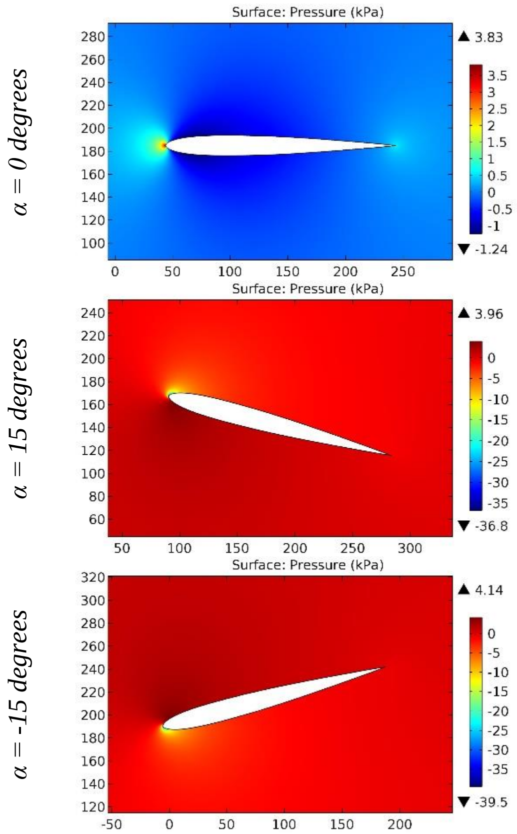


Figure 74. The pressure contours on the surfaces of the HN-316S airfoil.

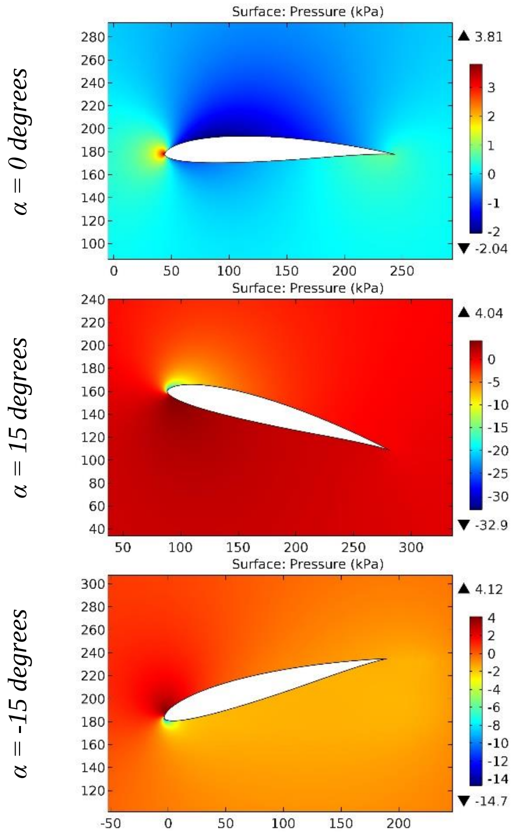


Figure 75. The pressure contours on the surfaces of the HN-319 airfoil.

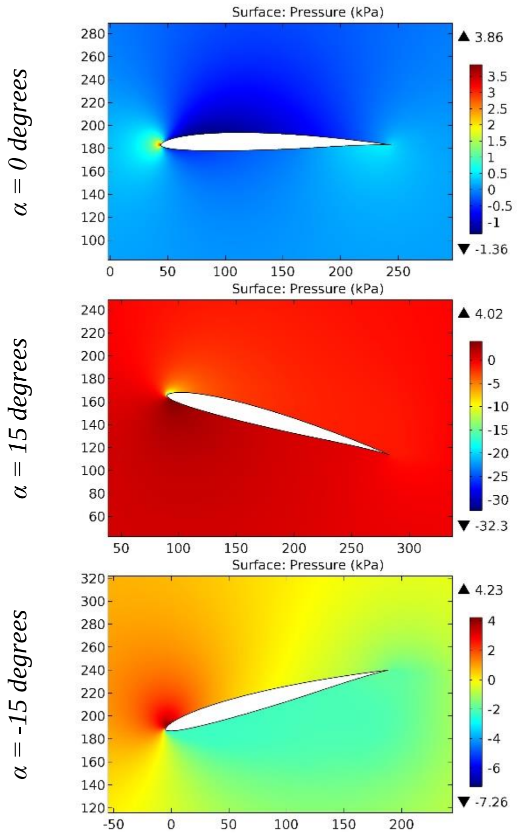


Figure 76. The pressure contours on the surfaces of the HN-321 airfoil.

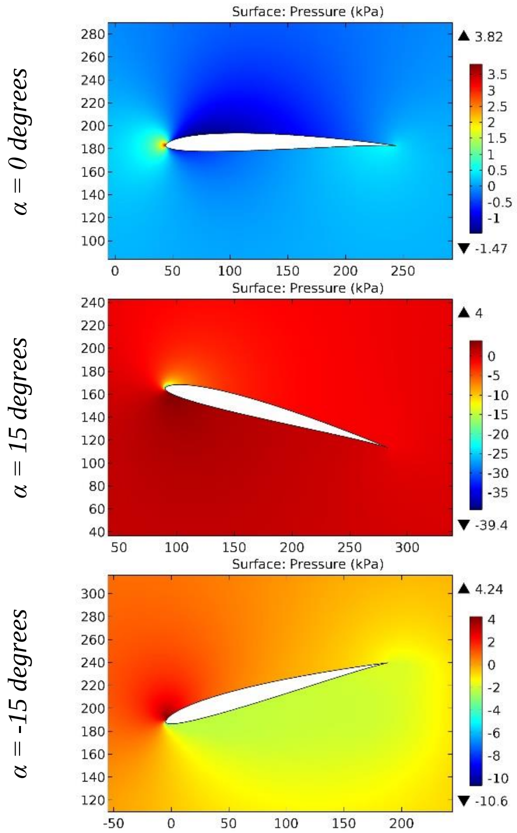


Figure 77. The pressure contours on the surfaces of the HN-326 airfoil.

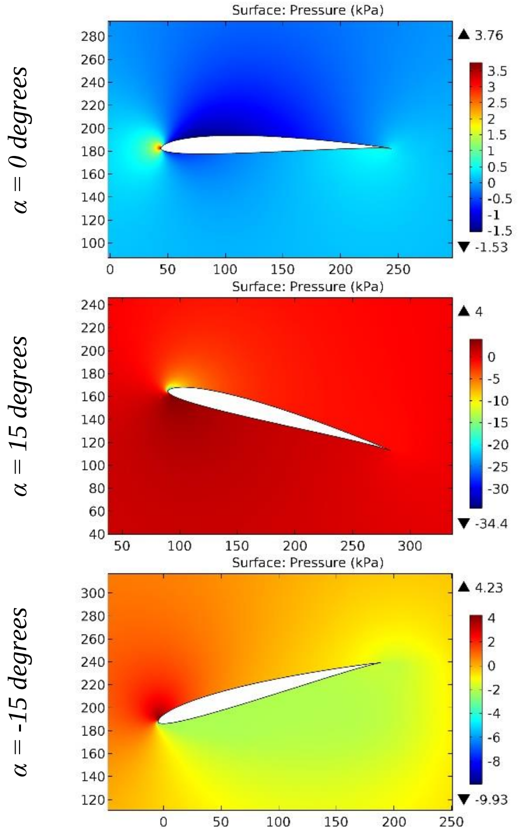


Figure 78. The pressure contours on the surfaces of the HN327 airfoil.

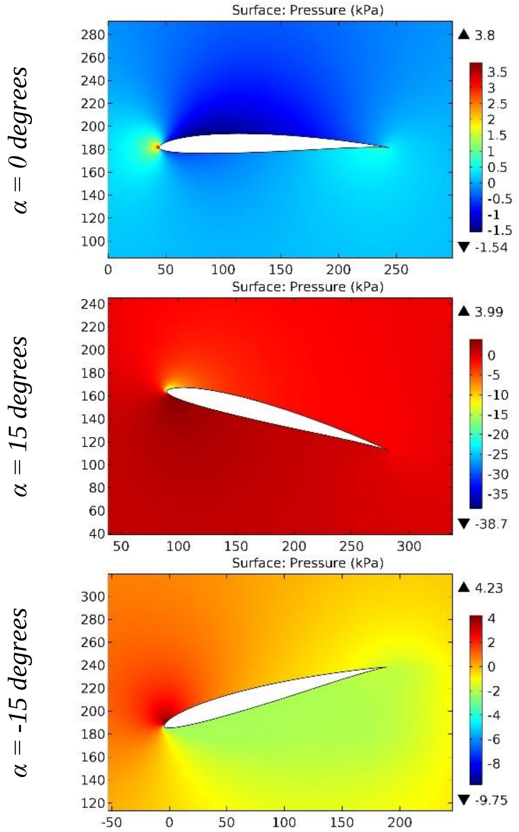


Figure 79. The pressure contours on the surfaces of the HN-333 airfoil.

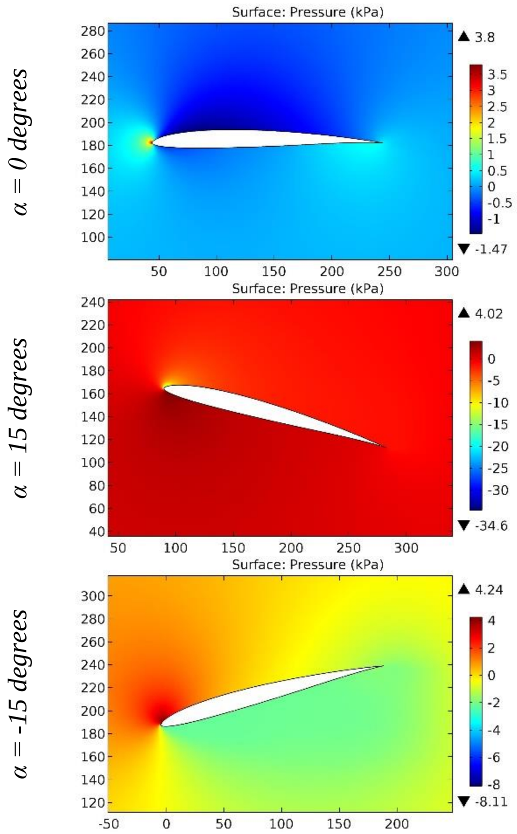


Figure 80. The pressure contours on the surfaces of the HN-350 airfoil.

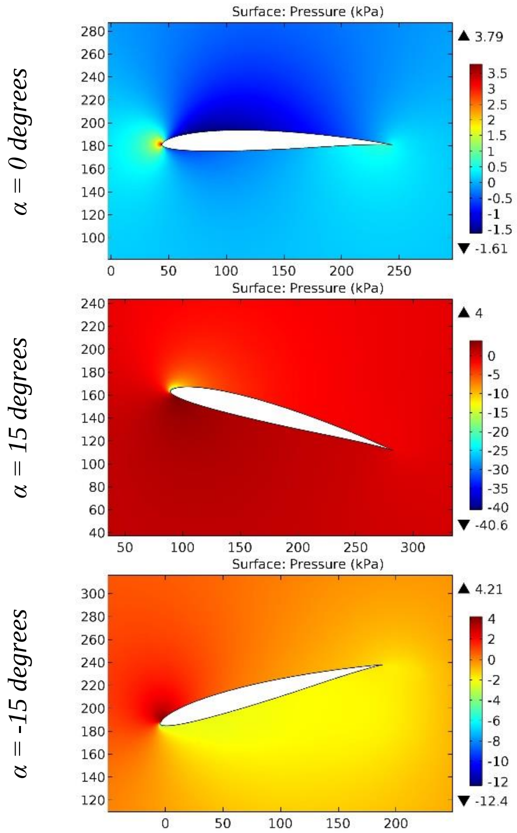


Figure 81. The pressure contours on the surfaces of the HN-350M01 airfoil.

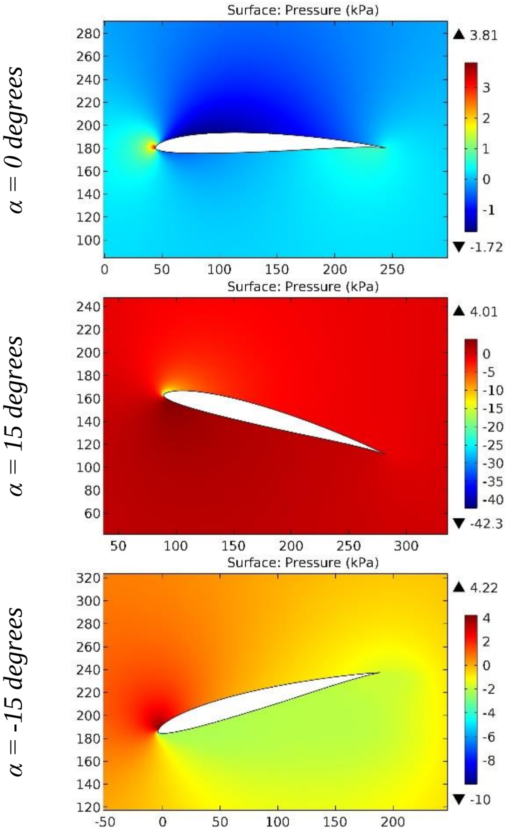


Figure 82. The pressure contours on the surfaces of the HN-350M02 airfoil.

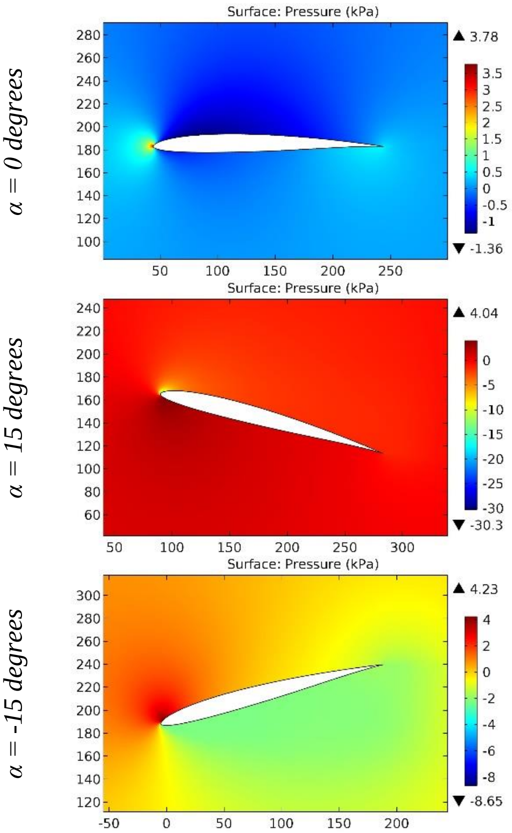


Figure 83. The pressure contours on the surfaces of the HN-352 airfoil.

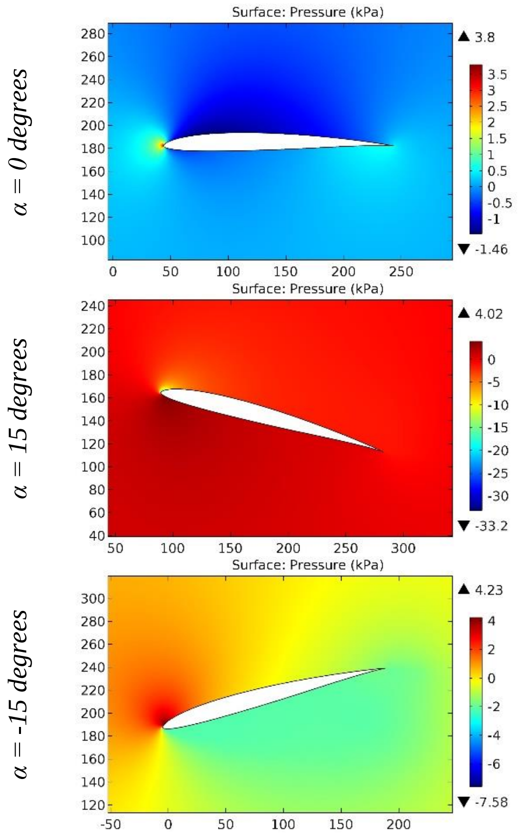


Figure 84. The pressure contours on the surfaces of the HN-354 airfoil.

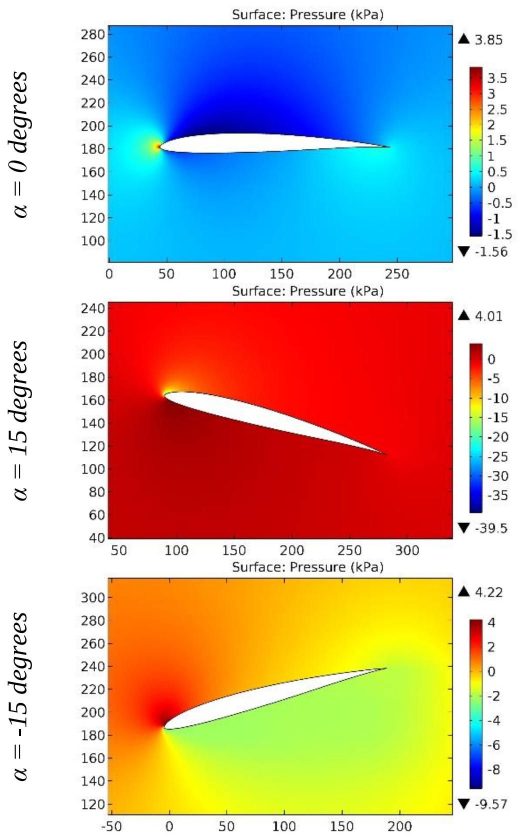


Figure 85. The pressure contours on the surfaces of the HN-354A airfoil.

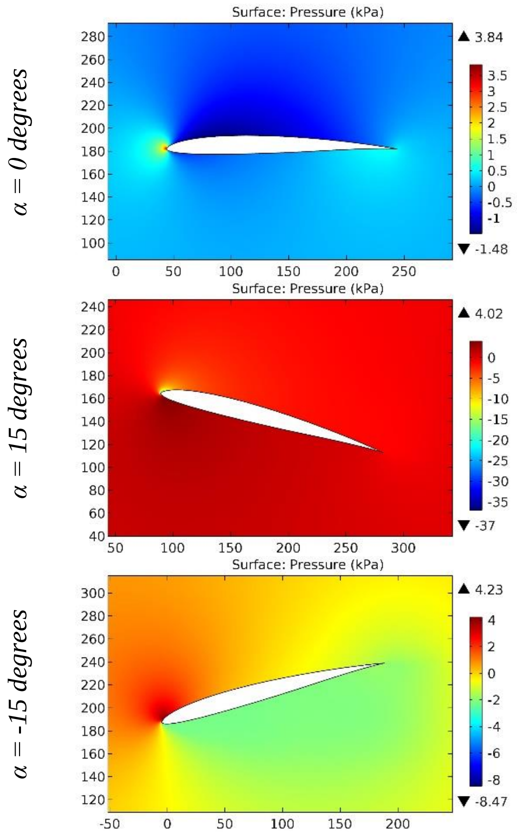


Figure 86. The pressure contours on the surfaces of the HN-354E airfoil.

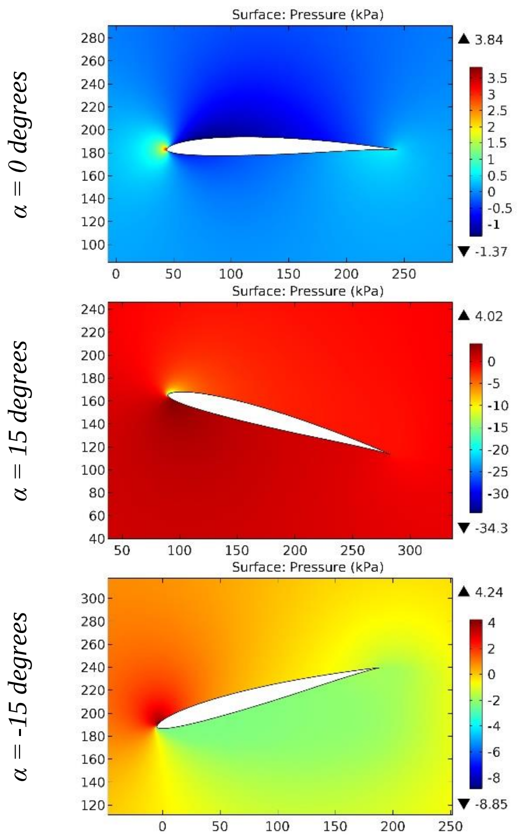


Figure 87. The pressure contours on the surfaces of the HN-354ES airfoil.

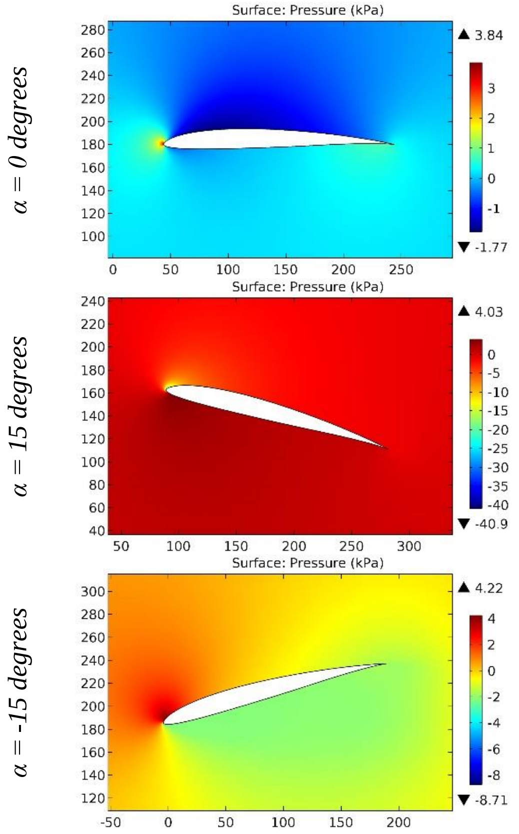


Figure 88. The pressure contours on the surfaces of the HN-354OC airfoil.

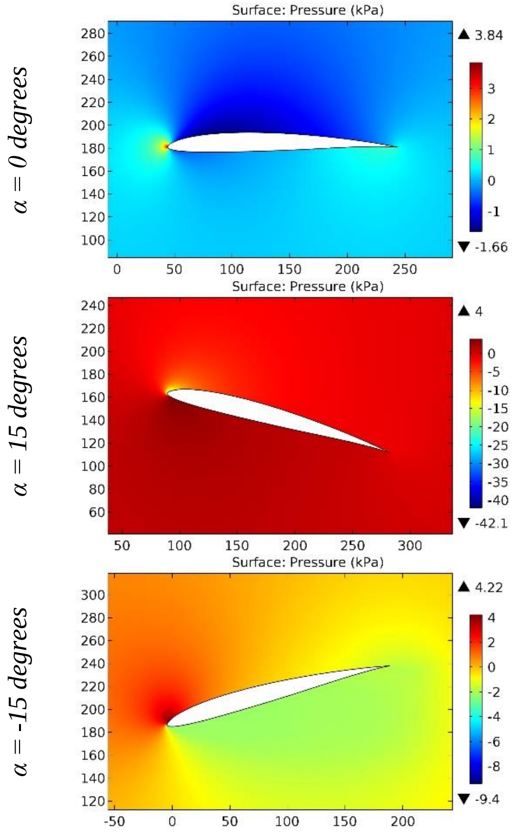


Figure 89. The pressure contours on the surfaces of the HN-354SM airfoil.

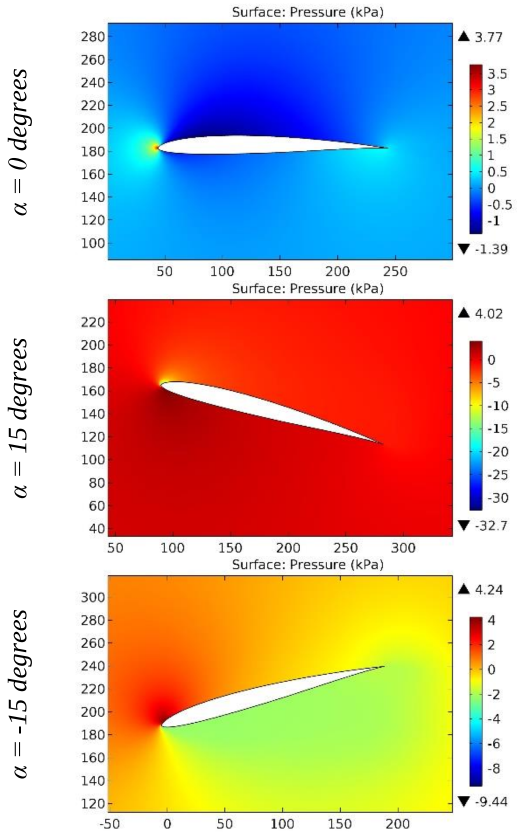


Figure 90. The pressure contours on the surfaces of the HN-354SR airfoil.

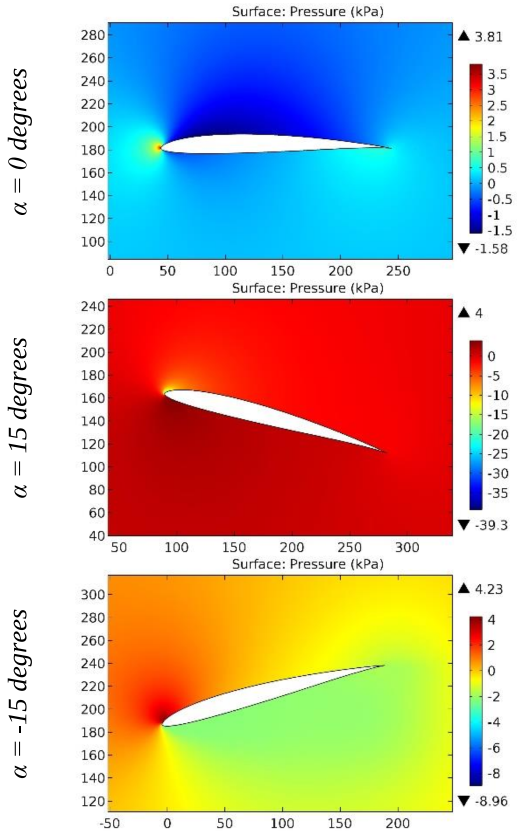


Figure 91. The pressure contours on the surfaces of the HN-360 airfoil.

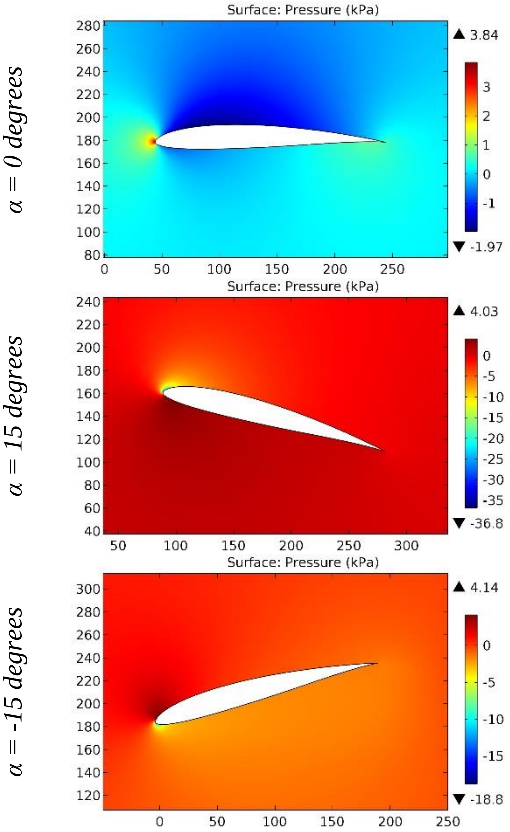


Figure 92. The pressure contours on the surfaces of the HN-409 airfoil.

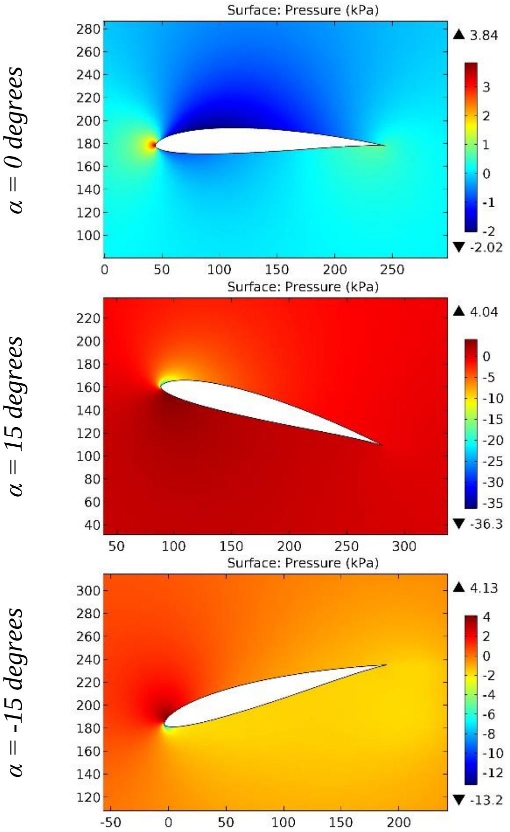


Figure 93. The pressure contours on the surfaces of the HN-411 airfoil.

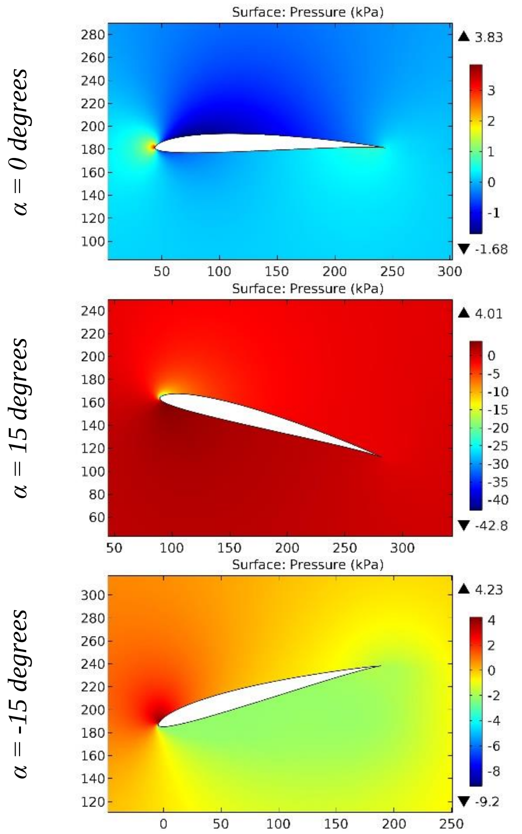


Figure 94. The pressure contours on the surfaces of the HN-417 airfoil.

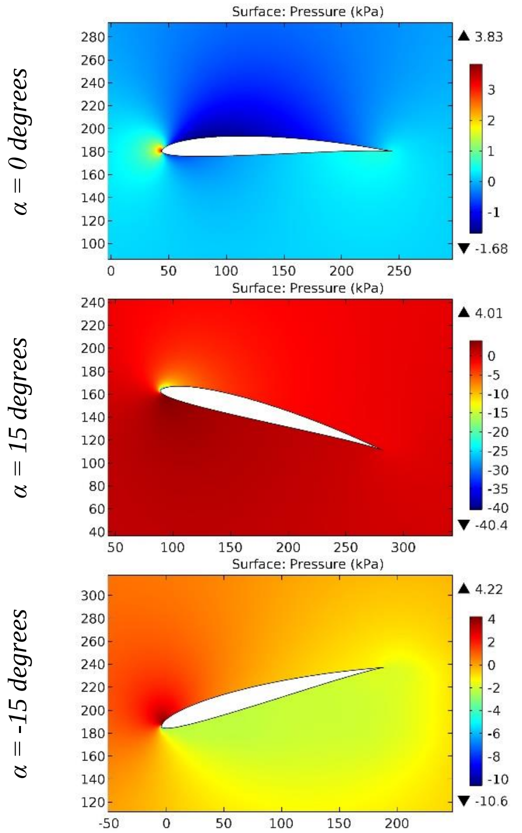


Figure 95. The pressure contours on the surfaces of the HN-418 airfoil.

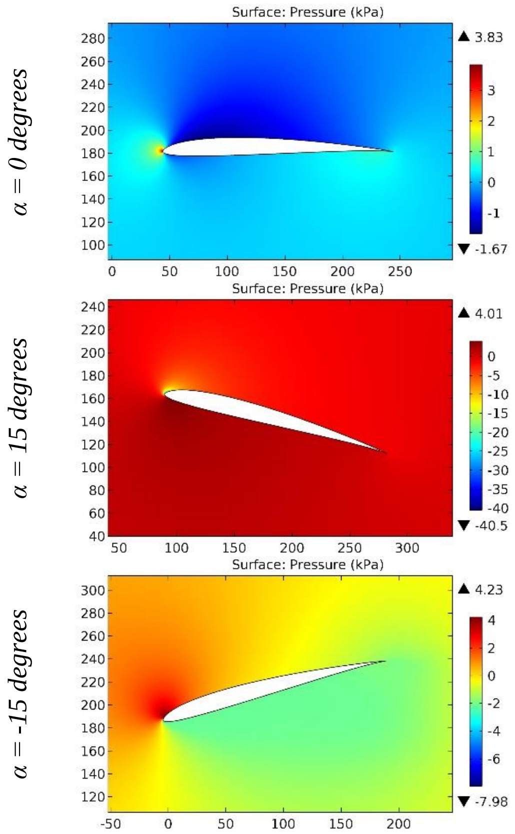


Figure 96. The pressure contours on the surfaces of the HN-419 airfoil.

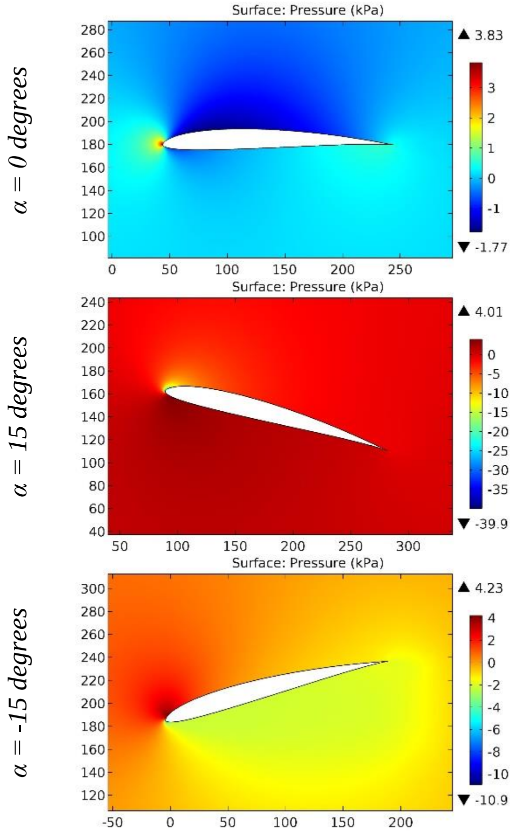


Figure 97. The pressure contours on the surfaces of the HN-424 airfoil.

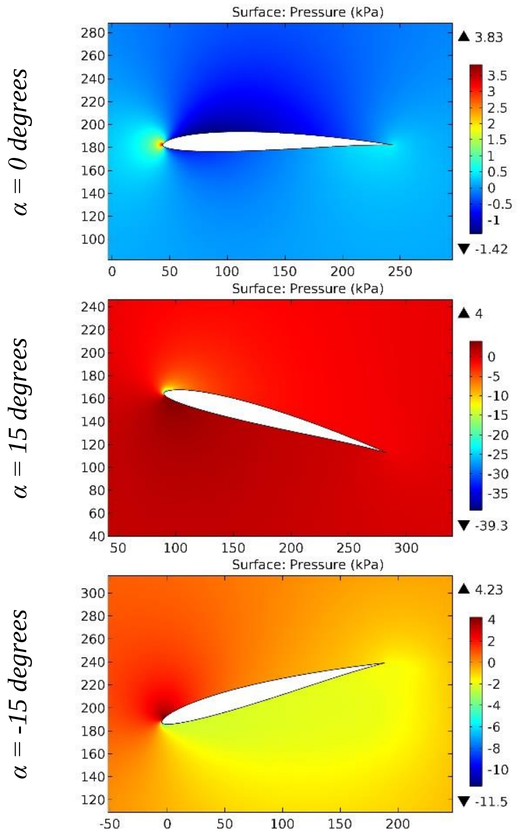


Figure 98. The pressure contours on the surfaces of the HN-436 airfoil.

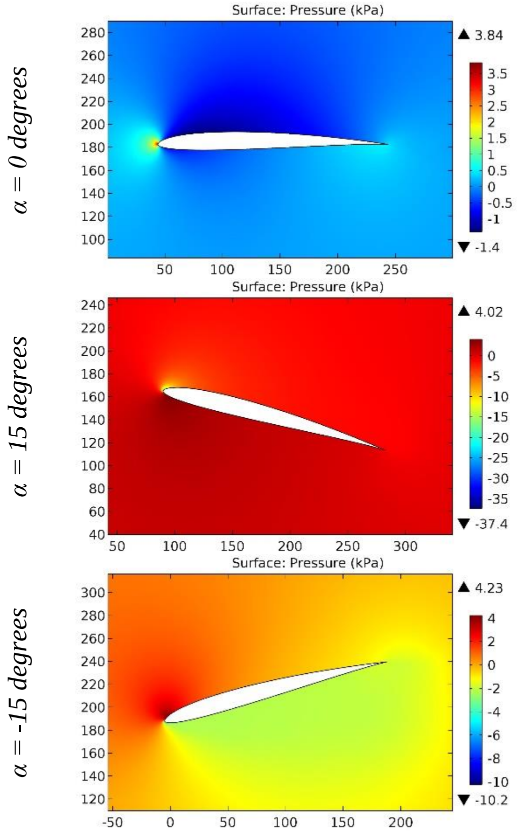


Figure 99. The pressure contours on the surfaces of the HN-446 airfoil.

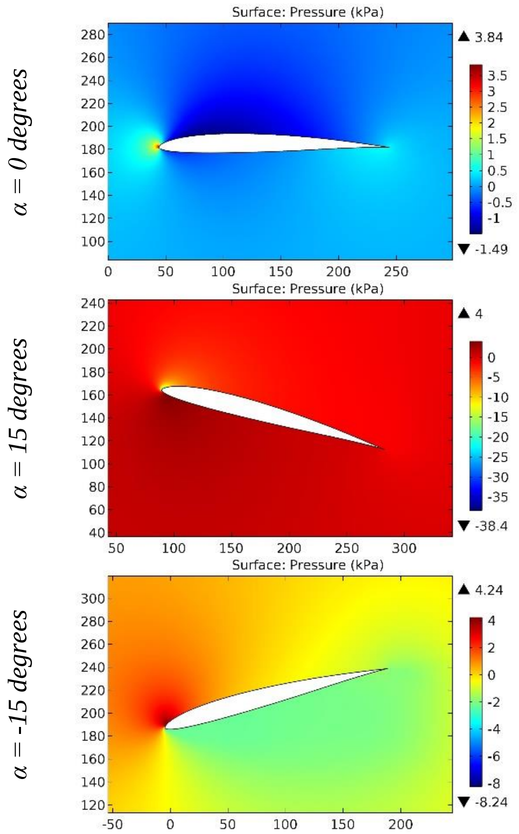


Figure 100. The pressure contours on the surfaces of the HN-450 airfoil.

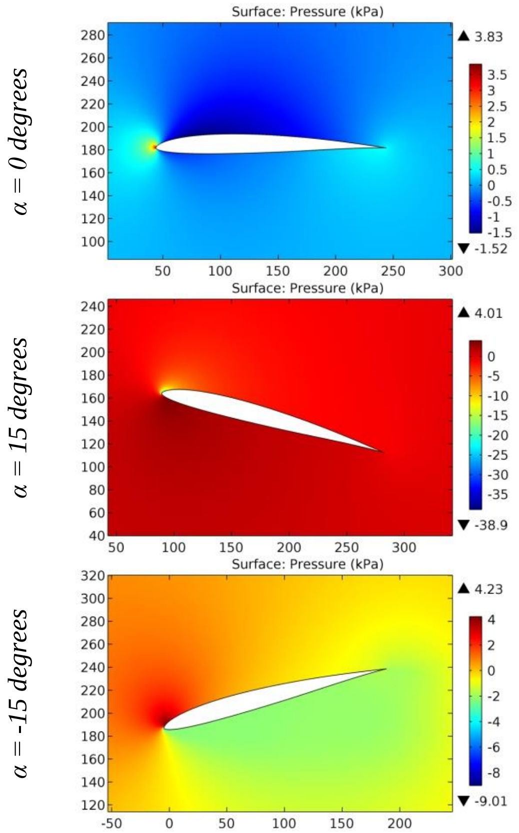


Figure 101. The pressure contours on the surfaces of the HN-450S airfoil.

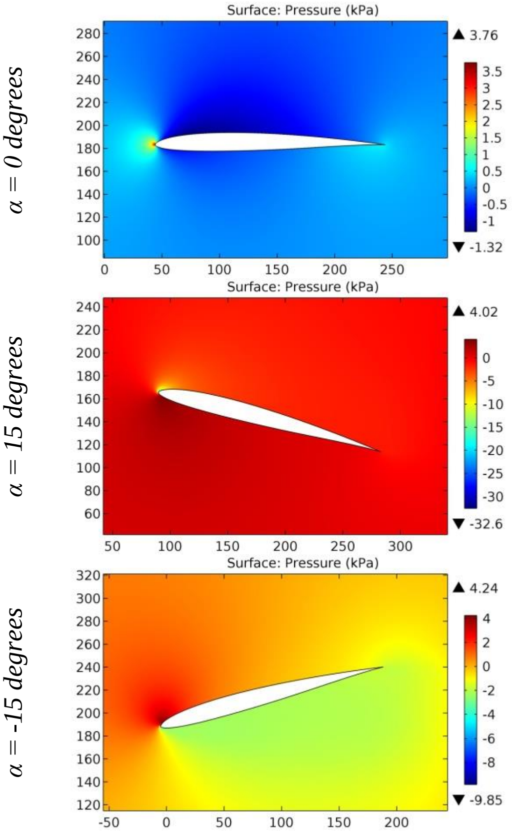


Figure 102. The pressure contours on the surfaces of the HN-462 airfoil.

The maximum increase in pressure on the leading edge occurs at the angle of attack of -15 degrees for the following airfoils: HAR, HAR2, HAR3, HAWKER TEMPEST 37,5% SEMISPAN, HAWKER TEMPEST 61% SEMISPAN, Hill SR 2, HILL-SR2, HL 80-13353, HL813353, HN-003, HN-153S, HN-274S, HN-276SA, HN-311S, HN-312S, HN-315S and HN-316S. The maximum increase in pressure on the leading edge occurs at the angle of attack of 15 degrees for the other airfoils.

Conclusion

The performed analysis of the simulation results showed that the airfoils of the HN series (HN-032, HN-033, HN-034 and further up to HN-462) have the good aerodynamic characteristics, such as the low drag. The large lift force, which affects the aerodynamics of the airplane, is observed when the airplane climb. The following airfoils can be noted that allow you to create the large lift force: H-6355, HANS6407, HAWKER TEMPEST 96,77% SEMISPAN, HN-032, HN-033 and HN-035.

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Issue Article

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LONGITUDINAL-RADIAL VIBRATIONS OF A CYLINDRICAL SHELL

Abstract: *The article solves the problem longitudinal-radial vibrations of a cylindrical shell. To solve the problem, we used the refined equations of oscillation of such a shell, derived earlier from the exact three-dimensional formulation of the problem and its solution in transformations. An extensive review of works devoted to the study of harmonic and nonstationary processes in elastic bodies on the basis of classical and refined Timoshenko type theories is given. Four frequency equations are obtained for the main parts of the longitudinal and radial displacements of the cylindrical shell. These frequency equations admit, as special cases, frequency equations and a thin-walled shell. Based on the solution of the obtained frequency equations, the frequencies of natural vibrations of the shell, including the thin-walled one, are determined. On the basis of the results obtained, conclusions were drawn regarding the applicability of the studied oscillation equations, depending on the waveform and shell length. In particular, it was found that all the considered equations are unsuitable for describing wave processes in short shells, the lengths of which are commensurate with the transverse dimensions of the shells.*

Key words: *shell, solutions, equations, longitudinal-radial vibrations, theory, algorithm.*
Language: *English*
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Scopus ASCC: *2200.*

Introduction

In various fields of science and technology, in particular physics and mechanics, researchers try to reduce the analysis of the behavior of waves in the general case to the analysis of the simplest harmonic waves [1]. In this case, the reverse transition, i.e. the transition from the characteristics of a harmonic process to estimates of the general wave motion in the body under consideration with the initial conditions is considerably difficult [2]. Despite this, much attention is paid to the study of harmonic processes in elastic bodies. This desire of researchers is due to the fact that already at the intermediate stage of solving the problem, it is possible to obtain important data on such characteristics of oscillatory systems as phase and group velocities, natural frequencies and modes of oscillations [3]. Such studies are carried out on the basis of refined equations of the Timoshenko type, taking into account the transverse shear deformation and the inertia of rotation [4]. When constructing new theories of shell vibrations, they try to derive refined equations of vibrations, taking into account certain factors of a physical, mechanical or geometric nature [5].

Depending on the factors taken into account, the methods for deriving the equations of oscillation, based on the dynamic theory of elasticity, are divided into several directions. The analysis of scientific research devoted to the derivation of equations of vibration and the development of refined theories of deformable solids, in particular, circular cylindrical layers, shells and rods, as well as a detailed analysis of various directions of this problem are given in monographs. In works [6,7], on the basis of the three-dimensional formulation of problems of the linear theory of viscoelasticity, general equations of longitudinal and transverse vibrations of viscoelastic plates, round rods and cylindrical shells, as well as the equations of vibration taking into account the environment and friction forces, were derived. The anisotropic properties and temperature of the plates and rods were taken into account (related theory). On the basis of exact equations, approximate equations of the type of equations of S.P. Timoshenko and others, containing derivatives with respect to coordinates and time of a higher order, are obtained. On the basis of exact and refined approximate equations, particular problems of vibrations of rods, plates and shells are solved.

In monograph [9], this method was developed for a circular cylindrical layer interacting with a deformable solid medium and an ideal liquid, taking into account the viscoelastic properties of the layer material and for various modes of contact between the layers and the medium. In it, for the first time, an intermediate surface was introduced as the main surface that carries information about the oscillation of the layer and passes, in limiting cases, to the inner, outer or middle surface of the layer, depending on the values χ of a certain parameter, which has a continuous spectrum of values, bounded from above and below.

It should be noted that in the works [5,8], a method was developed for deriving the equations of vibration, based on the use of general solutions in transformations of three-dimensional problems of elasticity theory. The method is based on the use of integral transformations in coordinate and time, and the use of general solutions in transformations of three-dimensional problems of elasticity theory with the subsequent expansion of these solutions in power series for the approximate satisfaction of the dynamic conditions specified on the boundary surfaces of the considered elastic system [10, 11].

An essential and successful application of this method to problems of dynamics was obtained in [12-13]. In them, the general equations of vibrations of circular cylindrical shells and rods are obtained taking into account the interacting viscous fluid and the rotation of the rod. The essence of the method is to study the constructed solutions under various types of external influences and to find out the conditions under which the displacements or their "main parts" satisfy simple oscillation equations, and to find an algorithm that allows calculating the approximate field values from the field of these "main parts" displacements and stresses in any section for an arbitrary moment in time.

In the works of the authors [14,15], equations of oscillation of circular cylindrical viscoelastic shells and layers interacting with a liquid were developed. The developments were carried out without the use of additional hypotheses and prerequisites of a physical or mechanical nature, from which it is possible to obtain the known classical and refined equations of oscillation. An algorithm is proposed that makes it possible to unambiguously determine the stress-strain state of points of an arbitrary section of the system under consideration from the values of the sought functions using the field of the sought functions.

The analysis of vibrations of elements of engineering structures, such as rods, plates and shells on the basis of both classical (Kirchhoff-Love) and refined (Timoshenko type) theories is carried out at the present time. At the same time, in most of such studies, the tendency to take into account the inertia of rotation, transverse shear deformation, as well as the multilayer structure prevails [16,17]. In addition, attention is paid to taking into account the rheological, in particular, the viscoelastic properties of the material [18, 19], as well as the interaction of structures with deformable media such as a viscous fluid [20] or dispersive waves [21]. The issues of studying natural frequencies and natural modes of vibrations of rods, plates and shells have also not lost their relevance. Proof of this statement can be found in publications where the problems of influence on the frequency characteristics of violations of the boundary forms [22] and the conduct of biharmonic [23] and frequency analyzes [24,25] are discussed.

Within the framework of this article, a circular cylindrical elastic shell is considered. The task is to study its harmonic longitudinal-radial oscillations on the basis of classical and refined theories. To carry out a comparative analysis of the numerical values of the frequencies of natural longitudinal-radial oscillations of an elastic cylindrical shell, obtained according to the equations proposed by the authors, according to the equations of the classical Kirchhoff-Love theory, on the basis of the refined theories of Hermann - Mirski (of the SP Timoshenko type) and Khudoinazarov Kh. As one of the equations of the refined theories, the refined oscillation equations developed by the authors [14, 15] are taken.

Methods.

In a cylindrical coordinate system (r,θ,z), we investigate natural longitudinal-radial vibrations of a circular cylindrical elastic shell, freely supported on the ends. The shell with length l has an interior and exterior radii, r_1, r_2 respectively. The direction of the coordinate axes, radii and displacements are shown in Fig. 1. It is believed that the shell is not exposed to external influences and its surfaces are also free from external forces.

In article [14], general equations of oscillation of a circular cylindrical shell were developed, and then they were generalized in [15] to the case of interaction of a circular cylindrical layer with a viscous fluid. To solve the problem, we assume that the terms responsible for the effect of the interacting fluid are equal to zero and the shell surfaces are free from external loads. Then, in the indicated equations, we pass to the dimensionless variables by the following formulas

$$U_{r,0}=U^*_{r,0};\ \ U_{r,1}=lU^*_{r,1};\ \ U_{z,0}=lU^*_{z,0};$$

$$U_{z,1}=U^*_{z,1};\ \ z=lz^*;\ \ r=lr^*;\ \ t=\frac{l}{b}t^*.$$

And for ease of writing, omitting the asterisks above the values in what follows, we obtain

$$q_1U_{r,0}+2\nu q_1\frac{\partial U_{z,0}}{\partial z}+\frac{1}{2}\partial_2 U_{r,1}+\frac{1}{2}\frac{\partial U_{z,1}}{\partial z}=0,$$

$$\nu q_1\frac{\partial U_{r,0}}{\partial z}+\partial_1 U_{z,0}-\frac{\partial U_{r,1}}{\partial z}-U_{z,1}=0,$$

$$q_1U_{r,0}+\nu q_1\frac{\partial U_{z,0}}{\partial z}+\left[\partial_2 q_2\ln\frac{r_2}{r_1}+2\frac{r_1^2}{r_2^2}\right]U_{r,1}-$$

$$-\left[\frac{q_2}{q_1}\ln\frac{r_2}{r_1}+\frac{1}{2}\right]\frac{\partial U_{z,1}}{\partial z}=0, \qquad (1)$$

$$\nu q_1\frac{\partial U_{r,0}}{\partial z}+\partial_1 U_{z,0}-\nu q_2\partial_2\frac{\partial U_{r,1}}{\partial z}-$$

$$-\left[\left(2q_2\frac{\partial^2}{\partial z^2}+\lambda_2\right)\ln\frac{r_2}{r_1}+2\frac{r_1^2}{r_2^2}\right]U_{z,1}=0,$$

where

$$\partial_1=\frac{b^2}{a^2}\frac{\partial^2}{\partial t^2}-\frac{\partial^2}{\partial z^2};\qquad \partial_2=\frac{\partial^2}{\partial t^2}-\frac{\partial^2}{\partial z^2};$$

$$q_1=-\frac{1}{1-2\nu};\qquad q_2=-\frac{1}{2(1-\nu)};$$

ν - Poisson's ratio of the layer material; a - the speed of propagation of longitudinal waves in the shell material. The boundary conditions of the problem of natural vibrations of a cylindrical shell with free feathering of its ends at $z=0$ and $z=l$, where l is the length of the shell, will have the form [9]

$$U_{z,0}=\frac{\partial^2 U_{z,0}}{\partial z^2}=0;\ \ U_{z,1}=\frac{\partial^2 U_{z,1}}{\partial z^2}=0;$$

$$\frac{\partial U_{r,0}}{\partial z}=\frac{\partial^3 U_{r,0}}{\partial z^3}=0;\ \ \frac{\partial U_{r,1}}{\partial z}=\frac{\partial^3 U_{r,1}}{\partial z^3}=0. \qquad (2)$$

Note that conditions (2) are written on the basis of expressions for the displacement values determined by the formulas

$$U_r(r,z,t)=\frac{r}{2}U_{r,0}(z,t)-\frac{1}{2}U_{r,1}(z,t),$$

$$U_z(r,z,t)=U_{z,0}-\frac{r}{4}U_{z,1}. \qquad (3)$$

Thus, the problem of natural longitudinal-radial vibrations of an elastic circular cylindrical shell is reduced to solving equations (1) under boundary conditions (2), which satisfy the series term by term.

$$U_{r,0}=\sum_m^\infty W_{0,m}(t)\cos(\gamma_m z)$$

$$U_{r,1}=\sum_m^\infty W_{1,m}(t)\cos(\gamma_m z)$$

$$U_{z,0}=\sum_m^\infty U_{0,m}(t)\sin(\gamma_m z)$$

$$U_{z,1}=\sum_m^\infty U_{1,m}(t)\sin(\gamma_m z)$$

where $\gamma_m=\frac{m\pi}{l}$, l -the length of the shell $m=0,1,2,3,\ldots$. Putting these series into the system of equations (1), we obtain

$$W_{0,m}(t)+\nu q_{12}\gamma_m U_{0,m}(t)-\bar\partial_2 W_{1,m}-\gamma_m U_{1,m}(t)=0,$$

$$\nu q_1\gamma_m W_{0,m}(t)+\bar\partial_1 U_{0,m}(t)+\gamma_m W_{1,m}(t)-U_{1,m}(t)=0,$$

$$q_1W_{0,m}(t)+2\nu q_1\gamma_m U_{0,m}(t)+$$

$$+\left[\left(q_2\ln\frac{r_2}{r_1}-\frac{1}{2}\right)\bar\partial_2+2\frac{r_1^2}{r_2^2}\right]W_{1,m}(t)-$$

$$-\left(\frac{q_2}{q_1}\ln\frac{r_2}{r_1}+\frac{1}{2}\right)\gamma_m U_{1,m}(t)=0,$$

$$-2\nu q_1\gamma_m W_{0,m}(t)+\frac{q_1}{q_2}\bar\partial_1 U_{0,m}(t)-$$

$$-\left[2\nu q_2\bar\partial_2\ln\frac{r_2}{r_1}+2\frac{r_1^2}{r_2^2}\right]\gamma_m W_{1,m}(t)+ \qquad (4)$$

$$+\left[\left(2q_2\gamma_m^2+\bar\partial_2\right)\ln\frac{r_2}{r_1}-2\frac{r_1^2}{r_2^2}\right]U_{1,m}(t)=0,$$

where $\bar\partial_1=(1-q_1)\frac{\partial^2}{\partial t^2}+\gamma_m^2$, $\bar\partial_2=\frac{\partial^2}{\partial t^2}+\gamma_m^2$.

In order for system (4) to have a nonzero solution, it is necessary that its main determinant, composed of the coefficients of the unknown functions $U_{i,m}(t)$ and $W_{i,m}(t)$ $(i=1,2)$, be equal to zero. Denoting this determinant by Δ_1 and introducing the following notation

$$\omega_1=\left(q_2\ln\frac{r_2}{r_1}-\frac{1}{2}\right)\bar\partial_2+2\frac{r_1^2}{r_2^2};\quad \omega_2=\frac{q_2}{q_1}\ln\frac{r_2}{r_1}+\frac{1}{2};$$

$$\omega_3 = 2\nu q_2 \bar{\partial}_2 \ln\frac{r_2}{r_1} + 2\frac{r_1^2}{r_2^2};$$

$$\omega_4 = \left(2q_2\gamma_m^2 - \bar{\partial}_2\right)\ln\frac{r_2}{r_1} - 2\frac{r_1^2}{r_2^2}. \qquad (5)$$

$$\Delta_1 = \begin{vmatrix} q_1 & 2\nu q_1\gamma_m & -\left(2-\frac{1}{2}\bar{\partial}_2\right) & -\frac{1}{2}\gamma_m \\ -\gamma_m 2\nu q_1 & \frac{q_1}{q_2}\bar{\partial}_1 & 2\gamma_m & -2 \\ q_1 & 2\nu q_1\gamma_m & \omega_1 & \omega_2\gamma_m \\ -2\nu q_1\gamma_m & \frac{q_1}{q_2}\bar{\partial}_1 & \omega_3\gamma_m & \omega_4 \end{vmatrix}$$

Expanding this determinant by the elements of the third row, we get

$$\Delta_1 = q_1 A_{31} + 2\nu q_1\gamma_m A_{32} + \omega_1 A_{33} + \omega_2\gamma_m A_{34}$$

where $A_{3i} = (-1)^{3+i} D_{3i}$ is an algebraic complement, D_{3i} are minors of the third row elements a_{3i}.

The resulting expression for the determinant can be rewritten as

$$\Delta_1 = q_1 D_{31} - 2\nu q_1\gamma_m D_{32} + \omega_1 D_{33} - \omega_2\gamma_m D_{34}.$$

Putting instead of ω_i $\left(i=\overline{1,4}\right)$ their expressions (5), we finally obtain

$$\Delta_1 = a_1\bar{\partial}_1\bar{\partial}_2^2 - \bar{\partial}_2 + a_3\bar{\partial}_1 - a_5\bar{\partial}_2 + a_6 \qquad (6)$$

where

$$a_1 = \frac{q_1^2}{q_2}\ln\left(\frac{r_2}{r_1}\right)\left(\frac{3}{2} - q_2\ln\frac{r_2}{r_1}\right);$$

$$a_4 = -4\nu^2 q_1^2 \ln\left(\frac{r_2}{r_1}\right)\left(q_2\ln\frac{r_2}{r_1} - 1\right);$$

$$a_2 = q_2\gamma_m^2(q_2+\nu) - \left(\nu q_1\gamma_m^2 + \nu q_2\gamma_m\right)\ln\frac{r_2}{r_1};$$

$$a_3 = 4q_2\gamma_m^2\ln\frac{r_2}{r_1} + 2\gamma_m^2 - 4\nu\gamma_m^2 + 2\nu\gamma_m;$$

$$a_5 = 2\nu^2 q_1^2\left[2\nu q_2\gamma_m^2 + \gamma_m^2\ln\frac{r_2}{r_1} + 4\ln\frac{r_2}{r_1} + {} + 4\gamma_m\frac{r_1^2}{r_2^2}\ln\frac{r_2}{r_1} + 4\nu q_2\gamma_m^3\left(\ln\frac{r_2}{r_1} + \frac{1}{2}\right)\ln\frac{r_2}{r_1}\right];$$

$$a_6 = 2\nu^2 q_1^2 2\gamma_m^2\left(1 - \frac{r_1^2}{r_2^2}\right) + 8\left(1 + \frac{r_1^2}{r_2^2}\right).$$

Putting into (6), the values of the differential operators $\bar{\partial}_1$ and $\bar{\partial}_2$ by formulas (4), we finally obtain

$$\Delta_1 = a_1\frac{\partial^6}{\partial t^6} + \left[a_1\gamma_m^2(3-2q_1) - a_2 - a_4\right]\frac{\partial^4}{\partial t^4} + {} + \left[a_1\gamma_m^4(3-q_1) - \gamma_m^2 + a_3 q_1\right]\frac{\partial^2}{\partial t^2} + a_1\gamma_m^6 - {} \qquad (7)$$

$$-(a_2+a_4)\gamma_m^4 + (a_3-a_5)\gamma_m^2.$$

Hence, each of the functions $U_{0,m}(t)$, $U_{1,m}(t)$, $W_{0,m}(t)$, and $W_{1,m}(t)$ must satisfy the equation

$$\Delta_1\zeta_m(t) = 0, \qquad (8)$$

where $\zeta_m(t)-$ is any of the above functions. Then, based on (3), the displacements U_r and U_z must satisfy the same equation.

In equation (8), we put $\zeta_m(t) = A_m e^{\omega t}$ and obtain the following frequency equation

$$a_1(1-q_1)\omega^6 + \left[a_1\gamma_m^2 q_1 - a_2(1-q_1) - a_4\right]\omega^4 + {} + \left[a_1\gamma_m^4(3-q_1) - \gamma_m^2(a_2 q_1 + 2a_4) + a_3 q_2\right]\omega^2 + {} + a_1\gamma_m^6 - (a_2+a_4)\gamma_m^4 + (a_3-a_5)\gamma_m^2 + a_6 = 0 \qquad (9)$$

The obtained equation is general for both the layer and the shell. To obtain a simpler frequency equation for the shell in the expressions for the coefficients a_i, it is sufficient to take $\ln(r_2/r_1) = 0$. In this case, the coefficients $a_i\, (i=\overline{1,6})$ take the form:

$$a_1 = 0;\ a_2 = -\frac{q_1^2}{2q_2}\nu\gamma_m(2\nu\gamma_m - \gamma_m - 1);$$

$$a_3 = \frac{2q_1^2}{q_2}\left[\gamma_m^2\frac{l_1^2}{l_2^2} - 2\nu\gamma_m^2 + \nu\gamma_m\left(2 - \frac{r_1^2}{r_2^2}\right) + 2\frac{r_1^2}{r_2^2}\right];$$

$$a_4 = 0;\ a_5 = 2\left(1 + \gamma_m - \frac{r_1^2}{r_2^2}\right);$$

$$a_6 = \gamma_m^4 + 6\frac{r_1^2}{r_2^2}\gamma_m^3 + 2\gamma_m^2 + 8\left(1 + \frac{r_1^2}{r_2^2}\right).$$

The equation in (9) takes the following form:

$$a_2(1-q_1)\omega^4 + \left[a_2(2-q_1)\gamma_m^2 - q_1 a_3\right]\omega^2 + {} + (a_2+a_4)\gamma_m^4 + (a_5-a_3)\gamma_m^2 + a_6 = 0 \qquad (10)$$

For a comparative analysis, let us calculate the frequencies of natural longitudinal-radial oscillations of an elastic circular cylindrical shell based on the oscillation equations of various theories. As such theories, we will take the classical Kirchhoff-Love theory [6] and the refined theories of Herman-Mirsky [4] and Fillipov-Khudoinazarov [5]. The corresponding frequency equations have the following forms:

Fillipov-Khudoinazarov

$$\omega^6 + \left[(g_2+g_3)\gamma_m^2 + g_5\omega_1\right]\omega^4 + {} + \left[g_2 g_3\gamma_m^4 + (1+g_2)g_5\omega_1\gamma_m^2 + \omega_1\right]\omega^2 + {} + g_2 g_4\gamma_m^6 + g_2 g_5\omega_1\gamma_m^4 + g_2 g_6\omega_1^2\gamma_m^2 = 0, \qquad (11)$$

Herman-Mirsky

$$\omega^6 + \frac{2y_1}{1-\nu}\left[k_T + y_1 y_4 + y_1(g+k)\right]\gamma_m^4 + \\ + \frac{4y_1}{(1-\nu)^2}\left[y_1 k_T \gamma_m^4 + 2\left(y_1 y_4 + \frac{k_T - k_E^2}{2}\right)\gamma_m^2 - \\ - y_2\gamma_m^2 + y_4 k_T \right]\omega^2 + y_1 k_T \gamma_m^6 + (k_T + y_1 y_4)\gamma_m^6 + \\ + (y_4 k_T - y_3)\gamma_m^2 = 0, \qquad (12)$$

Kirchhoff-Love

$$\omega^4 + \frac{2}{1-\nu_0}\left(\frac{1}{3}\gamma_m^4 + \gamma_m^2 + \frac{1}{\xi^2}\right)\omega^2 + \\ + \left[\frac{4}{3(1-\nu)^2}\gamma_m^6 + \frac{4(1+\nu)\cdot\gamma_m^2}{(1-\nu)\xi^2}\right] = 0, \qquad (13)$$

where

$$g_1 = \frac{3-4\nu}{8(1-2\nu)(1-\nu^2)}; \qquad g_2 = \frac{3(1-\nu)(1+4\nu)}{3-4\nu};$$

$$g_3 = 3-2\nu; \quad g_4 = 2-2\nu; \quad g_5 = 3+2\nu;$$

$$g_6 = 2+2\nu; \quad y_1 = \frac{1}{3}\left(1-\frac{1}{\xi^2}\right); \quad y_3 = k_T\frac{\nu^2}{\xi^2};$$

$$k_T = \frac{1-\nu}{2}k^2;$$

$$y_2 = \frac{3k_T\nu}{3\xi^2} + k_T^2 + \frac{\nu^2}{3\xi^2};$$

$$y_4 = \frac{1}{\xi^2}\left(1+\frac{1}{3\xi^2}\right); \quad \xi = \frac{R}{h};$$

R -radius of the middle surface, h -shell thickness, k_T -Tymoshenko correction coefficient.

Results and Discussions.

Frequency equations (9) - (13) were solved numerically using the MAPLE application programs with the following geometric data of the shell $r_1 = 1{,}0; r_2 = 1{,}1; h = 0{,}1$. Poisson's ratio was taken to be $\nu = 0{,}2$. The Timoshenko coefficient was taken to be 5/6. Table 1 shows the numerical values of the shell frequencies depending on the values of the waveforms calculated on the basis of equations (9) and (10). In Fig. 2, based on the obtained numerical values, the dependences of the frequency ω on the waveform γ_m are plotted. Table 2 shows the numerical values of the shell frequencies depending on the values of the waveforms calculated on the basis of equations (11) - (13). In Fig. 3, on the basis of the obtained numerical values, the dependences of the frequency ω on the waveform γ_m are plotted according to the classical and refined equations of various theories. On the given Tables 1, 2 it can be observed that the real parts of the roots of the frequency equations, except for the Hermann-Mirsky equations, are negative. From the physical meaning of the problem on the basis of the Hurwitz criterion [26] it follows that the roots of the frequency equations (respectively, cubic and quadratic equations with respect to ω^2) must be purely imaginary.

The obtained numerical values of the roots of the equations show that in reality such results follow from all equations, except for the Hermann-Mirsky equation (Table 2) up to a certain value of the

Table 1

γ_m		Equation (9)			Equation (10)	
		ω1	ω2	ω3	ω1	ω2
0,1	Д М	0 ±0,1624	0 ±2,3557	0 ±19,9508	0 ±1,0539	0 ±0,1549
0,3	Д М	0 ±0,4837	0 ±2,3659	0 ±19,9511	0 ±1,0539	0 ±0,4647
0,5	Д М	0 ±0,8062	0 ±2,3859	0 ±19,9517	0 ±1,0539	0 ±0,7745
0,7	Д М	0 ±1,1287	0 ±2,4154	0 ±19,9527	0 ±1,0844	0 ±1,0539
0,9	Д М	0 ±1,4512	0 ±2,4542	0 ±19,9539	0 ±1,3942	0 ±1,0539
1,1	Д М	0 ±1,7736	0 ±2,5019	0 ±19,9554	0 ±1,7041	0 ±1,0539
1,3	Д М	0 ±2,0961	0 ±2,5578	0 ±19,9572	0 ±2,0139	0 ±1,0539
1,5	Д М	0 ±2,4186	0 ±2,6214	0 ±19,9594	0 ±2,3237	0 ±1,0539
1,7	Д М	0 ±2,6921	0 ±2,7411	0 ±19,9619	0 ±2,6336	0 ±1,0539
1,9	Д	0	0	0	0	0

	М	±2,7694	±3,0636	±19,9647	±2,9434	±1,0539
2,1	Д	0	0	0	0	0
	М	±2,8526	±3,3861	±19,9679	±3,2533	±1,0539
2,3	Д	0	0	0	0	0
	М	±2,9412	±3,7086	±19,9714	±3,5631	±1,0539
2,5	Д	0	0	0	0	0
	М	±3,0347	±4,0311	±19,9753	±3,8729	±1,0539

Table 2

		Equation (9)			Equation Kirchhoff-Love		Equation Hermann-Mirsky			Equation Filippov-Khudoynazarov		
γ_m		ω_1	ω_2	ω_3	ω_1	ω_2	ω_1	ω_2	ω_3	ω_1	ω_2	ω_3
0,1	Д	0	0	0	0	0	0	0	0	0	0	0
	М	±0,1	±2,3	±19,9	±0,01	±0,16	±0,04	±0,24	±0,97	±0,25	±1,9	±3,21
0,3	Д	0	0	0	0	0	0	±0,04	∓0,04	0	0	0
	М	±0,4	±2,3	±19,9	±0,08	±0,50	±0,04	±0,74	±0,74	±0,77	±2,0	±3,23
0,5	Д	0	0	0	0	0	0	±0,39	∓0,39	0	0	0
	М	±0,8	±2,3	±19,9	±0,24	±0,84	±0,07	±0,89	±0,89	±1,28	±2,0	±3,27
0,7	Д	0	0	0	0	0	0	±0,57	∓0,57	0	0	0
	М	±1,1	±2,4	±19,9	±0,47	±1,18	±0,12	±1,05	±1,05	±1,79	±2,0	±3,33
0,9	Д	0	0	0	0	0	0	±0,73	∓0,73	0	0	0
	М	±1,4	±2,4	±19,9	±0,79	±1,52	±0,19	±1,21	±1,21	±2,14	±2,3	±3,40
1,1	Д	0	0	0	0	0	0	±0,87	∓0,87	0	0	0
	М	±1,7	±2,5	±19,9	±1,18	±1,85	±0,27	±1,39	±1,39	±2,21	±2,8	±3,50
1,3	Д	0	0	0	0	0	0	±1,02	∓1,02	0	0	0
	М	±2,0	±2,5	±19,9	±1,64	±2,19	±0,35	±1,56	±1,56	±2,29	±3,3	±3,60
1,5	Д	0	0	0	0	0	0	±1,16	∓1,16	0	0	0
	М	±2,4	±2,6	±19,9	±2,19	±2,53	±0,43	±1,75	±1,75	±2,39	±3,7	±3,85
1,7	Д	0	0	0	0	0	0	±1,31	∓1,31	0	0	0
	М	±2,6	±2,7	±19,9	2,82	2,87	±0,51	±1,94	±1,94	±2,50	±3,8	±4,36
1,9	Д	0	0	0	0	0	0	±1,45	∓1,45	0	0	0
	М	±2,7	±3,0	±19,9	3,21	3,52	±0,59	±2,13	±2,13	±2,62	±4,0	±4,88
2,1	Д	0	0	0	0	0	0	±1,60	∓1,60	0	0	0
	М	±2,8	±3,3	±19,9	3,54	4,30	±0,67	±2,32	±2,32	±2,75	±4,1	±5,39
2,3	Д	0	0	0	0	0	0	±1.74	∓1.74	0	0	0
	М	±2,9	±3,7	±19,9	3,88	5,16	±0,75	±2,51	±2,51	±2,89	±4,3	±5,90
2,5	Д	0	0	0	0	0	0	±1,89	∓1,89	0	0	0
	М	±3,0	±4,03	±19,9	4,22	6,09	±0,82	±2,71	±2,71	±3,03	±4,4	±6,42

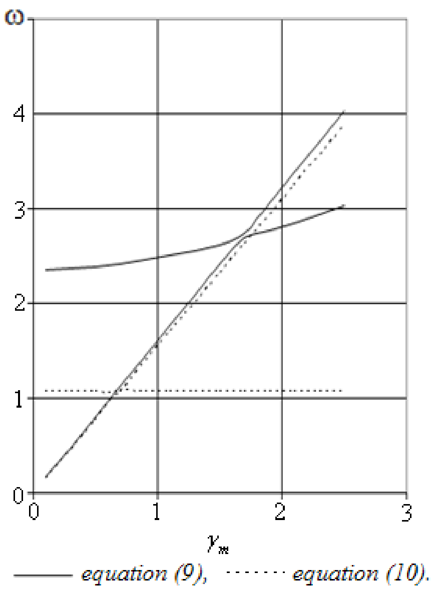

Fig.1. Comparison of natural frequencies theories (9) and (10).

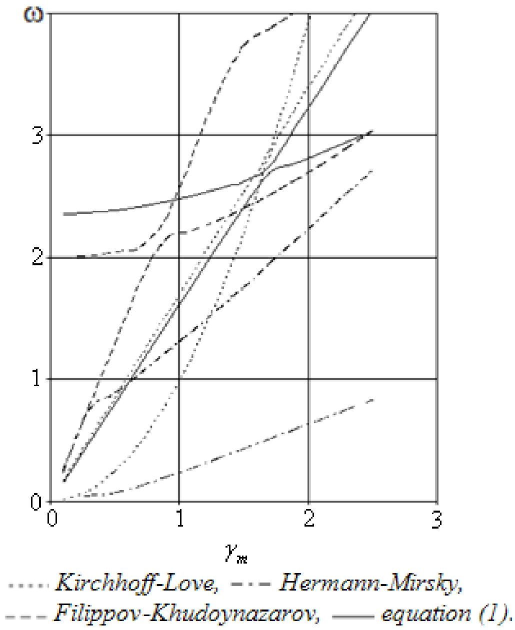

Fig.2.Comparison of natural frequencies of vibrations according to different longitudinal-radial according to equations.

parameter γ_m and at certain values of the transverse dimensions of the shell. As for the Hermann-Mirsky equations, such results can be obtained for separate values of the Timoshenko coefficient $k_T > 1$, which is impossible in principle.

Conclusions

From a comparison of the numerical results obtained by equations (9) and (10), it follows that in the case of equation (9) we have six frequency values, and for the equation for the shell four frequencies. When passing from equation (9) to equation (10) for the shell, two frequencies are lost. The obtained numerical results, at $r_1 = 1{,}0;\ r_2 = 1{,}1;\ h = 0{,}1;\ \nu = 0{,}2;\ k_T = \frac{5}{6}$, are shown in Table 2 and presented in the form of curves in Fig. 3. From Table 2 and Fig. 3 the following conclusions follow:

- the Hermann-Mirsky equation does not obey the Hurwitz criterion and gives imprecise results. More accurate results can be obtained that are consistent with the Hurwitz criterion only at certain values of the Timoshenko correction coefficient k_T. This conclusion completely coincides with the same conclusion of work [9];

from the graphs in Fig. 2 and Fig. 3 it follows that equations (1) describe well the wave process, like equations (11), in long shells ($l >> m\pi$) regardless of the values of the number m, i.e. with sufficiently low and high forms of wave formation;

- equations (1) are suitable for solving dynamic problems in shells of medium length with sufficiently low waveforms;

- these equations are unsuitable for describing wave processes in short shells, the lengths of which are commensurate with the transverse dimensions of the shells $l >> m\pi$.

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Issue Article

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PROBLEM ASPECTS OF THE INVESTIGATION OF ROAD AND TRANSPORT CRIMES COMMITTED IN RURAL AREAS

Abstract: *In the article, the author examines the forensic characteristics of road traffic crimes committed in rural areas, reveals the circumstances to be established in the investigation of road traffic crimes committed in rural areas, and analyzes the forensic problems of organizing the investigation and disclosure of road traffic crimes committed in rural areas.*

Key words: *Road traffic crimes, investigation of road traffic crimes, forensic characteristics of road traffic crimes committed in rural areas, circumstances to be established in the investigation of road traffic crimes committed in rural areas, forensic problems of organizing the investigation and disclosure of road traffic crimes, committed in the countryside.*

Language: *English*

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Introduction

Taking into account the conditions of the countryside, the objective factors influencing the course of the investigation, in our opinion, include the significant remoteness of the scene of the incident from the location of the internal affairs body; untimely receipt of information about the accident; intensive high-speed flow of vehicles on federal highways passing through rural areas, etc.

Subjective factors include the lack of protection of the scene of an accident; untimely arrival at the scene of the investigative-operational group and its incomplete staffing; improper qualification of employees; leaving the crime scene by the driver due to the need to deliver the victim to a medical institution; etc. The forensic characteristics of road accidents [1], committed in rural areas, according to some scientists, can be defined as a set of features characteristic of rural areas, features and relationships of this category of crimes, expressed in a specific setting and mechanism for committing a crime, personality traits of a criminal, as well as in individual personality traits of the victim.

The main elements of road accidents committed in rural areas, in our opinion, are: the situation at the scene of the crime; accident mechanism; characterization of the personality of the perpetrator of the crime; information about the identity of the victim [2]. A characteristic feature of the situation at the scene of an accident committed in a rural area is the fact that the streets and roads of settlements and their environs are little loaded with vehicles, the speed of movement is low. The streets of settlements often do not have roadsides and sidewalks.

They are not well lit; the surface of such roads, as a rule, has significant damage; road signs are missing. At the same time, high-speed roads with intensive traffic flow often pass through the territory of vast rural areas, which can have a pronounced direction (on Friday - from the city to the village; on Sunday - from the village to the city).

The situation at the scene of the accident, depending on where the accident occurred, is different. When studying the situation of an accident in a village, the investigator must take measures to detect signs of the past state of the environment, since a significant distance from the place of the accident from the location of the internal affairs body can mislead the investigator about the true picture of what happened [3]. In the course of a practical analysis of the situation of an accident committed in a rural area, the investigator must take into account other circumstances.

The specificity of the personality of the driver guilty of an accident is primarily determined by his age. In rural areas, due to the migration of young people to the city, older drivers are the majority. In addition, in our opinion, one can single out such a feature of a rural driver as a blunted sense of vigilance. Quite a calm and measured way of life in the village has a negative impact on the driver's reaction when driving a vehicle in rapidly changing traffic conditions [4]. On the other hand, a city dweller who has left the city on a fairly free highway or country road can relax (lower the seatback, turn on music, etc.), as a result of which the reaction time to the danger that has arisen will be slowed down. Among the features that affect the reaction time, we can also highlight the state of extreme fatigue of drivers going on vacation, who spend a large amount of time driving their cars. Wishing to get to a place of rest faster (sanatorium, sea, mountains, etc.) [5], they exceed the speed of movement, neglect stops along the way, which can lead to an accident.

The lack of proper control in rural areas by local law enforcement agencies significantly reduces the level of training of rural drivers and their knowledge of the Rules of the Road; often vehicles are driven by people who do not have driver's licenses at all [6].

Important for the characterization of road users in rural areas is their tendency to abuse alcohol and irresponsible attitude, which fully allows driving while intoxicated [7].

So, a specific circumstance that needs to be established in a collision involving agricultural machinery equipped with a trailer is the study of the possibility of deviation from the rectilinear direction of movement, which significantly affects the lateral interval. These vehicles may not have turn signals, or they may be so splattered with mud that they cannot be seen when turned on. If there was a collision with an agricultural machine, one should pay attention to the attachments and equipment protruding beyond the dimensions of the vehicle, take into account the degree of its illumination, etc. [8]. When investigating road accidents committed in rural areas, in our opinion, it is important to clarify such circumstances of the commission of a crime as the state of road conditions and vehicle.

For rural areas, among the well-known factors that determine road conditions, the most specific and significant are the accounting and assessment of weather conditions. So, in the winter season, it must be taken into account that in the village road work is usually carried out by agricultural machinery that does not have special devices. When wetting the road surface in rural areas, it should be taken into account that the roadway can be covered not only with an abundant layer of dust, but also with layers of soil, which significantly impairs the quality of adhesion. It is quite typical for rural areas with a steppe landscape to assess the possibility of influencing the conditions of vehicle movement by gusty and side winds [9]. One of the circumstances to be established during the investigation of an accident is the determination of the technical condition of vehicles. It should be borne in mind that most accidents in rural areas occur due to malfunctions of the brake system, the condition of lighting fixtures, tires and steering.

In order to ensure road safety, we consider it expedient for domestic manufacturers to take into account foreign experience and equip vehicles with anti-blocking devices that allow drivers to use the brake system more efficiently in emergency situations [10]. It is proposed to provide for a different degree of incandescence of the filaments of the lamps of the reversing lamps, depending on the intensity of braking. When establishing the state of lighting devices, it must be taken into account that a rural resident often adjusts the headlights of his vehicle, depending on the features of its operation, without adhering to the prescribed standards. The study of the condition of vehicle tires is of particular importance in rural areas, as drivers have to move along the roadway with different surfaces. In this case, the degree of loading often exceeds the permissible. For agricultural machinery, in order to ensure safety, in our opinion, it is necessary to provide for the installation of rear-view mirrors that display the status of attachments, as well as the regulatory fixation of the minimum limit of steering wheel play for all types of vehicles.

Given the large distances for timely response and prompt inspection of the scene of an accident committed in rural areas, in the opinion of the dissertator, it is advisable to introduce the position of an investigator at the checkpoints of the traffic police serving highways. This officer must be specially trained and live in an area close to the duty station. If complex agricultural machinery is to be inspected, it is advisable to include an auto technician specialist in the investigative team who will help sort out technical issues, as well as invite representatives of the affected farm, who can assist in organizing the subsequent evacuation of the damaged vehicle. Before leaving for an inspection, especially at night, it is necessary to decide on witnesses. It is not advisable to invite persons passing through the territory in transit as witnesses, since the inspection can drag on for a long time. In addition, later sometimes there is a need for their interrogation [11]. In this regard, it seems possible to invite as witnesses any persons not interested in the outcome of the case.

In some cases, when there is a medical institution on the way to the scene of the accident, where the victims were taken, it is advisable to promptly interrogate them about the circumstances of the accident. This is of particular importance when there are no eyewitnesses left at the scene of the incident and it is quite difficult for the employees of the investigative-operational group to recreate the picture of the incident on the spot. In addition, victims may be sent for surgery, given anesthesia, taken to another medical institution, they may die, etc. When conducting such interviews, in our opinion, it is advisable to make an audio recording of the explanation received. Subsequently, such a record can be used as one of the evidence in the event of the death of the victim, if it is impossible for him to sign this explanation, if the testimony is changed subsequently.

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Issue Article

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LEGAL FORM AND STRUCTURAL ELEMENTS OF THE BASIC LAW AS THE FUNDAMENTAL SOURCE OF THE LEGISLATION OF THE KYRGYZ REPUBLIC

Abstract: *The article reveals the main form of the constitution as a set of ways through the implementation of which the content of the basic law is formed. The author provides a classification of the basic law and analyzes the main features of the Constitution. In addition, in the course of his research, the author emphasizes the specific individual features inherent in the constitution.*

Key words: *legal form, Basic Law, Constitution, structural elements of the Constitution, principles of the constitution, source of legislation, characteristics of the constitution.*
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Introduction

Any constitution has a socio-political essence, reflected in the balance of political forces, political interests of various parts of society. The Constitution of the Kyrgyz Republic fixed that the state power in the Kyrgyz Republic is based on the principle of division of power into legislative, executive and judicial.

The form of the constitution is a set of ways by which the content of the constitution is formed, its essence is formed. Distinguish between internal and external forms. The corresponding terms are quite often found in the literature when there is a need for additional characterization of a particular constitution [4]. The oldest classification, which was used back in the 19th century, is still used today. In accordance with the internal form, the constitution includes: 1) the procedure for drafting the constitution, 2) the procedure for adoption, 3) the procedure for approval, 4) the internal structure. The external form of the constitution is expressed in such structural elements as: 1) the name of the constitution, 2) the order of enactment, 3) the order of implementation, 4) the order of revision, 5) the order of protection. The Constitution has the following legal properties (features that characterize it as the Basic Law). The main features of the Constitution can be distinguished:

1. The Constitution is one of the legal acts, is a law and has all its features. This is the adoption by the Parliament of a universally binding normative legal act, designed for repeated application, based in its action on the authority and strength of the state. The Constitution has legal supremacy.

2. The Constitution is the basis of the current legislation, in accordance with which the provisions of the Constitution are developed, its norms are concretized.

3. The constitution is characterized by a special procedure for its adoption and amendment [5].

The constitution has its own functions, so in the theory of constitutionalism they single out its constituent function, which legislates the independence of the state. The constitution also performs an organizational, political function [6].

We are in solidarity with the opinion of Soodanbekov S.S. and Ukusheva M.K. that the constituent function of the Constitution of 1993 of the Kyrgyz Republic is that it legislated the independence of the Kyrgyz state, thereby becoming a full-fledged subject of international legal relations [1]. Naturally, the Constitution fixes the most significant social relations, in contrast to the current legislation, which singles out separate parties and aspects of certain social relations as an object [7].

Each of the current constitutions has specific individual features, while at the same time, all constitutions have some common features:

a) all constitutions in one form or another proclaim the idea of popular sovereignty;

b) all constitutions in one form or another fix the institution of property;

c) the basic principles of the theory of separation of powers are reproduced and consolidated in constitutions;

d) all constitutions establish and fix the form of government of the state - a republic or a monarchy;

e) constitutions establish and fix the unitary or federal form of government;

f) all constitutions in one form or another proclaim and establish the rights and freedoms of man and citizen;

g) all constitutions define the principles of organization of the system of higher bodies of state power and the procedure for the activities of its constituent subsystems [8].

Some constitutions have rules governing the foreign policy of the state.

Principles act as an obligatory element of the theoretical basis of any science. It should be noted that in the legal literature there is a rather huge layer of interpretations of the concept of principles. The Constitution of the Kyrgyz Republic also establishes a fairly wide range of fundamental principles similar to the generally recognized universal, fundamental principles of constitutionalism [9].

The analysis of the norms of the Constitution of the Kyrgyz Republic shows that constitutional principles should be divided into two groups according to the form of expression: 1) fixed in the Constitution; 2) unfixed, introduced through the analysis of constitutional provisions. As it is clear from the list of principles given in the Constitution, the fundamental principles of the activity of the Republic must influence the entire state, its entire mechanism, society as a whole, and associations of citizens. In other words, all these entities should take these principles as the basis of their activities, which primarily include:

Consent of the governed. The basis of the national Constitution is the theory of the social contract. Public consent is achieved and maintained by the state, its bodies as a result of their permanent activity.

The principle of separation of powers. According to this principle, the state and its institutions can act within the limits established by the Constitution. The division of state power into branches is designed to ensure the necessary balance of interests, which makes public power whole and unified.

Noah. This balance is constitutionally guaranteed by the powers of the legislative, executive, and judicial bodies, and, accordingly, disputes between the branches of government must be resolved constitutionally, through a legal procedure, the mechanism of a system of checks and balances [10].

The Constitution of the Kyrgyz Republic enshrined the principle of legality and supremacy of the Constitution. This principle is defined as the principle, method and regime of strict, unswerving observance, execution of the rules of law by all participants in public relations (the state, its bodies, public and other organizations, labor collectives, officials, citizens).

One of the fundamental principles reflected in the Constitution of the Kyrgyz Republic is the principle of democracy. The essence of this principle is the creation of a mechanism that ensures effective functioning, in accordance with the will of the people, as well as direct decision-making by the people on the most important issues of the life of society and the state. The people of Kyrgyzstan are the bearer of sovereignty and the only source of power in the Kyrgyz Republic, the people exercise their power directly, as well as through the system of state bodies and local self-government bodies. In the same article, we are talking about the fact that the highest direct expression of the power of the people is a referendum and free elections [11].

Private property and its inviolability. The Constitution recognizes private property as an inalienable right of a person, a natural source of his well-being and secures its inviolability.

Open Society. The Constitution recognizes human rights and freedoms as natural and inalienable.

Personal inviolability. In accordance with this principle, the Constitution of the Kyrgyz Republic recognizes and guarantees the rights and freedoms of man and citizen in accordance with generally recognized principles and norms of international law, such as the Universal Declaration of Human Rights, the International Covenant on Civil and Political Rights, the CIS Convention on Human Rights and Fundamental Freedoms [2] .

Rule of law (principle of legal procedure). This concept, embodied in the national Constitution, assumes that laws should be applied fairly, without discrimination and in accordance with the norms of the law and the Constitution.

The principle of equality of all before the law. The Constitution establishes that all are equal before the law and the courts and guarantees equal protection of the law to all. Equality of opportunity is the main purpose of the Constitution.

The Constitution of the Kyrgyz Republic enshrined the principle of citizenship, which is understood as the obligation of the state to fully protect the rights and freedoms of the individual, enshrined in the Constitution, determined by citizenship. Citizenship in the Kyrgyz Republic is understood as a stable legal relationship of a person with the state, expressed in the totality of their mutual rights, duties and responsibilities, based on the recognition and respect for the dignity, fundamental rights and freedoms of a person [3].

Judicial control. The Constitution establishes that the Constitutional Chamber is the supreme body of judicial power for the protection of the Constitution; The supreme judicial body is the Supreme Court.

An analysis of the norms of the Constitution gives grounds to single out into a special group the legal ideas that are fixed in it, but not expressed as principles. These include the principle of the supremacy of the Constitution of the Kyrgyz Republic, supreme legal force and direct action, the principle of constitutional legality.

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Issue **Article**

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CURRENT ISSUES OF LEGAL STAGES OF LEGISLATION: ADOPTION AND WAYS OF AMENDMENT, INTERPRETATION OF THE CONSTITUTION, IMPLEMENTATION

***Abstract**: The article is devoted to topical problems of the organization of the legal stage of the implementation of legislative activity, in which the stability of the Constitution is one of its important legal properties, which affects the determining influence of the stability of political, economic and social relations. The author places special emphasis on the subject of the constitutional referendum, which is the draft of a new constitution, or constitutional reform or amendments to the constitution.*

***Key words**: lawmaking, legal stages of the legislative process, adoption of the constitution, amendment of the constitution, interpretation of the constitution, implementation of the constitution.*

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Introduction

The constituent power, when using the developed legal technology, uses the same methods, rules, categories, which is generally accepted in the legal environment. However, the legal technology of lawmaking and the legal technology of preparing and adopting constitutions are not the same, one might even say, they differ in many respects. Hence the slightly different legal properties of the constitution, which is what we are talking about.

The stability of the Constitution is one of its important legal properties, which affects the determining influence of the stability of political, economic and social relations. Revision of any provisions of the Constitution or amendments to it is a rather complicated procedure. Quite rightly noted by A.A. Mishin in the monograph "Constitutional (State) Law of Foreign Countries", the right to adopt the first or new constitution is a manifestation of constituent power and is exercised either by the electoral corps, or by a representative institution, or by the executive power [1]. These three main ways of adopting a constitution are used both in pure form and in various combinations.

The doctrine of constitutional law is based on the notion that the adoption of a constitution is an act of constituent power, where the latter belongs to the people (in accordance with the theory of popular sovereignty) or a body authorized to adopt the basic law [1]. The spread of referendums as a way to adopt new constitutions is a characteristic feature of the second half of the 20th century.

The referendum is an institution of direct (direct) democracy. In the exact sense of the word, a referendum is an appeal to the electoral corps for the final decision of some (mostly legislative or constitutional issue). Constitutional law provides for various forms of referendum and procedures for their application. It is customary to classify referendums into national, national, regional, and local referendums. It is generally accepted that referendums are divided into constitutional and legislative ones. The subject of a constitutional referendum is the draft of a new constitution, or constitutional reform or amendments to the constitution. The subject of a legislative referendum can be either a draft law or a law that has already entered into force [2].

We are in solidarity with A.A. Mishin, who argues that it is impossible to give an unambiguous assessment of the referendum. Democracy or reactionary nature of this institution depends on the real political circumstances and conditions in which the referendum is held [3]. The electoral corps cannot develop a draft constitution; this function is performed either by the Constituent Assembly or a specially created constitutional committee.

It is necessary to mention another method of adoption - the adoption of the constitution by bodies convened specifically for this purpose - constituent assemblies (constitutional assemblies, constitutional conventions). The very procedure for the work of such a body makes it possible to work out each article of the constitution. As a rule, the entire procedure for adopting a new constitution is carried out by the representative institution itself and the subsidiary bodies created by it [4].

The constitution can also be adopted by a unilateral act of executive power - this is an oktroirovanie, i.e. "gift". The project developed in this way is approved and promulgated by the head of state. The procedure for amending constitutions consists of several stages. The initiative to change the constitution is given to the parliament, or head of state. Approval of the proposed draft constitutional change makes Parliament a qualified majority vote. At the same time, the important procedural significance (on the example of the Kyrgyz Republic) is the condition according to which the law on amendments and additions to this Constitution can be adopted by the Jogorku Kenesh of the Kyrgyz Republic after at least two readings with breaks between readings of three months [5]. The Constitution also establishes a ban on the adoption of the Constitution, a new version of the Constitution of the Kyrgyz Republic or the introduction of amendments and additions to this Constitution during a state of emergency and martial law, which is due to the fact that the legislative body of the state in such periods should deal, first of all, with urgent, global character for the state affairs. Also, the Constitution has a rule of time within which the Parliament of the country, upon receipt of the opinion of the Constitutional Court of the Kyrgyz Republic, must adopt a law on amendments and additions to this Constitution. The norm provides for a period within which an unaccepted draft law cannot be submitted by the Parliament again. In the event that the Constitutional Court issues a negative opinion on the draft law on amendments and additions to this Constitution, this draft law is returned by the Jogorku Kenesh to its initiator [6]. The final approval of the adopted draft constitution is carried out either by the head of state or by the electoral corps through referees.

The adoption of the constitution by the electoral corps consists of two stages - the development of a draft constitution and its final approval, after which the constitution comes into force.

An equally important problem is the problem of interpretation of the law and has been the object of close attention of researchers in the field of jurisprudence for a long time. We could not ignore this problem of legal science, which has already become traditional. This is explained by the fact that the legislator, with all the desire, can neither identify nor resolve the whole variety of problems.

Interpretation is a complex, complex phenomenon. This is both the internal thought process of a person studying a legal norm (clarification of the norm), and the special activity of certain persons and bodies, expressed in the form of an official act of a state body or given by various organizations and individuals and not having a formally binding value of recommendations and advice (clarification of the norm).). The purpose of this activity is to ensure the correct and uniform application of the interpreted norm, to eliminate ambiguities and possible errors in its implementation.

In the legal explanatory dictionary, “interpretation” is defined as “the activity of state bodies, organizations, officials, individual citizens to establish the content of the rules of law, to reveal the will of the legislator in them” [7]. Depending on the legal consequences that the interpretation leads to, they are usually distinguished: an official interpretation given by authorized bodies, formulated in a special act, formally binding on a certain circle of people and being an official directive on how to correctly understand a specific norm, and unofficial, which is understood as all other cases of interpretation, clothed in the form of recommendations and advice.

The greatest significance among all types of interpretation of legal norms is characterized by an explanation that is the result of an official normative interpretation. Such an interpretation is obligatory for all persons, extends to the entire range of cases provided for by the interpreted norm, thereby ensuring the uniform and correct implementation of its prescriptions [8].

The Constitution, as a normative legal act with the highest legal force, serves as a guideline for all other normative legal acts of the Kyrgyz Republic. Thus, on the basis of the Constitution, the following normative acts that are part of the system of legal acts of the Kyrgyz Republic can be adopted: constitutional laws of the Kyrgyz Republic, laws, resolutions of the Jogorku Kenesh of the Kyrgyz Republic, decrees of the President of the Kyrgyz Republic, resolutions of the Government of the Kyrgyz Republic, acts of the National Bank of the Kyrgyz Republic, acts of ministries, state committees and state administrations and local governments that meet the requirements established by law.

For the first time, the institution of official interpretation was introduced in Kyrgyzstan as a result of constitutional changes in February 1996. Thus, the right of official interpretation of the Constitution was assigned to the competence of the chambers of the Jogorku Kenesh - the Legislative Assembly and the Assembly of People's Representatives [9]. An analysis in this regard of the legal status and constitutional foundations of the activities of the Constitutional Court of the Kyrgyz Republic, on the one hand, and the principles of organizing constitutional control, on the other hand, clearly indicated the expediency of assigning this authority not to the Parliament, but to the Constitutional Court.

It should be noted that A.A. Arabaev. The comparative-historical method of research allowed us to turn to the appeals of A.A. Arabaev in terms of the analysis of the current constitutional legislation of Kyrgyzstan, its theoretical developments and the practice of official interpretation of the Constitution. There is no doubt in his thesis that the Constitutional Court, exercising its main function - constitutional control, almost always deals with the interpretation of the Constitution. From which it follows that the recognition of laws and other normative acts as constitutional or unconstitutional is the prerogative of the Constitutional Chamber of the Kyrgyz Republic. He also noted that, despite the causality of interpretation, that is, of a secondary nature, since it is subordinate to the main task of substantiating the decision of the Constitutional Chamber, on the one hand, the completely independent nature of the normative interpretation of the Constitution, as evidenced by the very fact of fixing such in the Basic Law, with the other is that this function is carried out within the framework of constitutional control [10]. Which, in fact, is a powerful and effective institution for the legal protection of the Constitution - the main function of the Constitutional Chamber of the Kyrgyz Republic as the supreme body for the protection of the Constitution of the Kyrgyz Republic. It should be added that the Constitutional Chamber of the Kyrgyz Republic, according to the Constitution, is also assigned the most important role of an arbitrator between the highest bodies of state power, expressed in ensuring checks and balances of the authorities, and ensuring their balance, and in the legislation field. Such a function of the body of constitutional control as the interpretation of the Constitution helps to avoid situations that are close to a political crisis, especially in the context of an emerging disagreement between the legislative and executive branches of power.

Article 50 of the Law of the Kyrgyz Republic "On Normative Legal Acts" grants the authorities or officials who have adopted (issued) these normative legal acts the authority to officially interpret subordinate normative legal acts.

So, the existing legislation of the Kyrgyz Republic directly provides for the official interpretation of normative legal acts only in two cases: interpretation of the norms of the Constitution by the body of constitutional control and authentic interpretation of subordinate normative legal acts. Based on this, it can be concluded that only the Constitutional Chamber of the Kyrgyz Republic is authorized to give an official interpretation of the norms of laws, and the range of norms that it can interpret is limited only to the norms of the Constitution of the Kyrgyz Republic. It should be noted that it is not always an easy task to determine the entities that, in accordance with the current legislation of the Kyrgyz Republic, have the right to an official normative interpretation of laws.

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Issue **Article**

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TRANSVERSE VIBRATIONS OF A TWO-LAYER PLATE

Abstract: *The theory of unsteady vibrations of a two-layer elastic plate is developed on the basis of a plane formulation of the problem on the basis of exact solutions of the equations of the linear theory of elasticity in transformations. Equations of transverse vibrations of a two-layer plate are obtained with respect to two auxiliary functions, which are the main parts of the displacements of some intermediate surface of the middle layer. An algorithm is proposed that makes it possible to unambiguously determine the stress-strain state of an arbitrary layer of the plate from the field of the sought-for functions.*

Key words: *Plates, solutions, equations, oscillations, layer, algorithm.*
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ПОПЕРЕЧНЫЕ КОЛЕБАНИЯ ДВУХСЛОЙНОЙ ПЛАСТИНЫ

Аннотация: *Разработана теория нестационарных колебаний двухслойной упругой пластинки исходя из плоской постановки задачи на основе точных решений уравнений линейной теории упругости в преобразованиях. Получены уравнения поперечных колебаний двухслойной пластинки относительно двух вспомогательных функций, являющихся главными частями перемещений некоторой промежуточной поверхности срединного слоя. Предложен алгоритм, позволяющий по полю искомых функций однозначно определить напряженно-деформированное состояние произвольного слоя пластинки.*

Ключевые слова: *Пластинки, решений, уравнений, колебания, слой, алгоритм.*

Введение

В нашей стране и за рубежом в различных областях техники и строительства широко применяются многослойные, в частности двухслойные пластинки. При этом во многих случаях динамические расчеты пластин основываются на классические теории опирающихся на гипотезы Кирхгофа. К таким принадлежать немало работ. Дальнейшее развитие и уточнение классической теории осуществлялось С.Г.Лехницким, С.А.Амбарцумяном, Г.И.Петрашеном, И.Г.Филипповым, Х.Алтенбахом, E.Reysner, Э.И.Григолюком, В.П.Шевченко, М.В.Фоменко, Х.Х.Худойназаровым, М.Мирсаидовым, Р.И.Халмурадовым, А.Б.Ахмедовым и другими авторами, исследования которых, можно разделить на два направления: разработка асимптотических теорий и теорий типа Тимошенко и Рейсснера. За последние несколько десятилетий разработаны теории колебания пластин, основанные на методе точных решений в преобразованиях Г.И.Петрашеня.

Указанным методом разработаны различные варианты однородных и двухслойных пластин в упругой и вязкоупругой постановках профессором И.Г.Филипповым и его учениками. В них при выводе уравнений колебания трехслойных пластин допущены следующие предпосылки: 1) рассматри-ваются трехслойные пластинки только симметричной структуры; 2) в качест-ве неизвестных берутся главные части составляющих перемещений точек срединной поверхности заполнителя, количество которых в общем случае равно шести. Если же, при этом, граничные условия сформулировать точно, то число неизвестных возрастет, по признанию самих авторов до двенадцати; 3) граничные условия формулируются относительно главных частей переме-щений срединной поверхности, что в принципе не верно; 4) указанные факторы в конечном итоге вынуждают авторов к выполнению существенных упрощений, приводящие к некоторым неточностям, приближая получаемые уравнения колебания трехслойной пластинки к уравнению колебания однородной пластинки; 5) полученные уравнения колебания трехслойной пластинки, в частном случае не переходят в уравнения колебания двухслойной пластинки (из-за симметричности структуры рассматриваемой трехслойной пластинки, отсутствие одного из внешних слоев влечет за собой отсутствие второго внешнего слоя).

На сегодняшний день разработка теории нестационарных колебаний двухслойной трехслойной упругой пластинки с учетом упругих и свойств материалов в достаточной степени не изучены.

Постановка задачи.

Рассматривается бесконечная в плане двухслойная упругая пластинка. Считается, что рассматриваемая пластинка является трехмерным телом. Пластинка отнесена к декартовой системе прямоугольных координат $Oxyz$. Слои пластинки пронумерованы как на рис.1, т.е. верхний несущий слой назван первым слоем, нижний несущий слой – нулевым слоем.

Учитывая неограниченность размеров пластинки, в дальнейшем считается, что она находиться в условиях плоской деформации (рис. 1). При этом ось Ox направлена вдоль поперечного сечения Oxz по его средней линии, а ось Oz – вверх. Слои пластинки пронумерованы как показано на рис.1, т.е. верхний несущий слой назван первым слоем, нижний несущий слой – вторым, и заполнитель – нулевым слоем. Пусть h_1, $2h_0$ и h_2 толщины первого, нулевого и второго слоев; λ_m, μ_m- коэффициенты Ляме и ρ_m- объёмные плотности слоев.

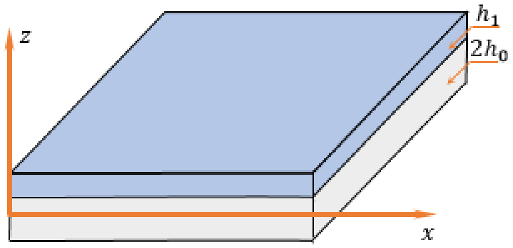


Рис. 1.

Зависимости $\sigma_{ij}^{(m)}$напряжений от $\varepsilon_{ij}^{(m)}$ деформаций в точках слоев пластинки описываются законом Гука.

$$\sigma_{ii}^{(m)} = \lambda_m \varepsilon_{ii}^{(m)} + 2\mu_m \varepsilon_{ii}^{(m)};\ \sigma_{ij}^{(m)} = 2\mu_m \varepsilon_{ij}^{(m)}. \quad (1)$$

Для описания движений точек составляющих слоев пластинки в системе декартовых координат $Oxyz$ приняты уравнения движения

$$\sigma_{ij,j}^{(m)} = \rho_m \ddot{\vec{U}}^{(m)} \quad (2)$$

где $\vec{U}^{(m)}$ – векторы перемещений точек слоев; t –время. Далее введены скалярные -φ_m и векторные - $\vec{\psi}_m$ потенциалы по формулам

$$\vec{U}^{(m)} = grad\varphi_m + rot\vec{\psi}_m \quad (3)$$

При этом считается, что векторные потенциалы $\vec{\psi}_m$ удовлетворяют условиям соленоидальности векторных полей

$$div\,\vec{\psi}_m = 0 \qquad (4)$$

Подставив (3) в систему (2) нетрудно получить уравнения движения точек упругих слоев пластинки в виде волновых уравнений для потенциалов продольных φ_m и поперечных $\vec{\psi}_m$ волн

В случае плоской деформации, учитывая, что векторы перемещений точек слоев $\vec{U}^m = \vec{U}^m(U_m, W_m)$ разлагаются только по единичным ортам $\vec{\imath}$, $\vec{k}$ уравнения движения приводятся к волновым уравнениям

$$\Delta\varphi_m = \ddot{\varphi}_m/a_m^2\,;\ \Delta\psi_m = \ddot{\psi}_m/b_m^2, \qquad (5)$$

где a_m, b_m- скорости продольных и поперечных волн в слоях; Δ – двумерный дифференциальный оператор Лапласа. При этом компоненты векторов перемещений, а также тензоров напряжений и деформаций слоев выражаются через введенные функции φ_m и ψ_m.

Предполагается, что при $t < 0$ пластинка находилась в покое, а в момент $t = 0$ к её граничным поверхностям прикладываются динамические воздействия. В силу линейности задачи можно представить полей смешений, в виде наложения симметричной и антисимметричной частей

$$\vec{U}_m = \vec{U}_m^s + \vec{U}_m^a,$$

где $\vec{U}_m^s$ – симметричная (продольная), $\vec{U}_m^a$- антисимметричная (изгибная) части полей перемещений слоев пластины. При этом симметричные части должны удовлетворять граничным условиям

при $z = (-1)^{i-1}h_i^*$, $h_i^* = h_0 + h_i$

$$\sigma_{xz}^{(i)} = f_x^{(i)};\ \sigma_{zz}^{(i)} = f_z^{(i)};\ (i = 1{,}2). \qquad (6)$$

Кроме того, на поверхностях заполнителя имеют места динамические и кинематические контактные условия:

при $z = h_0$

$$\sigma_{xz}^{(0)} = \sigma_{xz}^{(1)}, \sigma_{zz}^{(0)} = \sigma_{zz}^{(1)}, U_0 = U_1, W_0 = W_1. \qquad (7)$$

Начальные условия нулевые.

Метод решения.

Для решения поставленной задачи необходимо задать выражения для функций $f_x^{(0,1)}(x,t)$ и $f_z^{(0,1)}(x,t)$ из граничных условий. Следуя [5], функции внешних воздействий представим в виде

$$\left.\begin{aligned} f_x^{(0,1)} &= \int_0^\infty \left.\begin{matrix} coskx \\ sinkx \end{matrix}\right\} dk \int_{(l)} \tilde{f}_x^{(0,1)} e^{pt} dp \\ f_z^{(0,1)} &= \int_0^\infty \left.\begin{matrix} sinkx \\ -coskx \end{matrix}\right\} dk \int_{(l)} \tilde{f}_z^{(0,1)} e^{pt} dp \end{aligned}\right\} \qquad (8)$$

где $f_x^{(0,1)}$, $f_z^{(0,1)}$ – функции, регулярные при $Rep \geq 0$ имеющие конечное число полюсов, принимающие произвольные значения внутри некоторой области Ω, содержащий промежуток $(-i\omega_0; i\omega_0)$ мнимой оси, убывающие при $p \to i\infty$ не медленнее, чем $|p|^{-n_0}$, где $n_0 \gg 1$, и такие, что вне Ω их значения пренебрежимо малы. Кроме того функции $\tilde{f}_x^{(0,1)}$ и $\tilde{f}_z^{(0,1)}$ – аналитические, принимающие произвольные значения в промежутки $(0, k_0)$, убывающие при $k \to \infty$, как k^{-n_0}, и пренебрежимо малые при $k > k_0$; (l) – контур $Rep = \nu > 0$ на комплексной плоскости (p), оставляющего область Ω правее себя.

В соответствие с принятыми представлениями функций внешнего воздействия решение поставленной задачи также ищем в виде (4). Это позволяет получить из (5) обыкновенные дифференциальные уравнения второго порядка. В случае симметричных воздействий, когда будут иметь место продольные колебания пластины, решением полученных уравнений будет

$$\left.\begin{aligned} \tilde{\varphi}_m(z,k,p) &= A_m^1 ch(\alpha_m z) \\ \tilde{\psi}_m(z,k,p) &= B_m^1 sh(\beta_m z) \end{aligned}\right\} \qquad (9)$$

где

$$\alpha_m^2 = k^2 + p^2/a_m^2\,;\ \beta_m^2 = k^2 + p^2/b_m^2.$$

Перемещения U_m и W_m также представим в виде (8) и подставляя вместе с (9) в выражения перемещений, для преобразованных $\tilde{U}_m$ и $\tilde{W}_m$ будем иметь выражения через гиперболические функции и постоянные интегрирования. Далее с использованием стандартных разложений гиперболических функций в степенные ряды, получим

$$\left.\begin{aligned} \tilde{U}_m &= \sum_{n=0}^{\infty}\left[k\alpha_m^{2n}A_m^{(1)} - \beta_m^{2n+1}B_m^{(1)}\right]\frac{z^{2n}}{(2n)!} \\ \tilde{W}_m &= \sum_{n=0}^{\infty}\left[\alpha_m^{2n+2}A_m^{(1)} - k\beta_m^{2n+1}B_m^{(1)}\right]\frac{z^{2n+1}}{(2n+1)!} \end{aligned}\right\} (10)$$

В качестве искомых функций в уравнениях колебания трехслойной пластинки примем главные части преобразованных перемещений $\tilde{U}_0$ и $\tilde{W}_0$ такой поверхности нулевого слоя, расстояние от поверхности $z = 0$ которой определяется формулой

$$\xi = \chi \cdot h_0;\ -1 \leq \chi < 0; 0 \leq \chi < 1$$

где χ – постоянное число, удовлетворяющее неравенству $-1 \leq \chi \leq 1$. Для этого в выражениях (10) примем $z = \xi$, $m = 0$ и $n = 0$. Тогда введя обозначения $\tilde{U}_0^{(0)}$ и $\tilde{W}_0^{(0)}$ получим

$$\left.\begin{aligned} \tilde{U}_0^{(0)} &= kA_0^{(1)} - \beta_0 B_0^{(1)} \\ \tilde{W}_0^{(0)} &= \left[\alpha_0^2 A_0^{(1)} - k\beta_0 B_0^{(1)}\right]\xi \end{aligned}\right\} \qquad (11)$$

Решив систему относительно $A_0^{(1)}$ и $\beta_0 B_0^{(1)}$, выразим их через $\tilde{U}_0^{(0)}$ и $\tilde{W}_0^{(0)}$. Из контактных условий (7) находятся выражения для постоянных $A_m^{(1)}$ и $B_m^{(1)}$ при $m = 1{,}2$ Затем они подставляются в граничные условия (6). Это позволяет получить уравнения симметричных колебаний трехслойной пластинки в следующем виде

$$\left.\begin{aligned} A_1\left[\frac{\partial}{\partial x}W_0^{(0)}\right]+B_1\left[U_0^{(0)}\right]=S_1\left[f_x^{(1)}\right];\\ A_2\left[W_0^{(0)}\right]+B_2\left[\frac{\partial}{\partial x}U_0^{(0)}\right]=S_2\left[f_z^{(2)}\right],\end{aligned}\right\} \qquad (12)$$

где A_k, B_k, S_k −дифференциальные операторы одинаковой структуры, имеющие вид

$$D_k=D_{k1}\frac{\partial^4}{\partial t^4}+D_{k2}\frac{\partial^4}{\partial x^2\partial t^2}+D_{k3}\frac{\partial^4}{\partial x^4}+$$
$$+D_{k4}\frac{\partial^2}{\partial t^2}+D_{k5}\frac{\partial^2}{\partial x^2}+D_{k6}$$

D_{kj} равны A_{kj}, B_{kj} или S_{kj}:

$$\ldots, A_{26}=1-q_2,\ldots, B_{26}=-\xi(1+q_2);$$

где $i=1{,}2;$ $z_1=h_0+h_1;$ $z_2=h_0+h_2;$ $q_m=1-\frac{\lambda_m}{\mu_m};$ a_m, b_m- соответственно скорости продольных и поперечных волн в материале пластинки. При этом перемещения точек пластинки определяются по формулам

$$U_0=\left[(1-q_0)\frac{z^2}{2}\left(\frac{\partial^2}{\partial t^2}-\frac{\partial^2}{\partial x^2}\right)+1\right]U_0^{(0)}-$$
$$-\frac{q_0z^2}{2\xi}\frac{\partial}{\partial x}W_0^{(0)}; \qquad (13)$$
$$W_0=\frac{1}{\xi}\left[\frac{z^3}{6}\left(\left(\frac{1}{b_0^2}+q_0\right)\frac{\partial^2}{\partial t^2}-(1+q_0)\right.\right.$$
$$\left.\left.\cdot\frac{\partial^2}{\partial x^2}\right)+z\right]W_0^{(0)}+q_0\left[\frac{\partial^2}{\partial t^2}-\frac{\partial^2}{\partial x^2}\right]\frac{z^3}{6}\frac{\partial}{\partial x}U_0^{(0)};$$

Постановка прикладной задачи и её решение.

Рассмотрим задачу о симметричных колебаниях защемленной в продольном направлении пластины, при $x=0$ и $x=l$, где l – длина пластинки в направлении оси Ox. В качестве уравнений колебания примем систему (8). Граничные условия задачи имеют вид

$$U_0^{(0)}=0,\qquad \frac{\partial^2U_0^{(0)}}{\partial x^2}=0;$$
$$\frac{\partial W_0^{(0)}}{\partial x}=0,\qquad \frac{\partial^3W_0^{(0)}}{\partial x^3}=0.$$

Начальные условия считаются нулевыми.

Решение системы уравнений (12), удовлетворяющее условиям закрепления торцов, а также функции внешних воздействий представим в виде

$$\begin{aligned} U_0^{(0)}&=\sum_{m=1}^{\infty}u(t)sin\frac{m\pi x}{l};\\ W_0^{(0)}&=\sum_{m=1}^{\infty}w(t)cos\frac{m\pi x}{l};\\ f_x&=\sum_{m=1}^{\infty}f_{xm}(t)sin\frac{m\pi x}{l}; \\ f_z&=\sum_{m=1}^{\infty}f_{zm}(t)cos\frac{m\pi x}{l}.\end{aligned} \qquad (14)$$

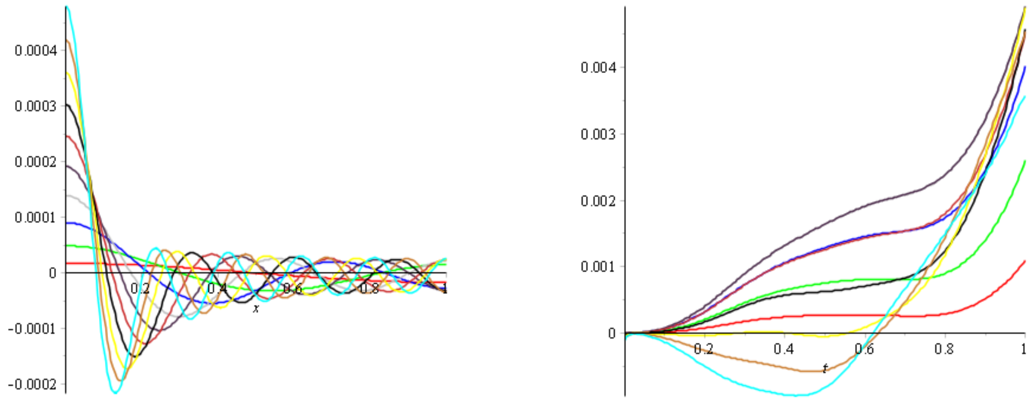
Подстановка (14) в (12) приводит к системе двух дифференциальных уравнений четвертого порядка относительно функций $u(t)$ и $w(t)$. Задача решена численно при следующих значениях физико-механических и геометрических параметров трехслойной пластинки:

$$\xi=0.9h_0, l=0.4m, h_0=0.04m, h_1=0.001m,$$
$$\rho_0=30\frac{kg}{m^3}, \rho_1=2700\frac{kg}{m^3}, E_0=0.1650\cdot10^9Pa,$$
$$E_1=69\cdot10^9Pa, \nu_0=0.03125, \nu_1=0.33,$$
$$f_{xm}(t)=t^2, f_{zm}(t)=3t^2.$$

По результатам решения системы дифференциальных уравнений (2.3.1) с помощью пакета прикладных программ “Maple-12” вычислены главные части продольного и поперечного перемещения точек срединного слоя в зависимости от времени и координаты. Полученные результаты приведены на рис. 2. а) б); рис. 3. а) б).

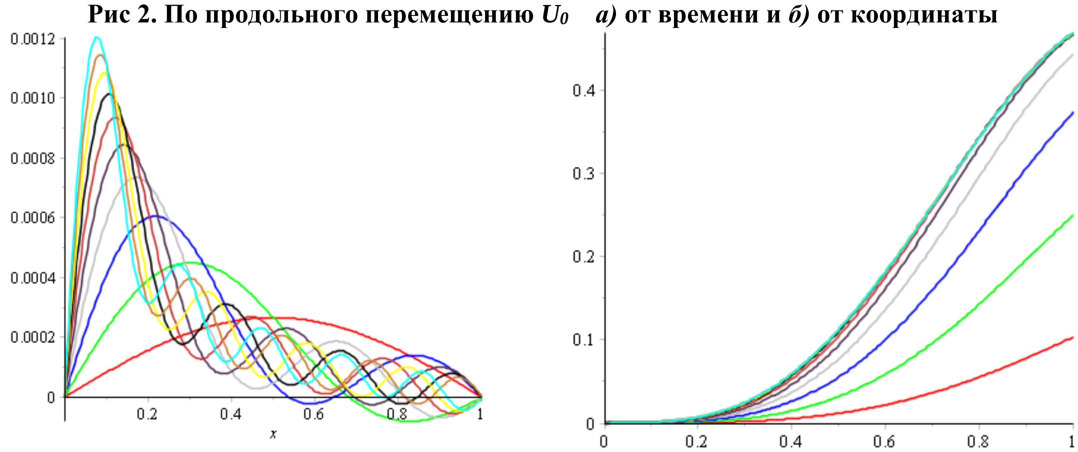
Выводы.

На рис.2-3 а, приведены графики зависимостей главных частей перемещений $U_0^{(0)}(x,t)$ и $W_0^{(0)}(x,t)$ от времени при различных значениях координаты x. На рис.2-3 б приведены графики зависимостей главных частей перемещений $U_0^{(0)}(x,t)$ и $W_0^{(0)}(x,t)$ от координаты x при различных значениях времени t.



а) *б)*

Рис 2. По продольного перемещению *U₀* *а)* от времени и *б)* от координаты



а) *б)*

Рис 3. По поперечного перемещению *W0* *а)* от времени и *б)* от координаты

Из приведенных графиков на рис. 2. а) и б) следует, что амплитуды главной части продольного перемещения слоя $U_0^{(0)}(x,t)$ в начале процесса имеют небольшие отклонения от нулевой отметки. В моментах времени больших, чем одной пятой части действия нагрузок, т.е. при $t > 0,2$, они начинают резко возрастать для сечений пластинки, расположенных до середины пластинки, т.е. до $x < 0,5$. Это указывает на то, что точки сечений пластинки, находящихся левее срединного сечения $x = 0,5$ получают положительные перемещения, т.е. продольные волокна пластинки в левой ее половине испытывают растяжения.

С другой стороны в тех же моментах времени точки сечений пластинки, находящихся правее срединного сечения $x = 0,5$, получают отрицательные перемещения, т.е. продольные волокна пластинки в правой ее половине испытывают сжатие. Данное двоякое поведение сечений, находящихся по разным сторонам срединного сечения пластинки, полностью согласуется с физической сущностью решаемой задачи.

При этом, левый и правый края пластинки испытывают продольные перемещения, абсолютные значения которых не превышает $0,25$ (величина безразмерная). При $x = 0,5$ главная часть $U_0^{(0)}(x,t)$ продольного перемещения $U_0(x,t)$ равна нулю. Это вызвано тем, что продольного перемещения $U_0^{(0)}(x,t)$ присутствует функция $\cos\frac{m\pi x}{l}$, которая при $x^{\bullet} = \frac{x}{l} = 0,5$ равна нулю.

Из рис. 2 б) следует, что изменение главной части продольного перемещения $U_0^{(0)}(x,t)$ носит синусоидальный характер. На левом и правом краях пластинки оно достигает максимальные значения, которая соответствует поставленным условиям задачи.

В поперечном направлении амплитуда главной части поперечного перемещения слоя $W_0^{(0)}(x,t)$ в начальный момент времени очень мала, которая начинает возрастать с течением времени. Деформация слоя в поперечном направлении становится значительной с течением времени.

При этом на торцах слоя $W_0^{(0)}(x,t)$ равна нулю. Максимальные значения $W_0^{(0)}(x,t)$ наблюдаются в сечении $x = 0.5$ в конце времени расчета при $t = 1$. Это показывает, что амплитуды

$W_0^{(0)}(x,t)$ в сечениях срединного слоя возрастают с течением времени (рис.3 а,б). Значение $W_0^{(0)}(x,t)$ в точке максимума небольшое и равно 0.0027, что примерно на один порядка меньше, чем соответствующее значение главной части продольного перемещения.

Следовательно, можно сделать вывод о том, что при симметричных колебаниях трехслойной пластинки можно пренебречь поперечными перемещениями точек. С другой стороны ясно, что появление незначительных поперечных перемещений точек пластинки вызвано действием продольных внешних нагрузок f_x, на лицевой и обратной сторонах пластинки.

В структуре главной части поперечного перемещения $W_0^{(0)}(x,t)$ присутствует функция $\sin\frac{m\pi x}{l}$, которая при $x^{\bullet}=\frac{x}{l}=0{,}5$, т.е. в срединном сечении равна единице, что обеспечивает достижение максимального значения перемещения $W_0^{(0)}(x,t)$ в этом сечении. Данный фактор также соответствует физической сущности поставленной задачи.

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Issue Article

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STUDY OF SULFUR MODIFICATION WITH UNSATURATED COMPOUNDS

Abstract: *In this article, a study of the physicochemical properties of sulfur modifications on the basis of compounds containing compounds, as well as the use of a product in the production of server concrete. The surface area and the composition of concrete were analyzed using SAM and elemental analysis.*
Key words: *sulfur, crotonaldehyde, elemental analysis, SEM analysis*
Language: *English*
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Introduction

Today, the world pays special attention to the creation of new modified sulfur binders. In this regard, modified sulfur concrete can be used to produce products that are resistant to industrial, climatic and other types of aggressive environments.

Structural properties of unmodified and modified gray concrete beams with steel reinforcement subjected to air-water curing. The sulfur concrete contained fly ash as a filler, while dicyclopentadiene and dipentene were used as modifiers[1-5]. Unmodified concrete beams have shown increased strength, stiffness and ductility as they age when cured in a dry environment. Modified concrete beams have shown improved performance over unmodified beams, but even when dry they have shown a loss of strength as they age and their long-term stability is questionable. The stability of sulfur concrete beams can only be guaranteed if they are unmodified and dry. In wet mode, sulfur concrete cannot be stable and durable [6-8].

Sufficient sulfur is recovered as a by-product in refineries and natural gas processing plants. The amount of sulfur currently produced exceeds the global demand for sulfur[9-10].

2. Experimental part

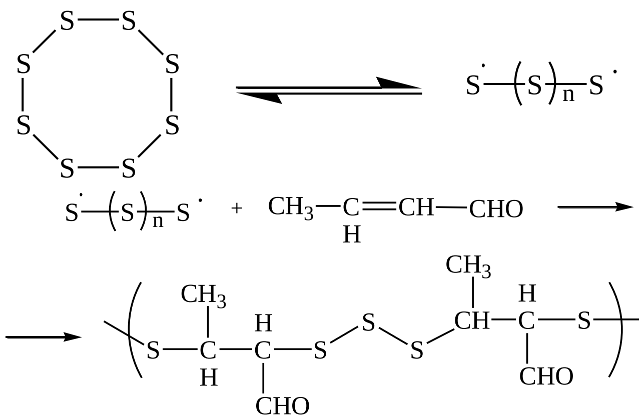
2.1.1. Materials and methods

Sulfur - used the production of the Mubarek gas processing plant. Under normal conditions, sulfur S is odorless yellow brittle crystals, easily soluble in carbon disulfide CS2. Physical constants: Mr = 32.066; Density - 2.07 g / cm3 (rhombic), 1.96 g / cm3 (monoclinic), T.melt. - 119.3 ° C, b.p. - 444.674 °C.

Crotonaldehyde-used by the production of Navoiazot LLC. The croton fraction contains from 57.0 to 67.0% crotonaldehyde, up to 10% acetone, up to 25% paraldehyde, up to 2.0% acetaldehyde, water, etc.

2.1.2 Modification of sulfur with crotonaldehyde and production of sulfur concrete.

Sulfur was heated in a glass beaker to 185°C in a thermostatically controlled oil bath with constant stirring until a transparent viscous orange molten sulfur phase was formed. Crotonaldehyde was then directly added to the molten sulfur phase. The resulting mixture was stirred at 185–190°C for 60–70 min, which led to some decrease in the viscosity of the reaction medium and the formation of black and yellow products for crotonic aldehyde comonomers with sulfur, respectively. The resulting products upon completion were taken directly from the beaker with a spatula and allowed to cool to room temperature. The reaction scheme for the polymerization of crotonaldehyde with sulfur is shown in Scheme 1.



Scheme 1. Scheme for the synthesis of polymeric sulfur.

The resulting sulfur copolymer was heated to 180–190°C in a stainless steel beaker equipped with a mechanical stirrer in a thermostatically controlled oil bath until a molten phase formed. Sand, crushed stone, fly ash were added to the molten medium of modified sulfur, and the resulting mixture was additionally heated at this temperature to form a homogeneous admixture of concrete with constant stirring in a molar ratio of 1:2.5 (polysulfide copolymer: sand, crushed stone, fly ash). The viscous mixture was placed in a self-made mold, and then immediately placed in an oven heated to 180–190 °C, held for 30 minutes, cooled to room temperature, and carefully removed from the mold.

3. Results obtained and their discussion.

On fig. 3.1. It can be seen that with the addition of 5 g of crotonaldehyde per 100 g of sulfur, the particle sizes of the dispersed phase increase significantly from -0.1 to 0.5 μm, while with the addition of 3 g of crotonaldehyde per 100 g of sulfur, there is no similar effect. observed. If crotonaldehyde is added to plasticized polymeric sulfur, then a significant increase in the size of the dispersed phase occurs in direct proportion to the increase in the content of the modifying additive.

Figure 3.2. shows the percentage of carbon, oxygen, sulfur, silicon, nitrogen, sodium and aluminum in the composition of sulfur concrete.

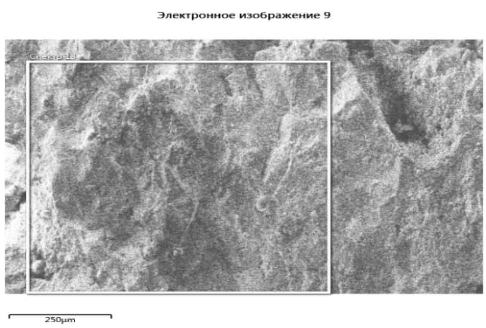


Figure 3.1. Micrograph of sulfur concrete.

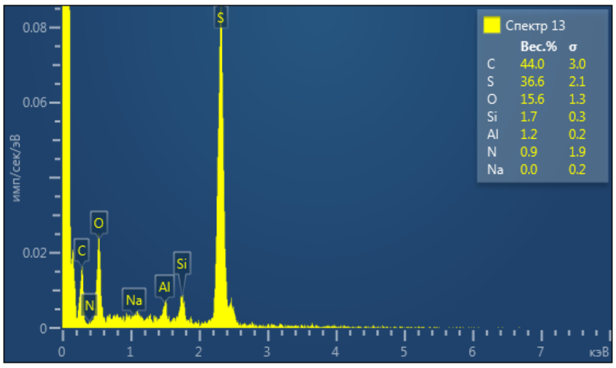


Figure 3.2. Elemental analysis data for sulfur concrete.

Data on the physicochemical characteristics of modified sulfur concrete (modified with sulfur by crotonaldehyde) are presented in Table 3.1.

Table 3.1. Physicochemical parameters of the synthesized oligomers

Properties	Indicators of modified sulfur concrete
Density, g/cm3 GOST 15139-69	2,158
T_{melt} °C	124
η_{hv}	0,065
Solubility	Insoluble
Appearance and color	Gray powder

In the IR spectrum of sulfur concrete in the regions of 2850-1470 cm^{-1} there are absorption bands, confirming the presence of $-CH_2-$ groups, and absorption bands in the region of 1650 cm^{-1}, confirming the presence of the -COH group in the free state. The IR spectrum contains absorption bands in the region of 3400 cm^{-1}, corresponding to primary –COH groups and absorption bands in the regions of 3300-3440 cm^{-1}, corresponding to secondary –COHR groups. The bending vibrations of all active groups appear as strong narrow bands between the usual bending vibration bands $-CH_2-CO-$ in the region of 1400 – 1405 cm^{-1}. The absorption bands at 800 and 1600 cm-1 confirm the presence of –CHO groups. The presence of groups containing S=O and S–C in the region of 1050–1015 cm-1 is confirmed by a wide intense band and sulfur-containing compounds in the regions of 462-779 cm^{-1}, 1040-1060 cm^{-1} and 1100-900 cm^{-1} [108; c. 202-205].

In addition, narrow low-intensity bands containing bonds of sulfur-containing compounds appear on the IR spectra in the regions of 1460 cm^{-1} and 648-779 cm^{-1}. When considering the IR spectra of sulfur concrete, it differs from modified sulfur by a strong intense $-CH_2-S-$ group with dimer indices of 1400-1440 cm^{-1}. (Fig.2.5.) [108; c. 202-205].

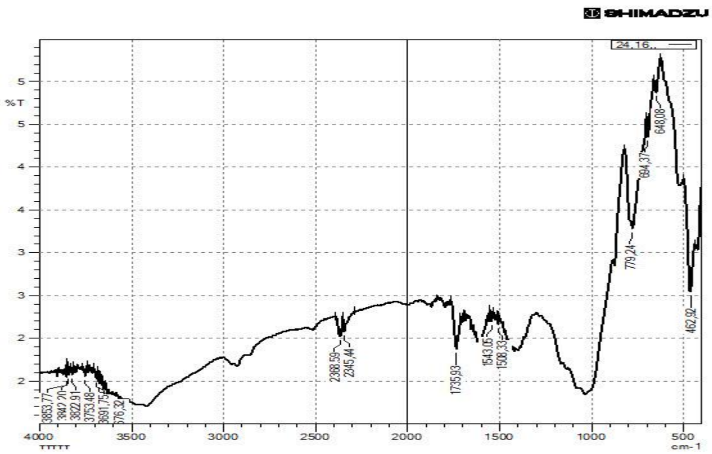


Figure 3.3. IR spectrum of modified sulfur concrete.

Conclusion.

It has been proved by IR spectroscopy that the presence of groups containing S=O and S–C in the region of 1050–1015 cm^{-1}, and a wide intense band and sulfur-containing compounds in the regions of 462-779 cm^{-1}, 1040-1060 1100-900 cm^{-1} confirms the reaction of sulfur with unsaturated compounds. A method is proposed for obtaining modified sulfur with high deformation strength and adhesive properties as a result of sulfur modification with the help of crotonaldehyde.

Crotonaldehyde was first used as a sulfur modifier and the optimal conditions for the copolymerization reaction were determined. The resulting compositions proved to be stable during storage and are recommended for the production of sulfur concrete.

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Issue Article

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POLITICAL, SOCIO-ECONOMIC LIFE OF GHAZNAVID'S STATE

***Abstract**: This article focuses on the formation, prosperity, and crisis of the Ghaznavid state, one of the most powerful Muslim states of the Middle Ages. It also covers the administration of the kingdom, the military, the economy, trade and monetary relations, and internal and external diplomatic relations. In addition, article describes the development of science, literature and art in the country, the patrons of enlightenment such as Sultan Mahmud Ghaznavi, the life and scientific and scholarly activities of encyclopedic scholars such as Beruni and Ibn Sino.*

***Key words**: Ghaznavid state, Abbasids, Samanids, Khorezm kings, Karakhanids, Seljuks, Gurians, Mahmud Ghaznavi, Mas'ud Ghaznavi, Ghazni Academy, Yamini Observatory, Beruni, Ibn Sina, Gardizi, Bayhaqi, Utbiy.*

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Introduction

The emergence of Ghaznavid's state. In the second half of the ninth century - the beginning of the tenth century, as a result of the weakening of the Abbasid caliphate, a number of independent states emerged [10, p. 80]. In the east of the Khalifah, several powerful statesmen and political dynasties led by them established their dominance. One such state was the Samanid state, founded in 865 by Nasr (865-876) in Movaraunnahr [6, p. 314] and Khorasan. The dynasty, the founder of this state, was ruled by the descendants of Somonkhudot, one of the largest landowners in the Bukhara oasis [2, p. 202] [1, p. 330]. In the last quarter of the ninth century, all the provinces of Movaraunnahr came under Samanid rule. This state, which reached its peak during the reign of Ismail Samanid, began to weaken in the middle of the 10th century. After the death of the Samanid ruler Abdulmalik in 961, the struggle for the throne of Bukhara intensified, and the state began to disintegrate. During this period, the prestige of the palace army of the state, consisting of Turkish pilgrims, increased. One of them, Hajib ul-Hujab (a title bestowed on high commanders) Alptegin (Ali Tagin in some sources) took advantage of this situation to sever ties with the Samanids and established the Ghaznavid state in an attempt to take control of Ghazni and Kabul provinces independently. He ruled the province of Ghazni from 962 to 963 as viceroy and army commander.

After Alptegin's death (963) Amir Ishaq Alptegin, Amir Bilgategin, Amir Piri and Amir Sabuqtegin Gazi ruled here respectively. The literal dominion of this dynasty was founded by Sabuqtegin (in some sources Sabuqtagin). He was a very capable and intelligent commander and a slave of Alptegin. He is believed to have been born in Barskhan on the shores of Lake Issyk-Kul. In addition to governing the state, he protected it from Karakhanid attacks on several occasions. He repeatedly took part in the Samanid struggle against the Karakhanids. As a result, he became very popular and received the honorary title of "defender of the state" ("Nasir ad-din and ad-davla"). However, it was not until 996 that the state was officially recognized as a political force.

"The golden age" of Ghaznavid's state. After Sabuktagin's death in 997, his son Ismail came to the throne for a while, then Mahmud (998-1030). There are various opinions and views around Sultan Mahmud Ghaznavi in history. It is expedient to summarize these ideas and analyze them on the basis of clear sources. During his reign, the kingdom flourished in all directions, reaching the peak of its power. After the end of the Samanid rule, Mahmud Ghaznavi conquered the entire territory of Khorasan, and in 1017 Khorezm, where he appointed his representative Altintash as his deputy. He also conquered Termez and Chaghaniyon. In addition, as a result of his march to Sughd, the area up to Omul (Charjoi) passed to him from the Karakhanids.

We know that the invasion of India by the Islamic army took place in 15 AH (636 AD) during the reign of Caliph Umar ibn Khattab. Then, during the reign of Caliph Walid ibn Abdul Malik, under the leadership of Muhammad Qasim al-Saqafi, the land of Sind (India) was conquered in 92 AH (710 AD). In 151 A.D. (768 A.D.), Molton and Kashmir were conquered. However, Sultan Mahmoud Ghaznavi's contribution to the establishment of Islam in the region was significant. He marched here seventeen times, dismantling local idols and spreading Islam. He is the first Muslim ruler to rule a number of Indian principalities. Historically, these marches have been called "holy wars." During his reign, the state's borders extended to the cities of Ray and Isfahan (in present-day Iran) to the west and the Caspian Sea, and from the northwest to the Khorezm and Aral Seas. In the east, it covers much of northern India and reaches southern Balochistan.

At the height of its power, the Ghaznavid state covered an area of about 3.4 million square kilometers. The capital, Ghazni, is flourishing. This ruler was given the honorary title of "Yamin ud-dawla and amin ul-milla" ("the right hand of the state and the trust of the nation") by the Abbasid caliph Al-Qadir, and the caliph sent him a certificate, flag and drum to the governor of Khorasan. [4, p. 4540] During this time [5, p. 45], the Ghaznavid state became the largest and most powerful Muslim state in the East.

During the reign of Sultan Mahmud, who had a strong devotion to the Islamic faith, the Muslim world was divided into sects and heretics. In particular, there has been a sharp confrontation between the Qarmatians and the Ismailis of the Shiites and the Ahl as-Sunnah wa'l-Jama'ah. As a result, the sultan waged a ruthless struggle against the forces that promoted ideas contrary to the pure Islamic faith.

Weakening and collapse of the state. After the death of Mahmud Ghaznavi, during the reign of his son Mas'ud Ghaznavi (1030-1041), the state gradually weakened, losing control of its provinces. Khorezm was originally separated from it. When the Ghaznavids were defeated by the Seljuks in 1040, much of Khorasan passed to the Seljuks. Mas'ud's son Mawdud (1041-1048) was defeated by the Karakhanids in the struggle for the lands on the right bank of the Amu Darya, and these territories were also lost. Although the Seljuks were defeated twice during the reign of Sultan Farrukhzod (1053-1059), the Seljuk Alp Arslan prevailed over the Ghaznavids.

As a result, the territory of the state will be limited to a part of North India. In the 1960s, a new force in the political struggle, the Guris, drove the Ghaznavids to northern India. Therefore, in 1161, the capital was moved from Ghazni to Lahore. In 1186, Lahore was conquered by the army of Ghiyasiddin Muhammad, the ruler of the Guris.

Sultans of Ghaznavid's. The following are the rulers of the Ghaznavid's state:

Alptegin (962–963)
Amir Ishaq Alptegin (963–965)
Amir Bilgategin (966–972 / 973)
Amir Piriy (972 / 973–976 / 977)
Sabuqtegin (977–997)
Mahmoud Ghaznavi (997–1030)
Muhammad (1030)
Mas'ud ibn Mahmud (1030–1041)
Muhammad ibn Mahmud (1041)
Mawdud ibn Mas'ud (1041–1049)
Masud II ibn Mawdud (1049)
Ali ibn Mas'ud II (1049–1051)
Abdurrashid ibn Mahmud (1051–1053)
Tugrul (1053)
Farrukhzod ibn Mas'ud (1053—1059)
Ibrahim ibn Mas'ud (1059-1099)
Mas'ud III ibn Ibrahim (1099—1115)
Sherzod ibn Ibrahim (1115-1116)
Arslanshah ibn Mas'ud (1116-1118)
Bahromshah ibn Mas'ud (1118—1153)
Khusravshah ibn Mas'ud (1153—1160)
Khusrav Malik ibn Khusravshoh (1160—1186)

Administration system of the country. The treasury system of government is somewhat complex. It is multifaceted and similar to the Samanid and Karakhanid administrations. This is due to the fact that these dynasties ruled in close proximity to each other, and the provinces of Khorasan, Seistan, Kabul, and Ghazni, which were part of the Ghaznavid state, became an integral part of the region.

At the center of public administration were the dargah and the devons. The Dargah included services related to the life and work of the supreme ruler (the treasury sultans held the title of "Amir"). Among them, the "pilgrimage" service has a special place. The Khajibs wore black robes and two-pointed hats. They also held the position of sheikhna or sipohsolor at the same time. The hajj, in turn, is divided into four levels:

Grand Hajib (one who sits closest to the ruler in official ceremonies, one of the leaders of major military campaigns, an inspector of specially selected units);

The lord of the palace (the gatekeeper of the palace);

The duty khojib;

Hojib-jomador.

The following employees also worked at the school:

Sipohdor (palace servant);

Inviter (personal documents of the supreme ruler, the person in charge of writing);

Pardador (mahram, secret keeper, pinhole performer);

Murtabador (a middle-ranking official in the palace);

Farrosh (from the younger servants in the palace);

Treasurer;

Head of the wardrobe, etc.

The devons (ministries) acted as executive bodies. The sources cite five of them, and they are:

Cabinet of Ministers (headed by the Prime Minister)

Office of Military Affairs;

Office of Diplomatic and Official Affairs;

Office of preparation and execution of documents;

Accounting (Finance) Office.

It also concludes that although the sources do not cite devons such as mushrif, (state control), mukhtasibs, the existence of such services in the field meant that they also had central devons. (For example, it is clear that there were positions such as city mushrif or provincial mushrif).

The provinces were governed by the governor and appointed by the governor himself. Amid led the regional executive. The mayor was called the chairman. There were also officials in the city, such as the head of the city fortress - shihna qutvol or qutvol, the owner of which was the devon (administrative manager).

Military field. The Ghaznavids had a strong army, mainly during the reign of Mahmoud Ghaznavi. The supreme command was at the disposal of the ruler. The Sipohsolor (commander-in-chief) was one of the most trusted members of the dynasty. Senior officers are called salors, and middle-ranking officers are called sarhang. The lower echelons of the army led the Hays (several dozen cavalry). The military had its own postal and judicial services. The supreme ruler also had a select military unit (special guard) and a strong navy. In addition to Turks, the military included Khorasanians, Afghans, Arabs, and others.

Public economy and monetary relations. The country's economic backbone was feudal land tenure, which included taxes levied on farmers. Livestock and, most importantly, urban handicrafts and trade duties also brought significant revenue to the treasury. In addition, military revenue from many occupied countries has increased government revenues.

Gold, silver and copper coins were used in monetary relations. The capital, Ghazni, had a large mint and minted various coins on behalf of the sultans.

Foreign policy and diplomatic relations. In foreign policy, the Ghaznavids have focused on regional and non-regional ties. In this regard, it regulates agreements, treaties, treaties and embassy relations on internal and external relations. This can be seen in the relations between the treasury rulers and the Karakhanids in Movaraunnahr, as well as the growing Seljuks in western Iran and parts of Khorasan. In foreign affairs, it is due to the fact that it has restored the respect of the Arab caliphate, which has lost its former high status. In addition, important trade and diplomatic relations were established with China, Iran and the Karakhanid state.

For example, in domestic diplomacy, there have been several correspondences between Sultan Masud and the Ghaznavid deputy in Khorezm, Altintosh. In particular, a letter written by Mas'ud reads: "… We keep the supreme hajib, my uncle, the Khorezm king Altuntash, to such an extent that our father kept the late Amir…"

Conclusion

To conclude, the Ghaznavid's state which emerged on the stage of history in the late tenth century, had a worthy place not only in the Muslim society of the Middle East, but also in the world of Islam as a whole, as well as in the civilization of world history. Located in an important strategic region with a unique adminstrative system, Ghaznavid's dynasty played an important role in the spread of Islam to the East, especially in Northern India. In addition, the country maintained its own diplomatic relations in local and international politics. Also, local and foreign trade relations are developed. Furthermore, the study of this period and the great personalities in it, especially the life, scientific and creative activity of a number of encyclopedic scientists and their peculiarities, is still very important today. Consequently, in this empire, where science, art and literature were highly developed in its time, the famous Ghazna Academy, which brought together more than four hundred scholars, the Yamin observatory was established under the leadership of Abu Rayhan Beruni. The first state madrasa in the Muslim East (1019), built on the initiative of Sultan Mahmud, as well as many educational institutions, mosques, various gardens and parks were built. The huge and rich libraries in the capital, Ghazni, and in the cities of Nishapur, Balkh, and Lahore, also show the importance of science in the lives of the people of this period.

It should be noted that this period was marked by the development of the scientific and cultural environment, the fate of which was directly or indirectly related to the political and social life of the country, left behind by many scholars, especially a number of encyclopedic scholars. the heritage of enlightenment has its rightful place even in the age of high development in which we live. The next two chapters of this dissertation deal with the life and scientific activity of encyclopedic scholars such as Abu Rayhan Beruni and Abu Ali Ibn Sino, who were born and raised in the Movaraunnahr and Khorezm regions and whose later life was directly or indirectly connected with the Ghaznavid's state. So that, I will focus on discovering new aspects, analyzing and interpreting them. In short words, we enrich our knowledge by studying the history of this period in more depth, searching for new information, analyzing and drawing more objective and reasonable conclusions.

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