Effect of impeller geometry change: Computational prediction.

Influence of intermediary shorten blades were computationally studied on the base of a new pump under development. Three types of impeller geometry are shown on Fig. 1, include 5 long blades (on the left, impeller #3), 5 long and 5 short blades positioned axial-symmetrically at the impeller exit (in the center, impeller #4), the same number of long and short blades but positioned non-axial-symmetrically at the impeller exit (on the right, impeller #5). Other types (impeller #6, 7 and 8) studied are shown on Fig. 2. All computations completed for the same pump casing of 30% radial gap and the same operation parameters. “Infinite – pipe” condition was defined at the pump exit.

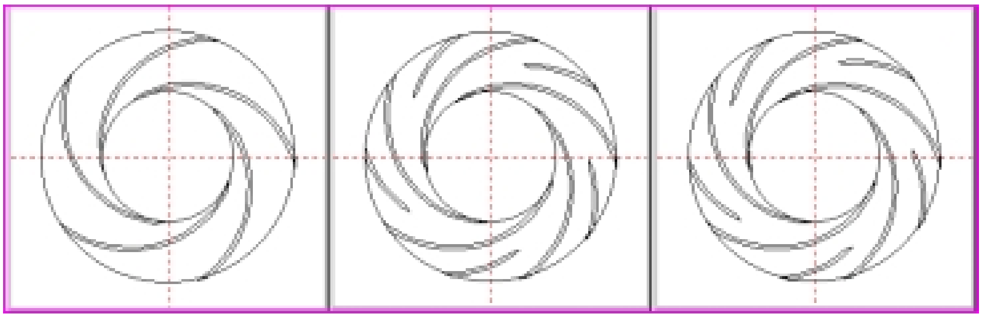

Fig. 1Impeller geometry (from the left) 3, 4, 5.

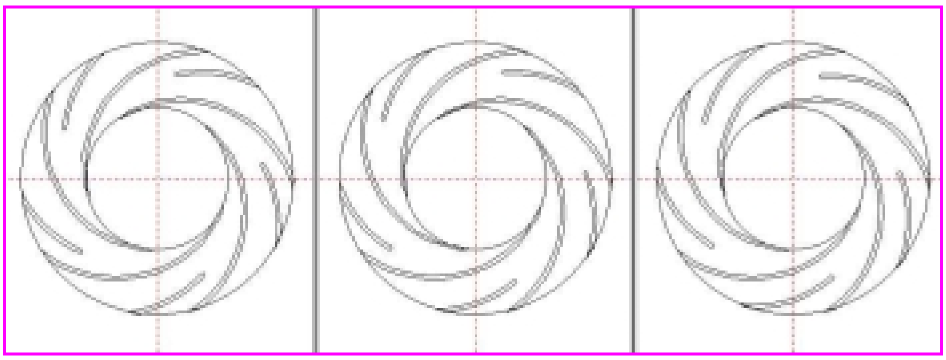

Fig. 2Impeller geometry (from the left) 6, 7, 8.

Impeller Geometry Change

It is well known that due to the effect of Coriolis forces and secondary flows, parameters of flow in a blade channel of centrifugal impeller distributed non-uniformly. Along the angle coordinate the relative velocity and flow angle are higher near the pressure side of the blade channel. Near the suction side of blade the low energy zone is formed.

The task was to act on the low energy zone of flow with intermediary shorten blades.

For better understanding of the impeller geometry change, Fig. 3 to Fig. 6 show consecutive changes in impeller geometry with adding different intermediary profiles to the long profile 3. Inlet edge of the short blade penetrates into the low energy zone. Besides the exit blade angle is altered as well to obtain more optimal result. In red color on Fig. 7 is represented profile 7 that gives the best result in reduction of BPF pressure pulsation. Profile 3 of the long blade was unchanged for all cases computed.

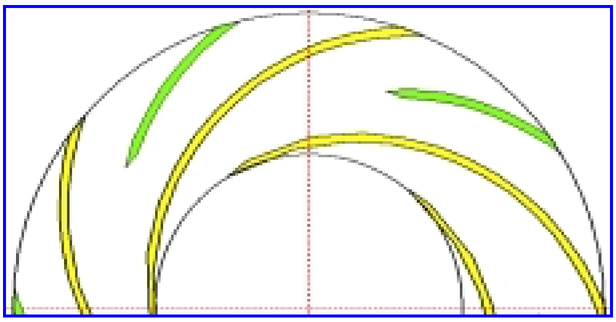

Fig. 3Impeller 3+4

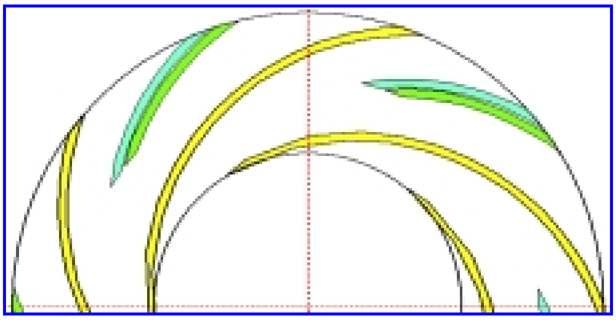

Fig. 4Impeller 3+4+5

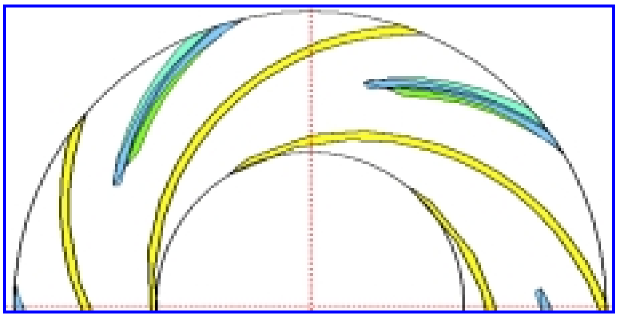

Fig. 5Impeller 3+4+5+6

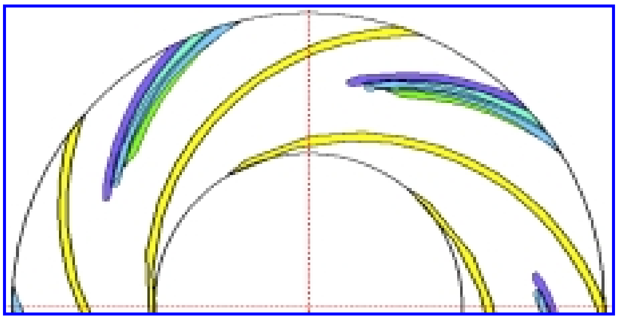

Fig. 6Impeller 3+4+5+6+8

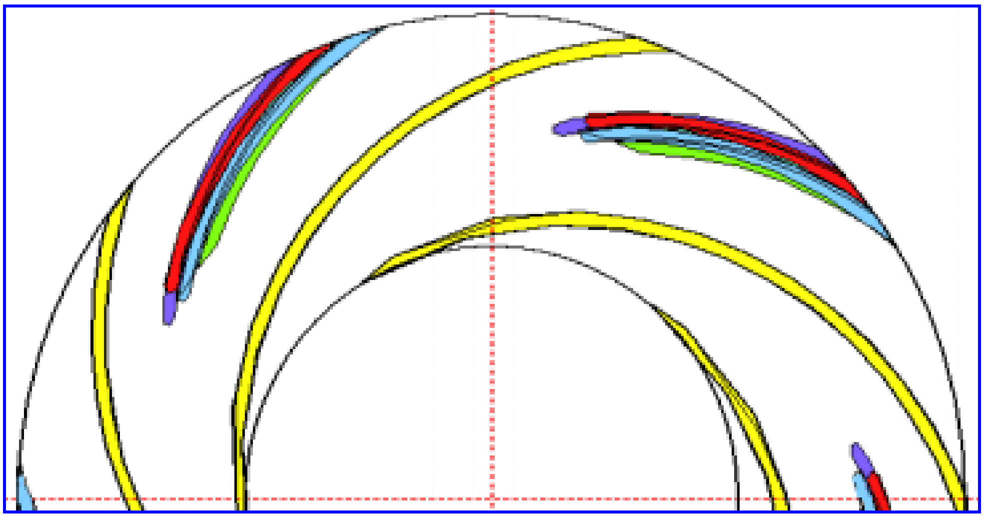

Fig. 7Impeller 3+4+5+6+7+8

Distribution Of Flow Parameters Along The Blade Channel Span

Distribution of radial (Fig. 8) and tangential (Fig. 9) velocity components along the blade span between two long blades shows a considerable change of non-uniformity of flow. Velocities were reduced with impeller tip velocity, pressure side of the blade channel is on the left, and rotation goes to the right.

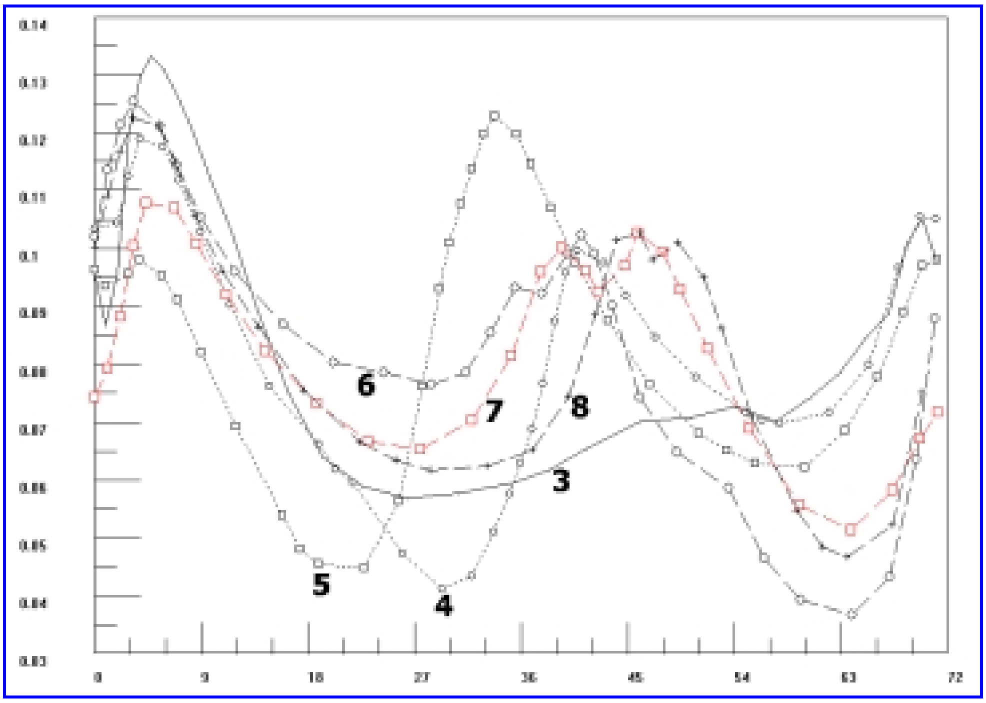

Fig. 8 Absolute velocity radial component

One can see that additional blades give an additional peak in the velocity distribution. For the profile 7 two peaks are approximately equal and give more balanced flow delivery at the impeller exit. Besides one can see for all impeller with intermediary blades, increasing of the tangential velocity that gives a rise of impeller head of 20%.

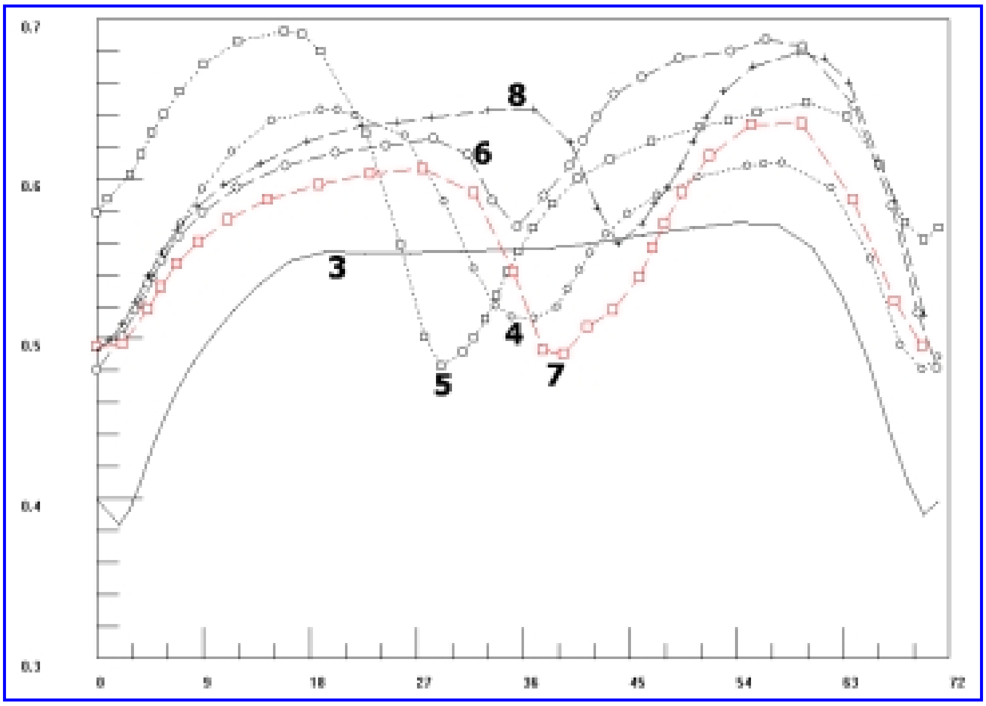

Fig. 9 Absolute velocity tangential component

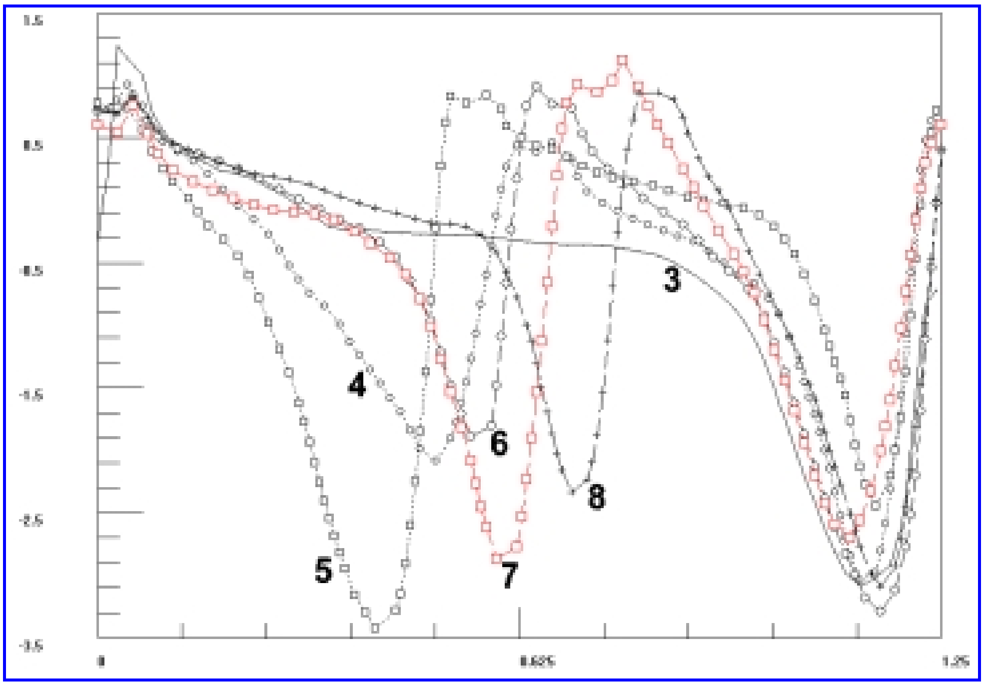

Fig. 10 Distribution of vorticity along the main blade channel span

It can be noted from Fig. 9 that non-uniformity of the distribution of tangential velocity component was reduced due to influence of intermediary blades.

It is especially interesting to look on the vorticity distribution along the long blade span. The initial negative peak was split on two approximately equal parts. For the profile

7 these parts are more balanced in value and space – one of the two peaks being situated in the middle of the main channel.

Impeller Head.

Impeller head coefficient is defined as a rise of full pressure (static and dynamic) averaged with a fluid delivery and reduced with a tip impeller velocity squared as it is shown in formula.

$$\hat{H} = \left[P_2 - P_1 + \tfrac{1}{2}\rho(C_2^2 - C_1^2)\right] / U_2^2$$

Table 1 Impeller head

Profile	$\hat{H}$
3	0,502
4	0,599
5	0,596
6	0,63
7	0,61
8	0,625

All designs with intermediary blades bring a rise of impeller head by approximately 20% because of increasing of tangential velocity.

Pressure Pulsation

AMPLITUDE MAP OF THE FIRST BPF HARMONIC

Fig. 11 to Fig. 16 shows the distribution of the amplitude of the first BPF harmonic. For all pictures the color scale is the same – from 1000 Pa (deep blue) to 10000 Pa (deep red). It can be seen that impeller geometry #7 gives a remarkable result. It looks like a complete elimination of the first harmonic. Certainly this is the effect of color visualization. Actually for this profile the amplitude does not exceed 3000 Pa even near the impeller exit.

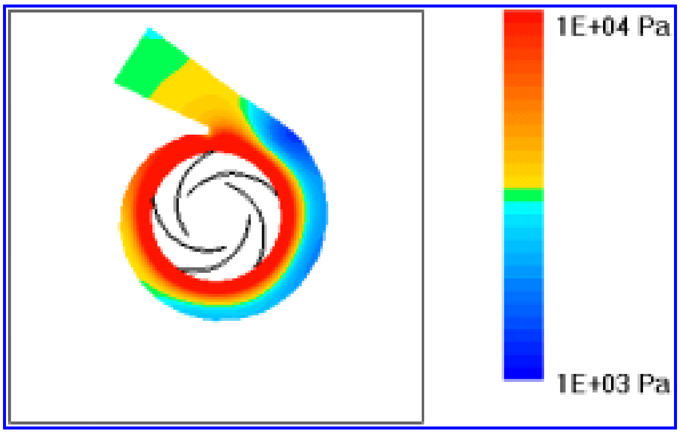

Fig. 11 Profile 3

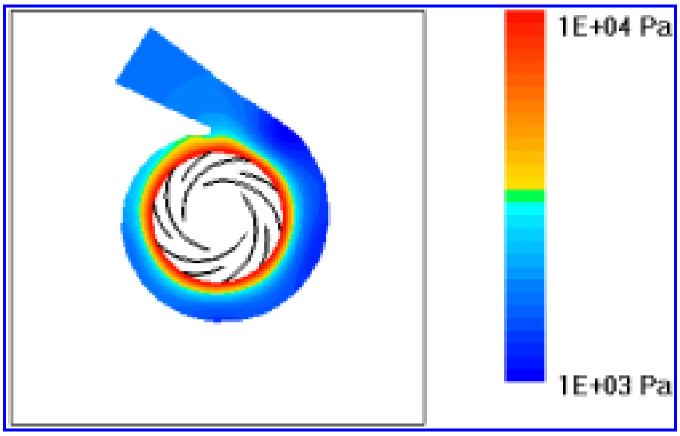

Fig. 12 Profile 4

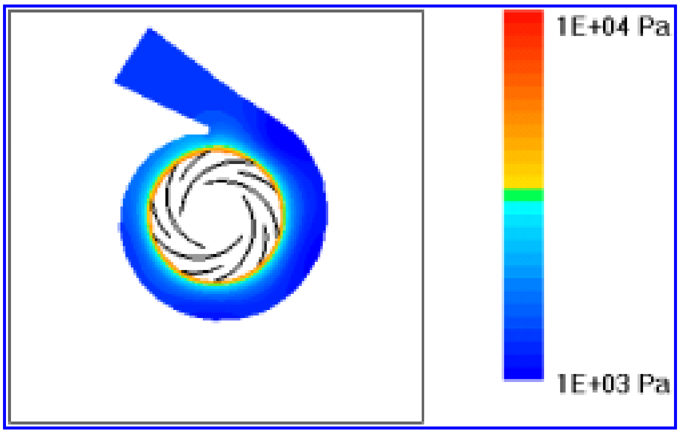

Fig. 13 Profile 5

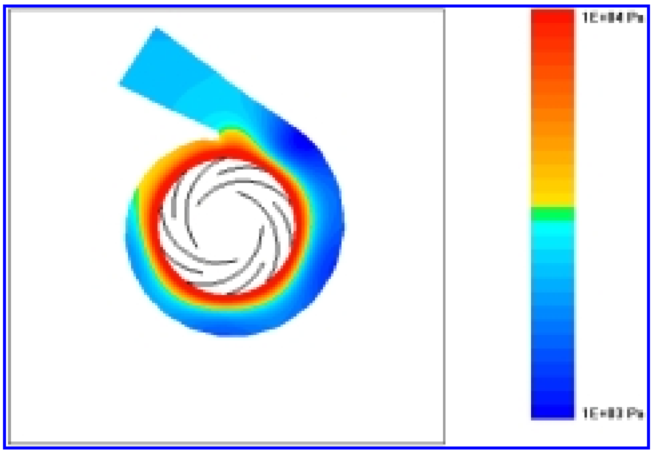

Fig. 14 Profile 6

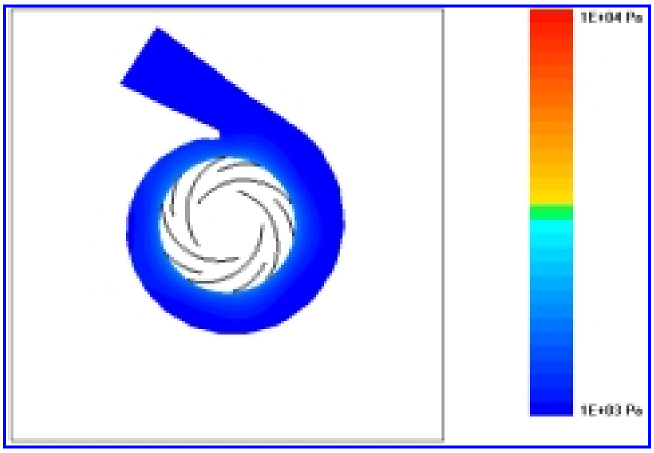

Fig. 15 Profile 7

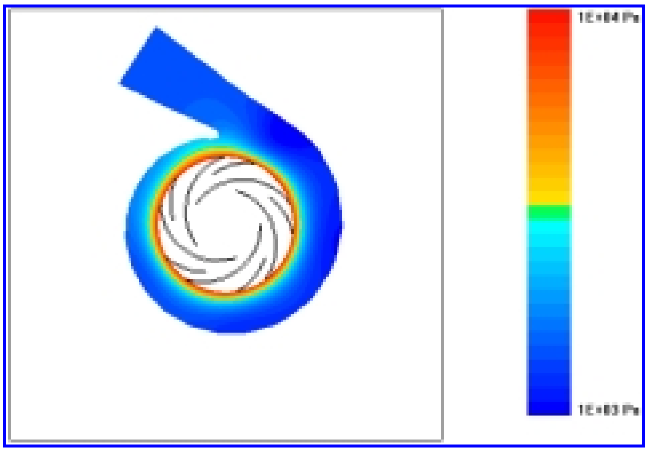

Fig. 16 Profile 8

This result shows the importance of providing specific impeller geometry to achieve a desired pressure pulsation spectra.

AMPLITUDE MAP OF THE SECOND BPF HARMONIC

Fig. 17 to Fig. 22 shows the distribution of amplitude of the second BPF harmonic.

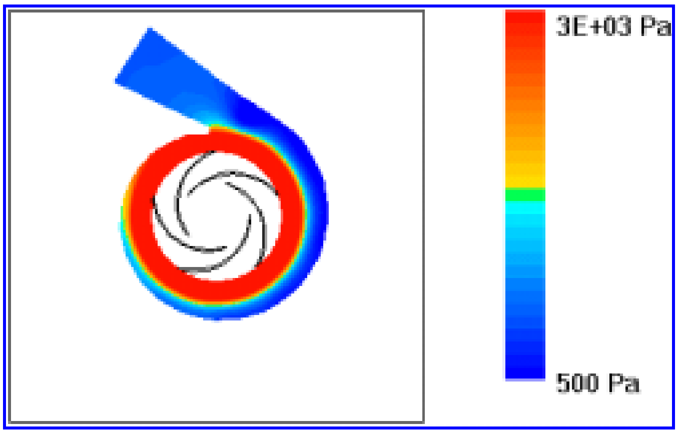

Fig. 17 Profile 3

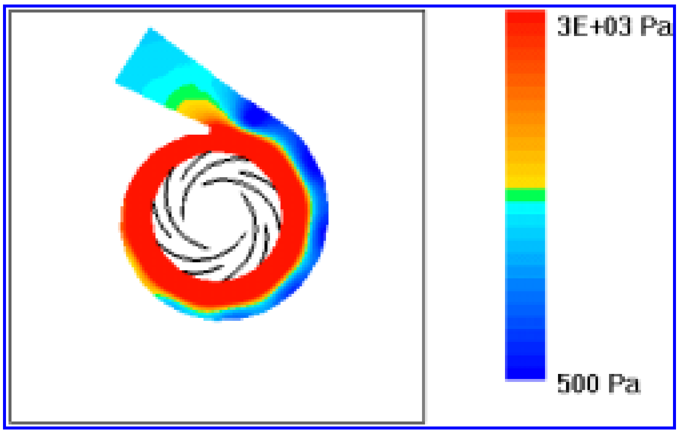

Fig. 18 Profile 4.

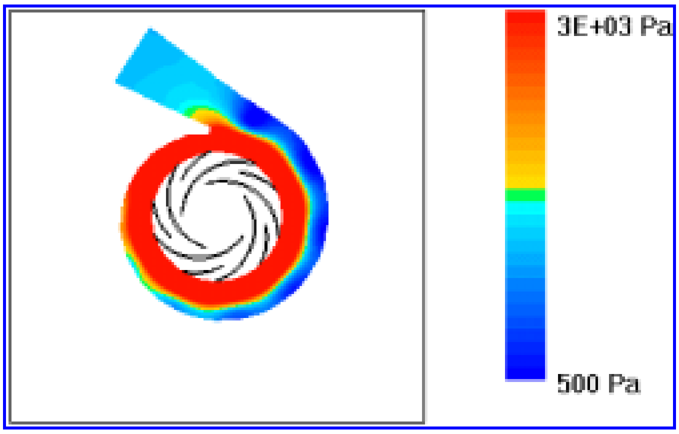

Fig. 19 Profile 5

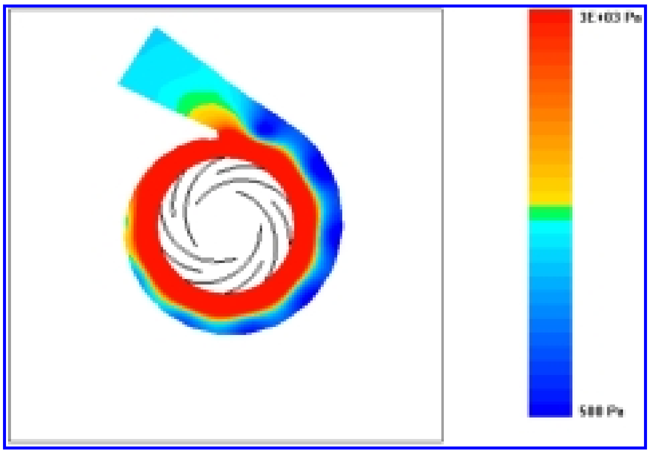

Fig. 20 Profile 6

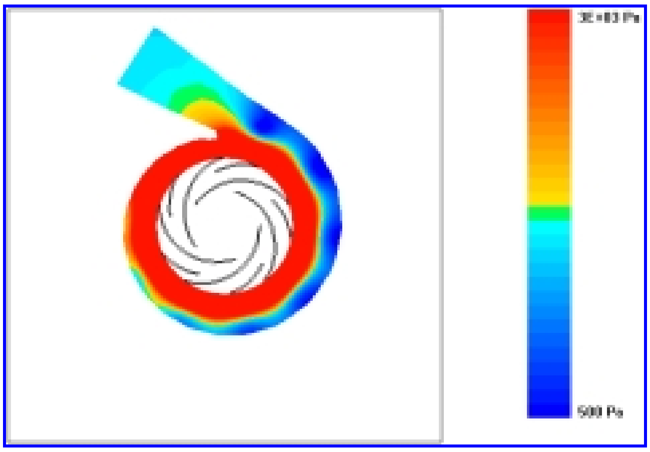

Fig. 21 Profile 7

For all pictures the color scale is the same – from 500 Pa (deep blue) to 3000 Pa (deep red). It can be seen that the level of amplitude of the second harmonic for all geometry types is comparable due to the fact of presence of two peaks of vorticity in impellers with intermediary blades. This brings some amplitude rise at the pump exit. But the level of amplitude is smaller then for the first harmonic. So the total amplitude of BPF pressure pulsation is reduced.

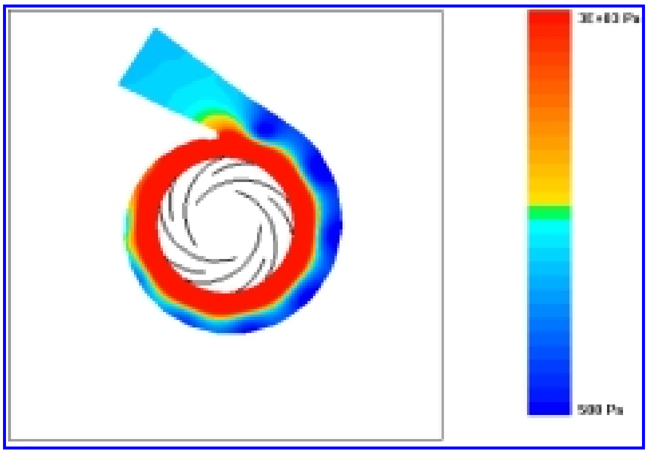

Fig. 22 Profile 8

PRESSURE PULSATION AT THE PUMP EXIT

Dimensionless pressure pulsation calculated at the pump exit (Fig. 23) shows a considerable change in amplitude as well as in shape of the signal. Intermediary blades give a relative rise of the second BPF harmonic but the total amplitude is lower.

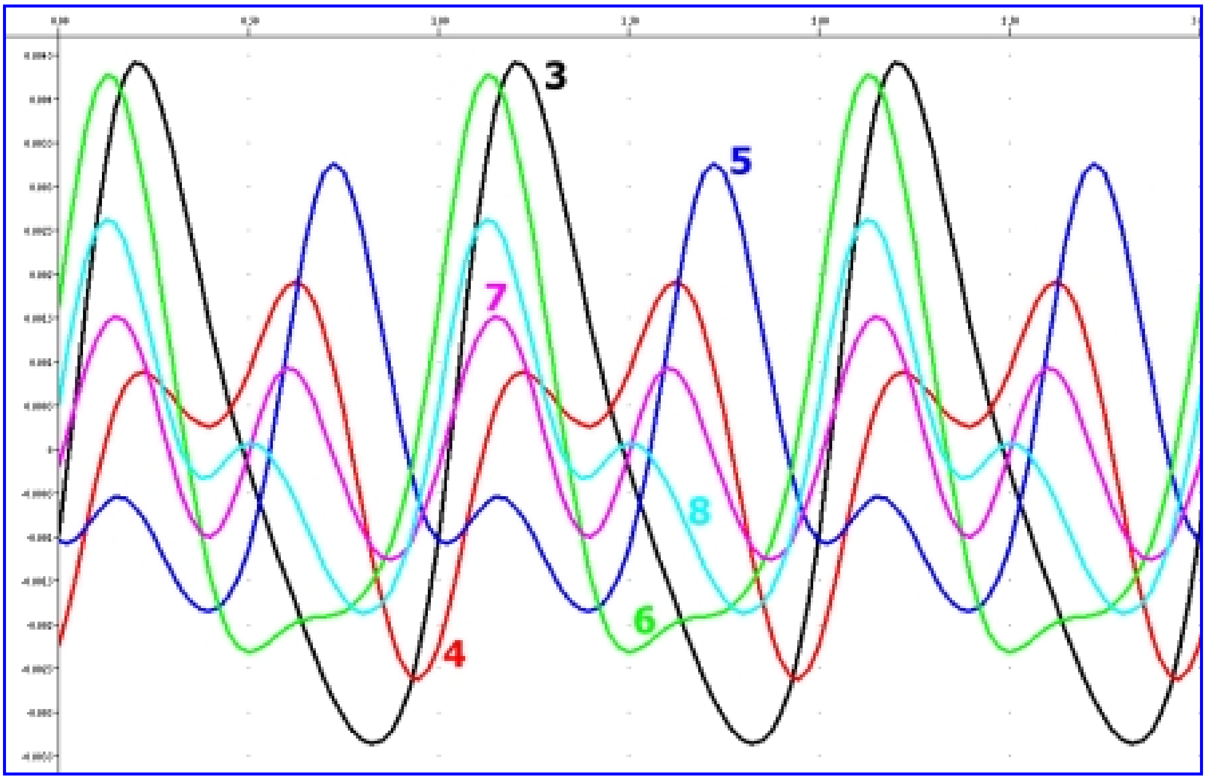

Fig. 23 Pressure pulsation at the pump exit

One can conclude that all profiles with intermediary shorten blades have an advantage as well in a full impeller head as in total amplitude of pressure pulsation.

Regarding the reduction of pressure pulsation profile 7 must be indicated as a very good perspective to reduce pressure pulsation on the main BPF frequency and total amplitude of pressure pulsation into the pump working cavity and in the outlet pipe. It gives a reduction of total amplitude by a factor of 3.

This study illustrates the main advantage of Harmony software to provide very rapidly computational experiments on the early stage of design to select the right direction of the whole project development without experimental costs.