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BOUNDARY LAYER CONTROL AT UPSTREAM CASING WALL OF IMPELLER INLET WALL TO IMPROVE PERFORMANCE CHARACTERISTICS OF TURBOMACHINERY

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ABSTRACTS

Practical impeller blades used to be designed for uniform upstream velocity distribution. Most of the problems seen at impeller blade's flow passage are caused at and near the tip radius of leading edge of impeller inlet. That is, separation of fluid particles from the blade surface is caused at and near the casing wall of leading edge of impeller inlet. It is well known that boundary layer is developed on the casing wall of conduit pipeline and axial component of velocity becomes small at and near the casing wall. Therefore, to improve the overall efficiency in practical operation of turbomachinery, improvement of fluids flow condition at casing wall, that is, boundary layer control just upstream of leading edge of impeller inlet is recommended. Some example grooves and notches are introduced.

1. INTRODUCTION

From our daily experiences and experimental observations on behavior of fluid particles in the flow passage of centrifugal, mixed flow, and axial flow turbomachinery, it could be said that fluids flow condition just upstream of impeller inlet is unstable and undesirable, extremely at and near the casing wall because of the viscosity of fluids. This unstable and undesirable condition at and near the casing wall has significant influence on impelling action of impeller blades at rotating flow passage because upstream flow condition affects directly to fluids flow condition at leading edge of impeller inlet. Therefore, it has very strong interrelation with overall efficiency and formation of overall efficiency curve in performance characteristics of turbomachinery. And improvement of flow conditions at upstream

of impeller inlet may has equivalent importance with the improvement of unstable and undesirable conditions at leading edge of impeller inlet.

This indicates that to perform a higher overall efficiency at design flow rate and to improve performance characteristic curve better or flatter at off design condition, countermeasure against the unstable and undesirable boundary layer condition and consideration for the technique and the way on the improvement about the fluids flow condition at just upstream of impeller inlet at and near the casing wall has to be proceeded. Therefore, improvement of fluids flow condition at upstream casing wall at leading edge of impeller inlet has equivalent meaning on those improvement of geometrical shape of impeller blades in all kinds of centrifugal, mixed flow and axial flow turbomachinery.

In this point of view, technical methods and the way, how to control boundary layer at upstream at and near the casing wall are discussed and practical plans the author wish to proceed are introduced in this paper.

2. INTERNAL FLOW CONDITION

In general, fluids flow condition in conduit pipeline, that is, distribution of axial component of velocity at just upstream of impeller inlet has been paid special attention slightly at the earliest stage of designing of impeller blades in all kinds of centrifugal, mixed flow, and axial flow turbomachinery. Velocity distribution at just upstream of impeller inlet is usually, regularly, and normally, and most of the case, assumed and recognized as uniform at the maximum efficiency point. That is, all the impeller blade's geometrical flow passages, that is, impeller blade's geometrical shapes are designed to make the hydraulic energy losses minimum at design condition and manufactured against the uniform upstream flow condition.

However, if we look at the practical installation or the operation of impeller blades, it seems that in most of the case, those prerequisite requirement, that is, uniform upstream flow condition is forgotten at all and lost somewhere else. Uniform fluids flow condition which is the basement of theoretical consideration and theoretical development in the design process of impeller blades, that is, uniform velocity distribution at just upstream of leading edge of impeller inlet has not been taken care of it that much for some reason. Straight pipeline is just joined upstream directly to the leading edge of impeller inlet without any question.

Every body out to know that fluids flow condition which is formed in the practical conduit pipeline is not uniform across the radius, especially it is obvious at and near the casing wall at any flow rate because of the existence of boundary layer developed on the casing wall. In this case, interrelation between impeller blades'

inlet angle and fluid's flow angle becomes inconvenient and causes mismatch between them at the leading edge of impeller inlet. Every one foreknows that this inconvenient interrelation and unsuitable and undesirable conditions are caused at the leading edge of impeller inlet. This would be easy to surmise from practical observation of internal flow condition in centrifugal, mixed flow, and axial flow turbomachinery.

Nevertheless, as a matter of practice it seems natural and as if it is understood regularly and most reasonably among peoples that if the geometrical shape of conduit pipeline at upstream flow passage of impeller inlet is straight and the conduit pipeline has a considerable straight distance in the axial direction, distribution of axial component of velocity at just upstream of impeller inlet becomes uniform throughout the radius in the conduit pipeline. However, this lazy concept and treatment may not be acceptable and appropriate for those engineers, who desire to obtain higher efficiency in practical operation of turbomachinery.

At all events, it is obvious that fluids flow condition, that is, distribution of axial component of velocity under above condition may not become uniform throughout whole radius in the conduit pipeline, especially at and near the casing wall because of the existence of boundary layer developed at and near the casing wall as described before. Axial component of velocity at and near the casing wall varies its magnitude from zero to that of main flow across the radius in the conduit pipeline. Therefore, it is not need to say that existence of boundary layer at upstream casing wall may be the pure source to make the internal flow condition unstable and undesirable at and near tip radius of leading edge of impeller inlet more than that at the radius range (flow passage) of main flow. Experimental observation has reported that separation of fluid particles is especially large at tip radius and outer radius of leading edge of impeller inlet. Therefore, it could be said that decreased axial component of velocity due to viscosity of fluids in the boundary layer, developed at and near the casing wall, may be the pure source of separation of fluids at leading edge of impeller inlet, which causes impeller blade's efficiency poor at design and off design condition.

This could be said also from the other point of view, known from the geometrical fact that even though distribution of axial component of velocity is uniform across the radius, fluids flow cross-area is larger at outer radius than that at inner radius. That is, fluids flow rate is different by the radius even though distribution of axial component of velocity is uniform across the radius. Therefore, if boundary layer condition is improved actually and if the axial component of velocity becomes larger at and near the casing wall, hydraulic resistance against the fluid flow reduces at and near the casing wall and impelling load decreases, and impeller blades impelling action becomes better throughout the whole flow passage and the overall efficiency and its characteristic curve may become an improved one.

3. BOUNDARY LAYER CONTROL

Results of above discussion indicate that if the boundary layer developed on the casing wall or the fluids flow condition at and near the casing wall is controlled, and if uniform axial component of velocity is formed throughout the whole radius range of conduit pipeline at just upstream of leading edge at impeller inlet and if the axial component of velocity at and near the casing wall becomes equivalent to that of main flow in the conduit pipeline, it indicates that fluids flow condition at just upstream of leading edge of impeller inlet consists perfectly with prerequisite requirement, that is prerequisite uniform fluids flow condition assumed at first stage of design process of impeller blades. This means that if upstream boundary layer is controlled and if upstream flow condition is formed uniform throughout whole radius of the conduit pipeline just upstream of leading edge of impeller inlet, impelling flow condition could be improved at leading edge of impeller inlet. That is, fluids flow condition in the impeller blades rotating flow passage may become a stable and desirable one. Because fluid particle approaches impeller blades at the most ideal uniform condition, which is assumed at first step of impeller blades' designing. Therefore, if those flow condition is realized, overall efficiency may be expected naturally to become a better one: not only it becomes a higher value at design flow rate, but also performance characteristic curve at off design condition becomes an improved one in practical operation of turbomachinery.

From these view points, it could be said that to accomplish the overall efficiency a higher one at design flow rate and performance characteristic curve an improved one at off design condition, boundary layer has to be controlled at upstream casing wall just upstream of leading edge at impeller inlet. That is, formation of distribution of axial component of velocity at just upstream of impeller inlet is expected to be formed uniform or improved. And uniform distribution of axial component of velocity is attempted for each of given practical turbomachinery, regardless centrifugal, mixed flow, and axial flow machine.

4. PRACTICAL METHOD

As a technical method to control fluids flow condition, that is, to control boundary layer thickness on the casing wall, a geometrical change of conduit pipeline's shape has to be made on the location just upstream of leading edge of impeller inlet. The purpose of geometrical change of conduit pipeline's shape is as described above to control or vanish boundary layer region from the flow passage on the casing wall at the location just upstream of leading edge of impeller inlet, and to

recover approaching fluids flow condition at the leading edge of impeller inlet and make its magnitude same to that of main flow and construct uniform distribution of axial component of velocity just upstream of leading edge at impeller inlet across the whole radius of impeller inlet.

For example, if a groove is set just upstream of leading edge of impeller inlet on the casing wall, two different fluids flow passages and two different fluids flow conditions are formed just upstream of leading edge of impeller inlet. One is the flow passage in the groove and the other is the original flow passage of main flow in the conduit pipeline. In the flow passage of groove, fluid particles may form a circulate flow. In the main flow passage of conduit pipeline, uniform axial flow may be formed across the radius because boundary layer thickness becomes zero or nearly equal zero on the surface at the location of groove. In other words, boundary layer thickness becomes zero at boundary surface between the groove and the casing wall of conduit pipeline, and axial component of velocity of fluid particles at the boundary between the circulating flow in the groove and the main flow at the casing wall in the conduit pipeline may become equivalent. This predict observation indicates that boundary layer can be controlled by forming a self circulating fluids flow movement in the groove on the casing wall, then uniform distribution of axial component of velocity can be formed. In other words, upstream flow condition can be improved by setting a groove on the casing wall just upstream of leading edge of impeller inlet in the practical operation of turbomachinery.

Other expected experimental example is to cut a notch instead of groove on the conduit pipeline just upstream of leading edge of impeller inlet. In case of notch, circulation of fluid particles is not possible to be expected. However, same kinds of effect with those of groove may be expected because boundary layer thickness becomes zero at the location of notch on the conduit pipeline.

To set a groove or a notch on the casing wall just upstream of leading edge of impeller inlet, many kinds of geometrical shape may be considered. Some of simple groove to be considered are shown in Figs 1, 2, 3, and 4. Some of notches are also shown in Figs 5 and 6. The author does not know which shape is much effective to obtain uniform velocity distribution and optimum flow condition just upstream of leading edge of impeller inlet and proceed rotating impeller blades flow passage optimum condition in turbomachinery. It may depend on type of turbomachinery. Anyhow, it could be said that if a groove or notch is set on the casing wall just upstream of leading edge of impeller inlet, impeller blades overall efficiency may be improved. However, their information is not reported yet. They are completely lack at this moment. In this meaning, experimental report may be requested.

As the geometrical circulating flow passage on the casing wall, several grooves and notches are considered. And their experimental results are requested to be

compare with those results of turbomachinery without circulating flow passage on the conduit pipeline. Those experimental results may give some valuable and fundamental information on this problem and they may bring to the improvement of overall efficiency at the maximum efficiency point and performance characteristic curve at off design condition of turbomachinery better one.

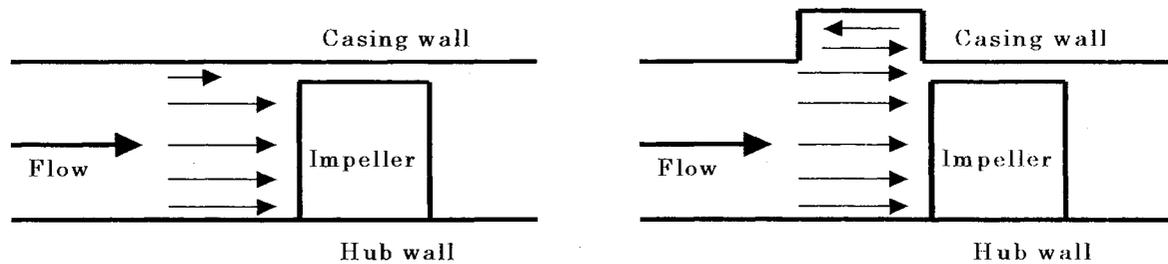


Fig. 1 Uncontrolled (left) and controlled (right) fluids flow condition at upstream of impeller inlet in axial flow turbomachinery.

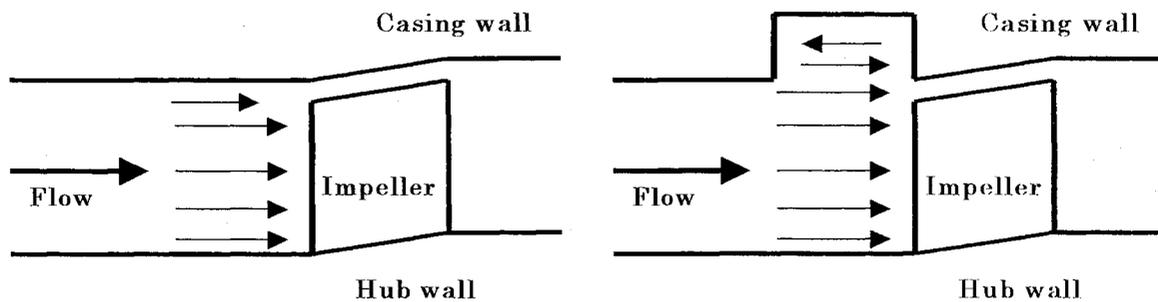


Fig. 2 Uncontrolled (left) and controlled (right) fluid flow condition at upstream of impeller inlet in mixed flow turbomachinery.

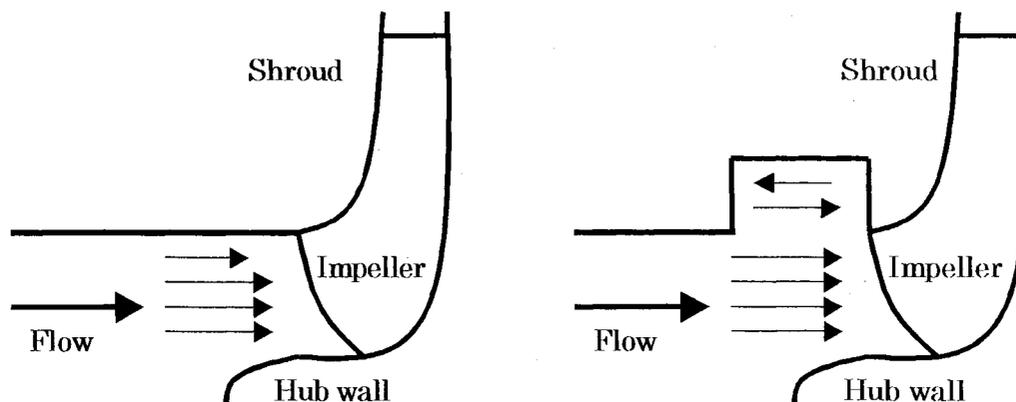


Fig. 3 Uncontrolled (left) and controlled (right) fluids flow condition just upstream of leading edge impeller inlet in centrifugal turbomachinery.

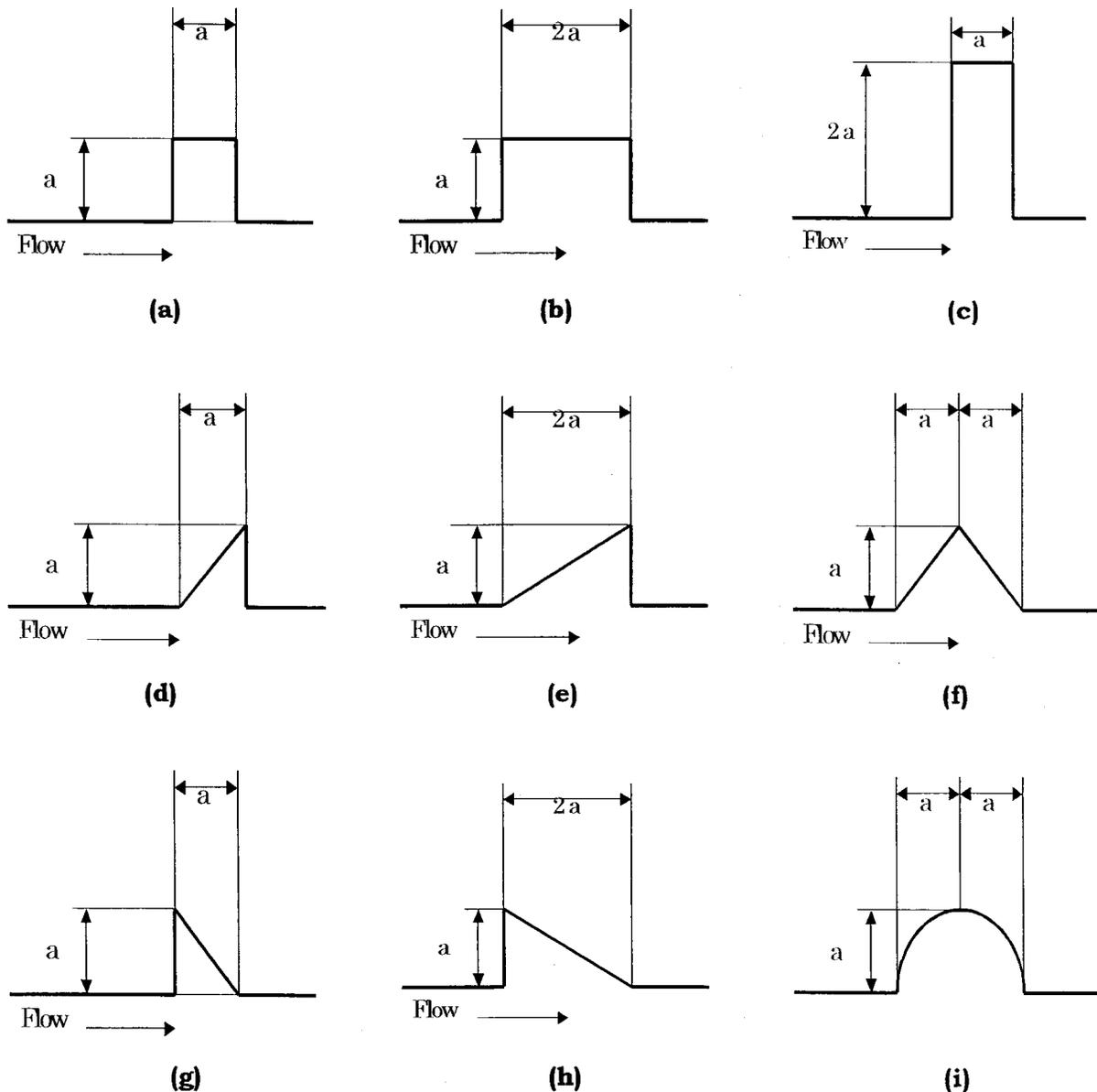


Fig.4 Illustration of geometrical shape of typical grooves and notches, which are suggested to set on the casing wall just upstream of leading edge of impeller inlet of centrifugal, mixed flow, and axial flow turbomachinery.

Among listed typical grooves and notches, shown in Fig.4, (a) and (b), or (c) and (b) would be considered as the basic and fundamental grooves or notches of experimental investigation for all of them. Because if we have grooves (a) or (c), experimental tests on notches (d) and (g) are possible in addition (a) or (c) themselves by reforming their shape by packing some materials on the corner of (a) or (c). Same way, if we have groove (b), experimental tests on notches (e), (f), (h), and (i) are possible in addition to (b) itself. Test results have to be shown and discussed with respect to the case of those a groove or a notch is not set on the casing wall in the turbomachinery.

Additional interests are the location's effect of groove or notch on the casing wall. That is the effect of distance between the trailing edge of groove, or notch, and the leading edge of impeller inlet how it related to overall efficiency characteristics of turbomachinery at the design and off design condition. The effect of groove or notch appears at the tip radius and the outer radius of leading edge of impeller inlet, and the fluid flow at and near the casing wall upstream leading edge of impeller inlet meets to clearance formed between the casing wall surface and the tip radius surface of impeller blades. And the effect of centrifugal force caused at those radiuses becomes the maximum at tip radius and the outer radius of the cross section, especially at the leading edge of impeller blades. That is, fluids flow direction is mostly tended radially outward at the tip radius of leading edge of impeller inlet in that flow passage regardless blades type for any centrifugal, mixed flow, and axial flow turbomachinery.

5. CONCLUSIONS

Practical impeller blades used to be designed for uniform upstream velocity distribution. Most of the problems seen at impeller blade's flow passage are caused at and near the tip radius of leading edge of impeller inlet. That is, separation of fluid particles from the blade surface is caused at and near the casing wall of leading edge of impeller inlet. It is well known that boundary layer is developed on the casing wall of conduit pipeline and axial component of velocity becomes small at and near the casing wall. Nevertheless, in the practical operation of turbomachinery, straight pipeline used to be set just upstream of leading edge of impeller inlet. Therefore, to improve the overall efficiency in practical operation of turbomachinery, improvement of fluids flow condition at casing wall, that is, boundary layer control just upstream of leading edge of impeller inlet is recommended. Some example grooves and notches are introduced.

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