Appendages surface finishing recommendations

Objective

To give a guideline to achieve certain criteria of smoothness of the appendages surface (boards, rudders and elevators).

The smoothness criteria are intended to minimize the drag of the appendages, making the performances as close as possible to design. This can be achieved within some limits, taking into account the unavoidable tolerances inherent in any manufacturing process.

Fulfilling common criteria also allows a more consistent comparison between appendages, eliminating (or equalizing) the unknown coming from different qualities of the surfaces.

Special attentions has been devoted to find criteria for those appendages that are designed to allow a significant extension of laminar flow over their surface.

Shape quality control

It is already practice to do a systematic check of the overall geometry of the appendages. This check is normally done using aluminium templates of a number of sections.

The aim is to check chord length, thickness and camber distribution along the chord, twist of the section if any.

Without going in the details of this part of the quality control, it should be remembered that good practice should be to have linear tolerances below 1%, and angle tolerances below 0.1 degrees.

Waviness and roughness

As the water mainly flows in longitudinal (chord wise) direction, here we are interested in the deviation of the real surface from the design surface along two dimensional longitudinal cross sections. Span wise (crossflow) deviations are believed to be of minor importance.

The deviation between the real and the design (average) surface along a portion of section, can be generically represented as a sum of “waves” of different lengths and amplitudes.

For our purpose we can call waviness the sum of those waves whose length is longer of about 5 or 10 mm, while with roughness we refer to waves of shorter length.

This quite arbitrary and empirical distinction is meant to separate those surface deviations that have a primary impact on pressure distribution (waviness) and only secondarily on the boundary layer, from those acting directly on the boundary layer (roughness).

Exceptions apart, for the characteristics dimensions, speed and purpose of our appendages, it is believed that reducing both waviness and roughness ideally to zero, would minimize drag.

The main effect of waviness is on laminar sections. Waviness produces chord wise pressure waves overlaid to the design pressure distribution. The rise of pressure between a peak and valley of a wave (adverse pressure) can prematurely disrupt laminar flow, rising the drag to the turbulent flow value. Within certain limits, waviness has small effects if the flow is already turbulent and/or the section is a turbulent type section.

Roughness should be minimized on any surface and section shape. In turbulent flow conditions an increase of roughness increases the drag of the turbulent flow. If the flow is meant to be laminar, roughness can promote transition to turbulent flow, increasing drag.

To avoid confusion, we are not considering here that kind of textured surfaces (such as riblets or super hydrophobic surfaces) specifically designed to reduced skin friction and banned by the AC rules.

A special case where a certain degree of roughness could be desired is if we would to trip laminar flow to promote transition to turbulent flow regime. This could be wanted to avoid laminar separation (that is draggier than turbulent attached flow), something that could happen at low speed on the shortest sections such as the boards and elevators tips. At the moment there is no evidence that this can happen on our appendages.

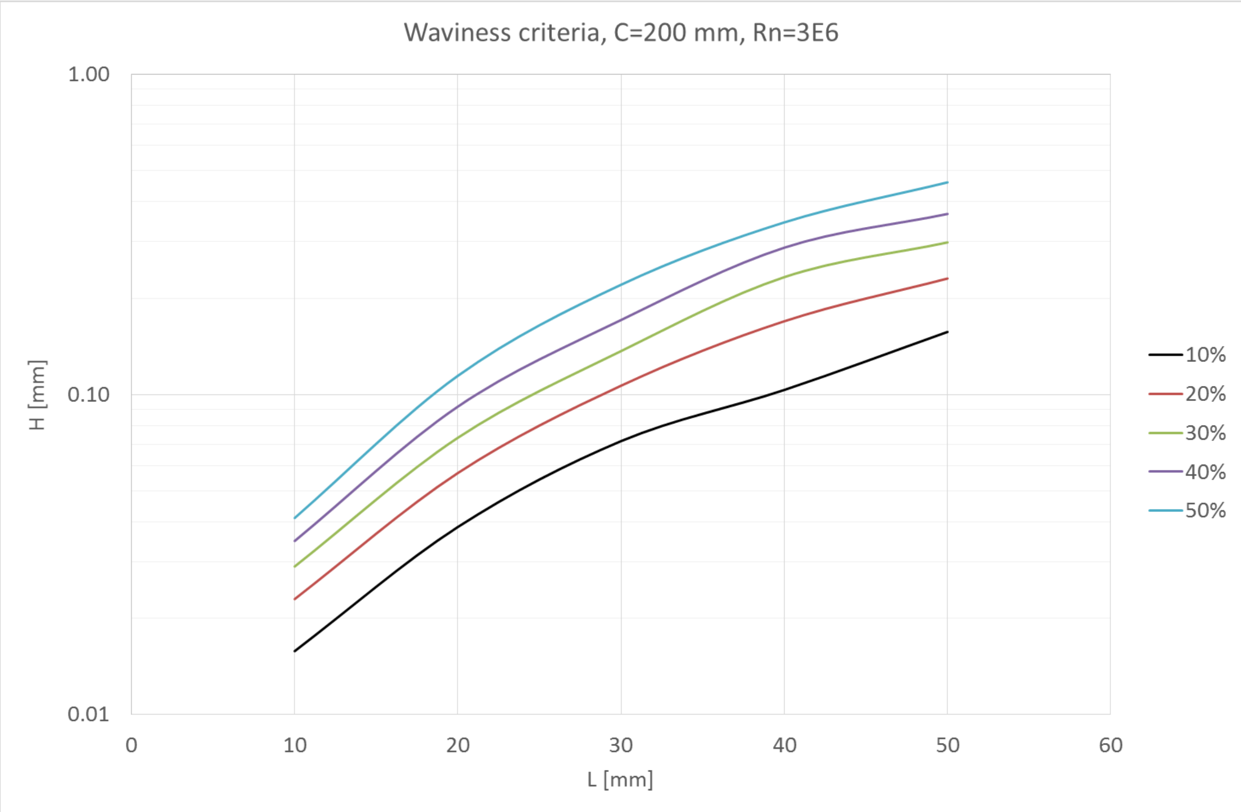
Waviness criteria

The waviness criteria here proposed is based on the computation of a typical laminar tip section, where waviness of different lengths and heights have been systematically superimposed to the smooth design surface.

The final result is presented in the following graph 1. Here it is shown how a (sinusoidal) waviness of length L and height H (peak to valley) distributed all along the section surface (lower and upper) degrades the value of the drag from the laminar value (0%) to the turbulent value (100%). For example a waviness of L=40 mm and H=0.1 mm gives a degradation of 10%, while for the same H=0.1 mm but L=18 mm the degradation is 50%, namely half of the achievable laminar flow is lost and the section drag is half way between the laminar and the turbulent values.

It is suggested a check of the surface waviness at some sections of the appendage to measure the average values (or distribution) of waviness length and height, and to compare with the lines in the graphs. A good criteria should be to stay below the 10% degradation line.

It is worth to say that by the nature of the flow, the speed and dimension of our appendages, when transition from laminar to turbulent flow occurs, there is no possibility to re-laminarize the flow downstream. This means that a special attention to fulfil the waviness criteria should be devoted from the leading edge to about 50% of the chord downstream.



Graph 1

Roughness criteria

As already pointed out, at the moment we don't see any reason not to have the smoothest possible surface all over the appendages. In case we should face problems of laminar separation, it will always be possible to repair locally tripping the flow.

According to theory, a distributed roughness on a flat surface has no effect on (turbulent) drag as long as the "grains" causing the roughness remain inside the so called laminar sublayer, namely the portion of the boundary layer closest to the surface. The maximum grain size not causing macroscopic flow disturbance is called "permissible grain size". Our appendages (and hull) surfaces should have a roughness below the permissible grain size.

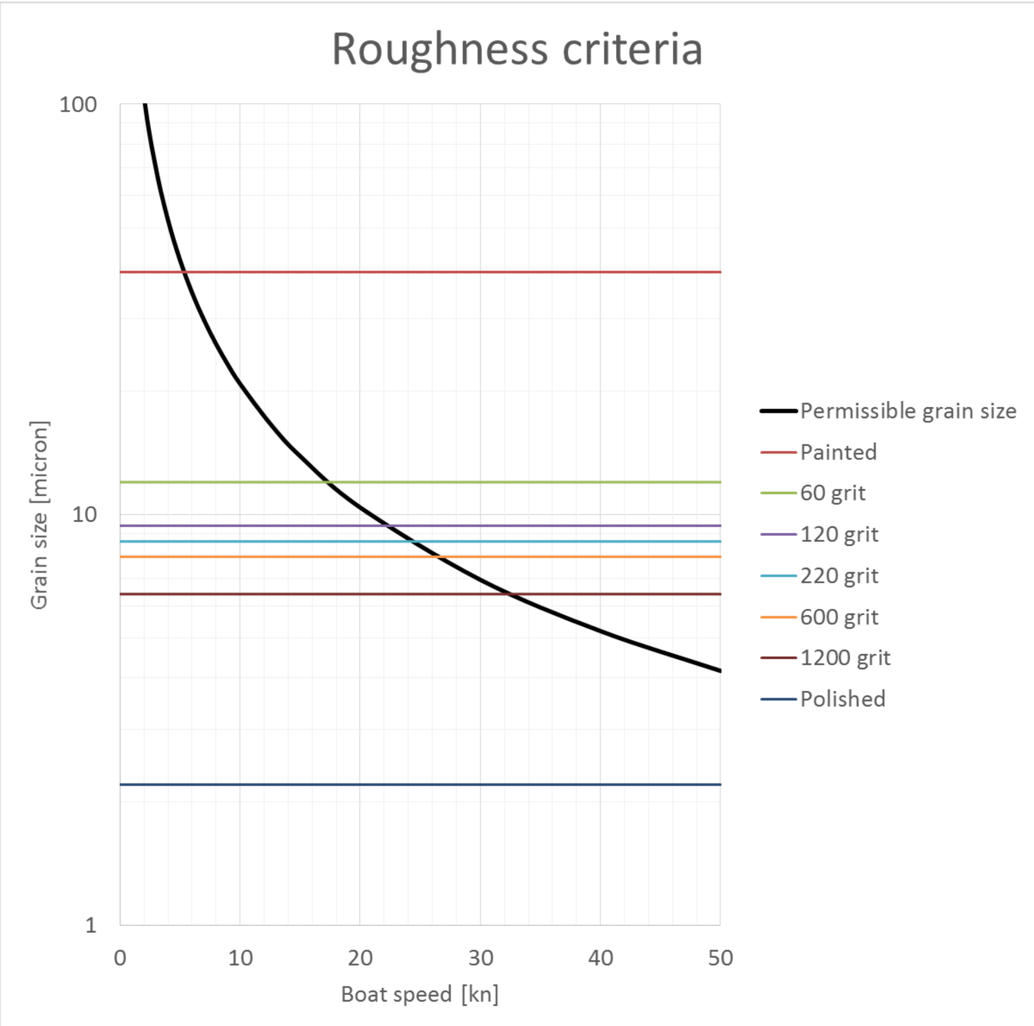
Most of the data available showing the correlation between roughness and drag are for flat surfaces (having no pressure gradient) and not for aerofoil, where pressure gradients affect the boundary layer thickness and shape. As a consequence the results here presented should be considered not conservative and some margin should be taken (in the sense of having even smoother surfaces than suggested by the criteria).

The next graph shows the permissible grain size versus boat speed, and the grain size achievable with different sand paper grits. Results are for salt water at 15 Celsius.

First it should be noticed that the permissible grain size drops steeply with speed. While at 10 knots a roughness of 20 micron is acceptable, above 40 knots we should go below 5 micron (4 times smoother). A faster boat requires a smoother surface.

From the (few) data available on the grain size achievable with different sandpaper grits on a painted surface, it seems that only the polished surface is capable to meet our requirements.

As a consequence, it is suggested to use the usual cycle of preparation **all over** the appendage surface, using progressively finer sandpaper (up to 1200 grit or more) and finally polishing the surface everywhere. Again, greater attention should be paid to the portion of surface closer to the leading edge.



Graph 2