Crowd Adaptive Mask

Dr Saurabh Kwatra Resolve
Trimmed Innovations

Introduction & Challenge; Function vs. Structure

Face masks are, would be & ought to be a priority in personal health care kits, least in present and till a while in future. Continuous discomfort from wearing breathing mask or respirator or alike is obvious. Fact remains that its functionality is accomplished only when other people are around. This causes an on-off effect in masking ; people when socially close to others pull it up, and when socially distant (relatively alone) pull it down or even remove and pocket it. If uncorrected, masks will soon evolve as face mask-neck band!

Not only is it an inconvenienced option, it can be an erroneous habit (forgetting many times to wear when mandatory). And frequent tinkering of protective nose-mouth device by not-always sanitized hands can increase chances of infection spreading. Mileage gained from use of mask can be lost or even overtaken by harm caused in such cases.

A social contradiction, viz. wearing or not wearing mask is transformed to a technical contradiction and solution outputted is an adaptive mask with holes of varying size. A mask with dual-structure needs to be designed and manufactured; mask with holes far-apart when one is alone & same mask with holes closer-by when one is in a crowd. A functionally and structurally adaptive mask.

Mask as a Technical System (**Product**/Process)

Most Useful Function (s) : To prevent infected air from reaching human respiratory system. More accurately, to filter out water droplets in air carrying pandemic-spreading viruses, bacteria, etc.

Most Harmful Attributes (s) : Mass, Dimensions & *Energy consumed*. (all these three properties of a system are considered a necessary evil, lesser they are, better it is. In other words, a lean, light and low power consumption product is most desirable and an ideal. This Industry 4.0 trend applies more remarkably and usefully to a military personnel for whom a low-weight, pocket-friendly & minimal power rated mask would be an asset.

Whereas all available masks are in general light & slim (no problem with Mass, Dimensions), there is a problem with Energy consumed! Here is the **challenge**: Energy consumed while breathing = Elastic potential energy that is supplied by respiratory system's muscles. Presence of mask puts an additional power load thus raising Energy consumed by mask. It also transforms quiet breathing into noisy one and causes quicker fatigue.

Challenge can be avoided

1. In solitary situations, which can be up to 75% of total time with mask-on, there isn't infected air and power consumed by mask is unnecessary and avoidable.
2. In crowded situations however, mask is highly useful as a preventive add-on wearable. *These situations may not exceed 25% of total time.*

Inspiration drawn from a quite different area in engineering

Example lifted from airplane: If wings of plane are broadened, lift increases but drag increases too. If wings of plane are narrowed, lift decreases but drag decreases too. In this case, 'width of wing' is a physical characteristic (one of important dimensions) of airplane, while lift and drag are system properties (actually forces in aerodynamics). If we frame this challenge in without 'width of wing', we get this: if lift improves i.e. increases, drag worsens, i.e. increases; if lift degrades i.e. decreases, drag improves i.e. decreases. Little need to mention, that lift is a desired property while drag is an undesired one- reduction of latter is effectually betterment.

We call this a **Technical Contradiction or TC. In TC,** improvement of one system property inevitably leads to worsening of another system property. The same challenge could have been stated in terms of wing span alone: wings of plane must possess large area and small area together.

We call this a **Physical Contradiction or PC, wherein one physical** characteristic like mass, size, length, temperature must have 'dual' values simultaneously. The aircraft designer finally came with (partially) retractable wings: separation on condition has occurred. During take-off and landing when lift is supreme and necessary under low speeds, flaps are opened. During cruise when high speed can easily provide lift and drag becomes a strong evil, they are withdrawn. So this PC is resolved without a compromise.


In-board Ailerons during cruise

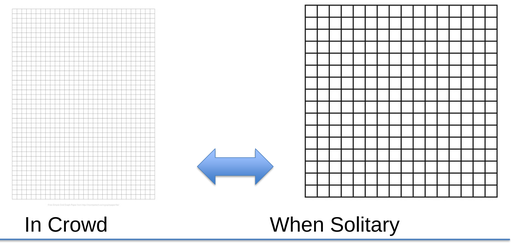

Out-board Ailerons during take-off

Challenge & its Design Solution

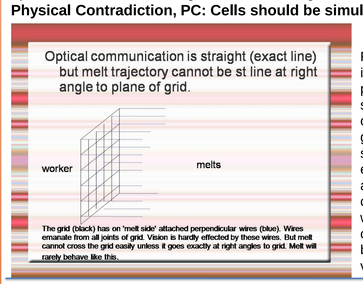
A conventionally designed mask has a fixed pore size. The pore size of any protective equipment is the main physical characteristic. It functions to permit or prohibit passage of concerned pathogen. Whether it is an advanced surgical face masks used as personal protective gear or ordinary cloth coverings serving as make-shift mask or a N95 respirator, they have a common fundamental parameter: a fixed pore size. There is however a discomfort in wearing masks all the time. When in crowd, it is absolutely essential but when alone it can be removed off for a sigh of relief. But this is bad habit and cannot be encouraged. Also frequent removal and placement can cause too many hand touches and in fact can itself be a threat. Mask must be worn at all times when out! What if a mask exists that changes it's pore size upon condition: bigger pore size when alone & smaller pore size when in crowd? A Physical Contradiction PC thus exists and needs be resolved.

If pore size is small, transmission of pathogen cannot occur but suffocation is felt,
If pore size is large, transmission can occur, but suffocation isn't felt.

So pore size (a physical characteristic) must be small and large. Of course at different times only. So, separation (separate pore sizes) upon condition is solution. When near people, pores size should narrow. When away from people, pore size should widen.

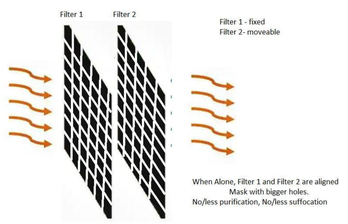

In Crowd When Solitary

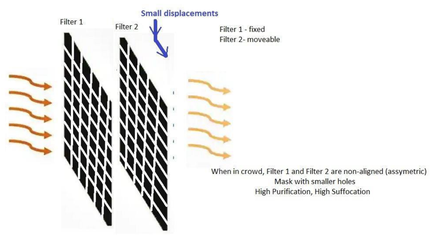
Parallel from Welding: **The operator of the melting device to produce special refractory melts should see the manipulator** well. Everything: capture of scoop with melt, line of crucibles, where melt be poured into. That's why he sits very close and he's got to be protected from hot metal sprays. People tried to use glass and many other materials, but nothing suited. They came to conclusion that only way of protection was a wire grid of the same metal. But they faced a contradiction: To see well, holes of the grid should be large (otherwise there should be no grid); For good protection from metal sprays, there should be small holes (smaller than sprays). The cells of grid should be small, in order well to defend eyes (face) of operator, and the cells of grid should be larger, in order to see without obstacles. **Physical Contradiction, PC: Cells should be simultaneously small-large.**

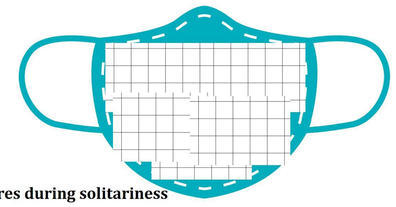


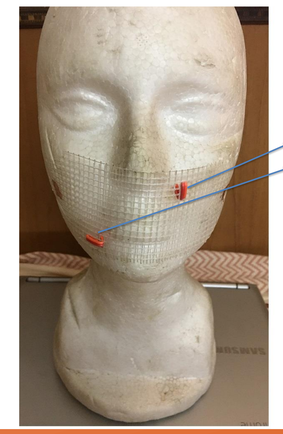
Final Technical Solution adopted in industry: To vibrate grid in the planes perpendicular to axis of sight. The frequency of oscillations is about 25 Hz (the grid becomes invisible). For the small cells the amplitude is low enough, for larger cells the amplitude should be close to ½ of cells size (in order to prevent the way of flying metal drops). In order words, grid of any size can be made and a commensurate vibration can be applied.

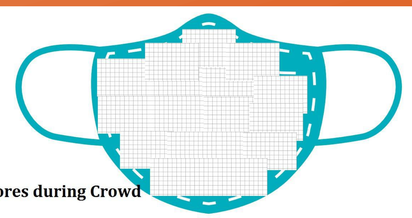
Returning to mask problem: Is a simple stretchable material suitable? How will it be stretched /relaxed? Will it be automatic or manual? Will it cause discomfort as forces act on facial structure. How many cycles can it endure? What be its fatigue strength? Can we use other controlling fields like electromagnetic on masks having ferromagnetic particles embedded in fabric? Optical fields?
Technical Solution 1: Dynamical trend: Use two identical, parallel air-filters both with larger holes, whose relative position adjustable.
Two states can exist:
When alone, filters aligned: mask with effectively larger holes
When in crowd, filters non-aligned: mask with effective smaller holes

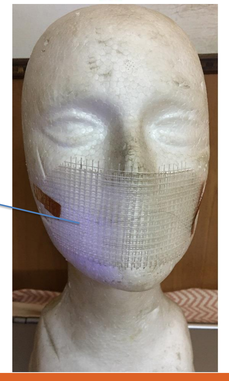





Open Pores during solitariness




Closed Pores during Crowd



Some Experiments & Tests Below: