Additive Manufacturing - From Trial and Error to a True Revolution

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We are witnesses of an interesting movement, the 3D Printing, or Additive Manufacturing (AM) process of building new things. As we watch it progress from just another technology hype to the next industrial revolution, one thing becomes very clear. Simulation tools that would allow us to get the parts "first time right" are very much a prerequisite for AM to really take-off.

Questions to answer - Around the globe, I see companies taking their best people and put them into a new focus area of additive manufacturing. There are budgets but not great experiences - yet. These companies are trying to gain enough experience to answer questions like:

- What kind of machines to buy?
- What are "AM friendly parts" considering factors like lot size, material, complexity, dimensions, assembly, tolerances, cost & tooling time.
- Can part counts in sub-assemblies be reduced?
- Can weight be saved without compromising part performance?

Failure to produce is happening quietly - It is hard to pass a week without another press release about 3D Printing and the revolution that it will cause in manufacturing. As exciting as AM is, with exciting stories of the printing of full cars, bridges and buses, there are many orders of magnitude more "sad stories" in terms of achieving production levels in printing metal parts. Companies trying to jump in and gain experience has proved very costly. Failures, cracks, high distortion in unexpected areas are all part of the learning process.

Take setting the machine parameters of a high capacity metal AM machine as an example. There can be up to 200 of these input parameters that can affect the outcomes of the resulting parts! Simply positioning the part and the location of support structures could make a big difference between getting it right and (more often than not) getting it wrong. Positioning the part wrong can result in an up to 160% increase in energy consumed. Today's reality is that perfecting the AM production of a bracket could take up to two years.

Getting it wrong is expensive - Considering that current speeds for AM production of metal parts can take 1-2 days, the cost of getting it wrong in terms of machinery, material and power is significant. According to a December, 2014 National Institute of Standards and Technology (NIST) report:

- Metal parts made from aluminum alloys was ~$3 per part for traditional manufacturing and ~$29 per part for additive manufacturing using selective laser sintering - a 10X cost increase.

- For additive manufacturing of plastics, the major costs are the machine cost per part, which is between 58.7 % and 65.9 % of the cost, and the material cost per part, which is between 29.1 % and 30.4 % of the cost. The P730 is cost effective for production volumes of 73 000 or less while the P390 is cost effective for 87 000 or less.
- Energy consumption, is an important factor in considering the cost of additive manufacturing compared to other methods of manufacturing, especially in terms of examining the costs from cradle to grave.

Getting it right going forward - To get parts "first time right" there are four important developments that have to be considered:

1) Material engineering- to design optimal microstructures.
2) Topology & Shape Optimization – to design lightweight parts that retain structural integrity and potentially decrease part counts in sub-assemblies.
3) Process Simulation – To predict part deformation based upon part design, support structure placement and machine conditions
4) Part Performance - to check for the structural integrity of a part based upon both the design and the manufacturing process.

Much of the attention has focused around Topology and Shape optimization. There has been so much expectation that strange-shaped, yet structurally-sound parts can be generated on the computer. What companies have come to learn is that just going from CAD to STL to machine is by no means sufficient. The big realization that manufacturers are coming to is that before tying up an expensive machine and delaying time to market, it is vital to run a simulation of that process first.

Successful simulation requires software tools that have to cover these minimum areas of capacity:

- Help the user to position parts most appropriately for the machine parameters
- Create only the support structures substantially needed to minimize distortion and prevent build job abortion.
- Provide analysis results fast enough to guide the users' decision making. The most value in results is now and the value of the results decrease with each hour and day that passes.
- Ease of use in the proper set up of manufacturing parameters which are key to achieving repeatability
- Simulation of the whole process post manufacturing process including the Hot Isostatic Pressure (HIP) process to reduce the residuals stresses in the part and insures that there is no porosity and the cutting process, which takes the support structure away from the part and also potentially takes away stiffness.
- Prediction of the microstructures in the part

A new superhero will emerge - So who is the engineer that can make sure that when the part is sent to the machine, it will come out perfect? Is it a CAD designer who will learn a lot of new skills in simulation and manufacturing? Is it as simulation analyst who needs to take on more of a role in initial part design? I think this superhero will come from both areas but one thing that is clear - it has to be someone who has a very flexible mind that thrives on learning new methods.

The future is very bright - The vital signs are all positive. Machine speed will get dramatically faster while machine and material cost will continue to decline. Simulation applications will evolve rapidly to ensure "first time right". In 1993, Apple introduced the Newton, the predecessor to the iPhone. It was a terrible failure. When the iPhone 3Gs were launched in 2008, Apple sold more than 1 million iPhones in just one weekend. Today, nearly 1 billion phones have been sold. So, it was not the hardware but the network speed and the applications that were key to the success - refinement in performance, usability and function. With additive manufacturing, I believe we are leaving the Newton age and moving toward the age of iPhone over the next 5 years. With rapid advancement of predicative applications to guide the user, the next manufacturing revolution is almost upon us.