High-Yield Yield Improvement

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Summary
This paper presents a technique for identifying castings that are the best candidates for yield improvement efforts. Traditionally, yield improvement has focused on the lowest-yield castings in the catalog of active products. However, in a jobbing environment, the low-yield products may not run for many years, preventing the foundry from realizing the gain from the investment of simulation time and pattern shop labor. Through the method explained in this paper, we are able to link yield values for each active product with current order information to calculate “opportunity pounds” potentially available. A sorted list of opportunity pounds allows us to focus our yield improvement efforts on the products with the highest potential for freeing furnace capacity for future scheduling.

Background
Southern Cast Products (SCP) is a steel jobbing foundry in Meridian, Mississippi. We have three no-bake molding lines. We have two induction melting furnaces; one furnace has two 3,750-lb. containers and the other has two 5,000-lb. containers. We produce castings from 1 lb. to approximately 4,000 lbs. in a wide range of plain carbon, low-alloy, corrosion-resistant, heat-resistant, and manganese alloys.

Defining the Problem
We define yield as:

$$\text{Yield} = \frac{\text{Casting Net Weight} \times \text{Number On}}{\text{Mold Gross Weight}}$$

Foundries naturally want to maximize yield. Paul Rudd [1] and John Cory [2] have documented the benefits of yield improvement efforts in a foundry. A high yield indicates that a high percentage of melted and poured metal is converted into sellable product.

But a jobbing environment can make plant-wide yield optimization challenging for a number of reasons:

- Many customers order castings in low-quantity batches, so a large investment in simulation is not feasible.
- Production runs may not be long enough on some products to optimize yield and validate the improvement.
- The large number of products in the active catalog makes the task of choosing where to focus the yield-improvement efforts overwhelming.

When we undertake yield improvement, we want to make sure our efforts will make a meaningful impact.

At SCP, the subject of yield improvement surfaced when we brainstormed project ideas for a summer intern. The intern had 3D modeling experience, so the task of running simulations seemed like a natural fit. Improving yield on a handful of selected patterns was a project that was well-defined, concise, and achievable in a summer, which was good for our intern, and it could provide real benefit to the foundry, which was good for SCP.

Our challenge was to select the list of candidate patterns.

The Typical Approach
When we have made yield improvement attempts in the past, we relied partly on data and partly intuition to determine which patterns received our focus. We could easily generate from our ERP (Enterprise Resource Planning) software a list of active products, sorted by yield in ascending order. That identified the products with low yield, but it was not clear when we would cast those products in the future. Therefore, we relied on our intuition to determine the frequent runners on the list. Those were the patterns that received the optimization attention.

However, the ultimate goal of yield improvement is to expand furnace capacity, and a list simply sorted by yield does not account for weight. A large yield improvement on a small casting may not save as many pounds as a small improvement on a heavy casting.

The typical approach was an educated guess, at best.

A New Approach

Our new approach to identifying candidates is data-driven. It utilizes not only yield data, but known order quantities to determine "opportunity pounds" that could potentially be saved with yield improvement. The equations for determining opportunity pounds have been coded into a user-defined report within our ERP system. With a simple prompt for a date range, the ERP system generates a list of yield-improvement candidates sorted in descending order of opportunity pounds.

The opportunity pounds are calculated relative to the historical average yield of our foundry. If a pattern's yield is lower than the shop average, that pattern has positive opportunity pounds. If a pattern's yield is higher than the shop average, it will have negative opportunity pounds. Opportunity pounds represent furnace capacity that could be used to melt sellable metal instead of potentially-oversized risers that cannot be sold.

In the examples below, we assume an average yield of 60%.

Table 1 is a representative output generated by the ERP system.

Sched. Qty	*Mold Qty*	*Product*	*Net Wgt*	*Nmbr On*	*Gross Wgt*	*Yield*	*Gross Wgt for Avg Yld*	*Excess Gross Wgt*	*Opportunity Pounds*
18	18	0000119	65	1	160	0.41	108	52	930
18	18	0000121	139	1	274	0.51	232	42	762
12	12	0000120	55	1	150	0.37	92	58	700
68	17	0000111	28	4	226	0.50	187	39	669
4	4	0000108	259	1	482	0.54	432	50	201
2	2	0000107	46	1	150	0.31	77	73	147
4	4	0000106	394	1	676	0.58	657	19	77
10	5	0000116	225	2	765	0.59	750	15	75
2	2	0000102	143	1	243	0.59	238	5	9
2	1	0000104	58.2	2	200	0.58	194	6	6
2	2	0000103	103	1	168	0.61	172	-4	-7
2	1	0000115	65	2	203	0.64	217	-14	-14
2	2	0000114	227	1	350	0.65	378	-28	-57
1	1	0000113	382	1	575	0.66	637	-62	-62
2	1	0000118	352	2	1,105	0.64	1,173	-68	-68
7	7	0000101	114	1	166	0.69	190	-24	-168
8	8	0000112	152	1	220	0.69	253	-33	-267
4	4	0000122	993	1	1,584	0.63	1,655	-71	-284
12	6	0000117	274	2	850	0.64	913	-63	-380
4	4	0000105	1,320	1	2,100	0.63	2,200	-100	-400
33	33	0000109	105	1	159	0.66	175	-16	-528
20	10	0000110	163	2	475	0.69	543	-68	-683
26	13	0000123	137	2	384	0.71	457	-73	-945

Table 1. ERP-generated list of products on order, sorted by opportunity pounds in descending order.

Table 1 is a summary view, which collapses the individual order information. To generate this summary data, the ERP system queries individual orders that fall within the date range specified by the user. Some examples of the summations are shown in Table 2.

Order Number	*Sched Qty*	*Mold Qty*	*Product*	*Net Wgt*	*Nmbr On*	*Gross Wgt*	*Yield*	*Gross Wgt for Avg Yld*	*Excess Gross Wgt*	*Opportunity Pounds*
92368	18	18	0000119	65	1	160	0.41	108	52	930
	18	18	0000119	65	1	160	0.41	108	52	930
92674	12	12	0000121	139	1	274	0.51	232	42	508
92583	6	6	0000121	139	1	274	0.51	232	42	254
	18	18	0000121	139	1	274	0.51	232	42	762
92367	12	12	0000120	55	1	150	0.37	92	58	700
	12	12	0000120	55	1	150	0.37	92	58	700
92588	68	17	0000111	28	4	226	0.50	187	39	669
	68	17	0000111	28	4	226	0.50	187	39	669
92380	4	4	0000108	259	1	482	0.54	432	50	201
	4	4	0000108	259	1	482	0.54	432	50	201
92684	1	1	0000107	46	1	150	0.31	77	73	73
92714	1	1	0000107	46	1	150	0.31	77	73	73
	2	2	0000107	46	1	150	0.31	77	73	147
92360	4	4	0000106	394	1	676	0.58	657	19	77
	4	4	0000106	394	1	676	0.58	657	19	77
91329	8	4	0000116	225	2	765	0.59	750	15	60
91330	2	1	0000116	225	2	765	0.59	750	15	15
	10	5	0000116	225	2	765	0.59	750	15	75
92618	2	2	0000102	143	1	243	0.59	238	5	9
	2	2	0000102	143	1	243	0.59	238	5	9
92036	2	1	0000104	58	2	200	0.58	194	6	6
	2	1	0000104	58	2	200	0.58	194	6	6
92037	2	2	0000103	103	1	168	0.61	172	-4	-7
	2	2	0000103	103	1	168	0.61	172	-4	-7
92036	2	1	0000115	65	2	203	0.64	217	-14	-14
	2	1	0000115	65	2	203	0.64	217	-14	-14
92038	2	2	0000114	227	1	350	0.65	378	-28	-57
	2	2	0000114	227	1	350	0.65	378	-28	-57
92287	1	1	0000113	382	1	575	0.66	637	-62	-62
	1	1	0000113	382	1	575	0.66	637	-62	-62
91156	2	1	0000118	352	2	1,105	0.64	1,173	-68	-68
	2	1	0000118	352	2	1,105	0.64	1,173	-68	-68
91538	7	7	0000101	114	1	166	0.69	190	-24	-168
	7	7	0000101	114	1	166	0.69	190	-24	-168
92026	3	3	0000112	152	1	220	0.69	253	-33	-100
92259	2	2	0000112	152	1	220	0.69	253	-33	-67
91882	2	2	0000112	152	1	220	0.69	253	-33	-67
92272	1	1	0000112	152	1	220	0.69	253	-33	-33
	8	8	0000112	152	1	220	0.69	253	-33	-267
92466	2	2	0000122	993	1	1,584	0.63	1,655	-71	-142
92032	2	2	0000122	993	1	1,584	0.63	1,655	-71	-142
	4	4	0000122	993	1	1,584	0.63	1,655	-71	-284
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					.					
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Table 2. Detail summation of order information for a product.

The columns are explained in Table 3.

Column Title	***Database or Calculated Field***	***Description***
Order Number	Database	Unique order number
Sched Qty	Database	Scheduled quantity of castings for the order
Mold Qty	Database	Scheduled number of molds required to produce the order quantity of castings
Product	Database	Unique identifier for the casting
Net Wgt	Database	Net weight of casting (lbs.)
Nmbr On	Database	Number on pattern
Gross Wgt	Database	Gross weight, or pour weight, of mold (lbs.)
Yield	Calculated	$\text{Yield} = \frac{\text{Net Wgt} \times \text{Nmbr On}}{\text{Gross Wgt}}$
Gross Wgt for Avg Yld	Calculated	$\text{Gross Wgt for Avg Yld} = \frac{\text{Net Wgt} \times \text{Nmbr On}}{\text{Average Shop Yield}}$
Excess Gross Wgt	Calculated	Excess Gross Wgt = Gross Wgt – Gross Wgt for Avg Yld
Opportunity Pounds	Calculated	Opportunity Pounds = Excess Gross Wgt × Mold Qty

Table 3. Definition of columns.

Key Points from the Examples

- In the example in Table 1, Product 0000119 would be the initial candidate for yield improvement efforts, since it has the greatest number of opportunity pounds.
- The product with the most opportunity pounds (0000119) is not the product with the lowest yield. Product 0000119 has a yield of 0.41, but Product 0000107 has a lower yield of 0.31.
- Two other products (0000120 and 0000107) have higher excess gross weights per mold than 0000119, but their lower order quantities make them less attractive for yield improvement efforts.
- Product 0000121 would be the second candidate for yield improvement, despite its respectable yield of 0.51. The product's relatively large weight and order quantity magnify the opportunity pounds available.
- Product 0000120 has a higher yield than Product 0000107, but the higher order quantity of 0000120 translates to more opportunity pounds for that product.

Benefits

When we identified opportunity pounds, we were able to generate a prioritized list of products for our summer intern to simulate. The knowledge that we had real orders for the products gave the project relevance. Now, we have this report saved in our ERP system. At any time, we can generate this list and see the best yield improvement candidates based on current open orders. This allows us to easily identify patterns to improve when our pattern shop is not busy.

Our summer intern's simulations and recommended rigging changes have been incorporated on products that have already run through our shop. The improved yield has opened capacity in our melting furnace, allowing us to fit more castings per heat.

Shortcoming of Method
This method does not consider the potential maximum yield for each casting's geometry. It is possible that a high-yield, heavy casting may still have significant yield-improvement potential. But if the yield of the pattern is higher than the shop average, the opportunity for improvement will be masked.

However, castings with high yield are probably not the products of “that-looks-about-right” rigging and are unlikely to be low-hanging fruit for expedient yield improvement.

Conclusion
By identifying opportunity pounds, we can easily identify from our product catalog the best candidates for yield improvement. The method accounts for the three significant variables affecting opportunity pounds: pattern yield, casting weight, and future order quantity. The formulas for calculating opportunity pounds can be programmed into a report within our ERP system. At any time, we can quickly generate a list of products with the greatest opportunity pounds, based on known order quantities.

References

[1] P. Rudd, "Yield Improvements," in *1997 SFSA Technical & Operating Conference*, Chicago, 1997.

[2] J. Cory, "Economics of Yield Improvement," in *1999 SFSA Technical & Operating Conference*, Chicago, 1999.