Calculations of efficiency in implementing progressive mold forming methods

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Abstract. The article provides a classical prime cost accounting, outlining steps for calculating the cost at production site. The calculations compare two methods of manufacturing titanium parts for the aviation industry. The first method uses the mold forming by drop forging and the second one uses a modern superplastic manufacturing technology. This comparative calculation will determine the price of production of one set of parts for the SU-30. The considered methods of manufacturing parts will show the prime cost of production and will draw conclusions on further cooperation between Irkutsk Aviation Plant and Irkutsk State Technical University in the field of titanium products mold forming for modern aircraft.

1. Introduction

At any stage of the company's life cycle, there is always the task of accounting, analyzing and managing costs. For example, in contrast to the question of managing a company, where new trends arise from year to year (today it is innovations, yesterday it was mergers and acquisitions, etc.), one question is trivial in the cost accounting: how to calculate them correctly? To solve the principal tasks (how much you need to sell and at what price, so that this product brings profit to the company), one needs to calculate how much it costs to produce one unit of production, that is, to calculate its prime cost. The calculation of the production prime cost is not a new task and is solved in almost every enterprise. The prime cost calculation method is passed “from generation to generation” and has credibility without any evidence.

The classic calculation of the prime cost of production unit implies two steps:

- the first one is the definition of costs, changing in proportion to the volume of production of a particular product (definition of variable costs per unit of production) The calculation is performed by the production of consumption rates of individual elements of the costs and their acquisition cost. The classic representatives of variable costs are raw materials, supplies, components, process energy, piecework wages.

- the second one is the summation of all other expenses incurred during the year, and their division into specific types of products (separation of overhead costs by type of products). The classic representatives of the “other expenses” are the expenses for the maintenance and repair of equipment, buildings, structures, salaries of administrative and management personnel, depreciation charges, administrative expenses. Often these “other” expenses are provided in special documents: statements (estimates) of general shop expenses, general business expenses, general production expenses. As a rule, total costs for individual types of products are divided
in proportion to the wages of the main production workers accrued on these types of products [1-6].

2. Results and discussion
The price of the set is calculated by the formula:

\[ C = K_1 \times K_2 \times S \]  

(1)

where \( C \) is the selling price, rub.; \( K_1 \) is the working course, rubles/c.u.; \( K_2 \) is the trade margin; \( S \) is the prime cost, c.u.

In turn, the prime cost, \( S \), is made up of the sum of the cost of raw materials, \( S_1 \), c.u.; of manufacturing costs, \( S_2 \), c.u.; of general shop expenses, \( S_3 \), c.u.:

\[ S = S_1 \times S_2 \times S_3. \]  

(2)

We define each component of the formula (2):

\[ S_1 = K_3 \times r \times V \times P_1 \]  

(3)

where \( K_3 \) is the utilization of raw materials; \( r \) is the density of the material, kg / m\(^3\); \( V \) is the volume of finished products, m\(^3\); \( P_1 \) is the cost of raw materials, c.u. / kg;

\[ S_2 = K_4 \times \sum_i P_2(i) \times T \]  

(4)

where \( K_4 \) is the total complexity factor; \( P_2 \) is the cost of the \( i \)-th operation, c.u. / h; \( T \) is the time required for the \( i \)-th operation, h; \( i \) is the operation;

\[ T = \frac{F_i}{Z_i} \]  

(5)

Here \( F_i \) are the dimensions of the finished product for this operation; \( Z_i \) is the performance of the operation. It is necessary that the units \( F_i \) and \( Z_i \) be consistent with each other. That is, if \( Z_i \) for this operation is determined in m\(^2\) / h, \( F_i \) should be measured in m\(^3\).

\[ S_3 = (S_1 + S_2) \times K_5 \]  

(6)

where \( K_5 \) is the ratio of general expenses.

Thus, we obtain the final formula for calculating the prime cost [6-15]:

\[ C = K_6 \times K_7 \times \left( K_3 \times r \times V \times P_1 + K_4 \times \sum_i P_2(i) \times \frac{F_i}{Z_i} \right) \times (1 + K_5) \].  

(7)

Using this method of calculating the prime cost, one can compare the processes of manufacturing parts and determine a more profitable production. As an example, let us compare two ways of making a set of parts.

As the consumption of metals grows, the continuously increasing demands of machine building in large forgings and details make it increasingly urgent for metallurgy to create more powerful and efficient equipment for metal forming. For many years, the manufacture of parts with the help of pressure is constantly progressing, and this progress makes it possible to improve the quality of parts and reduce the time of their manufacture. In our region, the strategic enterprise is the Irkutsk Aviation Plant (IAP), where much attention is paid to the development of production technologies, equipment modernization and the development of research and production base. Tens of millions of dollars are annually invested in technical re-equipment. The development of key competencies (technologies) is one of the main tasks facing the enterprise. These are the main technologies that ensure the production
of modern aircraft with the required quality and efficiency [2]. Though IAP uses advanced technologies
for the manufacture of parts, some workshops still need more in-depth modernization.

It should be noted that the drop forging method of manufacturing titanium parts is already outdated.
This mold forming technology no longer allows competing in the global market, and the quality of parts
is low compared with those of such competitors as Boeing, Airbus [4, 5, 16-19]. Analogs can be the
draw forming of a part into a rigid die, mold forming by an elastic medium [1, 20-22].

The mold forming of parts by drop forging can be replaced by progressive methods of forming in the
blank and forging production, namely, forming in the superplasticity mode. Irkutsk National Research
Technical University (INRTU) is engaged in this method of mold forming, where the laboratory of
"Advanced Forming Methods in Blank and Forging Production" was created. The laboratory equipment,
which costs 78 million rubles, is manufactured by special order of the university and is unique for
Russia. It is used for superplastic mold forming, combined with diffusion welding of sheet metal alloys.
The laboratory equipment allows you to work on the development and testing of new technologies for
forming sheet parts from aluminum and titanium alloys to produce a wide range of engineering products,
including those for aircraft production (production of parts for the SU-30), to conduct specialized tests
of metals and alloys in superplastic deformation modes. To evaluate the economic efficiency of the new
method of mold forming using superplasticity, the cost of manufacturing a set of parts was calculated
[7, 23-24].

A sheet of titanium with a cross section of 0.8 mm, size 600x1.500 mm at a price of 1525 rubles is
used to manufacture one set of parts at IAP (raw materials and materials). The process of manufacturing
parts is controlled by an engineer, the work is done by a workshop worker. The manufacturing
technology is the drawing of parts by drop forging. The equipment used for the manufacture of parts is
shown in table 1.

In INRTU titanium is also used for the manufacture of a set of parts. The parts are molded in the
superplastic mode on the presses SPF 60T 2011 (the cost is 3 million rubles).

Comparative calculation of the prime cost of manufacturing titanium parts using various technologies
is given in Tables 2-4.

Table 1. Equipment used at IAP for the manufacture of a set of titanium parts.

| Designation                        | Quantity, units | Cost (1,000 rubles) |
|-----------------------------------|-----------------|---------------------|
| Hardening furnace RK-180; 29.0 kW | 1               | 800                 |
| Hammer ML 1-5 1.5 t; 5.5 kW       | 1               | 700                 |
| Vibrating shears; 3.0 kW          | 1               | 150                 |

Table 2. Calculation of general business expenses, rub.

| Expenditure items                  | IAS                | INRTU technology park |
|------------------------------------|--------------------|------------------------|
|                                    | For year           | Per unit of production set | For year           | Per unit of production set |
| The salary of the enterprise managerial staff | 0.00               | 0.00        | 0.00               | 0.00 |
| Social charges                     | 0.00               | 0.00        | 0.00               | 0.00 |
| Corporate property tax*            | 36300.00           | 3630.00     | 66000.00           | 6600.00 |
| Total                              | 36300.00           | 3630.00     | 66000.00           | 6600.00 |

* are provided by the IAP accounting department and INRTU
Table 3. Calculation of general production (workshop) costs, rub.

| Expenditure items                                      | IAS     | INRTU technology park |
|--------------------------------------------------------|---------|-----------------------|
|                                                        | For year | Per unit of production set | For year | Per unit of production set |
| Remuneration of managerial production personnel: engineer* | 18000.00 | 1800.00               | 15000.00 | 1500.00               |
| Social charges’                                         | 6156.00  | 615.60                | 5130.00  | 513.00                |
| Maintenance of buildings and structures                 | 0.00     | 0.00                  | 0.00     | 0.00                  |
| Communication services                                  | 0.00     | 0.00                  | 0.00     | 0.00                  |
| Cleaning of production premises                         | 0.00     | 0.00                  | 0.00     | 0.00                  |
| Social charges                                          | 0.00     | 0.00                  | 0.00     | 0.00                  |
| Depreciation of industrial buildings and structures, workshop equipment* | 1212.00  | 121.20                | 1212.00  | 121.20                |
| Labor protection*                                       | 8000.00  | 800.00                | 8000.00  | 800.00                |
| Total                                                  | 33368.00 | 3336.80               | 29342.00 | 2934.20               |

* are provided by the IAP accounting department and INRTU

Thus, the calculation of the total prime cost is as follows:

Table 4. Calculation of the total prime cost of production, rub.

| Expenditure items                                      | IAS     | INRTU technology park |
|--------------------------------------------------------|---------|-----------------------|
|                                                        | For year | Per unit of production set | For year | Per unit of production set |
| Raw materials and supplies*                             | 15250.00 | 1525.00               | 15250.00 | 1525.00               |
| Transportation                                          | 0.00     | 0.00                  | 0.00     | 0.00                  |
| Fuel for process purposes                               | 0.00     | 0.00                  | 0.00     | 0.00                  |
| Electricity for process purposes*                       | 682.19   | 68.22                 | 718.574  | 71.86                 |
| Basic and additional wages of production workers*       | 11000.00 | 1100.00               | 26000.00 | 2600.00               |
| Social charges*                                         | 3762.00  | 376.20                | 8892.00  | 889.20                |
| Expenses for production preparation and engineering     | 0.00     | 0.00                  | 0.00     | 0.00                  |
| The cost of maintenance and operation of equipment*     | 31350.00 | 3135.00               | 57000.00 | 5700.00               |
| General production (workshop) expenses                  | 33368.00 | 3336.80               | 29342.00 | 2934.20               |
| Workshop prime cost                                     | 95412.19 | 9541.22               | 137202.57| 13720.26              |
| General business expenses                               | 36300.00 | 3630.00               | 66000.00 | 6600.00               |
| Manufacturing prime cost                                | 131712.19| 13171.22              | 203202.57| 20320.26              |
| Non-manufacturing (commercial) expenses                 | 0.00     | 0.00                  | 0.00     | 0.00                  |
| Total prime cost                                        | 131712.19| 13171.22              | 203202.60| 20320.26              |

* are provided by the IAP accounting department and INRTU

Thus, the calculation of the total prime cost is as follows:
• social charges = staff labour remuneration x 0.342;
• overhead (workshop) costs = the salary of managerial and production personnel + social charges + depreciation of industrial buildings and structures, workshop equipment + maintenance of buildings and structures + payment for communication services + cleaning of production premises + labor protection;
• general business expenses = the salary of enterprise managerial staff + social charges + corporate property tax;
• shop cost = raw materials and materials + transportation + fuel for process purposes + electricity for process purposes + basic and additional wages of production workers + social charges + expenses for production preparation and manufacturing + expenses for maintenance and operation of equipment + general production (workshop) expenses;
• production cost = shop prime cost + general business expenses;
• total prime cost = production prime cost + non-manufacturing (commercial) expenses;
• price for one set of parts = total prime cost x 1.4 + total prime cost x 1.4 x VAT [3, 25-29].

Based on the calculations presented in Tabl. 2-4, it can be concluded that the price for one set of parts for the set manufactured at IAS was 21,758.85 rubles, price for the set manufactured at the technology park of INRTU was 33569.07 rubles.

3. Conclusion
As you can see, the production of a set of titanium parts, according to the old technology, is cheaper. However, the use of a new technology of superplasticity makes it possible to obtain parts from brittle heat-resistant alloys, previously made by casting (turbine disks with blades, etc.). This allows us to obtain significantly better properties due to a more uniform microstructure. This improves the quality of parts, prolongs their service life, reduces production time and labor intensity of the process. The use of superplasticity turned out to be more expensive, but, as they say, you have to pay for quality. If we want our modern production to be at its highest and able to compete with Western aviation giants, then it is necessary to switch to modern technologies. At the moment, if there are no potential investors to promote superplasticity in aviation, then it is worth re-qualifying the current trend to private enterprises or in more popular production.

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