Efficiency of material consumption in sustainable conventional machining practices

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Abstract. Control of the use of conventional machining materials in engineering majors has not been well controlled. Waste of costs by budgeting new work pieces for each new type of work is valued as a swelling of operational financing practices. Through the efficiency of material consumption that is sustainable in conventional machining practices can streamline the process, save time and cost of production, and maximize the use of old or used work pieces to develop 11 competencies achieved. By comparing five jobs in machining practice in VHS with a job called job modification capable of providing 30% efficiency of operational costs, a time required, and more minimalist material consumption while still attending to the achievement of competencies. The research analysis uses design assistance and iProperties in Autodesk Inventor 2012 software.

1. Introduction

The advent of Sustainable Development Goals (SDGs) transforms the work in the consumption of equipment and materials used to a minimum. The challenge of the future SDGs is to make domestic consumption efficiency where there is an increase from 1.2 kg to 1.3 kg per unit of GDP from 2000 to 2010 and total use of household materials from 48.7 billion tons to 71.0 billion tons [1]. The effects caused when excessive product consumption leads to emissions of waste and pollutants that could endanger generations [2], [3] in both micro and macro scale. In the manufacturing perspective, the term consumption efficiency in the microscope tends toward the efficient use of tools, machinery, and material consumption [4], while on a macro scale relates to energy use, process efficiency, and product recycling.

The micro scale deals with material consumption issues that need to be restricted. Slowly but surely, the materials used in the manufacturing process will be increasingly eroded and have high selling value. The depletion of both excessively exploited metallic and non-metallic natural materials makes the need for an effective method guided by the concept of sustainability [5].

At the education level, the consumption of both metal and non-metallic materials is found in the world of vocational education. Vocational education is more prone to special education in the formation of skills that are developed reproductively [6]. Reproductive means performing repetitive work processes to achieve the expected competencies that certainly impact on the use of large practice materials so that there is the possibility of the waste of production costs. In addition, material consumption in vocational practice is commonly found in the fields of manufacturing science [7]–[9].
In the scope of mechanical engineering education is known by two terms of machining practice that is conventional and non-conventional machining. Conventional machining is a non-digital machining, and machining is digital and computerized machinery [10]. When looking at machining practices in existing vocational schools in Indonesia, an average of 70% of machining practices still use traditional machining. The reason, the machining practice has an economic value in terms of procurement of machines rather than non-traditional. For that reason, all the technologies used in machining practice are expensive and therefore need to be approached with SD [11]. The problematic becomes something unique if vocational researchers begin to shift its paradigm to emphasize the learning process that is environmentally friendly, saving material consumption, and sustainability.

The current vocational manager has not optimally machined the machining practice process either from the use of tools, machines, and the utilization of work pieces. Much waste material is wasted from the production process resulting in wasteful costs when viewed in the economic side [7], [12]. In fact, SD can run effectively if the manager of vocational and production section economic integrated understanding in the learning process in the workshop.

In conventional machining practice, wasteful use of materials is often found when they practice lathe and hemming [13]. Work pieces used by students tend to be new for each type of work. If the object used is done, then the object is thrown away or sold at kilo’s price. This is certainly inconsistent with the echo of vigor in managing vocational education in conventional, elementary-oriented machining practices. The apparent financing gap is due to the machining workshop manager not being able to regulate the use of practice materials used in machining practice. There needs to be an efficient analysis of the use of practice materials by utilizing work pieces on an ongoing basis. Sustainability practices still take into consideration the competencies required in conventional machining practices.

2. Research analysis

This research uses Autodesk Inventor software analysis approach to analyze material consumption of conventional machining practice. The analysis of the work piece is divided into two conventional machining practices which use five practice items for five conventional machining products and practices with one practice material but for five products. The conventional machinery used is the practice of lathe. The two methods both want to achieve 11 basic turning competencies, including: C1 (planning), C2 (roughing), C3 (finishing), C4 (chamfering), C5 (centering), C6 (Threading), C7 (growing), C8 (cartelling), C9 (coning), C10 (radius), and C11 (boring) [14]. This selection is to focus analytical studies on the consumption of the use of pivot shaped materials. The following are the product images analyzed.

![Figure 1. Conventional machining products made by VHS students.](image1.png)

![Figure 2. Job modification lathe that covers many competencies.](image2.png)
Analysis of material consumption using iProperties from Inventor 2012 [15] paying attention to the iProperties [16] it can see how far the material is wasted over the process done so far in the vocational high school of mechanical engineering. Here is a view of iProperties Inventor 2012.

![iProperties Inventor 2012 display.](image)

Figure 3. iProperties inventor 2012 display.

In addition, this study also analyzed by observing the time on the length of work done from the six jobs in general, and one more efficient job in the use of materials. In the trial, the material used is mild steel. The use of mild steel as an experimental material because the material is widely used for training, machinability, and production costs are cheaper [17], [18]

3. Result and discussion

Conventional machining practice in vocational school always refers to Basic Competence to be achieved. The results of observation and documentation of conventional machining work in Yogyakarta vocational schools, among others:

| Table 1. Job type in VHS department of mechanical engineering. |
|---------------------------------------------------------------|
| **Conventional Machining Practices** | **Job Analytic** | **Number of Practices** |
|--------------------------------------|-----------------|-------------------------|
| Turning practices                    | Flat shaft      | 7 Session               |
|                                      | Terraced shaft  |                         |
|                                      | Handle with terraced shaft work, hollow shaft, carteling, tapering, and radius |                         |
|                                      | Threaded and grooved shafts, etc. |                         |
|                                      | Making Cubes    |                         |
|                                      | Rack gear       |                         |
|                                      | Straight and oblique gears |                         |
| Milling practices                    | Helix gear      | 8 Session               |
|                                      | Worm gear       |                         |
|                                      | Bevel gear      |                         |
|                                      | Pivot groove creation, etc. |                         |
|                                      | Surface terraced |                         |
| Shaping practices                    |                 | 1 Session               |

In accordance with the limitations of the study, the assessment of consumption efficiency in conventional machining practices is focused on the lathe work. The analysis of the lathe work is based
on the worksheet used by the instructor in teaching. Based on the observations in the practice shop, concluded that every job done in a vocational school is identical to the new work piece. In the eyes of the workshop management budget, the financing is allocated exclusively for the five job of the lathe. The price of material in spindles gives production expenditure for 5 jobs of the lathe for each learner that is equal to Rp. 105.450, -.

More rigidly, completion of the students' turning competence is done with the help of the worksheet. Job sheet was built to provide visual information assistance for conventional machine operators to work [19]. Job sheet taught to students at least meet the criteria C1 (planning), C2 (roughing), C3 (finishing), C4 (chamfering), C5 (centering), C6 (Threading), C7 (growing), C8 (cartelling), C9 (coning), C10 (radius), and C11 (boring).

The observation of time for the lathe work is done to find out the time needed to hone students' competence in turning conventionally in an effective time. Based on Table 2 shows that the effective time students take to complete all competencies in the conventional lathe is 1,240 minutes or 20 hours which means it only takes 4 to 5 sessions. The details of the work time as follows:

| Job analysis         | Raw material   | Identify the competencies achieved in the minutes | Total Time One Semester |
|----------------------|----------------|-----------------------------------------------|-------------------------|
| Basic turning job    | MS Ø32 x 40 mm| C1 45 60 30 20 10 C2 45 100 30 20 10 | 165                     |
| Threading shaft      | MS Ø16 x 95 mm| C1 45 30 20 10 C2 45 100 30 20 10 | 225                     |
| Cartelling job       | MS Ø16 x 85 mm| C1 45 30 20 10 C2 45 100 30 20 10 | 360                     |
| Boring shaft job     | MS Ø51 x 55 mm| C1 45 30 20 10 C2 45 100 30 20 10 | 60                      |
| Eksentris job        | MS Ø25 x 55 mm| C1 45 90 30 20 20 C2 45 100 30 20 20 | 235                     |

Table 2. Analysis of working time usage conventional lathe.

* Design of sustainable production job

Viewed from table 2 shows that there is efficiency in achieving student competence in conventional lathe practice. Nearly one-third of the time is trimmed with job modification that utilizes a work piece. Although production processes are cut, the competencies achieved remain the same according to the practice of machinery in general.

The efficiency of material use can be seen from the material it processes [20]. The material uses mild steel with workmanship using a lathe. The results of the analysis using iProperties and 3D image inventor obtained the following results.

| Job analysis         | Used material  | Mass (kg) | Area (mm²) | Volume (mm³) |
|----------------------|----------------|-----------|------------|--------------|
| Basic turning        | MS Ø32 x 40 mm| 0.316 0.112 0.204 6.534,513 3.593,28 8 | 2.941,225 40.212,386 14.191,621 26.020,765 |
| Threading shaft      | MS Ø16 x 95 mm| 0.150 0.096 0.054 5.177,345 4.134,89 7 | 1.042,448 19.100,883 12.221,319 6.879,564 |
| Cartelling job       | MS Ø16 x 85 mm| 0.134 0.086 0.048 4.674,690 3.449,02 9 | 1.225,661 17.090,264 10.991,793 6.098,471 |
| Boring shaft job     | MS Ø51 x 55 mm| 0.562 0.253 0.309 10.321,703 9.693,38 4 | 628,319 71.498,722 32.246,878 39.251,844 |
| Eksentris job        | MS Ø25 x 55 mm| 0.212 0.092 0.120 5.301,438 3.053,79 7 | 2.247,641 26.998,062 11.722,853 15.275,209 |
| Modification Job*   | MS Ø30 x 75 mm| 0.389 0.155 0.234 8.011 5.572,30 2 | 2.439 49.480 19767.463 29712.621 |

Table 3. Analysis of the calculation of material consumption in each type of work.

Analysis of the table of the consumption of the eye shows that there is wasteful use of materials other than the modification job with the total weight value is 0.615 kg with the wasted volume 78.250,644 mm³. Compared with the mass and volume wasted by modification job, we can emphasize the efficiency of material usage by 30%. These results indicate that efficient material consumption can be reduced by 30% when conventional machining practice learning uses a modified work piece and facilitates 11
competencies required in the development of turning competencies. The emphasis on costs can also be reduced to 30% cheaper than the financing of existing practices.

Based on the results of research both cost efficiency, time and material consumption, the use of old or used work pieces has great benefits when used optimally. The minimal use of materials provides a reduction in material consumption that affects future survival [21], [22]. The skyrocketing of science and technology demands many ways to pass the time, energy, and cost [23], [24].

4. Conclusions
This study gives the conclusion that the use of organized job modification in 11 achievements of competency is considered to provide good work efficiency with time and material consumption of 30%. Consideration of using old or old work pieces in conventional machining practices can minimize costs to a minimum by not reducing the competencies achieved. In addition, the achievement of competence can be achieved effectively without wasting time. This research provides recommendations to conventional machining engineers to empower a work piece to achieve many competencies so that material and operational financing becomes cheap, the enrichment of teaching materials becomes profound, the time required for production to be short, and the effectiveness of the use of materials as optimal as possible.

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