

IMPLEMENTATION OF ENGINEERING PRODUCT DESIGN FOR SMALL-SCALED MECHANICAL WORKSHOP : A STUDY IN PURBALINGGA, CENTRAL JAVA, INDONESIA

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ABSTRAK

Desain rekayasa produk dapat dipahami sebagai kumpulan kegiatan rekayasa yang harus diikuti untuk menghasilkan produk-produk industri dengan kualitas baik. Dalam bentuk yang paling sederhana hal tersebut dapat dibangun dari tiga tahap utama, yaitu spesifikasi persyaratan desain, gambar dan purwarupa (prototyping). Untuk memberikan gambaran pelaksanaannya terkait dengan bengkel permesinan skala kecil purwarupa mesin penekuk plat dibangun sepenuhnya dari tahap spesifikasi persyaratan desain. Mesin ini dianggap penting karena mendukung proses manufaktur plate forming pada industri knalpot di Purbalingga, Jawa Tengah, Indonesia. Selama pembuatan purwarupa, komunikasi antara desainer, drafter dan bagian produksi telah diidentifikasi sebagai faktor utama yang bertanggung jawab dalam memproduksi kesalahan desain pada mesin tersebut di setiap tahap. Dengan demikian, strategi yang diusulkan, misalnya implementasi perangkat lunak rekayasa desain dan pengembangan pusat rekayasa desain di universitas, untuk meminimalkan hal tersebut dibahas secara singkat berdasarkan pendekatan kuantitatif.

Kata kunci: rekayasa desain, purwarupa, mesin bending, Purbalingga

ABSTRACT

Engineering product design can be understood simply as a collection of engineering activities that must be followed to produce good industrial products. In the simplest form it can be constructed from three major stages, i.e. specification of design requirements, drawing and prototyping. In order to give an overview of its implementation related to small-scaled mechanical workshop a prototype of plate bending machine is built completely from its design requirements. The machine is considered important because it supports standard manufacturing processes, i.e. plate forming, of muffler industries in Purbalingga, Central Java, Indonesia. During prototyping, communication among designer, drafter and manufacturer has been identified as the major responsible factor for producing design errors on the machine for each the stages. Thus, the proposed strategies, e.g. implementation of engineering software design and development of engineering design center in university, to minimize them based on quantitative approach are briefly discussed as well.

Keywords : engineering design, prototype, bending machine, Purbalingga

INTRODUCTION

Engineering product design can be defined as a complex process to transfer a functionality onto physical structures or product with the help of art and applied sciences (see Tong et al,

1992). Pahl and Beitz (1996) have defined necessary stages related to it as conceptualizing, embodying, detailing, and drawing with some necessary computations. All of them result in complex relationship among involved design parameters that can only be

managed by proper technical documentation of each stages as ruled by ISO Standard (ISO 10209:2012), for instance. While for customers the documentation must be transformed to user manual of product or equipment, for producers it is known as blue print or as built drawing for proper maintenance or development purposes.

From industrial point of view, lack of knowledge in engineering product design has been considered as the main obstacle for manufacturing industries in Indonesia, or Purbalingga in particular, to maintain global competition. Here, documentation of design activities mentioned before are still considered impractical due to some reasons, e.g. time consuming and costly. Drawings or prototypings or some related documents either for users or producers are often found not in systematically and standard manner. Hence, due to lack of technical specification and user manual this type of industries are still best known mainly to produce art products not industrial products. Additionally, Schrage and Peters in *Serious play: how the World's best companies simulate to innovate* (1999), for example, have suggested that design in general will be success as a product if idea can be realized first by drawing and prototyping.

To the best of author knowledge, studies on the engineering design aspects in remote industrial area similar to Purbalingga are none. Previous attempts are only focused on integrated solution of industrial supply chains and manufacturing systems. For examples, behavior of metal clustered-industries measured using dynamic system analysis has been proposed by Agustina et al (2011) to give correct prediction of appropriate policy by respective authorities. On the other hand, Hartono and Mulyantoin (2013) consider that product design is important aspect in metal casting industries in Ceper, Klaten, Central Java, but they offer solution only to improve technical skill on producing dies not for the products themselves.

This work is aimed to enrich the previous works by promoting engineering design approach to speed up technological development in dedicated industries in Purbalingga. It is obtained from implementation of the engineering design stages to manufacturing of plate bending machine with help of local workshop, i.e., Unit Pelaksana Teknis Daerah (UPTD) Logam Purbalingga. This participation is necessary to find actual information regarding current capability of the workshop to implement the approach. During manufacturing of the machine prototype,

communication among designer, drafter and manufacturer are identified and studied to find the major obstacle to build the bending machine from its prescribed design requirements. After the obstacles are identified, some recommendation for the respective authority and stakeholders are given.

This article will consist of six sections involving this section. In the following section, we present an overview of popular muffler industry in Purbalingga as the potential user of the bending machine. In third section, specification of design requirements of the bending machine is created and followed by sketching and drawing in the fourth section. While in the fifth section, manufacturing of prototype of the machine is discussed with respect to the previous design activities, concluding remarks involving recommendations are given in the last section.

Muffler industry in Purbalingga: an overview from engineering design aspects

Traditional ways of making mufflers in Purbalingga have been done for years though no reports indicate its starting date precisely. However, they only gain their popularity just in recent decades due to massive marketing by authority and respective communities. Nowadays, simple mufflers manufacturing technique by hand are still used with little additional supports from standard production equipment such as drilling and press machines. Information regarding previous attempts to improve technological aspects on manufacturing is limit though in fact several training on manufacturing such products by responsible office, i.e. Dinas Perindustrian Purbalingga have been held regularly. One of probably the most reliable article is written by Tjahjono et al. (2013) which focus on production aspect and product design of mufflers instead of studying for manufacturing machines for mass production.



Figure 1. Example of mufflers production site with simple or handmade manufacturing processes

Although in some industries application of standard manufacturing equipment is favorable, most of manufacturing process and respective equipment used in this industry are still not standard or hand-made as shown in Figure 1. On the other hand, demand on the standard equipment is often mandatory to increase production rate and to maintain reliable products based upon quality control requirements, simultaneously. Hence, to serve huge market from the growth of automotive industries in Indonesia, this demand has to be full filled first during technological leaving design of muffler products afterwards. The reason behind this can be understood from two different point of views. First, design of mufflers is not main issue in Purbalingga since there are numerous type of mufflers from Purbalingga successfully sold on-line in the internet. Second, there are some intensive efforts from the authority to supply automotive industries with muffler products from Purbalingga (Nugroho, 2011). Surely, in this case, mass production is the main critical issue instead of muffler designs.

After several visit to the industries, some important equipment are listed to three major categories according to their function in manufacturing of mufflers, i.e. bending, press and cutting. The bending machines are used to reforming the plate into shell of mufflers casing either by rolling mechanisms or direct flexural forces. While the press machines are dedicated to support a lot of activities such as stamping and punch working, the cutting machines serve as tools for reducing raw material of plate into desirable results for next manufacturing processes. However, since this work is just at the beginning into study of engineering product design of manufacturing equipment the bending machine is only chosen here. Additionally, muffler product design parameters are also

omitted in this work and left for future assessment.

Specification of Design Requirements

Since the focus on this work is to introduce only the use of standard engineering design stages and to gain feedback from it, design specification requirements of the bending machine will not be derived from intensive market research or dedicated survey in muffler industries. Otherwise, they are defined simply to ensure that the machine is complex enough and contains controlled mechanisms which requires multidisciplinary approach among designers, drafters and manufactures. This strategy offers an opportunity to assess capabilities and experiences of involved people in this project to work in a team until prototype of the machine is finished.

First design requirement is that the machine must be different in mechanism from commercially plate bending machine. This is also necessary to guarantee that the work will involves a few research activities not just copying similar equipment. Meanwhile, to increase production rate the machine must work using only 3 steps, i.e. (1) inserting plate, (2) simultaneously bending and pressing and (3) releasing, saving one step for pressing and bending compared to common plate bending equipment as shown in Figure 2.

Second design requirement is defined to ascertain that all materials for them are available in Purbalingga and its surrounding area. This requirement is important that the equipment can be constructed in Purbalingga in allowable time and prices with available skill. For example, steel profil used here as main frame of the machine must be sold in Purbalingga.

Finally, third design requirement supposes that the machine is simple in construction and mechanism which can be manufactured and assembled using existing equipment in workshop of the UPTD Logam Purbalingga. Thus, due to lack of CNC machine in the workshop, all parts of the machine are not allowed to have complex geometry which require advanced machining technique for example using computer aided manufacturing (CAM). Dimension of the machine must also support regular steel plates for mufflers with 50 cm in width and thickness of 1.2 mm. Its minimum height is 100 cm.

Sketching and Drawing

All requirements above are then proceed to sketching of the proposed machine configuration. Schuetze et al. (2003) has found that high quality in design outputs are related to proper sketching processes. To the best of author knowledge and after investigation since 2012 there have been a few muffler industries regularly working with sketching. However, none of them are interested to sketch their manufacturing machine in demand before. In fact, the industries has taken advantages from sketching with their capability to compete in national and even global market, e.g. the Van Volker muffler. Furthermore, because this work is intended to produce bending machine but not muffler, art design sketching is not the main objectives here.

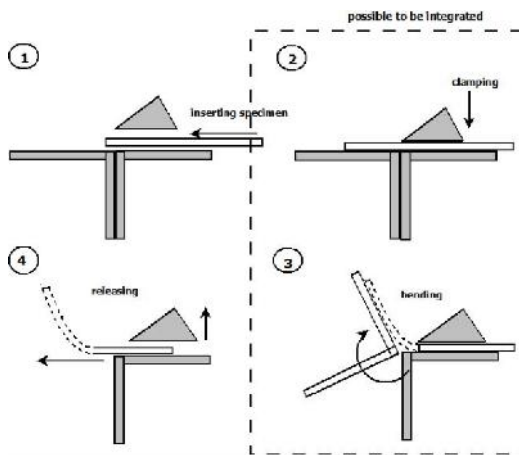
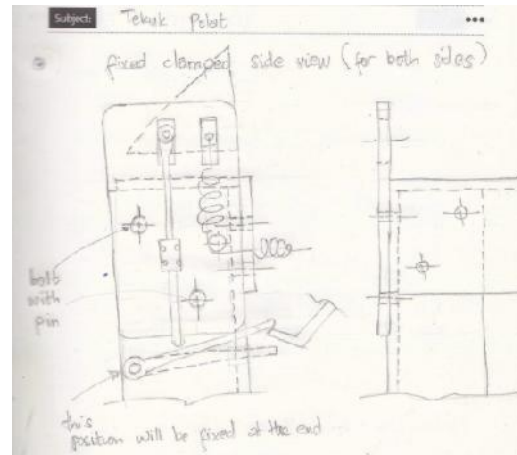
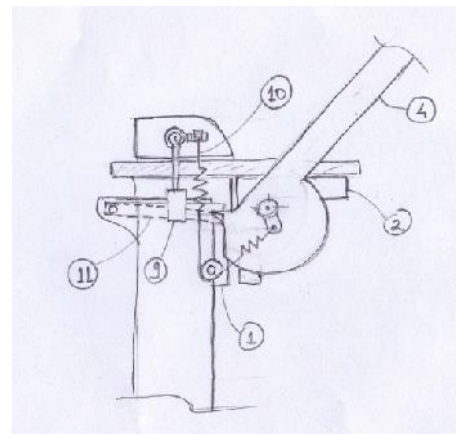


Figure 2. Regular bending mechanism of plate consist of four basic steps, i.e. inserting (1), clamping (2), bending (3) and releasing specimen (4). To increase rate of production this work proposed a mechanism to combine clamping and bending in one action.

The goal of this stage are to obtain the first geometrical impressions of the previous design spesifications by visualizing them without dimensioning or scaling. Here, the first design requirement is represented by sketch drawing as shown in Figure 3. In the figure spring mechanism is required to accomodate single handed system for clamping-bending-releasing processes. This system is much different than conventional bending machines commonly found in market which uses three different operations by hand.



(a)



(b)

Figure 3. The spring (in standard symbol) is used to transfer energy from hand-lever to clamping part by two alternative configuration (a) and (b) with numbering in (b) to identify different components.

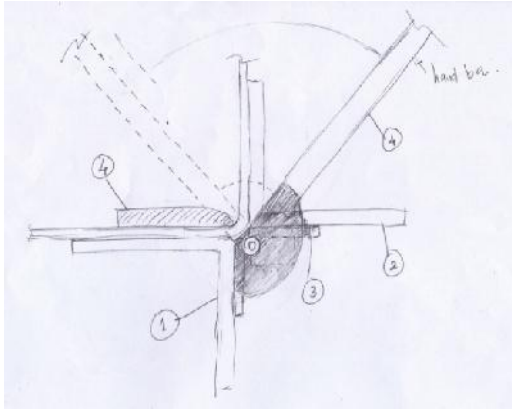


Figure 4. L-beam is used both for moving part to bend and structural components.

The second requirement is fulfilled by sketch drawing described in Figure 4 where no special materials are used, e.g. commonly found L-beam 40x40 used for structures and regular tensile-compressive spring. Although it is obvious that this machine does not require special material, the sketching process is still necessary to determine the most efficient use of raw materials. For examples, all supports for moving and stationary components are required to have same profile as the main structure.

Finally, the third requirement is implemented for example in overall structure which is simple and minimizing use of materials as shown in Figure 5. The height is not determined yet but must be less than 100 mm as mentioned before. Only regular milling and cutting processes are involved to form hole by drilling and to re-shape plate.

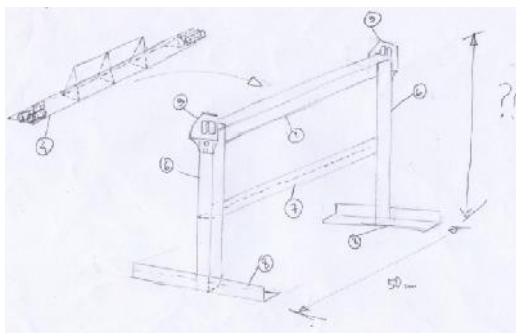


Figure 5. Structure of the bending machine is simple and using as few as materials and machining processes.

All of sketch drawings are then transformed by drafter to produce technical drawing with dimension. An example of such drawing can be shown in Figure 6 for the stationary clamping component. The sketch drawings are found very important for the drafter since they provide first information regarding configuration of the machine and location of its supporting components. Thus, comparing to direct drafting procedures by omitting sketching, dimensioning with such way has been found much faster since the drafter can focus only with the sketch and does not have to frequently access information directly from the design requirement specifications.

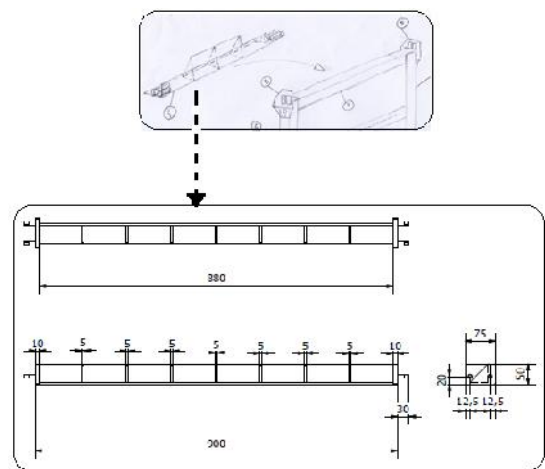


Figure 6. An example of transforming sketch drawing into technical drawing for the clamping component with minor modification for reinforcement and end-support. As reported by the drafter, the sketch is helpful not only to give initial impression for dimensioning but also to improve the design based on ease of manufacturing.

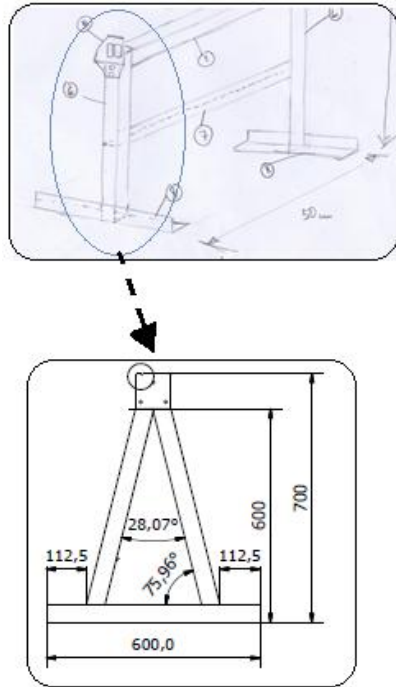


Figure 7. Further improvement in the main frame due to perceptual aspect of its sturdy

In general, during this stage problems related to disability of the sketch drawings to represent the design requirements are not identified yet. The transforming processes are quite smooth with respect to the drafter because modifications are still allowed, e.g. changes of the main frame in Figure 7, but not for major one such as in bending mechanism. However, cares must be taken at this time to ensure that the technical drawing produced are easy to be manufactured.

Analysis of prototyping

Manufacturing process of the machine is done in workshop of Unit Pelaksana Teknis (UPTD) Logam owned by the Purbalingga Authority. This workshop has been provided with standard machining i.e. lathe, drilling, cutting and milling, and welding equipment as shown in Figure 8. This typical workshop is commonly found in Purbalingga but less equipped than the UPTD Logam.

After examining the technical drawing, a person in-charge from the UPTD Logam dedicated to this project is chosen. Due to less complexities of machining processes and projects in hand, this is typical operating procedures in traditional workshop where

specializations are not important. For customers with new design or mechanism similar to this work the advantages of such procedure is obvious since discussion on necessary modifications on it can be done more effectively. However, in general this procedure is not recommended to be followed in case of precision and reliability of equipments or machines are the major concern which requires highly specialization personal in machining and joining techniques.

Converting the digital drawing to prototype of the bending machine during this work is quite difficult and tricky mainly because drafter and production personals do not have possibilities to make direct communication within each other due to distance. Consequently, several major modifications, i.e. related to improve mechanism and functionalities, in the drawing must be done without proper confirmation to the drafter. This even follows by further issue regarding modification in the drawing itself to accompany the semi-finished prototype. For example, one of major changes requiring radical modification in the technical drawing has been implemented to the clamping mechanism by re-location of spring and an addition of steel wire to control the clamping-releasing process.



Figure 8. Situation at the workshop of UPTD-Logam Purbalingga as the main manufacturing site for this work. Not all equipments shown here are involved directly during production process of the bending machine.

Furthermore, other two major design errors from the design stage are also found during prototyping, i.e. related to moving part supporting bending mechanism. The first error is detected due to assumption of no friction forces during

design, sketching and drawing. Omitting such forces lead to redesign of spring and other related component as seen in Figure 9. The second error has been detected after testing of prototype related to workpiece releasing procedures from clamping part. Not surprisingly, this fact is normal since several prototypes are commonly produced even in well-developed machine industries industry, e.g. automotive, to better fit the design requirements. On the other hand, both errors show importance of the use of simulation softwarebased on computer integrated design (CID) for which they can be detected earlier by using appropriate simulation.

From underlying technical aspects, capability of the UPTD Logam are quite high on making interpretation of the dimensional drawing for manufacturing purposes but moderate for analyzing kinematics employing velocity and acceleration. Because basic technical drawing capability had beentaught in senior technical school (SMK), the drawing interpretation is surely not a major obstacle even in many smaller workshop. What exactly required by the UPTD Logam and the similar workshop to capable on working with kinematic mechanisms is mechanical engineers with good background in design and experiences enough in manufacturing process. In case of difficulties to recruit such engineers, the major concern for improvement is relied in special training dedicated to kinematics related topics by focusing on spring-mass-friction combination and ways of design with it.

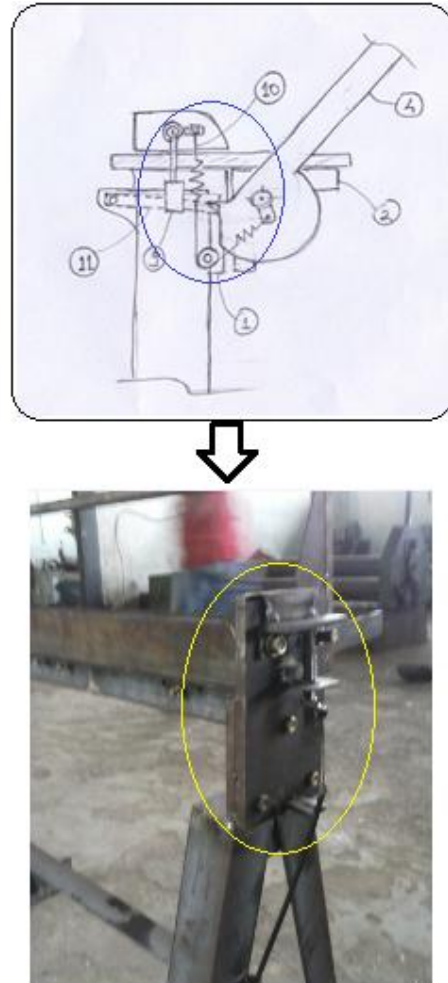


Figure 9. Necessary modification involving spring and steel wire (marked with circle) to accommodate clamp-release mechanism.

Another solution comes to universities to establish mechanical workshop with computer integrated design (CID) capability to serve integrated environment for virtual design and prototyping process simultaneously. In the future, it will be important for global competition since concurrent engineering using CID will dominate as it is proven to significantly shortening time and reduction cost for overall engineering product design stages.

CONCLUSION

Based on the prototyping analysis above, two main problems in Purbalingga, i.e. lack of design center and mechanical engineering workshop in university, have been identified responsible for improper results of the bending machine prototype. In the design center, the

above trial-error processes during design specification and sketching process can be done more effective to achieve the most reliable result for prototyping. As far as the author knowledge, it is unfortunately very rare located in rural area similar to Purbalingga. Finally, the absence of mechanical consultancies by nearby universities have led to difficult situation when kinematic mechanisms design need to be developed.

Surprisingly, none of problems are found related to production aspects such as joining, welding and milling at least for the bending machine prototyping. Capabilities of the workshop in the UPTD Logam to assembly and to build the machine are good enough.

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