Reducing steel scrap in fabrication of steel storage tanks

1Luma A H Al-Kindi and 1Wadood K K Al-Ghabban
1Asst. Prof. Dr. Production Engineering and Metallurgy Department, University of
Technology/Baghdad/Iraq

Email: luma.alkindi@gmail.com

Abstract. This paper focuses on reducing steel scrap in the process of fabrication of steel storage tanks. Reducing steel scrap is important for society to decrease the environmental influence, save natural resources and to decrease the greenhouse gas emissions and energy usage associated with steelmaking that is considered as a valuable resource in industry. “4Rs” i.e. Reduce, Reuse, Recycle and Restoring the materials are being considered as strategies of solid waste management. Production of any product causes waste which has little economy for the main production process, but those waste products also have an economic value, which can be improved by processing. A methodology to reduce steel scrap is proposed and applied on a case study which is; a job order for manufacturing (17) storage tanks of capacity (55) m$^3$ in the Heavy Engineering Equipment State Company (HEESCO). Scrap evaluation for each area, volume and weight is calculated. The percentage of area, volume and weight of plates used in the current situation are (13.609%), (15.875%) and (15.875%), respectively. After applying the proposed method the percentage of area, volume and weight of plates used are (6.666%), (8.154%) and (8.153%), respectively. The amount of improvement rate in reducing steel scrap generated is (51.017%) of the area (48.636%) and volume (48.642%) of weight. This amount of improvement rate and the evaluation of the steel scrap generated are considered as a valuable resource in steel fabrication industry.

Keywords
Reduce, Steelmaking, Valuable resource, Steel scrap, Storage tanks fabrication.

1. Introduction
Reduce, reuse, recycle and restore of material, the "4Rs", could be a source of raw material in industry. Steel scrap plays an important role in the processing and final production of new products [1]. Suitable reuse and recycling of solid waste produced in steel manufacturing process can meet the request of a potential resource for satisfying growing shortages of energy and materials [2]. Generation of the waste in industry is related to the industrial growth process and rise in demand. Production of any beneficial product frequently causes waste, but the question is that “Are they really a waste” [3]. Steel waste utilization is reliable with the ‘zero waste’ policy and they should be additionally investigated, taking into account the opportunities of development, modernization and construction [4]. With rising shortages of energy and materials, waste could be treated as a possible resource complying with Environmental law and regulations and the economics of disposal [5].

Steel is undoubtedly the essential material of the up-to-date technology driven society. Since steel covers a class of over 2500 different grades presently produced and used, there is an extensive variety of properties leading to an even broader spread of uses. Ferrous scrap is very important for society to lessen the environmental impact related with steelmaking. Recycling considers melting of scrap into new products, which substitutes natural resources used for steelmaking [6]. Recycling of ferrous
This section presents different studies published in the recent years concerning the paper’s subject that utilizes different approaches; these literature reviews can be summarized as follows:

**Sarkar and Mazumder (2015)** [2] focused in their study on the increasing shortages of energy and materials, waste to be treated as a possible resource complying with Environmental rule and regulations and the disposals’ economics. They concluded that in Indian steel industry most economic management practices for reducing the generation of solid wastes and maximizing the recycle of collected wastes can be opted in considering the waste as raw material of related industry on the base of avoiding secondary pollution. Solid wastes as possible raw materials are to be reused and also to be altered into new products. Reducing solid waste, by reusing and recycling to make a zero waste generation is really a challenge to the steel industry nowadays. **Smol (2015)** [4] focused on the efforts of Poland steel sector to lessen their impact on the environment, adopting the principles of cleaner production (CP). The restructuring of the industry and application of new eco-technologies affected an increase in share of material recycling, including steel scrap recovered in production processes and from post-use recycling. Depending on the form of steel waste, it can be returned to the method as energy source or raw material for steel production or else be traded as co-product to further industrial applications. Such directions of steel waste utilization are consistent with the strategy of ‘zero waste’. **Milford (2010)** [9] presents a study that focuses on reuse without melting, reuse of steel scrap has the potential to reduce CO₂ emissions that depend on the style of metal. Steel sheet is typically manufactured by a primary route and has an emissions factor of (2.51) kg CO₂ per sheet, ignoring any additional emissions arising from reuse. Reuse chances exist for the steel and aluminum scrap being produced, but more opportunities could be generated for future scrap by the adoption of design for reuse principles, such as mechanical fastenings and part standardization. Other opportunities for reuse could exist for other steel and aluminum products such as in building and civil engineering, mechanical engineering /machinery, shipbuilding and other classes. Changes in product design could raise the potential of reuse. **Nkansah et al. (2015)** [10] in their study about scrap metal’s role in circular economy in Ghana, using Sunyani as a case study, focused on scrap of metals that create jobs in Ghana. Reuse and recycle as a resource in a circular economic growth for Ghana encourages scrap metals usage, to improve economy, reduce use of virgin materials by transferring scrap into appropriate collection sites and foundry stations for recycling. This work recommended that the Sunyani city and the government of Ghana should offer policy, educational and sensitization tools to the public about the value and chances of scrap metals as business unit and job creation. Additional recommendation focused on construction of new recycling and foundry stations to avoid high transportation cost due to long shipping distance.
to final destination points of sales and recycling or reuses. Okechukwu et al. (2015) [11] in their study “The evaluation of costs rework and scrap in manufacturing industry”, focused on cost volume analysis. Rework and scrap caused by errors, omissions, failures, change orders, machine failure, poor maintenance, poor staffs training, poor quality management and poor design. They tried to lessen the money spent on rework by recommending preventive maintenance, motivation of workers, enhance quality management, procuring of materials and repair parts, etc. These policies if properly applied will help to improve products and process performance regarding cost, time and quality in industry. Al-Kindi (2016) [12] in her paper suggested a "Road Map" for a heavy engineering equipment company to make use of huge amounts of steel by using Lean Manufacturing as one of the best ways to run in industrial sector. Steel is one of the most used materials in the fabrication of heavy engineering equipment industry and steel scrap presents a real problem. Applying Lean concepts to reduce and eliminate steel scrap accumulation over the years is performed, and accordingly save a lot of resources. Suggestions are to make use of this expensive waste by using it for other items or rehabilitate it and preparing the rest waste by pressing it to blocks in order to simplify shipping for foundries for recycling.

3. Aim of this Study
The aim of this study is to build a methodology for reducing scrap for solid waste focusing on steel products by:
- Minimizing generation of steel scrap.
- Reduction of steel scrap in manufacturing process.
- Reduce costs and environmental damage by evaluation of steel scrap.

4. The Proposed Method
The proposed method defines a preparation stage in production of any product; Scrap is evaluated in this stage before applying manufacturing processes. Figure (1) shows the proposed method. Where: (Spp) is the calculated scrap according to preparation stage, (Tpi) is the total plate input, (Lm) is the loss metal and (X) is a percentage of cutting loss metal determined according to each company.

5. Design Stage

![Figure 1. The Proposed Method](image-url)
Design is the creation of a plan or convention for the construction of an object. Design often requires considering the dimensions and measurements required for a particular product. It could be a design according to the customer’s demand or according to standards. In this stage the following steps are performed.

5.1 Preparation of the bill of material for the product
It is the first step of this stage where preparation of bill of material is performed as tables consisting of Part No., Description, Metal type, Specification, No. of pieces and Net size.

5.2 Providing of actual dimension
Selection of material and providing of actual dimension is performed on which the next step depends.

5.3 Preparation
After using new store materials, the paper preparation is followed. Traditional method is often used in paper preparation to build graphic detail parts for a product and with the possibility of try and error. This is an old way and consumes a lot of metal, time and cost. Solving such problem requires advanced ready software to simplify process solution and get accurate cutting pattern results.

5.4 Calculate the utilization rate of scrap
The next step is calculating the utilization rate of scrap. Percentage of utilization rate of scrap is calculated by dividing scrap generated due to paper preparation (Spp) on total plate input (Tpi) using the following equation:

\[
\text{Utilization rate of scrap} = \frac{\text{Spp}}{\text{Tpi}} \times 100\% 
\]

The percentage of utilization rate of scrap generated from preparation is calculated for area, volume and weight using the following equations:

\[
\text{Utilization rate of area} = \frac{\text{scrap area}}{\text{total area of plates used (input)}} \times 100\% \quad \text{…..Eq. (1)}
\]

\[
\text{Utilization rate of volume} = \frac{\text{scrap volume}}{\text{total volume of plates used (input)}} \times 100\% \quad \text{…..Eq. (2)}
\]

\[
\text{Utilization rate of weight} = \frac{\text{scrap weight}}{\text{total weight of plates used (input)}} \times 100\% \quad \text{…..Eq. (3)}
\]

5.5 Asking whether the utilization rate of scrap is > 10%
If it is greater than (10 %) then improving preparation is required and if not then proceeding for the next stage is adopted. To improve paper preparation proposed method could be used. The aim is to minimize the amount of scrap in sheet metal produced during cutting. Different software could be used which aims to minimize the amount of scrap in the raw material by analysing the shapes to be produced and using algorithms to determine how to lay parts in a sheet metal for producing the required quantities of the shapes. The purpose is to place and interlace various shapes of same thickness on a given plate in such a way that the utilization of the plate is maximized whilst the scrap is minimized. Similar is a process that tries the combination of parts like a jigsaw puzzle.

The main goal of this stage in the proposed method is to help fabricators to get most parts from every sheet of metal. Less scrap means fewer sheets and, thus, lower material costs. Then to be transported to the next stage; Manufacturing process stage.

6. Implementation the Proposed methodology
In this paper an implementation of the proposed methodology has been adopted as a case study in the Heavy Engineering Equipment State Company (HEESCO). The quantity, value, and type of scrap are evaluated. The field work was started in January 2016 and ended in Augusts, 2016 lasting a period of eight months. Hence, this period of study was chosen for effective collection of data, for the purpose of completing the study. In this case study a job order is selected with the number of (111/5) for manufacturing (17) storage tanks of capacity (55) m$^3$ which are used for the storage of petroleum products; the customer is the ministry of oil. Figure (2) shows a model for full storage tank with a capacity of (55) m$^3$. The manufacturing process in the Heavy equipment factory is followed up, taking into consideration the amount and type of scrap generated in the preparation process in order to apply the proposed methodology.

![Figure 2. Storage tank with a capacity of (55) m$^3$ [13]](image)

7. Current Situation for preparation of Job Order No. (111/5)

The engineers seek to minimize the scrap value by best use of the available plates. To reach zero scrap, that is a great challenge in product design optimization. It is supposed to use standard plates to lessen scrap. This process in the company is traditional, where ratio of error is high because of depending on trial and error in preparation. Preparation is not accurate, required much time and more amount of scrap is generated.

![Figure 3. Preparation as used in the company](image)

Figure (3) shows the traditional process for preparation used in the company. In this figure it is noticed that large amount of scrap is generated due to such traditional preparation. The data used for this study were collected from the company through direct observation and interviews with the staff. The method used for preparation is drawing with AutoCAD program, depends on try and error besides engineers’ skills and experience. Preparation is transferred to the cutting machines that use oxygen and gas. The amount of scrap generated will be calculated for the storage tank product.

To illustrate the scrap generated while manufacturing the job order number of (111/5) storage tank; area, volume, weight are calculated for scrap generated in according to the method used in the company. Table (1) shows the bill of materials for manufacturing (17) storage tank with the name of each part of the storage tank; type of metal used, net size of each part, the required number of pieces to manufacture parts for (17) storage tank, the size of the plates available in the company's store, the amount of plate required to manufacture each part, as well as the scrap area, volume and weight calculated for each part. Table (2) illustrates the amount of required plates to manufacture (17) storage
tanks, with the details of dimensions and thickness for each, besides calculation of total summation of the area, volume, and weight.

**Table 1.** Bill of material for manufacturing (17) storage tank

| No. | Item name       | Metal  | Net size                        | Volume use plate | Pieces require | Size available plate | Volume real plate | Amount plate | Scrap area m² | Scrap volume m³ | Scrap weight Kg |
|-----|-----------------|--------|---------------------------------|------------------|----------------|---------------------|-------------------|--------------|----------------|----------------|----------------|
| 1   | Shell           | St37   | 8.640*1.5m*5mm                  | 77.75            | 102            | 6*1.5m*6mm          | 54                | 153          | 55.68         | 331.5          | 2802.3         |
| 2   | Head            | St37   | Ø 2.93m*6mm                     | 53.91            | 34             | 6*1.5m*8mm          | 72                | 34           | 77.61         | 615.05         | 4828.3         |
| 3   | Man way cover   | St37   | Ø 0.72m*10mm                    | 4.09             | 17             | 6*2m*10mm           | 120               | 1            | 5.081         | 50.82          | 393.93         |
| 4   | Man way flange  | St37   | Ø 0.057m*10mm                  | 1.24             | 17             | 6*1.5m*10mm         | 120               | 1            | 9.892         | 98.92          | 776.52         |
| 5   | Bolt and nut    |        |                                 |                  |                |                     |                   |              |               |                |                |
| 6   | Pad-A           | St37   | Ø 0.057m*6mm                   | 1.63             | 17             | 6*1.5m*6mm          | 54                | 2            | 13.359        | 80.29          | 630.27         |
| 7   | Pad-B           | St37   | Ø 0.3*3.89m*6mm                | 2.88             | 17             | 6*1.5m*6mm          | 54                | 1            | 0.704         | 5.04           | 32.56          |
| 8   | Pad-C           | St37   | Ø 0.3*3.6m*8mm                  | 5.64              | 34             | 6*1.5m*8mm          | 72                | 1            | 42.74         | 251.22         | 1972.07        |
| 9   | Lifting lug     | St37   | 0.14*0.15m*20mm               | 0.294            | 34             | 6*1.5m*20mm         | 180               | 1            | 8.5           | 170            | 1334.5         |
| 10  | Lifting pad     | St37   | 0.2*1.0*6mm                    | 0.12             | 34             | 6*1.5m*6mm          | 54                | 1            | 8.32          | 49.92          | 379.19         |
| Total|                |        |                                 |                  |                |                     |                   |              | 264.162       | 2007.01        | 15755.05       |

* All shaded blocks are calculated by the researches

**Table 2.** Total summation of plates used in the current state

| No | Amount plate | Dimension (m) | Thickness (mm) | Area plates | Volume plates | Weight plates |
|----|--------------|---------------|----------------|-------------|---------------|---------------|
| 1  | 169          | 6*1.5         | 6              | 1521        | 9126          | 71639.1       |
| 2  | 43           | 6*1.5         | 8              | 387         | 3096          | 24303.6       |
| 3  | 2            | 6*2           | 10             | 24          | 240           | 1884          |
| 4  | 1            | 6*1.5         | 20             | 9           | 180           | 1413          |
| Σ  | 215          |               |                | 1941        | 1264.2        | 99239.7       |

To calculate the percentage of area, volume and weight of plates used to manufacture the job order of No. (111/5) that consist of (17) storage tank, the following equations are used.

\[
\text{Utilization rate of area} = \frac{\text{scrap area}}{\text{total area of plates used (Input)}} \times 100\% = \frac{264.162}{1941} \times 100\% = 13.609\%
\]

\[
\text{Utilization rate of volume} = \frac{\text{scrap volume}}{\text{total volume of plates used (Input)}} \times 100\% = \frac{2007.01}{12642} \times 100\% = 15.875\%
\]

\[
\text{Utilization rate of weight} = \frac{\text{scrap weight}}{\text{total weight of plates used (Input)}} \times 100\% = \frac{15755.05}{99239.7} \times 100\% = 15.875\%
\]

Where; (264.162), (2007.01) and (15755.05) are calculated as mentioned in Table (1) (1941), (12642) and (99239.7) are calculated as mentioned in Table (2)
8. Applying the Proposed Methodology

Applying the proposed methodology aiming to reduce steel scrap generated during preparation, reusing of scrap generated to be used for a second product or recycling. To improve preparation in the company, maximization of the beneficial areas in a plate should be adopted to reduce scrap generated. The advantage of rearranging parts as suggested in the proposed method is to get the lowest amount of scrap generated, fast production process, less time in the cutting process and precision of preparation in allowances used. Figure (4) shows a prototype for rearranging preparation to be adopted in (HEESCO).

![Prototype for preparation to minimize scrap](image)

Figure 4. Prototype for preparation to minimize scrap

To compare the difference between the method used in the company and the proposed method, Table (3) shows the bill of materials includes the area, volume, and weight of the remaining scrap of each part of manufacturing (17) storage tank.

Table 3. Bill of material with area, volume and weight calculation

| No. | Item name       | Metal | Net size                      | Volume use plate | Pieces require | Size available plate | Volume real plate | Amount plate | Scrap area m² | Scrap volume m³ | Scrap weight Kg |
|-----|-----------------|-------|-------------------------------|------------------|---------------|----------------------|-------------------|--------------|----------------|-----------------|-----------------|
| 1   | Shell           | St-37 | Ø 0.72m*10mm                 | 0.640*1.5m*6mm   | 77.75         | 102                  | 6*1.5m*6mm       | 54           | 147           | 7.01           | 215.04          |
| 2   | Head            | St-37 | Ø 0.62m*8mm                  | 3.91             | 34            | 6*1.5m*8mm           | 72                | 34           | 77.01          | 615.08          | 4828.2          |
| 3   | Man way cover, flange | St-37 | Ø 0.72m*10mm, OD 0.72m*10mm, ID 0.61m*10mm | 4.069 | 17 | 6*2m*10mm | 120 | 1 | 4.58 | 45.86 | 360 |
| 4   | Man way flange, Lifting lug | St-37 | Ø 0.62m*10mm, ID 0.61m*10mm, 0.14m*0.10m*10mm | 1.24 | 13 | 6*2m*10mm | 120 | 1 | 9.38 | 73.63 |
| 5   | Man way gasket  |       |                               |                  |               |                      |                  |              |               |                 |                 |
| 6   | Bolt and nut    |       |                               |                  |               |                      |                  |              |               |                 |                 |
| 7   | Pad-A, Pad-B    |       |                               |                  |               |                      |                  |              |               |                 |                 |
| 8   | Man way neck, Pad-B |       |                               |                  |               |                      |                  |              |               |                 |                 |
| 9   | Pad-B, Lifting pad, Man way neck, Pad-A |       |                               |                  |               |                      |                  |              |               |                 |                 |
| 10  | Pad-C           |       |                               |                  |               |                      |                  |              |               |                 |                 |
|     | Total           |       |                               |                  |               |                      |                  |              |               |                 |                 |

Table (4) illustrates the total summation of plates when using the proposed method, it indicates the amount of input plates, required for manufacturing (17) storage tanks, with the details of dimensions and thickness for each, also total summation of the areas, volumes, and weights is mentioned.

Following of the proposed method the percentage of area, volume and weight of plates used in manufacturing of job order number (111/5) that consists of (17) storage tank is calculated using the following equations:
Where; (119.799), (944.25) and (7412.15) are calculated as mentioned in Table (3) (1797), (11580) and (90903) are calculated as mentioned in Table (4)

Table 4. Total summation of plates used in the proposed state

| N0 | Amount of plate | Dimension (m) | Thickness (mm) | Area plates | Volume plates | Weight plates |
|----|----------------|---------------|----------------|-------------|--------------|--------------|
| 1  | 158            | 6*1.5         | 6              | 1422        | 8532         | 66976.2      |
| 2  | 39             | 6*1.5         | 8              | 331         | 2808         | 22042.8      |
| 3  | 2              | 6*2           | 10             | 24          | 240          | 1884         |
| Σ  | 199            |               |                | 1797 m²     | 11580 m³     | 90903 Kg     |

9. Comparison calculation and discussion result

To compare the current method of preparation in the company and the proposal; improvement rate calculation is conducted. The improvement rate in area, volume and weight, between the two situations can be measured using the equation illustrates below; the Table (5) shows summary results for comparison between two methods and the improvement rate in area, volume and weight.

\[
\text{Improvement rate in area} = \left(\frac{13.609 - 6.666}{13.609}\right) \times 100\% = 51.017\%
\]

\[
\text{Improvement rate in volume} = \left(\frac{15.875 - 8.154}{15.875}\right) \times 100\% = 48.636\%
\]

\[
\text{Improvement rate in weight} = \left(\frac{15.875 - 8.153}{15.875}\right) \times 100\% = 48.642\%
\]

Table 5. Summary of the results comparing between two situations

|            | First method | Second proposed method | Improvement rate |
|------------|--------------|------------------------|------------------|
| Area       | 13.609 %     | 6.666 %                | 51.017 %         |
| Volume     | 15.875 %     | 8.154 %                | 48.636 %         |
| Weight     | 15.875 %     | 8.153 %                | 48.642 %         |

These results are obtained as shown in Table (5) the amount of improvement rate in reducing steel scrap generated in the process of the preparation is (51.017%) m² of the area, (48.636%) m³ of the
volume and (48.642%) Kg of the weight. These percentages represent the amount of improvement rate as an evaluation of the scrap generated that is considered as a valuable resource in the industry.

The outcome has been summarized to compare the difference between the current situation and proposed method. The cost saving of the weight scrap remaining is calculated, the result is (8,342.9 Kg). To evaluate its cost, the price for each kilogram of steel-37 is (1.5) dollar. Accordingly, the cost saved using the proposed method is equal about (12,514.35) dollar.

10. Conclusion
The main conclusions are:
1- Evaluation of solid waste toward increasing the percentage of reduced materials and cost reduction is performed focusing on steel industry.
2- A case study in the Heavy Engineering Equipment State Company (HEESCO) is applied to compare between the improvement rate in the current situation and the after applying the proposal.
3- The proposed method is adopted in the preparation processes for manufacturing (17) storage tanks in (HEESCO); results show that the amount of scrap generated is reduced with the percentage of (51%) in the area, (48%) in the volume and (48%) in the weight.
4- The weight of scrap remaining in this case study for this job order is (8,342.9 Kg) which means that and the cost saved is about (12,514.35) dollars.

References
[1] Burgess S C and McMahon C A 2006 Reducing waste: remanufacture or recycle Sustainable Development 14(4) pp 257-267
[2] Sushovan S and Debabrata M 2015 Solid Waste Management in Steel Industry - Challenges and Opportunities International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering Vol 9 No.3
[3] Mukuldev K 2018 Process Waste Generation and Utilization in Steel Industry Department of Metallurgical & Materials Engineering. OP Jindal University Raigarh India International Journal of Industrial and Manufacturing Systems Engineering Vol 3 No.1 pp1-5 Received: April 14(2018) Accepted: May 2 (2018) Published: May 11(2018)
[4] Marzena S 2015 Towards Zero Waste in Steel Industry: Polish Case Study Journal of Steel Structures & Construction 1:1, DOI: 10.4172/2472-0437.1000102.
[5] Sushovan S and Debabrata M 2016 Solid wastes generation in steel industry and their recycling potential https://www.researchgate.net/publication/275654751 Conference Paper March 2015, All content following this page was uploaded by Sushovan Sarkar on 21 February 2016
[6] Cygler M and Wolf M 1986 Continuous strip and thin slab casting of steel an overview Iron Steelmaker 13(8), pp 27-33
[7] Martchek K J 2000 The importance of recycling to the environmental profile of metal products Fourth International Symposium on recycling of metals and engineered materials Pittsburgh USA
[8] Zaman A U and Lehmann S 2011 Zero Waste City Zero Waste South Australia Research Centre for Sustainable Design and Behaviour School of Art Architecture and Design University of South Australia, pp 14-15
[9] Milford R 2010 Re-use without melting: scrap re-use potential and emissions savings Mechanical engineering 17
[10] Nkansah A Attiogbe F and Kumi E 2015 Scrap metals’ role in circular economy in Ghana, using Sunyani as a case study African Journal of Environmental Science and Technology 9(11) pp 793-799
[11] Ezeanyim O C Onwurah U O Okoli N C and Okpala C C 2015 An Evaluation of Actual Costs of Rework and Scrap in Manufacturing Industry Journal of Multidisciplinary Engineering Science and Technology ISSN: 3159-0040 Vol. 2

[12] Al-Kindi L A 2016 Sustainability for Heavy Engineering Equipment Industries Using Lean Concepts Eng. &Tech. Journal Vol. 34 Part (A) No. 4

[13] Https://www.heesco-iraq.com