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Sustainability for Heavy Engineering Equipment Industries Using Lean Concepts

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Abstract

Steel is one of the most used materials in the industry. In particular, Steel is the dominating material used in the fabrication of heavy engineering equipment. It is estimated that the world's annual production of Steel is 1500 Million tons. One of the best ways to reduce such environmental hazard is by recycling of Steel. Recycling of Steel is widely implemented and in terms of tonnage Steel is the most recycled material in the world. Currently, it is estimated that 85% of annual steel production is recycled worldwide. Sustainability benefits of recycling steel include conserving valuable natural resources and raw materials and eliminate negative environmental effects. However, in many cases, handling and transportation of scrap steels to recycling facilities and locations may not be feasible due to many reasons such as transportation cost, scrap bulky sizes and shapes, or scrap quantities. Therefore, in such cases Steel scrap presents a real problem to relevant industries; heavy engineering equipment industries present an example of suffering industries.

Lean Manufacturing is one of the best ways to run a manufacturing company and Lean principles have been successfully applied in many industries in the last two decades or so.

In this paper a "Road Map" for a heavy engineering equipment company is suggested to make use of huge amounts of steel by recycling. A case study is selected to be on one of the Iraqi Ministry of Oil Companies. The aim is to develop and apply Lean concepts to reduce and eliminate Steel scrap accumulation. The paper takes into consideration the actual accumulated Steel scrap resulting from the company processes for ten years. The results of the paper show that applying of the Lean concept will beneficially lead to reducing the accumulated scrap over the years and accordingly save a lot of resources. The conclusions demonstrate that sustainability is fruitful to be adopted in this area.

Key words: Sustainability, lean, heavy engineering industry, recycling

الاستدامة في صناعة المعدات الهندسية الثقيلة بأستخدام مبادىء الترشيق

الخلاصة:

يعتبر الحديد الماد الاساسية والأكثر استخداما في الصناعة، وعلى وجه الخصوص في تصنيع المعدات الهندسية الثقيلة. وتشير التقديرات إلى أن الإنتاج السنوي من الصلب في العالم هو ١٥٠٠

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مليون طن. على الرغم من وفرة خردة الصلب فانه يتفكك ويعود مرة أخرى إلى الطبيعة من خلال الأكسدة (عملية الصدأ)، ولكن الوقت اللازم لهذه العملية قد يستغرق سنوات خصوصا إذا كان حجم الخردة كبير إلى حدما. ولذلك فان خردة الصلب قد تشكل خطرا على البيئة.ان من أفضل الطرق للحد من هذا الخطر البيئي من خلال إعادة تدوير الصلب. يتم تنفيذ إعادة تدوير الصلب على نطاق واسع عالميا ويعتبر الصلب المادة الأكثر وزنا المعاد تدويرها في العالم . حاليا، تشير التقديرات إلى أن ٨٥ ٪ من إنتاج الصلب سنويا يتم إعادة تدويرها في جميع أنحاء العالم . ان إعادة تدوير الصلب تؤثر ايجابيا على الاستدامة من خلال الحفاظ على الموارد الطبيعية الثمينة والمواد الخام، والقضاء على الآثار البيئية السلبية. ومع ذلك، في كثير من الحالات فان إعادة التدوير للحديد قد لا تكون ممكنة لعدة أسباب منها صعوبة النقل والمناولة لخردة الحديد والتي تؤدي الى تكاليف اضافية بسبب خصوصية المواقع والأحجام والأشكال الضخمة لكميات الخردة. لذا تعتبر خردة الصلب مشكلة حقيقية للصناعات ذات الصلة وبالأخص صناعات المعدات الهندسية الثقيلة.

يعتبر التصنيع الرشيق احد أفضل الطرق لتشغيل الشركات الصناعية وان مبادئ الترشيق قد طبقت بنجاح في العديد من الصناعات في حدود العقدين الأخيرين.في هذه الورقة تم اقتراح "خريطة الطريق" لشركة المعدات الهندسية الثقيلة للاستفادة من كميات ضخمة من الصلب عن طريق إعادة تدوير . تم اختيار حالة لدراستها في واحدة من شركات وزارة النفط العراقية بهدف تطوير وتطبيق مفاهيم الترشيق للحد والقضاء على تراكم الصلب الخردة. وتأخذ الورقة بعين الاعتبار خردة الصلب الفعلية المتراكمة الناتجة عن عمليات التصنيع في الشركة لعشرة سنوات. نتائج الورقة تبين أن تطبيق مفهوم الترشيق تؤدي إلى الحد من الخردة التي تراكمت على مر السنين، وبالتالي انقاذ الكثير من الموارد الثمينة. وتبين النتائج أن الاستدامة مثمرة ومن الواجب اعتمادها في هذا المجال.

الكلمات المرشدة: الاستدامة، الترشيق، صناعة هندسية ثقيلة، اعادة التدوير

INTRODUCTION

As a result of the rapid development of industry, air pollution by waste smokes and gases formed by industrial processes has become a problem of vital importance. There is constantly up to 9 million tons of aerosols in the Earth's atmosphere, further development is inevitable and, consequently, so is an increase in the amount of harmful substances released into the atmosphere. Millions of tons of iron and steel are diverted from the waste stream to the recycling stream. Recycling saves energy for the recycled products require less energy to manufacture, thus conserving oil and reducing greenhouse gas emissions. More than 14 Million cars in North America were recycled in 2006 [1].

Lean stresses on Eliminating waste, not just a reduction, of all types of waste and creating value, and lean principles have been successfully applied in many industries. Sustainability is “meeting the needs of the current generation without compromising the ability of future generations to meet their needs.” Sustainability (like lean) has a good track record of improving company finances because of the emphasis on eliminating waste.

Ecology is a subject of worldwide interest in contemporary international relations. It is defined as a correlationship of living organisms between themselves and their adaptations to the environment. The impact of technology on global environments has focused attention on the study of ecology so that man lives in harmony with the physical and biological environments and with other living organisms [2]. It is necessary to examine the extent of sustainable development that global environments can permit.

Lean concepts:

"Lean Thinking" [3] stresses on Eliminating waste, not just a reduction, of all types of waste and creating value. Lean operation is a concept that involves eliminating non-value added activities [4]. Lean is concerned with delivering more value for the business and its customers by increasing the velocity of throughput and minimizing wasteful practices by balancing process flow [5].

Lean manufacturing was first coined in 1990 in the book "The Machine that Changed the World" as a result of a five years benchmarking study across many automobiles organizations with the sole purpose of understanding differences in quality and productivity to reflect the waste reduction nature of the Toyota production system and to contrast it with craft and mass forms of production [6]. Although there are many quoted origins for many of the founding concepts for lean production, most people recognize the Toyota Production System (TPS) as initially bringing together all of the essential elements required to implement a complete lean manufacturing process.

Lean Principles [7] are Build Value, Eliminate Waste, Build Integrity In, Amplify Learning, Localize Responsibility, Delay Commitment, Deliver Fast and Optimize the Whole.

Eliminating Waste:

Lean Thinking [3] is the removal of muda. Muda- Is a Japanese word for waste. Waste is any activity that absorbs resources & creates no value.

Waste is considered in the widest sense as any activity which does not add value to the operation [4]. Lean defines different types of waste that are tackled to minimize or eliminate them. They are as follows [5,8,9 and10]:

1. Waste of Overproduction occurs if more products are manufactured than it was planned.
2. Waiting Time, Delays & Transportation are clearly unwanted non-value adding activities which should be minimized and avoided wherever possible.
3. Extra-Processing is additional unnecessary stages within the process, such as an intermediate packing activity that could be improved through facility re-layout.
4. Over Stocking occurs either through poorly synchronized purchasing practice or over production.
5. Waste of Unnecessary Movements of people such as operators and mechanics walking around, looking for tools or materials.
6. Waste due to a routine manufacturing process which is accomplished due to process plan, such as waste of sheets when performing cutting to get the required shapes.
7. Waste of Defects and rework appears on locations where semi-manufactured products accumulate and therefore intermediate storage is required.
8. Excessive Motion within the process should be avoided. The point of output from one process stage should ideally be the point of use for the next stage.

Common lean tools for capturing and analyzing processes toward achieving the objective of eliminating the eight forms of wastes, in order to bring the most value to the customer are [5]:

- Process Mapping
- Value Stream Mapping
- Pareto analysis
- 5S (Workplace Organization)
- Fishbone analysis
- Poke Yoke (error proofing)
- Total Productive Maintenance

- Kaizen and Kaikaku
- Standardized Work

The 5s System is originated from 5 Japanese words that starts with 'S' Seiri, Seiton, Seiso, Seiketsu and Shitsuke. These words translated into English are; Sort, Set Shine, Standardize and Sustain. Some companies add a sixth S, Safety, to classic 5S, which implements the social side. A few add a seventh S, Sustainability [1]. Kaizen and Kaikaku is simply means, "Continuous improvement" in Japanese and is used as an improvement tool [8].

Sustainability and steel recycling:

Although abundant or scrap Steel disintegrate and return back to nature by the oxidation (rusting process), the time required for such process may take years if scrap size is considerably larger. Hence, Steel scrap may present hazards to the environment. In urban areas, heavy metals in soils and dusts can be accumulated in the human body via direct inhalation, ingestion, and dermal contact absorption [11]. Millions Tons of iron and steel are diverted from the waste stream to the recycling stream due to steel's magnetic properties that make it the easiest material to separate from the solid waste stream [12]. Steel products can be recycled repeatedly without loss of strength.

More than 80 Million tons of steel are recycled each year in North America. But more steel is recycled than paper, plastic, aluminum and glass combined. Table (1) shows the tons recycled in North America from January 2015 till May 2015 [13].

Table (1). Tons recycled in North America from January 2015 till May 2015 [13]

Material	Steel	Paper	Aluminum	Glass	Plastic
Tons	30,681,046	20,817,838	1,859,457	1,265,239	953,982

Sustainability (like lean) has a good track record of improving company finances because of the emphasis on eliminating waste and the substantial increase in creativity by employees at all levels [1]. Figure (1) shows the huge amounts of metal waste.

Figure (1). Huge amounts of metal waste

Sustainability benefits of recycling Aluminum and Steel by conserving valuable natural resources and raw materials. Avoiding air and water pollution by using recycled materials generally creates less pollution and save landfill space by closing the loop. Recycling ensures materials don't become litter and reducing the need to dig for virgin materials conserves soil integrity and wildlife habitats. When buying steel, it is always recycled [10]. Recycling saves energy for the recycled products require less energy to manufacture, thus conserving oil and reducing greenhouse gas emissions [14]. Gases and dust are formed in the Calcining plant when the products of combustion of gas and fuel oil are sucked through the layer of pellets [15]. Trends in the production and use of metals show that worldwide stocks of metals in use by society are increasing. At the end of its use, this metal stock is an increasingly valuable resource. Therefore, future metal production must not only focus on ore mining, but also on recycling [12].

Proposed Road Map Construction:

Heavy engineering equipment industries are specialized in designing and/or manufacturing of heavy engineering products such as fuel storage tanks of various capacities, various towers, pressure vessels, heat exchangers, steam boilers and variety of equipment for oil production, petrochemical and food industries...etc. Most of these equipments are made of steel with different types, stainless steel and sometimes Aluminum; these raw materials are very expensive. The manufacturing process for producing such heavy products leads to huge amounts of waste. For heavy engineering equipment industries waste accumulated due to point 6 (Waste due to routine manufacturing process) and point 7 (Waste of Defects and rework) as stated previously within lean concepts. The core of the suggested methodology to construct the "Road Map" in this paper is focusing on lean concepts by reducing and recycling of waste.

In workshops that fabricate heavy engineering equipment, special facilities is required besides depending predefined raw materials. According to the historical data and experience in such workshops the raw material requirements for main three products that are heat exchangers, storage tanks and pressure vessels; are as follows [16]:

- For Heat Exchangers: 33% plate sheets, 17% Tube sheets (forged disks), 4% dish heads, 39% tubes, 7% nozzles, 10% sections.
- For Storage tanks: 20% lower end, 20% upper end, 52% shell, 8% nozzles.
- For Pressure vessels: 67% shell, 14% dish heads, 11% pipes and sections, 8% nozzles.

Welding electrodes for these equipments are aproximately 5%, while the waste percentage is about 20%.

The proposed road map methodology is shown in Figure (2). This methodology could be applied after creating two workshops besides a scrap yard as follows:

1. The first workshop is for rehabilitation.
2. The second workshop is for preparing waste for recycling.
3. Scrap yards.

The decision regarding location of such facilities requires a careful balancing of several factors. These factors are [17] Available of raw material, Nearness of market for the finished product, Availability of fuel and power, Transport facility, Availability of labor and Availability of water.

The first workshop has cutting operation, welding operation and machining operations. If the waste is plates with dimension of one meter square and more, then it will follow the following route:

Cutting with right angles corners ⟶ welding preparation ⟶ welding ⟶ measuring ⟶ Stamping ⟶ to store

Figure (2). Proposed road map methodology

If the waste is less than one meter square, but more than 6mm thickness then the following route is recommended:

Cutting to one of the shapes shown in figure (3) ⟶ Machining if required ⟶ Measuring ⟶ Stamping ⟶ To Store

This workshop is located as near as possible from fabrication workshops in order to receive waste plates for refabricating; as well as near the stores of raw material to stamp the rehabilitated plate as a finished product of this workshop. This location enables availability of fuel and power, transport facility, labour as well as water.
The second workshop has pressing operation and handling facilities. It is located near the scrap yard and near the shipping point with the availability of fuel and power, transport facility, labour as well as water. The waste which is not rehabilitated is accumulated in the scrap yard to be transferred to the press machine in order to press it as blocks to make it easier for handling and shipping. These scrap blocks as shown in Figure (4) are ready for shipping to the steel foundry for recasting.

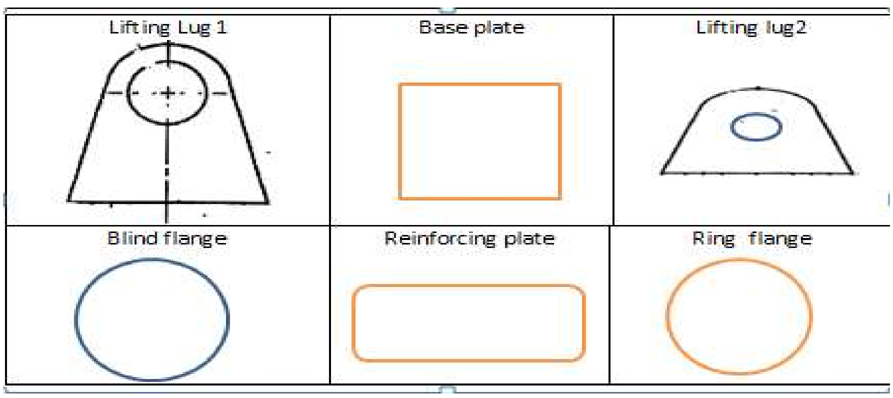


Figure (3). Some shapes to be used in heavy engineering equipment

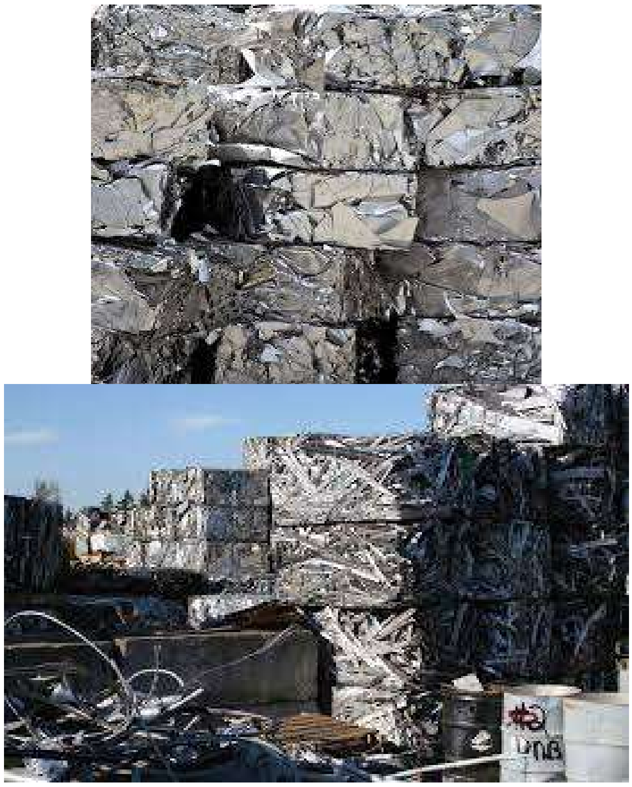


Figure (4). Scrap blocks after pressing

Case study in the Heavy Engineering Equipment Company:

Heavy Engineering Equipment Company (HEESCO) is an important industrial company in Iraq and it is the biggest company in the field of heavy industries. It was established in 1963. HEESCO is specialized in designing and/or manufacturing of heavy engineering. The company has occupied a working area of more than 55000 m^2 and more than 2700 employees (engineers, technicians, workers and administrators) involved.

The case study in HEESCO takes into consideration three sights of view. Firstly a description of the factories and workshops is presented to take the decision regarding location of the proposed workshops and scrap yards, making use of Google earth map. Secondly, the calculation of the waste is performed according to the designed capacities and actual capacities for ten years depending data gathered from the company. The third point of view focus on the waste due to routine fabrication by adopting a product (pressure vessel) and discuss the probabilities of waste and how to be rehabilitate of recycled.

Firstly:

The company has four factories and sixteen workshops that could produce heavy equipment up to five meter diameter, thirty meter length and eighty tons weight as shown in Table (2).

The four factories of the company are:

(a) Vessels and Storage Tanks Factory: The factory has separate independent workshops (W). These workshops are:

- Workshop for producing under/over ground storage tanks and transportation storage tanks, plus parts for huge storage tanks (W3).
- Workshop for producing pressure vessels with light weights made of carbon steel (W4).
- Workshop for producing pressure vessels and towers made of carbon steel (W5).
- Workshop for producing stainless steel products (W6). This workshop has a 3500 Ton press, which is not fully occupied.
- Machining workshop (WM). This workshop has many turning and milling machines.
- Sand-blast workshop (WSB)

Each of the first four workshops can produce final product, the main operations and workstations in these workshops are cutting, preparing, and bending, rolling, welding, assembling, and testing.

(b) Heavy Equipment Factory: This factory is the biggest one. The factory consists of six dependent workshops' halls (H). H1 and H2 is for preparation, the main operations in these halls are sandblasting, hot and cold cutting, bending and rolling. H3 is specialized in machining; while H4, H5 and H6 are for assembling**.**

Table (2). Specifications and dimensions of the products [18]

Product	**Volume and Dimention**	**Material Thickness**
1. Storage tank for imported oil products	1100 m^3 - 8200 m^3	6 - 31mm
2. Refining towers and high pressure vessels	diameter: 2m -5m length is: 15 m per piece weight is: up to 70 ton per piece *	10 -65 mm
3. Heat-exchanger	diameter is: 0.35-2m length is: 15 m weight is: up to 30 ton	8 -10 mm for shell 25–300mm (tube-sheet)
* If vessel weight exceeds 70 ton, or 15 meter long, manufacturing should be in pieces and to be assembled or constructed on-site.		

(c) Heat Exchangers Factory (HE): This factory has three workshops for shell side and tube side heat-exchangers manufacturing.

(d) Steam Boilers Factory (HM): This is specialized in producing fire tube boilers and parts of water-tube boilers. It has two halls (HM1) for preparing and (HM2) for assembling.

All these factories have almost the same facilities with some differences in worker's experience, machine's capabilities, and transportation and handling facilities. The suggestion location for the first and second workshops and the scrap yard in HEESCO pointed in the google earth map shown in figure (5). The 1st workshop is near the stores and near the machining workshop, while the 2nd workshop is near W6 which has the Press with 3500n Ton. Two scrap yards are suggested and located as shown in figure (5). The scrap yards is located near the railway for cargo train to facilitate transfer the scrap blocks to the foundries.

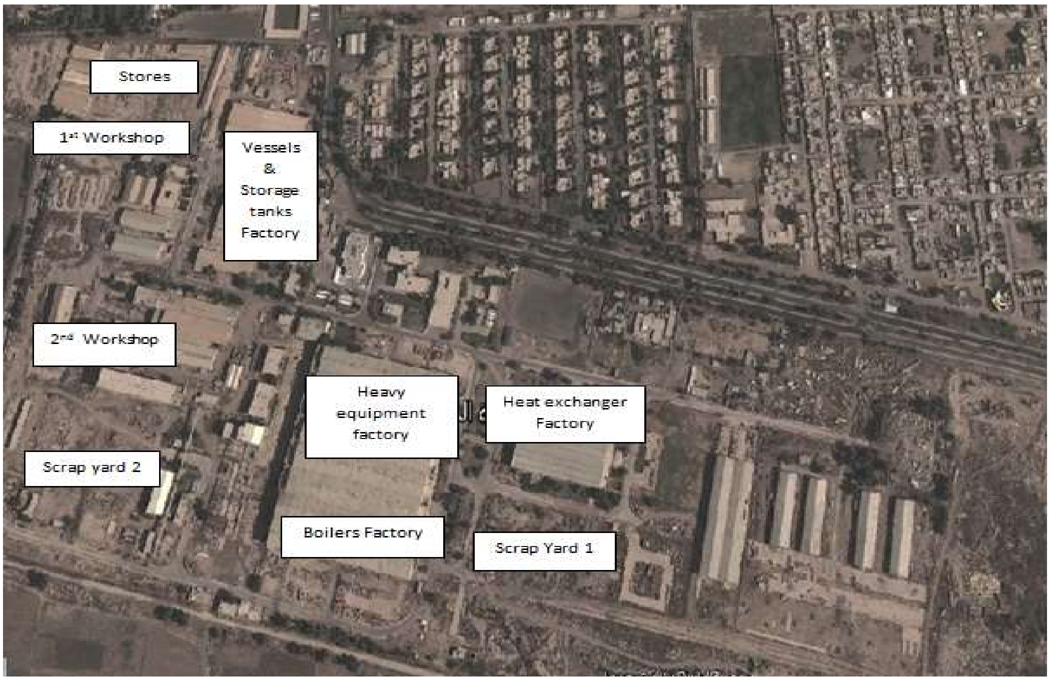


Figure (5). Google earth map for HEESCO's Factories and Workshops

Secondly:

The designed capacities for HEESCO according to the type of equipment are shown in table (3) as well as calculated plates used in fabrication of these equipment according to the percentage mentioned previously.

According to the calculation in Table (3) it is noticed the average waste per year due to the designed capacity is 4852 ton. That means approximately 4.852 million US dollars yearly. This value is compared by the value calculated according to actual achieved capacities for HEESCO during ten years as shown in Table (4).

The actual capacities and related calculation for ten years shows that the average value of waste per year is approximately 1.166 million US dollars. The waste to be checked for rehabilitation is 1166 ton yearly following the proposed road map.

Table (3). Waste Calculated According to Designed Capacities in HEESCO

	Product Name	Designed Capacity	Calculated % of plates used	Plates used per (Ton)
1	Storage And Exporting Fuel Tanks	20000 Ton /Year	92%	18400
2	Towers And High Pressure Vessels	6000 Ton /Year	81%	4860
3	Heat Exchangers and boilers	2000 Ton /Year	50%	1000
Sum				24260
Waste				4852

Table (4). The Actual Achieved Capacities during Ten Years [18]

Year	Production Quantity (Ton)	Waste (Ton) 20%	Cost for waste Waste(Ton)* (1000$)
1	7757	1551.4	1551400
2	8545	1709	1709000
3	7134	1426.8	1426800
4	7430	1486	1486000
5	4860	972	972000
6	4475	895	895000
7	6812	1362.4	1362400
8	5030	1006	1006000
9	3118.77	623.754	623754
10	3141.64	628.328	628328
Sum	58303.41	11660.682	11660682
Average/ year		1166.0682	1166068.2

Thirdly:

One of the products that could be manufactured in HEESCO;s workshops is pressure vessels, Figure (6) shows a sample of detailed drawing for such products and another figure more detailed for this product is shown in Figure (11) Appendix (A). The bill of material of this pressure vessel consists of 32 item. Item 1 is the shell with the dimension as follows:

Internal diameter ID=1200 mm

Length L= 2300 mm

Thickness Thk=20 mm

For preparation of shell, first calculation of the required plate is performed as follows:

The length of the required plate = (1200+20/2) * π = 3800

The width of the required plate = 2300

Thickness = 20

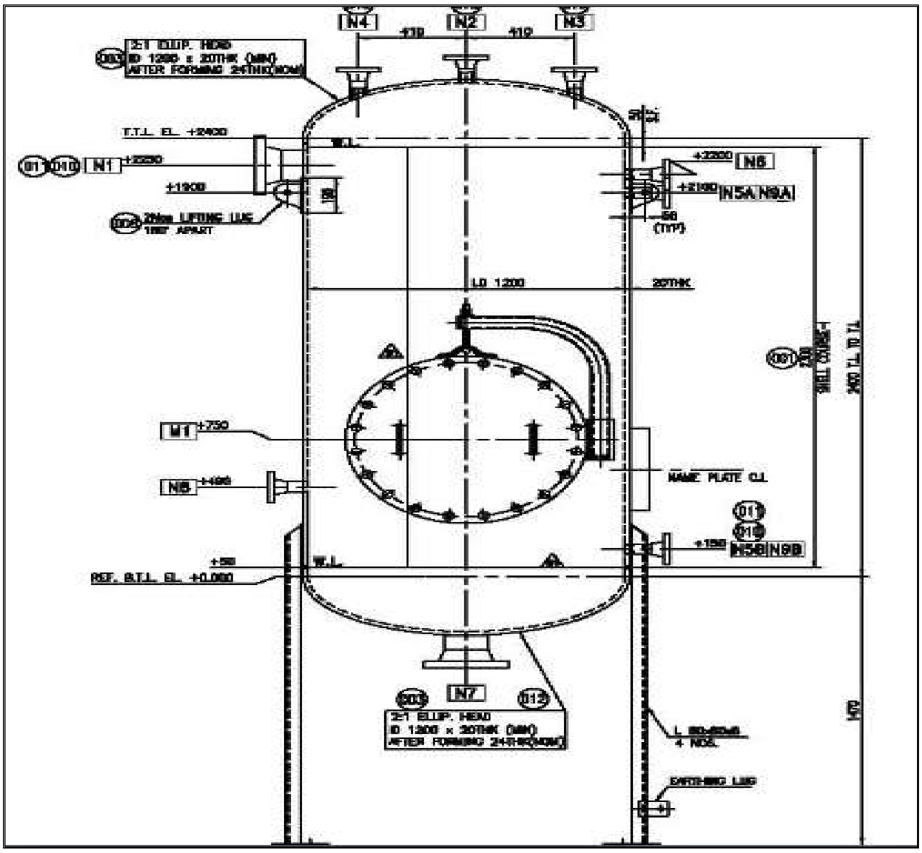


Figure (6). Sample of a Pressure Vessel

The dimension in millimeter of the raw material plate might be one of the following:

- 6000 *2000*20
- 6000* 3000*20
- 12000* 2000*20
- 12000* 3000*20

Figures (7), (8), (9) and (10) shows the preparation of the shell as only one item of the pressure vessel respectively.

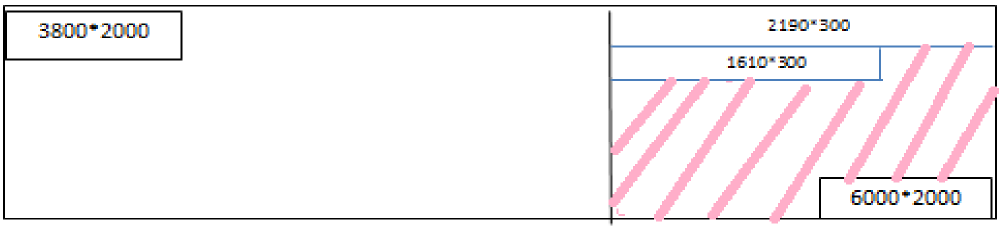


Figure (7). Preparation Using 6000*2000mm Plates

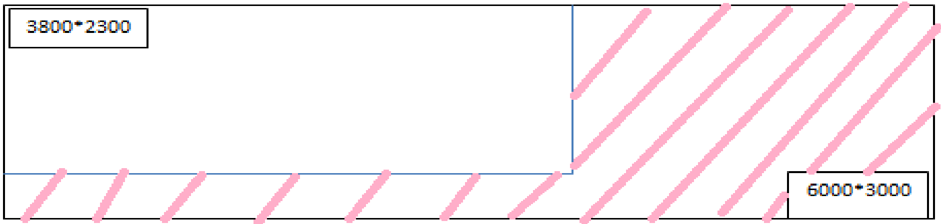
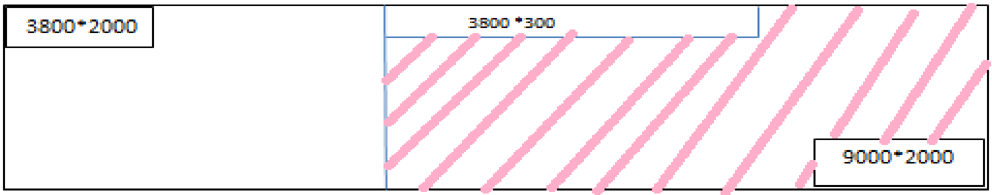


Figure (8). Preparation Using 6000*3000mm Plates



Figure(9).Preparation Using 900*2000mm plates

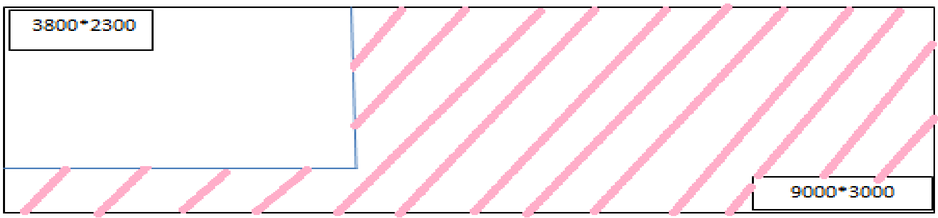


Figure (10). Preparation using 9000*3000mm plates

Following the road map methodology starting with raw material that could be one of the plates mentioned above, then manufacturing in workshops and the waste is due to routine manufacturing. Figures (7), (8), (9) and (10) show preparation of the shell (item 1) using four different plates and how the remaining areas of the plates differ accordingly. Calculation of the cost of the rest of the plates for these figures are as follows:

- Length * Width * Thickness * Density
  600cm*200cm*2cm*7.85g/cm3= 1884000 g = 1.884 ton
  {(380*200)+(219.6*30)+(161*30)*2*7.85 = (76000+6588+4830)*15.7=1372462.6=1.372
  1.884 – 1.372 ≈ 0.5 ton
  It's worth ≈ 500$
- Length * Width * Thickness * Density
  600*300*2*7.85= 2826000 g = 2.826 ton
  380*230*2*7.85 = 1372180 g =1.372 ton
  2.826 – 1.372 = 1.454 ton
  It's worth ≈ 1454 $
- Length * Width * Thickness * Density

900*200*2*7.85= 2826000g = 2.826 ton
{(380*200) + (380*30)}*2*7.85 = (76000+11400) *15.7 = 1372180 g = 1.372 ton
2.826 – 1.372 = 1.454 ton
It's worth ≈ 1454 $

- Length * Width * Thickness * Density

900*300*2*7.85= 4239000g = 4.239 ton
380*230*2*7.85 = 1372180 g =1.372 ton
4.239 – 1.372 = 2.867
It's worth ≈ 2867 $

Noticing the cost of the rest of these plates after cutting the plates for the shell motivates following the proposed methodology. Accordingly the rest of the used plates are dimension measured and the if it is not less than 1meter square, then the next step is rehabilitation by cutting, welding and stamping to get plates with square ends to be stamped and transferred to the stores. The rest of the plate could also be used for preparation of other items with or without welding. According to the road map if the waste is less than one meter square, but with thickness more than 6mm, then it worth rehabilitation especially for making items such as shown in Figure (3).

Conclusions and suggestions:

The steel price worldwide is very high and heavy industries deals with huge amounts of steel, therefore a waste of heavy equipment manufacturing worth thousands of dollars. Following the proposed road map in this paper means making use of this expensive waste by using it for other items or rehabilitate it and preparing the rest waste by pressing it to blocks inorder to simplify shipping for foundries for recycling. A case study in heavy engineering equipment company HEESCO is adopted from three points of views, firstly a decision for the location of the proposed workshops is made to make use of Google earth map and the existed facilities especially the press machine and the machining workshop and the scrap yard is located near the railway to facilitate transfer by cargo train. Secondly, the calculation of the waste is performed according to the designed capacities and actual capacities for ten years, depending data gathered from the company, it is noticed that the average waste per year due to the designed capacity is 4852 ton which means approximately 4.852 million US dollars yearly. The actual capacities and related calculation for ten years shows that the average value of waste per year is approximately 1.166 million US dollars. The waste to be checked for rehabilitation is 1166 ton yearly following the proposed road map which is the third point of view that focus on the waste due to routine fabrication by adopting a product (pressure vessel) and discuss the probabilities of waste and how to be rehabilitate of recycled.
The Suggestion for extending this work might deal with Preparing for detailed design for the shaped obtained from waste cutting and Adopting nesting software for the maximize benefiting of waste plats.

Appendix (A)

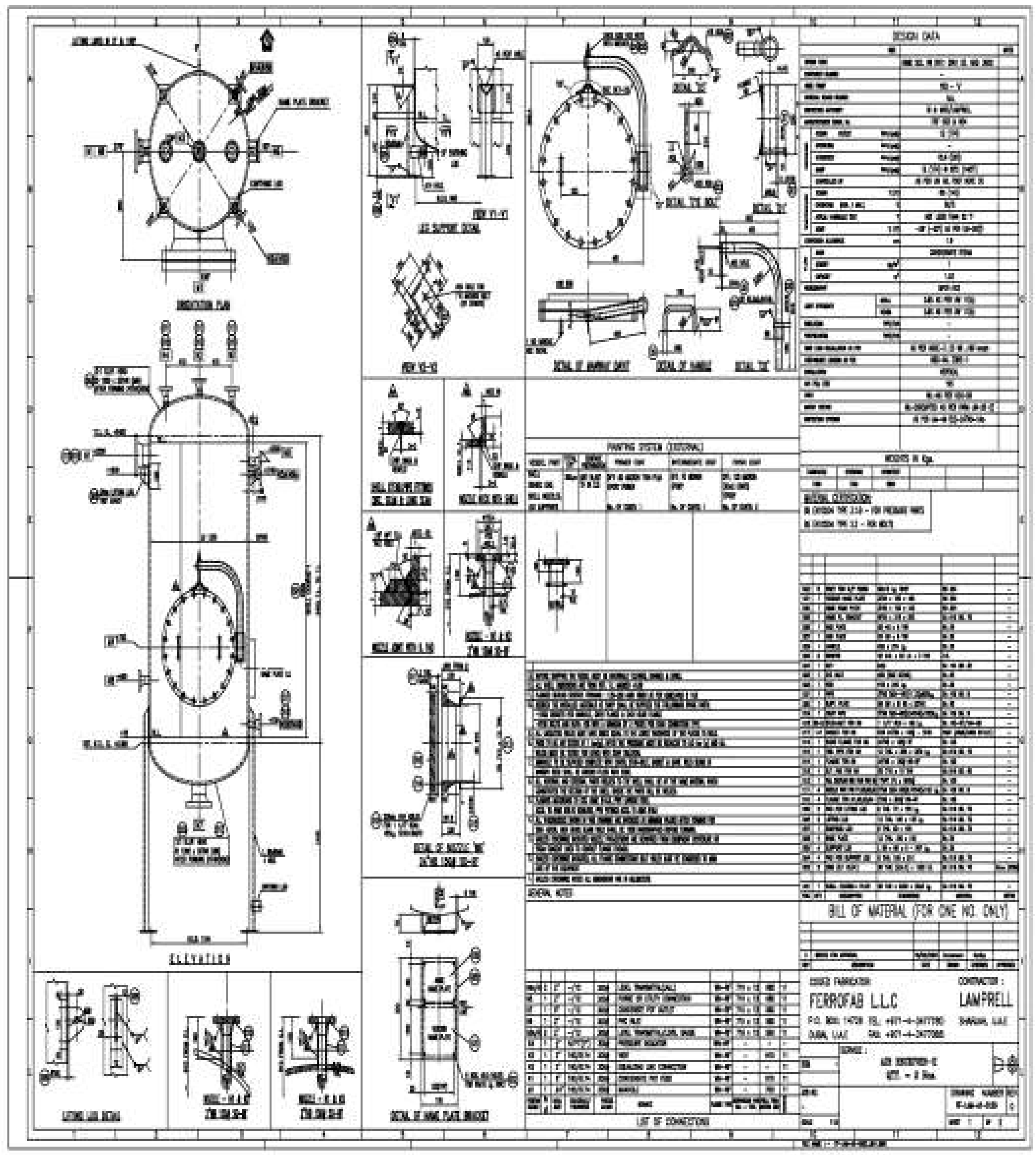


Figure (11). Blue Print shows the pressure vessel with more details

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