1st Questionnaire Exemption No. 6a (renewal request)

Exemption for „Lead as an alloying element in steel for machining purposes and in galvanised steel containing up to 0,35 % lead by weight“

Response to the Oeko-Institut questionnaire on RoHS exemption 6a prepared and submitted by EGGA and EUROFER

Abbreviations and Definitions

Pb	Lead
EEE	Electrical and Electronic Equipment
EGGA	The European General Galvanizers Association
EUROFER	The European Steel Association
WEEE	Waste of Electrical and Electronic Equipment

Background

The Oeko-Institut and Fraunhofer IZM have been appointed within a framework contract[1] for the evaluation of applications for the renewal of exemptions currently listed in Annexes III of the new RoHS Directive 2011/65/EU (RoHS 2) by the European Commission.[1]

The European Steel Association (EUROFER) and the European General Galvanizers Association (EGGA) have submitted a joint request for the renewal of the above mentioned exemption, which has been subject to a first evaluation. The information you have referred has been reviewed and as a result we have identified that there is some information missing and have formulated a few questions to clarify some aspects concerning your request.

Eurofer & EGGA propose an altered wording which is similar to the currently existing wording of the corresponding exemption 1(a) under the ELV Directive 2000/53/EC:
“*Lead as an alloying element in steel for machining purposes and in batch hot dip galvanized steel items containing up to 0.35% lead by weight*.”

[1] Contract is implemented through Framework Contract No. ENV.C.2/FRA/2011/0020 led by Eunomia

Questions

1. **Eurofer & EGGA state that "*Batch galvanized steel is used in a variety of small components (eg brackets/fixings) and fasteners used in electrical equipment within the scope of WEEE*."**
    a. **Please provide an exhaustive list of the Electrical and Electronic Equipment (EEE) applications for which batch galvanized steel is applied (alternatively please provide a list of application sub-groups).**

An exhaustive list is not feasible. Batch galvanized items may include ancillary items such as fasteners and support brackets/fixings for a range of EEE items such as lighting units that require high levels of durability in outdoor or aggressive environments. Specific components include transformer housings and heat exchangers (although some of these items may be outside the current scope of the EEE directive). It must be emphasized that the term 'small' is a relative one and is used in the renewal request in the context of the range of items that are batch galvanized – a range that includes large structural steelwork of up to 25m length. Components that are termed 'small' in this request may not be 'small' in the wider context of EEE components.

    b. **Please provide an estimation of the share in batch hot dip galvanization that still need the intentional addition of lead and the share where lead is present as an impurity of zinc.**

No data exists to respond with any meaningful estimation. It must be noted that there are no other limitations on the use of lead in the galvanizing process and the proportion of components coated that are within the scope of the WEEE directive is very small in volume terms. Decisions on the intentional use of lead or the use of recycled zinc would not be solely influenced by the processing of EEE-related components.

2. **Please provide details on the unintentional content of lead in the recycled zinc used for batch galvanizing processes.**
    a. **Please provide information where the recycled zinc is typically derived from (what end-of-life applications?) to clarify how the lead is introduced.**

Recycled zinc may be from two main sources:

- Recovery and remelting of scrap zinc sheets from roofing/gutter applications. Many of these scrap arisings are from roofs of cities such as Paris that have been installed >100 years ago. These roofing sheets/gutters were historically joined with lead-based solders. These solders are impossible to separate from the scrap zinc sheets and enter the recycling circuits – giving rise to lead levels in recycled zinc of 1-2%.
- Recovery and remelting of metallic zinc that is entrained in zinc ash generated during the galvanizing process (through surface oxidation). These residues are fully recyclable and the metallic zinc part is separated and returned to the galvanizing bath. In a particular region, the lead content of the recycled zinc from this route will reflect the lead content of the galvanizing bath(s) that supply residues to a specific recycler. Note that those prevailing levels may be influenced by both intentional use and use of recycled zinc. Levels are therefore variable and can be in the range 0.5 – 1.2%.

In some cases, recycled zinc may be produced from a mix of the above routes. Please also note that there is not a direct correlation between the lead content of the process bath and the lead content of the galvanized steel component. Typically, the lead content of the coating is lower than the content of the bath from which it is produced.

b. How do you expect the lead content to decrease in the future as articles, manufactured after the lead restrictions of the RoHS and ELV Directives were introduced, reach end of life?

As a proportion of a total 7 million tonnes of steel that is batch galvanized in Europe, the volume of components in the scope of ROHS and ELV is extremely small (they are technically important but low volume to the batch galvanizing industry). Also, no other components in the scope of ROHS/ELV interface with the recycling circuits mentioned above. However, there are other factors that will eventually lower the lead levels – notable customer-driven requirements for lower lead levels in markets outside EEE/ELV and the occasionally higher price of lead than zinc (affecting intentional use). There will also, in the longer term (> ~50 years due to the very long product life), be a reduction in the lead-content of recycled zinc arising from scrap roofing/gutters (as new solders are introduced).

3. **As for the lead in steel alloys used for machining purposes, Eurofer & EGGA state that "*Machining steels are used in a diverse range of final applications within electrical and electronic equipment, including finished products, fixed installations etc.*"**
   Please provide an exhaustive list of EEE applications or of application sub-groups for which such steel is applied.

The supply chains for free cutting steels are long and complex, with many different actors, including stockists and intermediate processors. The producer of the free-cutting steel itself rarely has detailed, if any, contact with the final EEE producer (or even the producer of the components that become part of EEE). As such, it is only possible to identify a non-exhaustive list of the EEE products / components that leaded free-cutting steels are typically used in / specified for. Typical components are fuel injector systems, hydraulic clips, keys, motor shafts, fasteners, printer shafts, and a wide range of office equipment parts, for example, lap top screen screws.

Free-cutting leaded steels may be produced via either the BOS steelmaking route or the EAF steelmaking route. The two process flow descriptions below have been provided by one company that produces leaded steels through both routes:

BOS route: The feedstock is hot metal from a blast furnace, typically supplemented with 15% to 20% of pre- and post-consumer scrap. This is refined to remove carbon and other unwanted elements such as phosphorous in a BOS converter. Lead is added under controlled conditions in a secondary steelmaking operation. Liquid steel is then continuously cast to a 283 by 230mm bloom and hot rolled in a rod mill in sizes from 5.5mm to 16.0mm. The material is a semi-finished product. Downstream customers clean the as-rolled rod and apply a light draw to the material to produce a true round. This is generally a "bright draw" to give a mirror surface. The material will then be machined depending on the end application.

EAF route: The feedstock is ~100% pre and post-consumer scrap. It is melted in an electric arc furnace (EAF). Lead is added under controlled conditions in secondary steelmaking. This is continuously cast into large bloom then hot-rolled to 100mm slab at a billet mill. This is then hot rolled to strip (typically 3.5-5mm thick) at a strip mill and pickled in HCl solution for supply to the immediate customer. Typically, this material will then be cold rolled, annealed and then cold rolled again (~40-50% total reduction), slit, stamped, nickel plated and finally machined.

4. **Please provide data as to whether the 0.35% threshold of lead in steel can be reduced further for either galvanisation applications or for machining purpose applications.**

Batch Galvanized steels

For batch galvanizing applications, it may be possible to lower the threshold as the current limit originates from the requirements for steel for machining purposes. Assuming any wording continues to make clear it is calculated for the entire steel item, a limit of around 0.2% may be feasible without compromising recycling circuits. However, this would require further consultation before a definitive position can be taken.

Machining steels

A collaborative project between Saarstahl and Tata Steel has been undertaken recently with the specific aim of exploring this question. While the work on the project has been completed the results have yet to be publicly disseminated. A short summary of the work conducted is given here to provide evidence regarding the likely effect of reducing the 0.35%Pb threshold on machining operations.

Tata Steel and Saarstahl produced several casts of low carbon free cutting steels with Pb contents from 0.11% up to 0.35%. Tata Steel produced 19.05mm bright drawn bar and tested the machinability of the material using their component production test as described in Reference 1. This entails producing a component on a single spindle automatic lathe (BSA Speedturn 32) using high speed steel tools under neat oil coolant and determining the maximum production rate than can be achieved. It gives a good measure of machinability in the forming, parting and drilling operations at cutting speeds in the range 70-100m/min.

The composition of the steels used for this test are shown in Table 1 and the relative production rates for the component are plotted as a function of lead content in Figure 1. A relative production rate of 100% is assigned to the average result from the three casts containing >0.30%Pb (L1060H, L1094H and L11102H).

Table 1 Cast analyses (wt.%) and hardness of materials for the component production test

Cast no.	C	Si	Mn	P	S	N	Pb	HV30
L1024A	0.067	<.005	1.08	0.057	0.29	0.009	<0.01	194
L1098A	0.071	0.010	1.09	0.051	0.31	0.009	<0.01	206
L0004A	0.068	<.005	1.02	0.051	0.31	0.011	0.12	193
L2835H	0.060	0.008	0.97	0.054	0.30	0.007	0.25	199
L1092H	0.066	<.005	1.13	0.057	0.28	0.009	0.30	194
L1060H	0.067	0.010	1.08	0.058	0.30	0.009	0.33	202

L1094H	0.070	0.008	1.18	0.060	0.29	0.010	0.33	202
L1102H	0.059	<.005	1.11	0.059	0.31	0.009	0.34	201

Cr, Cu, Ni, Mo at typical residual levels, Al <0.004%

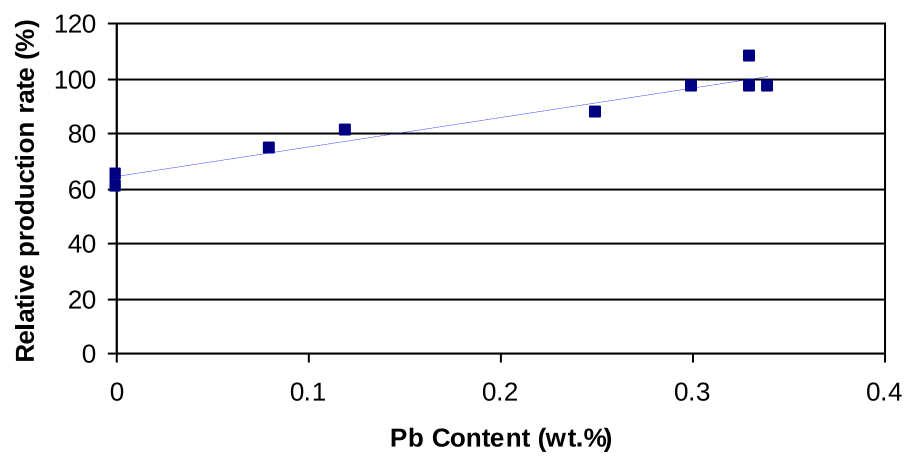


Figure 1 Effect of Pb on production rate in the component production test

Saarstahl carried out a similar programme of work on 25mm diameter bright drawn bar of similar base composition to the Tata Steel materials with lead levels in the range 0.20 – 0.34%. The cast analyses of these materials are presented in Table 2 and are typical for a low carbon free cutting steel. Tool wear tests were conducted using a Spinner TC 67L lathe. An uncoated carbide insert with nose radius of 0.4mm was used to carry out longitudinal turning using a 2mm depth of cut at a feed rate of 0.1mm/rev. The tests were carried out dry at cutting speeds in the range 100 – 150 m/min. and then under soluble oil at a speed of 200m/min. to assess a very high productivity cutting condition. Cutting forces were measured at the start and finish of the test along with the evolution of tool wear. The time taken to achieve 200µm flank wear is summarised in Figure 2 and the effect of Pb on cutting force is shown in Figure 3.

Table 2 Cast analyses (wt.%) and hardness of materials used for turning tests

Cast No.	C	Si	Mn	P	S	N	Pb	HV30
740625	0,069	0,014	1,11	0,052	0,325	0,0060	0,20	184
712747	0,071	0,010	1,10	0,046	0,315	0,0053	0,29	182
712744	0,071	0,016	1,15	0,046	0,322	0,0039	0,34	181

Cr, Cu, Ni, Mo at typical residual levels, Al <0.004%

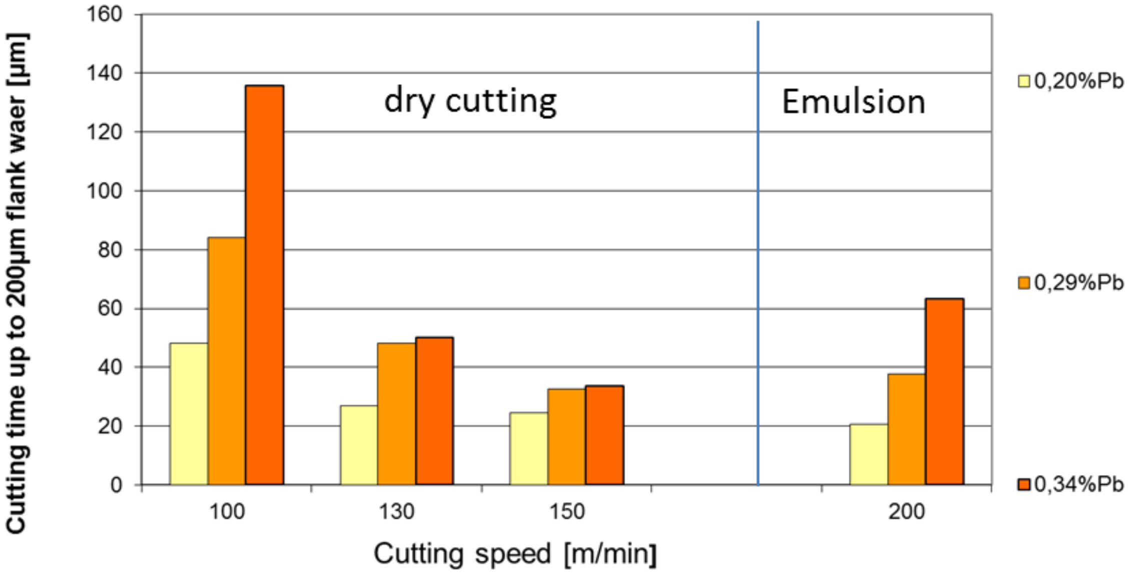
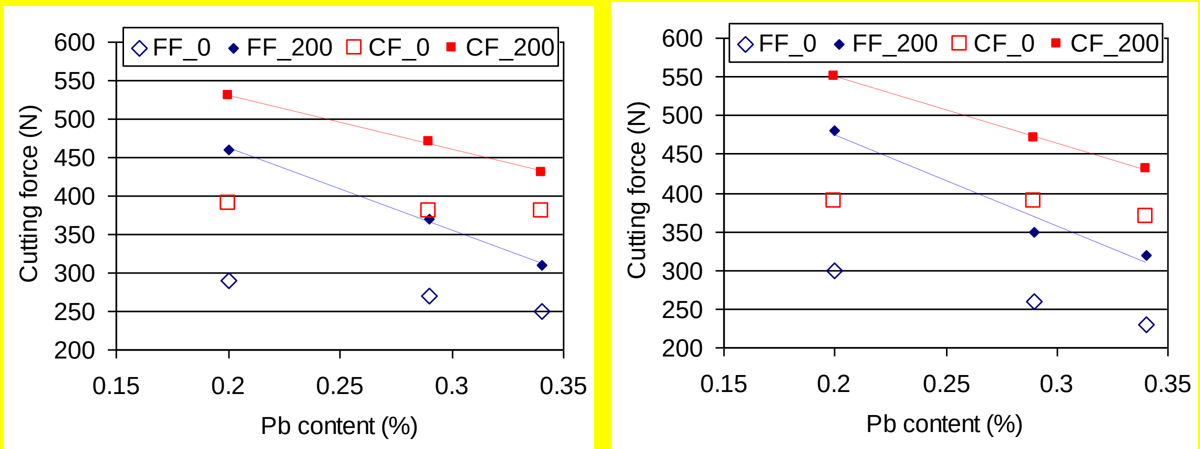


Figure 2 Effect of Pb content on tool life in longitudinal turning with an uncoated carbide tool



a) Dry cutting 100 m/min. b) Dry cutting 130 m/min.

Figure 3 Effect of Pb content on feed force (FF) and cutting force (CF) at the start of the test (_0) and after machining 200 components (_200)

Figure 2 demonstrates that even within the lead range 0.2 to 0.35% a deterioration in tool life will be observed as a result of reducing the Pb content. The relative change depends upon the machining conditions chosen but in all cases increased consumption of cutting tools can be expected as a result of reducing the Pb threshold. Similarly after machining 200 components a clear beneficial effect of Pb in lowering cutting forces can be observed. Higher cutting forces are generally associated with increased risk of vibration, resulting in a deterioration in surface finish, especially in slender components.

Discussion

Both tests with high speed steel tooling and uncoated carbide tooling illustrate that reductions in Pb content below the current threshold of 0.35% will result in progressive deterioration in machinability. The two aspects highlighted here are production rate / tool life and cutting force. This results in either increased useage of cutting tools or longer machining times. Longer machining times result in increased energy usage on the machine tool and hence higher CO_2 emissions as outlined in reference 2.

A factor that also has to be considered is the capability of steel manufacturers to produce leaded steels within a specification range that is acceptable to minimise the variability in machinability experienced by a customer. One of the largest manufacturers of leaded steels in Europe has supplied the following analysis of capability for control of Pb content in steelmaking to Eurofer. The figures show the distribution of the lead values for a total of 75.000 tons produced since October 2014.

Leaded Free-cutting Steel since October 2014.

About 75.000 tons of steel produced

Descriptive Statistics: PB (B)_1

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median
PB (B)_1	532	0	0,27040	0,000655	0,01510	0,22300	0,26300	0,27200

Variable	Q3	Maximum
PB (B)_1	0,28000	0,31400

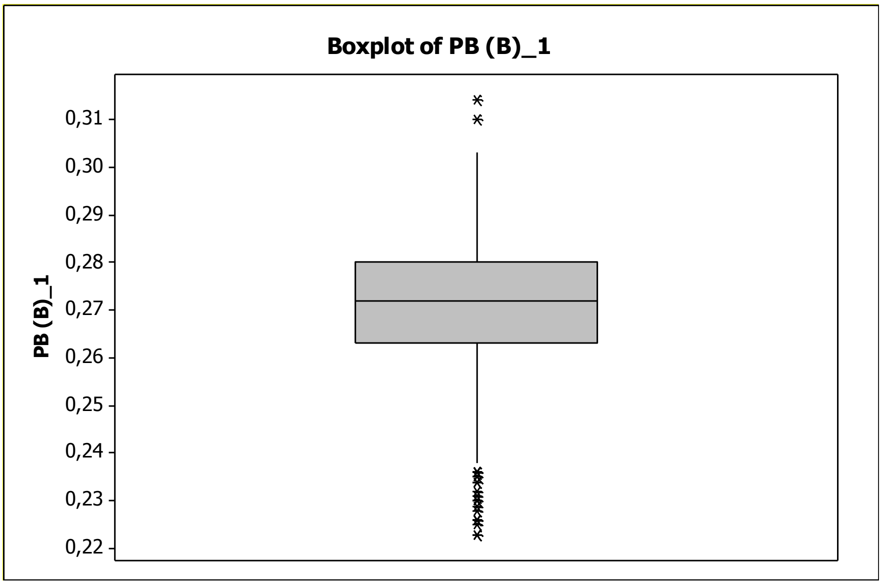


Figure 4 Box plot showing Pb ranges

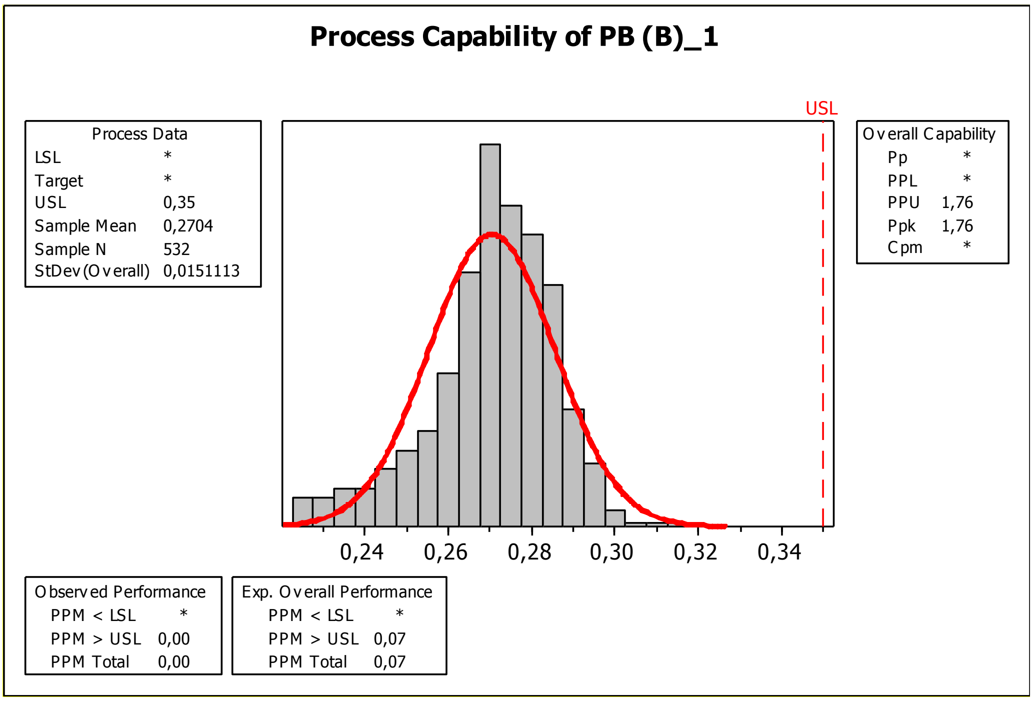


Figure 5 Pb distribution from 532 heats

The graphs show the values of concentration of lead from 532 heats.

The distribution shows that the mean value is 0.270 %.

The standard deviation is 0.015%

25% of the values are below 0.263 %.

25% of the values are higher than 0.280 %

0% of the values are higher than 0.35 %. This is obvious, because 0.35% is the limit specified by the standard.

Taking into account that these are the figures of one single steelmaker, it should be accepted that the standard deviation values among different steelmakers are likely to be higher than 0.015%, so the specified limit of 0.35% should be kept.

5. **Eurofer & EGGA reference earlier research into substitutes, referring to the project "technically and commercially viable alternatives to lead as machinability enhancers in steels used for automotive components manufacture (REF*7210-PR/306)*[2] funded by the European Coal and Steel Research (ECSC)".**
   a. **On this basis, Eurofer & EGGA state that alternatives tested in the past did not show sufficient performance in relation to various indicators. Please provide data so that the differences claimed between possible alternatives and steel using lead can be quantified.**
   b. **Please clarify – has substitution been possible for any types of applications or is lead present in all steel applied in EEE for machining purposes or in batch hot dip galvanized steel?**

Batch Galvanized steels

Some batch galvanizing plants that are either (i) not using recycled zinc in their input material and/or (ii) are not processing components of complex geometry (for all their product mix) may operate with lead levels in the galvanizing bath that would comply with the default requirements of ROHS requirements in the EEE products they would process and would not require exemption. It would not be appropriate to describe this as 'substitution' and could not presently be extended across the whole industry or for all components.

Machining steels

a. **Please provide data so that the differences claimed between possible alternatives and steel using lead can be quantified.**

   The relative performance of different grades in a variety of machinability tests has been quantified in report EUR 21912 [1]. The production rates (time per component) achievable for a standard part at cutting speeds in the range 80 – 100 m/min. using high speed steel tools and neat cutting oil are shown in Figure 1 (direct copy of Fig. 18 in ref. 1). This translates directly into an increase in machining costs. In the same test (Table 11 of ref. 1) the surface finish of the 11SMn30Bi and 11SMn30Pb steels were shown to be equivalent whereas a deterioration in rough form surface finish of at least 20% was observed for all of the other grades. The surface finish results from Table 11 of ref. 1 have been converted into % change from the leaded grades in Figure 2 below (a higher % indicates a deterioration in surface finish).

[2] http://cordis.europa.eu/project/rcn/66565_en.html

A summary of the quantitative performance of the different low carbon free cutting steels tested in Ref. 1 under a wider range of machining conditions is presented in Figure 55 of that report. This shows that none of the grades offers the best performance under all machining conditions tested and optimum grade selection will be part and machine specific.

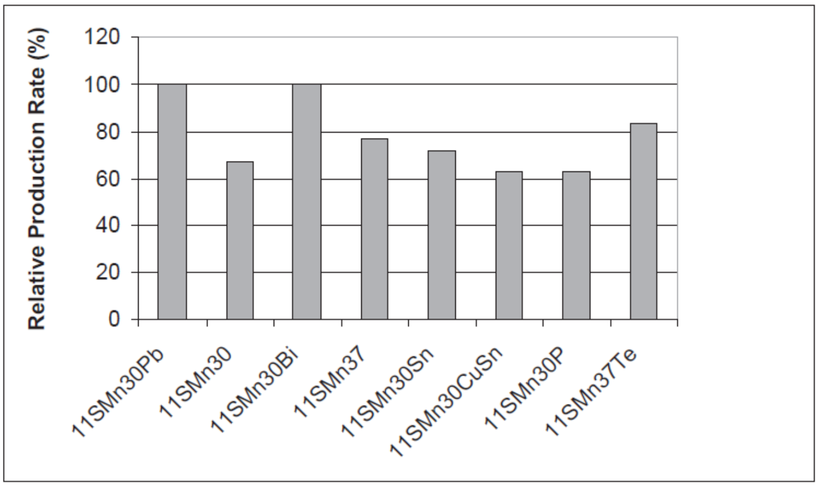


Figure 1 Relative production rate of 11SMn30 steels in autolathe tests at Tata Steel (then Corus)

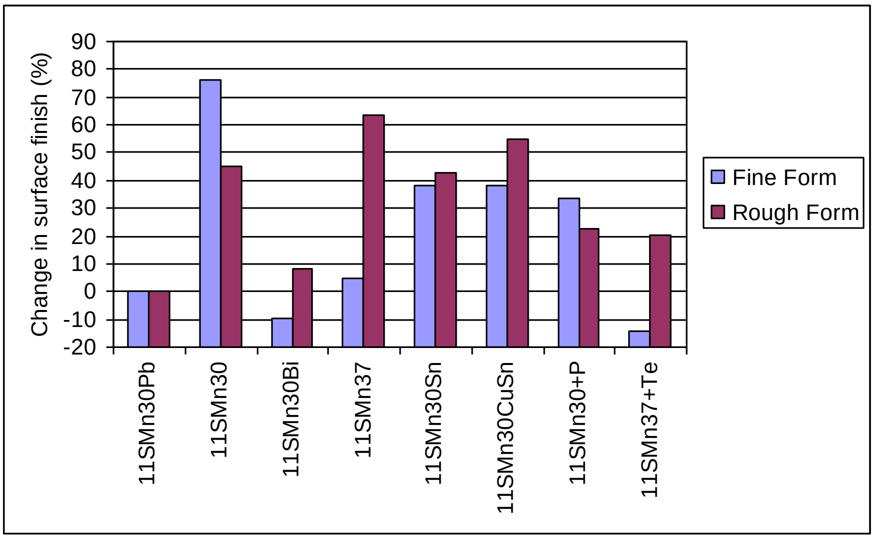


Figure 2 Relative surface finish in autolathe tests at Tata Stee; (then Corus) based on results from Ref. 1

Deep hole drilling feed force results on C45 materials conducted by Bosch (Ref. 1) are presented in Figure 3 below (direct copy of Fig's 78 and 80 in Ref. 1).

	C45 Pb	C45Pb lh	Cm45	C45 Pb mh	C45Bi	C45Bi lh	C45Bi mh	C45Ca	C45Sn	C45Ca lh	C45Ca mh	Cm 45 lh	Cm45 mh	C45Sn lh	C45Sn mh
Vc = 40 m/min f = 30/50	+	+	+	+	+	+	+	+	+	+	○ +	○ +	○ 0	○ -(0)	○ -(0)
Vc = 40 m/min f = 50/69	+	+	+	+	+	+	+	+	+	+	0	0	-	-	-
Vc = 53 m/min f = 70/90	+	+	+	+	+	+	+	+	○ +	○ +	-	-	-	-	-
Vc = 70 m/min f = 100/120	+	+	+	○ +	○ +	○ +	○ +	○ +	0	0	-	-	-	-	-
Vc = 70 m/min f = 130/153	○ +	○ +	○ +	0	0	0	0	0	-	-	-	-	-	-	-

+ drilling is possible

0 drilling with problems

- tool breaks

○ Cutting parameters for long term testing

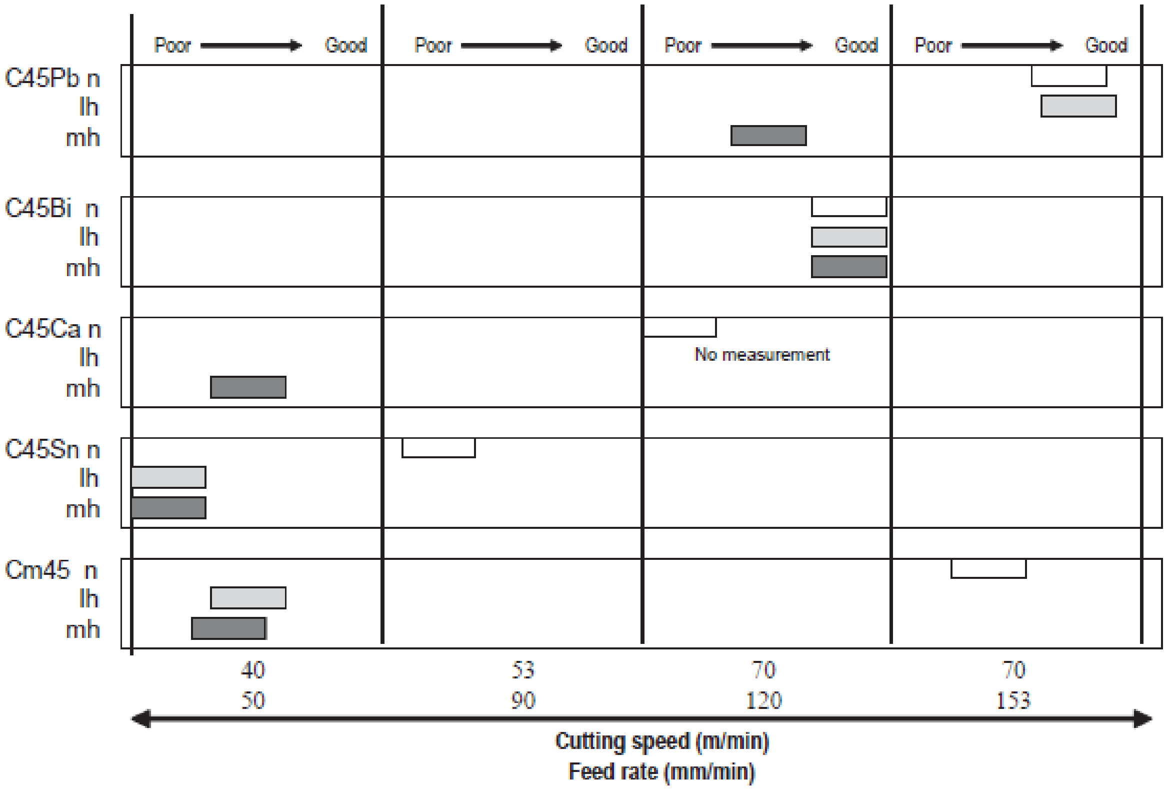


Figure 3 Deep hole drilling results for C45 variants in short term tests

These demonstrate that only the leaded and Bi treated steels could be drilled in all hardness conditions (n = normalised, lh = low hardness, mh = medium hardness) at the high productivity condition of 70 m/min. and 120 mm/min. although the Ca treated and normalised standard variant could be machined at the higher productivity settings. The highest levels of productivity could only be attained in the leaded steel. In the long term deep hole drilling tests problems were observed with chip morphology for many of the grades – this leads to chips becoming tightly packed in the hole and potential drill breakage. Figure 4 (direct copy of Fig. 82 ref. 1) demonstrates the benefits of Pb in ensuring good chip morphology under all cutting conditions tested.

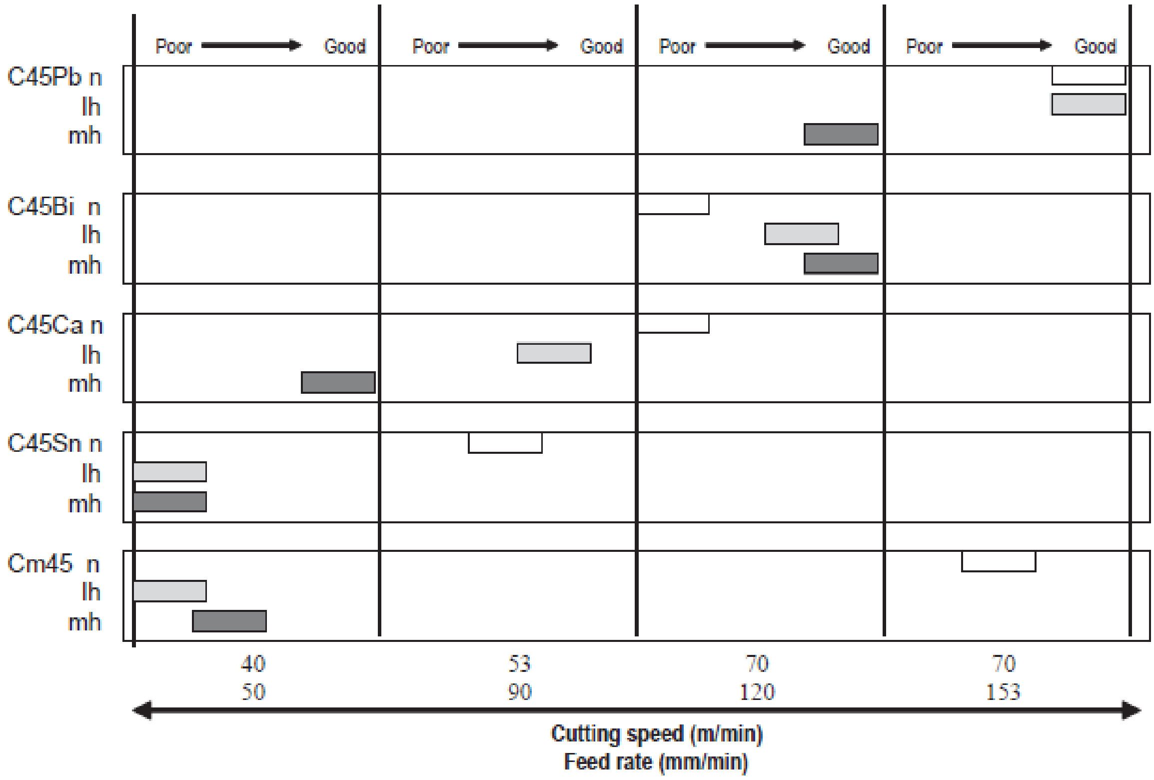


Figure 4 Chip formation in long term deep hole drilling tests on C45 variants

b. **Has substitution been possible for any types of applications or is lead present in all steel applied in EEE for machining purposes?**

Leaded steels are only used for electrical equipment parts that are particularly machining intensive or require specific high tolerance or high surface finish features. Substitution of leaded steels has been possible for very specific applications and often these applications have very specific machining conditions associated with them that mean a given lead alternative solution is viable. Additionally claims have been made for lead substitution in steel types where it is unusual to add lead for routine supply of the grade. The major advantage of leaded low and medium carbon free cutting steels is that they machine well over the full range of machining conditions that may be required to produce a given component and hence are suited to the production of all parts. Bismuth alloyed low carbon free cutting steels have been supplied for certain applications but it is not viable to replace leaded steel production with Bi alloyed free cutting steel on account of poor hot workability (this is a particular problem for smaller diameter material that is commonly used for electronic equipment application), low availability and high price of Bi.

Nippon Steel and Sumitomo Metal Corporation claim to have developed a lead free steel that is suited for the manufacture of printer rails [3], which are often manufactured from leaded low carbon free cutting steel. These parts are surface quality critical and hence are manufactured using very low feed rates that lead to specific problems related to built up edge formation on the cutting tool. They have therefore patented a new steel that contains finer MnS inclusions compared to the traditional free cutting steel grades and claim that this material is routinely being supplied for this specific application. There is no evidence that the new material is being used more widely than this.

Toyota claims to have developed an alternative to a lead alloyed C45 free machining steel [4]. The RFCS project referenced in response to question 5a evaluated the performance of C45 material and showed that in deep hole drilling Ca, applied for sulphide and oxide modification as considered in this paper does not give the required machinability in the higher hardness conditions. These types of materials are frequently used without Pb in the automotive market in components where lead is not required in order to machine complex features or very high length to diameter ratio holes. This type of steel would not commonly be applied for electronic equipment.

The use of Bi as a technically viable alternative to Pb in low carbon free cutting steels was proposed in a PhD thesis [5] that covers the work contributed by WZL to the project 'Technically and commercially viable alternatives to lead as machinability enhancers in steel used for automotive component manufacture' and concludes that the best all round performance is obtained using Pb in low carbon free cutting steels although Bi provides a technically suitable alternative with the caveats around hot ductility and raw material availability being mentioned.

6. **Please indicate the efforts your organisations' members have made since the last revision of Exemption 6(a) respectively the last revision of the corresponding ELV exemption 1(a), to find and implement lead free alternatives for machining steels. Please clarify the strategy of such efforts.**

In addition to the joint project conducted by Saarstahl and Tata Steel to assess the potential to reduce Pb contents referenced in response to question 4, a major European free cutting steel producer has attempted to commercialise Bi low carbon free cutting steels and the results of those trials are summarised below.

Since 2010, this steel producer has carried out seven interconnected full scale trials related to the use of bismuth as an alternative to lead. During the last trial in 2012, a new 10MnSBi grade of steel (1215Bi) was manufactured under normal production conditions and supplied to customers. A total of five casts of 140 tonnes each were produced with a bismuth content of between 0.062 & 0.076 wt% and a lead content of less than 0.015 wt%. Apart from a single anomalous result, the cleanness of the steel was good and met customer requirements. For the trial, the steel was rolled to the following products for 14 customer orders:

- 17.5 mm Round Coil
- 20.5 mm Round Coil
- 45.0 mm Round Straight Bar
- 30.0 mm Hexagon Coil
- 36.5 mm Hexagon Coil
- 30.0 mm Hexagon Straight Bar
- 36.5 mm Hexagon Straight bar

Straight round bars were subject to automated surface inspection, whilst the other products were examined visually. The amount of steel scrapped from the orders subject to trial monitoring was:

- Total amount of steel rolled = 490 tonnes

- Total amount of steel scrapped after inspection = 152 tonnes (31%)

Inspection results varied considerably between orders and were independent of processing parameters, geometry and product type. The results from this and previous trials have indicated that bismuth steels are much more prone to surface break-up than normal leaded steels and the associated yield losses are not sustainable for routine production.

From the trial rollings, there were a number of customer complaints (in addition to the material scrapped after internal inspection) for two of the casts monitored:

- 3.242 tonnes - Shell
- 0.551 tonnes - Surface Break-Up
- 3.646 tonnes - Surface Break-Up
- 26.534 tonnes - Surface Break-Up

There were also customer complaints related to orders from these casts that were not monitored as part of the trial.

It was concluded that there were significant difficulties and inconsistencies with rolling the 1215Bi grade because of the potential for surface break-up. Consequently, the producer has been unable to develop a viable manufacturing route for large scale routine production of this material.

Machinability tests were carried out on steel from the trial and the results from the 1215Bi grade approached those from a standard 12L14 leaded low carbon free cutting steel.

Overall the results of these trials confirm the conclusions from the collaborative ECSC project where bismuth was shown to be a potential alternative to lead for the purposes of enhancing machinability but that low hot ductility and limited availability (of Bi) could prevent the material being a feasible commercial product.

Concerning the availability of Bi, According to the *Mineral Commodity Summaries 2015 , US Geological Survey* , reserves of bismuth are usually based on bismuth content of lead resources because bismuth production is most often a byproduct of processing lead ores. In China, it is also a by-product of tungsten ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products. Bismuth, at an estimated 8 parts per billion by weight, is the 69th element in order of abundance in the Earth's crust and is about twice as abundant as gold. Typically, 30 to 200t of lead are produced to obtain 1t of bismuth.

Since there is a strong link between lead and bismuth production, it is difficult to envisage that future demand for lead would be sufficient to supply enough Bismuth, as a by-product, to meet the need for Bismuth. This is further exacerbated by the growth in the use of recycled lead, which means fewer requirements for new primary lead. In the situation where bismuth demand grows relative to lead, the dominant material (lead) would need to be disposed of as, at that stage, it would have limited commercial value. This would place higher environmental and economic burdens on bismuth. The increasing demand for bismuth might result in a strong rise in the bismuth price and consequently an increase in production costs.

7. **Can Eurofer & EGGA agree to limit the scope of the exemption on batch galvanized steel to small components for which such steel is used, adding a size/weight threshold to the exemption formulation?**

It is emphasized that the exemption has already been revised to exclude continuously galvanized steel that hitherto comprised the majority of galvanized steel used in EEE products. This renewal request is made mainly on the basis of the importance of not disrupting the recycling circuit of the batch galvanizing industry and the life cycle advantages of retaining high levels of durability of EEE that would be lost if EEE could not be processed in batch galvanizing plants. This factor would not be limited to small components.

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1.

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Please note that answers to these questions are to be published as part of the available information relevant for the stakeholder consultation to be carried out as part of the evaluation of this request. If your answers contain confidential information, please provide a version that can be made public along with a confidential version, in which proprietary information is clearly marked.