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PROCEEDINGS

Volume 58, book 4.1.
Transport and Machine Science

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Book	Code	Faculty and Section
		Agrarian and Industrial Faculty
1.1	FRI-8.121-1-AMT&ASVM	Agricultural Machinery and Technologies and Agrarian Science and Veterinary Medicine
	FRI-1.202-1-MR	Maintenance and Reliability
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1.2	FRI-2.209-1-EC	Ecology and Conservation
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1.3	-	
		Faculty of Mechanical and Manufacturing Engineering
2	FRI-1.417-1-MEMBT	Mechanical Engineering and Machine-Building Technologies
2.1	FRI-SSS-XXX	
		Faculty of Electrical Engineering Electronics and Automation
3.1	FRI-10.326-1-EEEA	Electrical Engineering, Electronics and Automation
3.2	FRI-2G.303-1-CST	Communication Systems & Network Technologies
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		Faculty of Transport
4	FRI-2.203-1-TMS	Transport and Machine Science
4.1	WED-SSS-TMS	Transport and Machine Science
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5.1	FRI-2G.404-1-EM	Economics and Management
5.2	FRI-2G.509-1- ESIR-LIPC	European Studies and International Relations: Linguacultural, Intercultural and Political Communication
5.3	WEN-SSS-EM	Economics and Management
	WEN-SSS-ESIR&LIPC	European Studies and International Relations: Linguacultural, Intercultural and Political Communication
		Faculty of Natural Sciences and Education
6.1	FRI-1.414-1-MIP	Mathematics, Informatics and Physics
6.2	FRI-2G.307-1-PP FRI-2.207-1-HEF	Pedagogy and Psychology History, Ethnology and Folklore
6.3	FRI-2G.405-1-LL FRI-2G.407-1-AS	Linguistics and Literature Art Studies
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11.1	XXX-SSS-XXX	
12	FRI-1.311.-1	**Workshop"CAM-2018"**

The papers have been reviewed.

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TRANSPORT AND MACHINE SCIENCE

Content

Забележка: Докладите, които са включени в Best Paper, също фигурират в електронния сборник с код и заглавия на английски език отпред в съдържанието

WED-SSS-TMS-1

INVESTIGATION ON GASOLINE ENGINE CHARACTERISTICS WITH SINGLE ENTRY AND TWIN ENTRY TURBINE [1]

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Abstract: *Modelling and study of power and exhaust emission characteristics of a turbocharged gasoline engine with one and two turbine entrances is presented in this paper. A one-dimensional analysis using AVL "Boost" software was performed in the study. The model was designed considering the parameters of the engine and turbocharger, based on an Audi TT 1.8 SI gasoline engine with turbocharger with one and two turbine entrance. The study focuses on comparing engine performance with turbochargers with one and two turbine entrance in terms of torque, rotation speed and compressor efficiency at low engine speeds in the 1000-4000 min^{-1} range. This study shows the potential benefits of introducing a twin entry turbocharger.*

Keywords: *Twin entry turbine, Single entry turbine, AVL Boost, Gasoline engine*

INTRODUCTION

Turbochargers improve engine power and torque without increasing the volume of cylinders. However, the turbine has slower reaction at low engine speeds in 1000-4000 min^{-1} range. There are different solutions to this problem, such as variable geometry turbochargers, two-stage turbochargers and various combined methods. In one of the studies (Arnold D., 2004) it is noted that at a small angle of the blades in the turbine housing and at low engine speeds the exhaust flow to the impeller increases, thus increasing the productivity of the compressor. In another study (Hawley J., Wallace F., Cox A., Horrocks R. & Bird G., 1999) to overcome slow turbine reaction at low engine speeds, the turbocharger is coupled to a transmission that directly is connected to the crankshaft of the engine. This allows the turbocharger to act as a compressor at lower rpm. Another method (Chadwell C.J. and Walls M., 2010) to overcome the slow turbine reaction is the use of two turbochargers for low and high pressure, running in series.

EXPOSITION

One method that is not fully explored is the use of a twin entry turbocharger. These turbochargers are known as turbochargers with impulse turbines. They can improve the turbine response at lower engine speed, mainly due to a split-pulse manifold, thus avoiding the interaction between the various exhaust gasses pulses in the collector and improving the transmission of energy from the exhaust gas to the turbine impeller. This improves turbine performance. In Fig. 1 is shown a turbocharger with single entry turbine and in Fig. 2 is shown a twin entry turbocharger.

[1] The report was presented at a student scientific session on May 27, 2019, with an original title in Bulgarian: ИЗСЛЕДВАНЕ ХАРАКТЕРИСТИКИТЕ НА ДВИГАТЕЛ С ПРИНУДИТЕЛНО ВЪЗПЛАМЕНЯВАНЕ, С ЕДИН И ДВА ВХОДА НА ТУРБИНАТА

Twin entry turbochargers are already being used in high-power engines, but research on smaller power engines is still insufficient (Aghaali, H & Hajilouy Benisi, Ali., 2008). Therefore, more research is needed to see the benefits of using this type of turbocharger.

Fig. 1. Turbocharger with single entry turbine

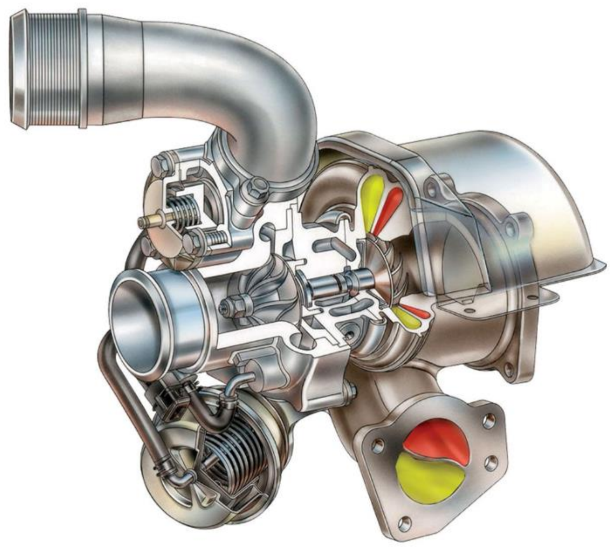

Fig. 2. Turbocharger with twin entry turbine

The data from the Audi TT 1.8 SI gasoline engine used in the 1-D model (Figure 3) (Bellisa V., Marellib S., Bozzaa F., Capobiancob M, 2010) was used as a basis for the study. The engine is equipped with a single entry turbine as part of its standard specification. The research includes a standard engine analysis and the same engine equipped with a twin entry turbine. Tab. 1 shows the basic parameters needed to build the model in AVL Boost.

Table 1. Basic parameters needed to create a model in AVL Boost

Engine	**1.8L SI**
Piston diameter	81 mm
Piston stroke	86 mm
Exhaust valve stroke	9.3 mm
Intake valve stroke	7.67 mm
Degree of compression	9.5:1
Number of cylinders	4
Valves per cylinder	5

Fig. 3. Gasoline engine with single entry turbine Audi TT 1.8 SI

For the purpose of this study, engine modeling is based on Audi TT 1.8 SI and has been simulated with variable engine speed in the range from 1000 min^{-1} to 5000 min^{-1}. The profiles and dimensions of the filling and exhaust manifolds are defined on the basis of data from the manufacturer in order to achieve real operating conditions in the combustion cycle. The data for single and twin entry turbine are taken from the manufacturer. This provides more precise boundary conditions, as the flow characteristics of the compressor will only be influenced by the differences in turbine configurations and the corresponding exhaust manifold geometry.

In Fig. 3 is shown an Audi TT 1.8 SI engine model with standard turbocharger configuration. The exhaust manifold geometry is configured so that the four exhaust manifolds are combined into one common pipeline. This means that the energy transfer from the exhaust to the turbine impeller is not optimized, thus not fully realizing the exhaust gas potential.

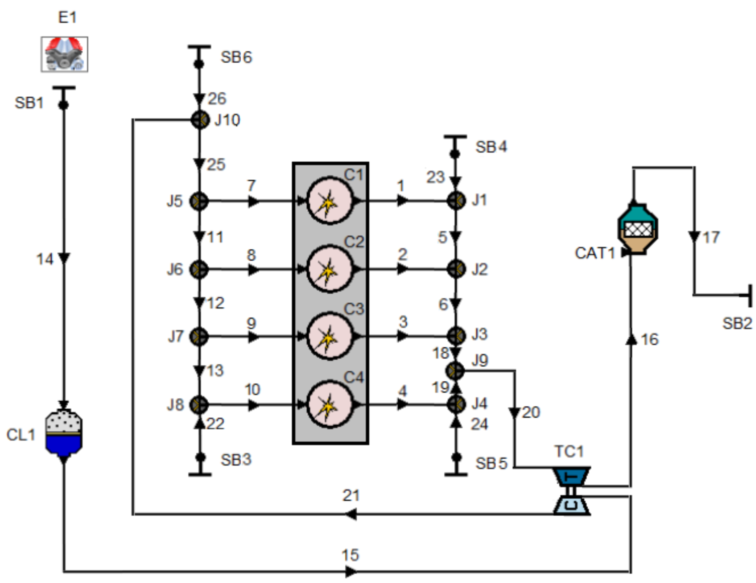

Fig. 4. Model of gasoline engine Audi TT 1.8 SI with single entry turbine

A firing line (1-3-4-2) is used in which the four exhaust manifolds of the exhaust manifold are combined in one common line and changed so as to allow the exhaust gases from the cylinders 1 and 4 to remain separated by 2 and 3, as shown in Fig. 4.

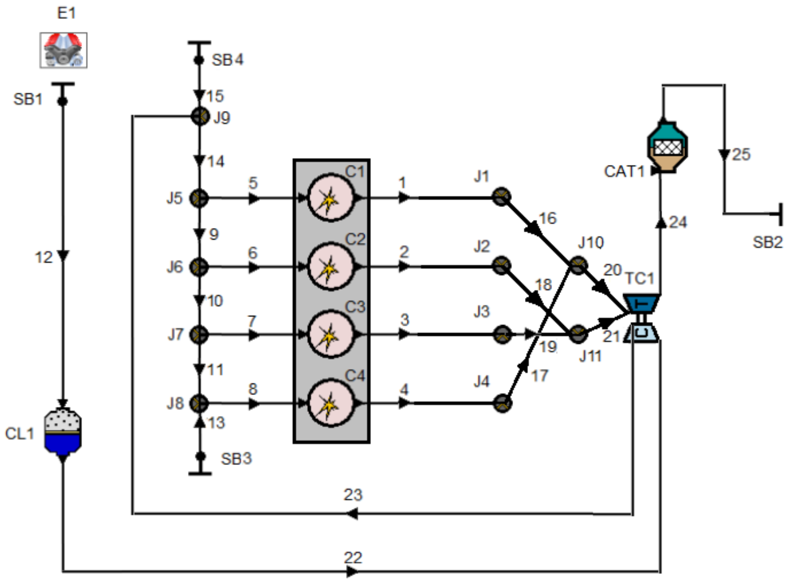

Fig. 5. Model of gasoline engine Audi TT 1.8 SI with twin entry turbine

Verification of the model was performed using parameters of a standard Audi TT 1.8 SI single-input turbocharged engine and the results were compared with those provided by the manufacturer. The engine data that is shown in Table 1 was used.

Fig. 6 and Fig. 7 shows the power and torque respectively as a function of engine speed in the range of 1000 min^{-1} to 7000 min^{-1}. It is clear that the simulated engine model has produced relatively accurate calculations for maximum power at an engine speed of 6500 min^{-1} compared to the manufacturer's data 6000 min^{-1} shown in Fig. 6. For torque results, there are some discrepancies between the simulation data and the manufacturer. This is probably due to the combustion shape parameter, which determines the combustion characteristics within each cylinder in the AVL Boost simulation code.

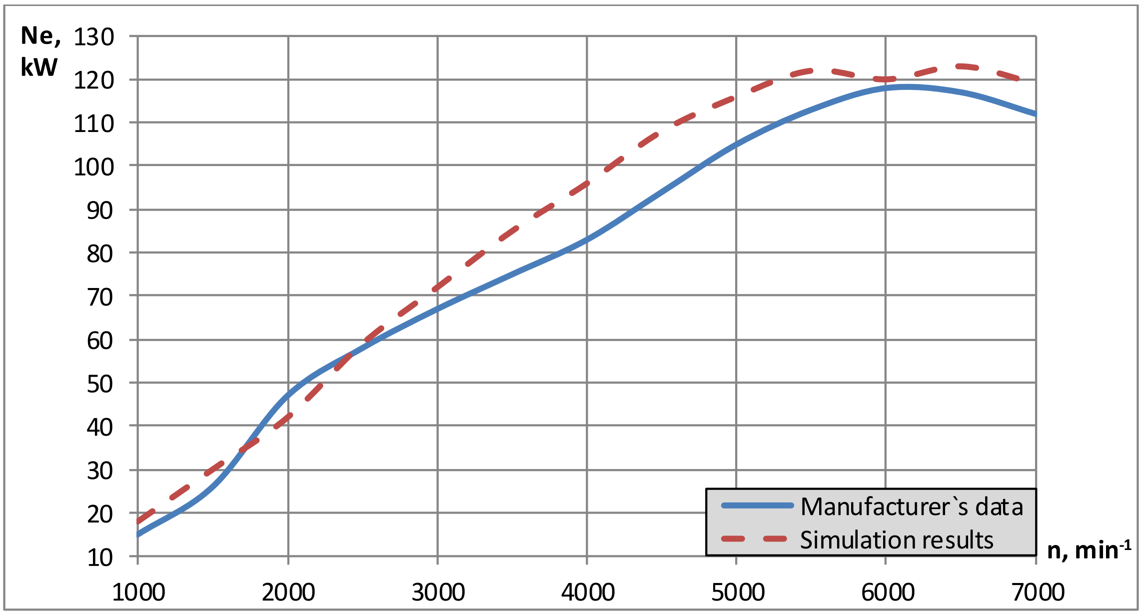

Fig. 6. Change of engine power (Audi 1.8L SI) at different speeds

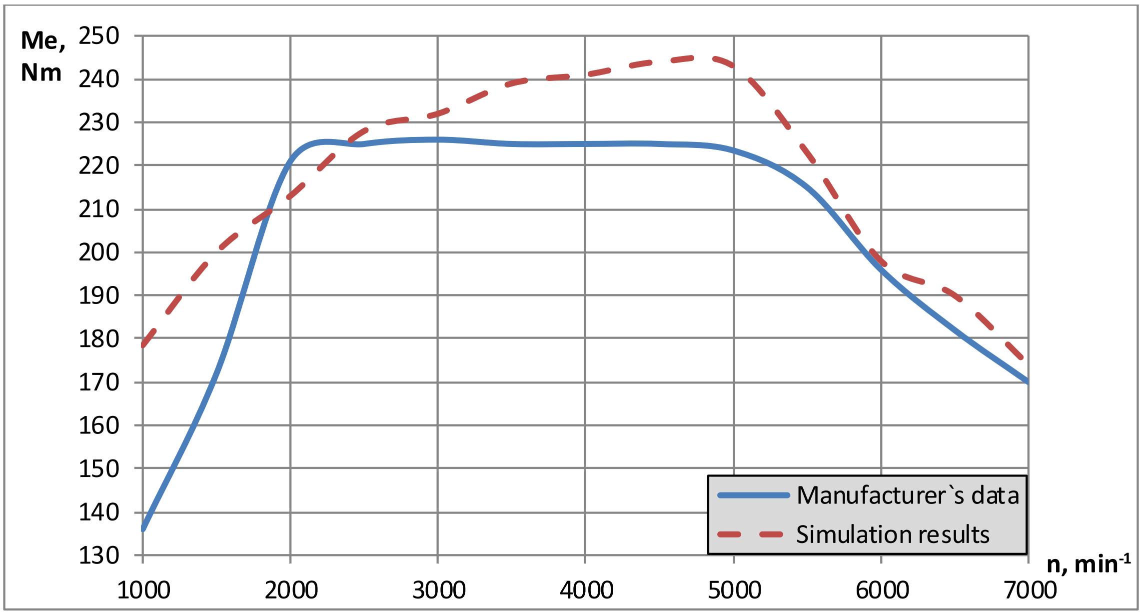

Fig. 7. Torque variation of the engine (Audi 1.8L SI) at different speeds

Based on the results above, it can be concluded that the simulation model of an Audi 1.8L SI engine, equipped with a single-input turbocharger, provides relatively accurate simulation results.

In low-power engines, low speeds are an essential area for the turbocharger with twin entry turbine. A common turbocharger problem with these engines is the turbine response time, which must reach a high enough speed to allow the compressor to work efficiently.

Fig. 8 shows comparison of power between single and twin entry turbine. The highest power gain for the twin entry configuration reaches 5500 min^{-1}, providing approximately 15% extra power. This increase in power is the result of increased compressor performance, due to improved power transmission from exhaust to turbine.

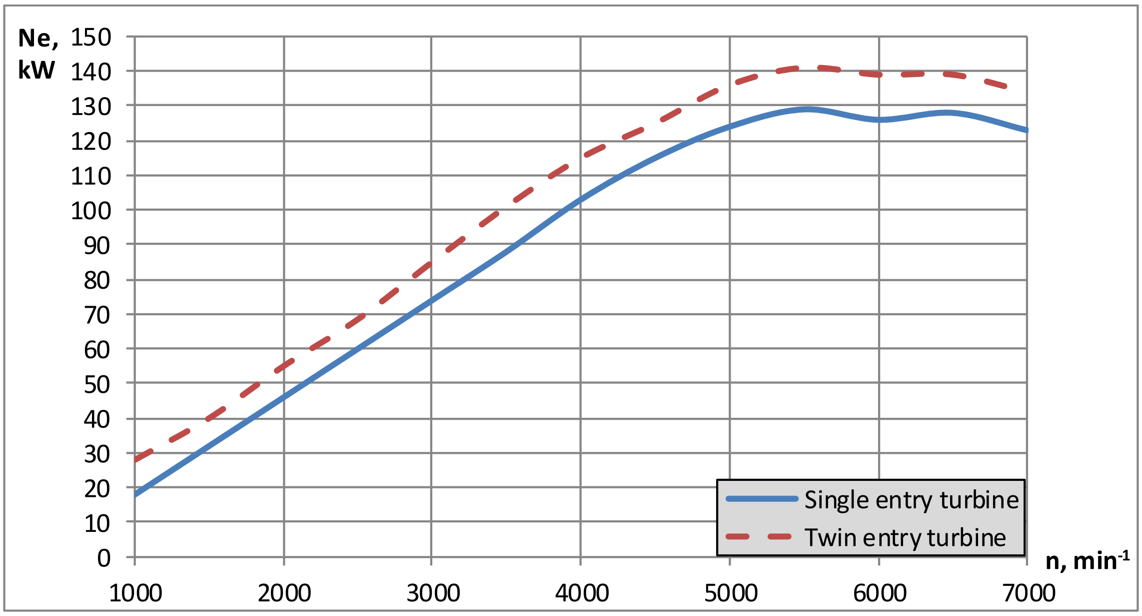

Fig. 8. Engine`s power variation (Audi 1.8L SI) of turbocharger with single and twin entry turbine

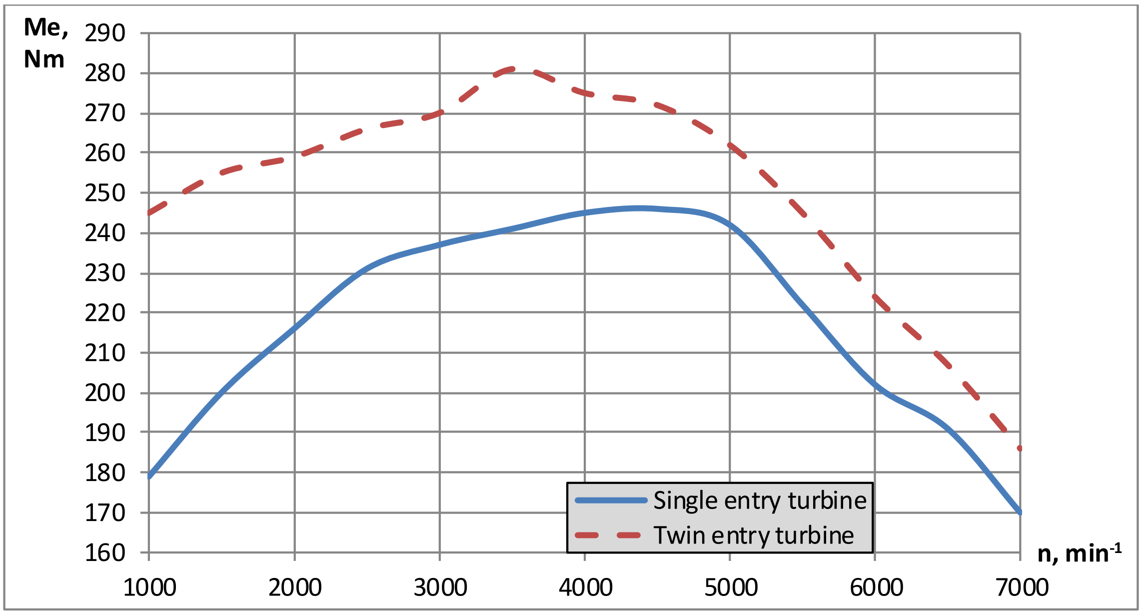

Fig. 9. Engine`s torque variation (Audi 1.8L SI) of single and twin entry turbine

The results of the simulation (Fig. 10) also showed that the mean effective pressure is increased by 16% after using the twin entry turbine engine model. Tab. 2 shows the summary results of the improvements obtained from the simulation with AVL Boost.

Table 2 - Summary of obtained improvements

Engine	1.8L SI
Power	14.80%
Torque	14.00%
BMEP	16.00%

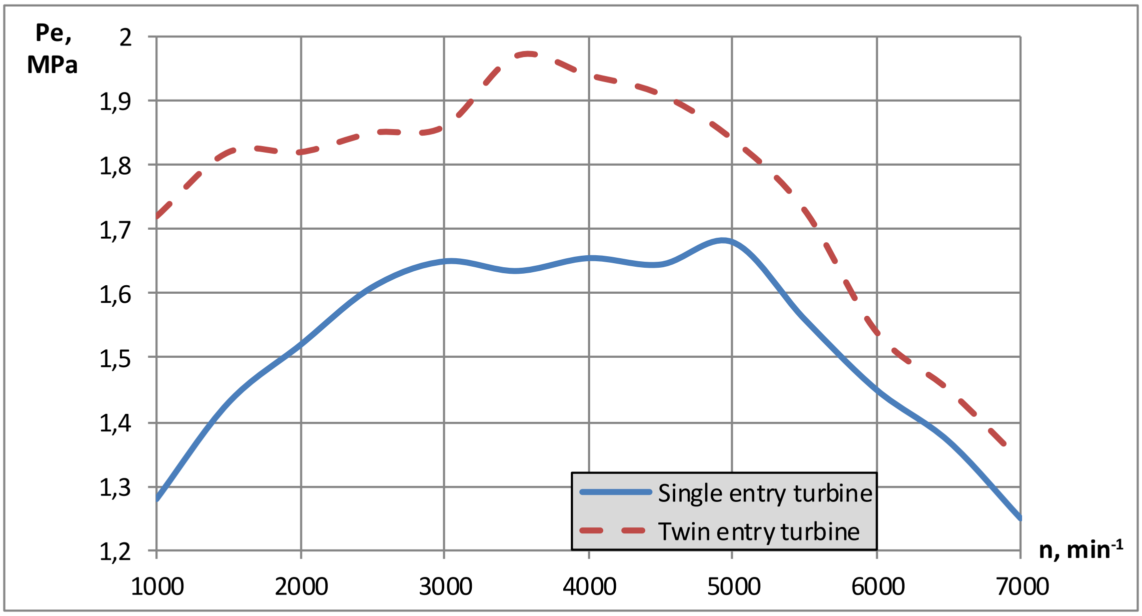

Fig. 10. Variation in mean engine pressure (Audi 1.8L SI) with single and twin entry turbine

CONCLUSION

- The simulation results with the AVL Boost software show potential improvements in engine performance due to the use of a twin entry turbine with a modified exhaust manifold configuration.
- The simulation results obtained for the Audi 1.8L SI engine show that implementation of a twin entry turbine increases engine power at low speeds, with the highest efficiency being in the range of 1500 min^{-1} to 4000 min^{-1}, as the maximum power increment is 25%, while the mean effective pressure rise up with 27%.
- Torque and engine power are also increased by 14.8% and 14% respectively at 2000 min^{-1}. Power and torque are significantly improved at low speeds by the constructive design change of the exhaust manifold and the turbine.

ACKNOWLEDGMENTS

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WED-SSS-TMS-2

DESIGN AND RESEARCH OF WORM GEAR TRAINS [2]

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Abstract: *The paper reviews some important existing methods of calculation and research of worm gear drives. Special geometry and strength characteristics of these gear trains are analysed. The importance of certain special characteristics of the tribology behaviour of wrom gear drives is intoduced. The paper compares special features of different European stadards concerning this type of gear drives. Conclusions are deduced.*

Keywords: Worm Gear Trains, Geometry and Strength features, European standards

ВЪВЕДЕНИЕ

Изследването на червячни предавки представлява особено важен и актуален проблем. Неговото решаване е пряко свързано с усъвършенстване на стратегията за съвременното развитие на машиностроенето с цел повишаване на конкурентоспособността на сектора. Подобряването на енергийната ефективност и на функционалната годност на червячни предавки поставя значими изследователски проблеми пред научната общност.

Изследователският проблем за подобряването на експлоатационните характеристики на разглежданите червячни предавки, освен това, е и интердисциплинарен проблем. Неговото решение е възможно чрез прилагане на съществуващи теоретични модели, чрез разработване на авторски приложни продукти и чрез прилагането на съвременни методи, подходи и средства.

ТЕОРЕТИЧНО ИЗСЛЕДВАНЕ НА ЧЕРВЯЧНИ ПРЕДАВКИ

Механичните предавки включват задвижващ компонент, свързан с входящия вал, една или няколко двойки междинни предавки и задвижван компонент, монтиран към изходящия вал. Съществува голямо разнообразие от различни видове механични предавки. Всяка една от тях притежава предимства и недостатъци и налага различен подход при избора и конструирането ѝ. Един от критериите за избор и оптимизация на механични предавки е тяхното експлоатационно и трибологично поведение.

На Фиг. 1, (Джонсън, М., 2008) са показани различни механични предавки: цилиндрични еволвентна зъбна предавка, конусни зъбни предавки с прави и наклонени зъби и чярвячна предавка. Големината на силата на плъзгане се увеличава с нарастване на кривината на профила за зацепените компоненти. Зъбното зацепване: червяк/червячно колело се характеризира с най-голяма стойност на плъзгането в зацепването в сравнение с показаните на Фиг. 1 цилиндрични и конусни зъбни предавки.

[2] Докладът е представен на студентската научна сесия на 8 май 2019 в секция Транспорт и Машинознание с оригинално заглавие на български език: ПРОЕКТИРАНЕ И ИЗСЛЕДВАНЕ НА ЧЕРВЯЧНИ ПРЕДАВКИ

Фиг. 1. Трибологични особености на механични предавки, (Джонсън, М., 2008)

Поради тази причина, червячните предавки обикновено се характеризират с по-нисък коефициент на полезно действие в сравнение с други механични предавки. Голямата стойност на плъзгане води до обстоятелството, че много често загряването и съответно – топлинното изчисляване - са определящата граница на товароносимостта за тези предавки.

Но някои техни предимства като: високи предавателни числа в една степен, ниско ниво на вибрациите и на шума, възможност за самоспиране – ги прави важни компоненти при производството на трансмисии.

Червячните предавки са много подходящи за осъществяване на големи предавателни числа в една степен. При червячните предавки са възможни големи предавателни отношения в една степен: от 5 до 70, като при малки мощности предавателното отношение може да достигне до u = 100. Най-често приложение намират червячните предавки с предавателни отношения от 15 до 50.

Осите на червяка и на червячното колело се кръстосват най-често под 90°. Цилиндричният червяк наподобява винт, който при въртенето си задвижва червячното колело, чието зацепване отговаря приблизително на резбата на гайка. Главни особености на червячното зацепване са:

- спрямо винтовите предавки – линеен контакт;
- спрямо еволвентните цилиндрични зъбни предавки – значително плъзгане.

Значителното плъзгане и малката скорост при влизане в зацепване на зъбните профили води до безшумна работа на предавките и до намаляване на вибрациите. Нивото на шума е средно с около 7dB по-ниско в сравнение с цилиндричните зъбни предавки.

Тяхно важно предимство спрямо многостепенните цилиндрични и конусни зъбни предавки е използването на малък брой машинни елементи, което е икономически изгодно при малки габарити на необходимите предавки.

Червячните предавки имат висока товароносимост спрямо винтовите предавки, които също се характеризират с кръстосани оси, благодарение на контакта по линии и на едновременното зацепване на повече зъби – обикновено от 2 до 4.

Важна тяхна особеност е вероятността при големи предавателни числа да се получи самозадържане при обръщане на посоката на силовия поток, т.е. коефициентът на полезно действие в зацепването ηz става приблизително равен на нула при задвижващо колело.

Особено важен параметър на зацепването е коефициентът на диаметъра q на червяка, който зависи от стойността на модула, от ъгъла на наклона на винтовата линия, от броя на ходовете и от средния диаметър на червяка.

Този параметър характеризира основните параметри на червяка и съответно съпротивителния момент срещу провисване на червячния вал. С помощта на този коефициент могат да се изчисляват размерите на предавката в аксиално сечение на червяка, аналогично на цилиндрична зъбна предавка.

Коефициентът на триене в зацепването е основен параметър, характеризиращ трибологичното поведение на червячни предавки и якостното им изчисляване. Коефициентът на триене по време на пусковия период μ_{zA} при скорост на плъзгане, равна на нула, е особено важен в момента на пускане и самоспирането. Този параметър почти не зависи от формата на зъба и изменението на контактните линии. По-нататъшното изменение на μ_z зависи от двойката материали, грапавината на профилите, смазочния материал, натоварването и формата на червяка.

ОСНОВНИ ОСОБЕНОСТИ НА СТАНДАРТИТЕ ЗА ЧЕРВЯЧНИ ПРЕДАВКИ

В методиката за геометрично и якостно изчисляване на червячни предавки по Ниман и Винтер са заложени данните от германските стандарти за червячни предавки - DIN 3975 (1988) и 3976 (1980). Стандартът DIN 3976 се състои от две основни таблици. От първата таблица - при предварително определени модул, делителен диаметър и брой ходове на червяка могат да бъдат избрани: стъпката, коефициентът на диаметъра на червяка, върховият и петовият му диаметри и ъгълът на наклона на винтовата линия. От втората таблица - при предварително определени междуосово разстояние, предавателно отношение и модул се избират някои геометрични параметри, в това число и коефициент на изместване в предавката. В този стандарт двете таблици са свързани.

Българският стандарт БДС 15764-83 (1983) съдържа информация, аналогична на тази в DIN 3976 (1980), а именно зависимости между модула, броя ходове на червяка и коефициента на диаметъра на червяка. В германския стандарт таблицата е разширена с други геометрични параметри, които липсват в БДС.

Недостатък на българския стандарт е, че липсват данни за шестходови червяци. Прави впечатление и това, че според DIN 3976 диапазонът на изменение на големината на коефициента на диаметъра на червяка е с по-ниска горна граница - близо два пъти.

Липсва български стандарт, напълно аналогичен на Табл. 2 от DIN 3976, в който да е отразена зависимостта между междуосовото разстояние и основните геометрични параметри като предавателно отношение, модул, делителен диаметър и брой ходове на червяка, ъгъл на наклона на винтовата линия, брой зъби на червячното колело и коефицинет на изместване на изходния контур на червячното колело.

Фиг. 2. Загуби на мощност в червячна предавка, (Дирейн и кол., 2016)

В някои стандарти и каталози е посочена информация относно загубите на мощност в червячни задвижвания. Подобна информация е представена от авторите в (Дирейн и кол., 2011) и в (Стокман и кол., 2010).

Данни за механични и хидравлични загуби на мощност в червячното зацепване са анализирави от (Хьон и кол., в 2007) и в публикацията на (Йенти и кол., 2013). Учените подчертават, че общите загуби в една механична предавка представляват комбинация от загуби в лагерите, в уплътненията, загуби от разпръскване на маслото и загуби в зацепването, както е посочено на Фиг. 2.

Незначителен брой публикации анализират общия коефициент на полезно действие на червячна предавка. Производителите задават този параметър в каталозите като функция на броя на степените на механична предавка. Поради тази причина, дадена стойност на общия коефициент на полезно действие съответства на голям диапазон червячни предавки, която я прави относително неточна.

Това кратко представяне на състоянието на проблема има за цел да уточни най-важните проблеми при проектирането и изследването на червячни предавки.

ИЗВОДИ

От направеното теоретично изследване могат да бъдат изведени следните изводи:

- Разгледани и анализирани са някои важни особености в конструкцията на червячни предавки;

- Различни национални методики се характеризират с различно ниво на осигуреност със стандарти. Липсва международен стандарт за изчисляване на червячни предавки.

На базата на този анализ може да се обобщи, че е необходимо да се допълнят критериите за изчисляване и проектиране на червячни предавки. За да може да бъде постигната тази цел, е необходимо да се анализира възможно най – пълно и точно сложното поведение на червячни предавки.

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COMPARISON OF MECHANICAL ENGINEERING CURRICULA[3]

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Abstract: *The paper presents a comparative analysis of Mechanical engineering curricula in two European Higher education institutions. Some important basic similarities and differences are emphasized. The advantage of some differences concerning students' exchange is highlighted. The importance of facilities and laboratory equipment is shown up. The paper compares special features of different kinds of mobility within Erasmus exchange and the link between mobility, contents of the Bachelor degree course curricula, facilities and laboratory equipment. Conclusions are deduced.*

Keywords: *Mechanical Engineering Curricula, Subjects, Facilities, Laboratory Equipment, Erasmus exchange*

ITRODUCTION

The Bachelor programme "Mechanical engineering" is an established engineering degree, which is available in many European Universities and other Higher education institutions. An interesting circumstance is the situation that almost every institution has created its own almost unique curriculum concerning this Bachelor degree program. Curricula differences are connected in some cases to strategies and policies of the European country concerned, (Kamenov et al, 2017).

Most probably some other differences are consequences of the qualification of the academic staff available. The determination of the magnitude of these differences is particularly important in the area of academic exchange within European programs and especially: Eramus plus program.

COMPARISON OF MECHANICAL ENGINEERING CURRICULA

The Mechanical Engineering curricula of two Higher education institutions have been compared: TTK Univesrity of Applied Sciences in Tallinn, Estonia (TTK) and the University of Ruse in Bulgaria (UoR). The TTK curriculum is described in the tables, shown on Fig.1 and Fig. 2. The Mechanical Engineering curriculum at the University of Ruse is given in: https://www.uni-ruse.bg/en/education/students/curriculum. The comparative analysis was done based upon the obligatory (non-optional subjects) in both institutions. The total amount of ECTS for this Bachelor degree program is equal to 240 in both institutions.

The share of subjects from the area of general natural sciences: mathematics, physics and chemistry is 24 ECTS (10 %) at TTK and 27 ECTS (11 %) at UoR. The part of fundamental technical subjects such as: Engineering graphics, Machine elements and CAD systems is 18 ECTS (8 %) at TTK and 21 ECTS (9 %) at UoR. The subjects from the area of technical mechanics such as statics, dynamics, and strength of materials are presented with the following quota: 6 ECTS (2 %) at TTK and 16 ECTS (7 %) at UoR.

The group of subjects in the field of other fundamental technical areas such as: Materal Science, Fluid Mechanics, Fundamentals of Electrical Engineering are reprepresented with 12 ECTS (5 %) at TTK and 17 ECTS (7 %) at UoR.

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The subjects in the area of informatics and foreign languages in both institutions are well covered. Besides, it is well known that the knowledge and skills in these fields are accumulated not only during the study process at Universities, but also in different extracurricular learning and training courses.

Name	ECTS	Year	Semester	Optional
ır 1				
Engineering Materials	6	1	F	-
Data Processing	3	1	F	-
Basics of Science Philosophy	3	1	F	-
Engineering Materials Workshop	3	1	F	-
Communication, Creativity and Cooperation	3	1	F	-
Physics I	3	1	F	-
Mathematics I	3	1	F	-
Descriptive Geometry	3	1	F	-
Theoretical Mechanics	3	1	F	-
Estonian for Non-native Students (support study)	3	1	F	+
Studies at Higher Education Level	3	1	F	+
Physics II	6	1	S	-
Mathematics II	6	1	S	-
Engineering Graphics	3	1	S	-
Tolerancing and Measurement Technique	6	1	S	-
Electrical Engineering and Electrical Equipment	6	1	S	-
English for Special Purposes I	3	1	S	+
German for Special Purposes I	3	1	S	+
Estonian for Non-native Students (support study)	3	1	S	+

Strength of Materials	3	2	F	-
Universal Equipment and Appliances	3	2	F	-
Mathematics III	6	2	F	-
CAD Systems	6	2	F	-
Basics of Machining	6	2	F	-
Automation Technology and Numerical Control Systems	3	2	F	-
English for Special Purposes II	3	2	F	+
German for Special Purposes II	3	2	F	+
Micro- and Macroeconomics	3	2	S	-
Machine Elements + Project	6	2	S	-
Cutting and Cutting Tools	3	2	S	-
Programming of CNC Tools	3	2	S	-
Enterprise Practice	12	2	S	-
Self-expression and Debate Practice	3	2	S	+
Statistics	3	2	S	+
German for Advanced	3	2	S	+
Physical Education	3	2	S	+

Fig. 1. Mechanical Enginering: First and second year of study at TTK Univesrity of Applied Sciences, Estonia

The comparison of general technical subjects delivered leads to the following conclusion: these subjects are almost equally represented in the Mechanaical engineering curricula at TTK University of Applied Science and at the University of Ruse.

The situation when comparing the special subjects (Fig.2), which are connected with the professional development of students, is quite different. The number of identical or almost identical subjects is relative small. Some of them are: Basics of Machining, Cutting and Cutting Tools, CAM systems, Automation, etc.

Enterprise Informatics	3	3	F	-
Welding Technology Workshop	3	3	F	-
Entrepreneurship and Marketing	3	3	F	-
Design of Appliances	3	3	F	-
Hydraulic and Pneumatic Equipment	3	3	F	-
Basics of Programming	3	3	F	-
Welding Technology and Equipment	6	3	F	-
Metal Forming Technology	3	3	F	-
Russian for Beginners	3	3	F	+
German for Beginners	3	3	F	+
Flexible Manufacturing Modules	3	3	F	+
Industrial Design + Course Project	6	3	F	+
Hoisting and Conveying Equipment	3	3	F	+
Basics of Hydraulic Drive Calculation	3	3	F	+
Engineering Practice	12	3	S	-
CAM Systems	6	3	S	-
Design of Pneumatic Systems	3	3	S	-
Technology of Metal Structures and Appliances	3	3	S	-
Economics of Machine Building Enterprise	3	3	S	-
Sensors and Actuators	3	3	S	-
Russian for Special Purposes	6	3	S	+

Ecology and Environmental Protection	3	4	F	-
Labour Law, Occupational Health and Safety	3	4	F	-
Project Management	3	4	F	-
Heat Treatment Technology and Equipment	3	4	F	-
Technology of Metal Structures and Appliances - Course Paper	3	4	F	-
Economics of Machine Building Enterprise - Course Project	3	4	F	-
Industrial Robots	3	4	F	-
Quality Science	3	4	F	+
FEM Calculations	3	4	F	+
English (Business Language)	3	4	F	+
German (Business Language)	3	4	F	+
Russian (Business Language)	3	4	F	+
Optional Subjects	3	4	F	+
Industrial Property and its Legal Protection	3	4	F	+
Stamps and Die Sets	3	4	F	+
Microprocessors	3	4	F	+
Composites, Coatings and Engineering Plastics	3	4	F	+
Economic Mathematics	3	4	F	+
Presentations of Visiting Lecturers	3	4	F	+
Graduation Thesis	15	4	S	-
Pre-diploma Practical Training	12	4	S	-
Graduation Thesis Seminar	3	4	S	-

Fig 2. Mechanical Enginering: Third and Fourth year of study at TTK Univesrity of Applied Sciences, Estonia

ACADEMIC EXCHANGE OF STUDENTS – BENEFITS AND CHALLENGES

The identified differences in the type of specialized subjects available at both institutions are probably also related to the following circumstances: different facilities and laboratories' equipment.

The equipment of the Flexible Manufacturing Modules at the Industry 4.0 laboratory at TTK University of Applied Science is especially modern and beneficial for the practical training of students, Fig. 3.

Fig 3. Flexible Manufacturing Modules at the Industry 4.0 laboratory at TTK University of Applied Science

The University of Ruse is famous with its scientific contracts with industry enterprises. A great number of modern test devices and equipment of some laboratories at the university are donated by industrial companies. Other laboratories and facilities have been equipped through national and international projects.

Fig 4. Laboratories at the University of Ruse

As it is known, there are two types of mobility within Erasmus plus program: academic exchange for study process and internship. Concerning the first kind of mobility, the best period for implementing it would be the second year of study. The subjects during the first 4 semesters are overlapping to a great extend. This circumstance makes the process of creating appropriate Learning agreements and recognizing the subjects (after the mobility is over) much easier.

Concerning the second kind of mobility – the ineternship, the differences of curricula and facilities can be considered as great advantages because the students can acquire different practical professional skills in different institutions due to their specific facilities and laboratory equipment.

CONCLUSIONS

The research made leads to the following conlusions:

The advantages of some curricula differences concerning students' exchange is highlighted;

The importance of facilities and laboratory equipment is emphasized.

The paper compares special features of different kinds of mobility within Erasmus exchange and the link between mobility, contents of the Bachelor degree course curricula, facilities and laboratory equipment.

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